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(PROCFish/C/CoFish)

PALAU COUNTRY REPORT:

PROFILES AND RESULTS FROM SURVEY WORK AT NGARCHELONG, NGATPANG, AIRAI AND KOROR

(April to June 2007)

by

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

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

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EXECUTIVE SUMMARY

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

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

Other programme outputs include:

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

Survey work in Palau covered three disciplines (finfish, invertebrate and socioeconomic) in each site, with a team of eight programme scientists and several local counterparts from the Bureau of Marine Resources, the Department of Conservation and Law Enforcement, and a seconded field officer from Conservation International in Alatau, Papua New Guinea. The fieldwork included capacity building for the local counterparts through instruction on survey methodologies in all three disciplines, including the collection of data and inputting the data into the programme's database.

In Palau, the four sites selected for the survey were Ngarchelong, Ngatpang, Airai and Koror. These sites were selected based on specific criteria, which included:

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

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

Results of fieldwork in Ngarchelong

Ngarchelong is a village located at the extreme north–northwest tip of the island of Babeldaob, the main island of the Palau archipelago. The approximate position is 07°45'N, 134°37'E. The fishing area extends between 7°53'N and 8°06'N over a length of about 13 nautical miles. It is an open-access area. A marine conservation area is located in the northwest of this area, positioned at 7°46'4N, 134°34'5E, with a total surface of 90 km². This reserve has been effective since 1994. The southern lagoon receives a little terrigenous influence from the rivers. The coastal reefs are bordered in many places by small mangroves. Intermediate reefs are more abundant in the northern area. The eastern reefs and all back-reefs are very sandy.

Socioeconomics: Ngarchelong

Fisheries are not an important sector for income generation in Ngarchelong. Only 12% of all households obtain primary income from fisheries, and another 24% obtain secondary income. In contrast, salaries provide 56% of all households with first income; other income sources, mainly welfare, retirement payments and handicrafts, make up 32% of first-income sources. Agriculture is of minor importance. Fresh fish consumption, 57 kg/person/year, is above the regional average but lower than the average of all CoFish sites in Palau (68.8 kg/person/year). Invertebrate consumption is moderate (~10 kg/person/year).

Most finfish fishing is done by males; only a few females exclusively fish for finfish, collect invertebrates or target both finfish and invertebrates. Finfish fishers mainly target the lagoon, but one quarter of all male fishers also fish the outer reef. The sheltered coastal reef is the least targeted habitat. While more than half of finfish catches in Ngarchelong are sold outside the community, presumably to Koror, fishing pressure remains low due to the large area of fishing ground. Handlining is the main fishing technique used in all habitats. However, handlining may be combined with trolling for pelagic fish at the outer reef, and with spear diving and gillnetting in the lagoon. Most fishing is done using motorised boats and, in rare cases, non-motorised boats.

Invertebrate collection focuses on soft benthos (seagrass) for bêche-de-mer and reeftop for giant clams. Mangrove gleaning and diving for lobsters are rarely done, and mainly performed by males. Invertebrate fisheries mainly serve the community’s subsistence needs, but are also used to generate income. Highest fishing pressure is observed for the soft benthos (seagrass) and to a lesser extent for the reeftop fisheries.

Finfish resources: Ngarchelong

The assessment indicated that the status of finfish resources in Ngarchelong at the time of surveys was average and the habitat was found to be generally healthy, with good representation of different substrate types and live coral. However, the site was classified as impacted, especially in the intermediate lagoon reef, where most fishing was done. Fish density, biomass, and especially biodiversity displayed values only slightly lower than the richest site in the country, Koror, and average to high compared to regional values. However, size ratios were low compared to other sites; fish everywhere reacted warily to the presence of divers, even inside the reserve, suggesting that spearfishing is a very common practice; large-sized species of parrotfish were only rarely observed; a total absence of large groupers and napoleon wrasses, as well as other carnivores was also noted. Apex (top of the food chain) predators were also extremely rare.

Moreover, differences were detected in coral cover among the four reef habitats. At both coastal and intermediate reefs, coral cover was on average fairly good; however, very poor in some areas. In front of the northern islands and on the outer-reefs coral coverage was good, but poor in the back-reefs. Finfish resources also varied among habitats. The coastal reefs were particularly rich in fish fauna (abundance, biomass, size and species diversity), although dominated by Acanthuridae. In contrast, the lagoon and back-reefs displayed the lowest values of density, biomass, average size and diversity. Average sizes of several targeted fish families were much lower than the 50% of their maximum recorded value, indicating an impact from fishing. Fishing was more intense on lagoon reefs and the most targeted families were Lethrinidae, followed by Lutjanidae, Serranidae and Scaridae. The outer reefs displayed intermediate conditions between coastal and lagoon reefs in Ngarchelong, but were relatively poor when compared to the outer reefs of the other country sites.

Invertebrate resources: Ngarchelong

There is a wide range of shallow-water reef habitats suitable for giant clams. A complete range of giant clam species were present, some of which are becoming rare in other parts of the Pacific. There were few management issues to consider for the smaller species of clams (*Tridacna maxima* and *T. crocea*), and the larger clam species, although not at high density, have a better coverage here than at most other CoFish sites around the Pacific. In general, the status of giant clams at Ngarchelong was healthy, especially for the most common species, indicating that populations of giant clam are only partially impacted by fishing.

Local reef conditions at Ngarchelong constitute an extensive and good habitat for juvenile and adult *Trochus niloticus*, the commercial topshell. Commercial stock was common at easily accessible shallow-water reefs close to the main harbour, and on the lagoon-side back-reef at the barrier and near the passage. The exposed reef slope also held trochus, but no high-density aggregations were recorded. The density of trochus within the ‘core’ aggregations (where trochus are typically in greatest abundance) and across reefs in general suggests there is still significant potential for stocks to increase in number. The majority of areas had not reached the 500 shells/ha, the minimum threshold for considering commercial harvests. The blacklip pearl oyster, *Pinctada margaritifera*, was relatively common at Ngarchelong, and at greater numbers than at the other CoFish sites in Palau.

Ngarchelong has extensive habitats suitable for sea cucumbers. The range of sea cucumber species recorded at Ngarchelong was large, partially reflecting the varied environment, but also the fact that the export fishery is highly controlled in Palau (Commercial export has been banned for 15 years.) Presence and density data collected suggest that sea cucumbers are not under significant fishing pressure and stocks typically taken for commercial export are only lightly or moderately affected by past fishing. The species fished by domestic fishers for subsistence are more impacted, and marine protected areas designated near Ngarchelong need to be well managed to ensure these stocks are not depleted.

Recommendations for Ngarchelong

- Spearfishing be controlled and regulated.

- A monitoring system be set up and implemented with community input to follow any further changes in finfish resources.

- The existing marine reserve be patrolled in order to ensure compliance with regulations.

- Groups of large, older clams are protected from fishing to ensure there is sufficient breeding stock to create the next generation. The presence in small numbers of *Hippopus porcellanus*, which is not recorded in many other places in the Pacific, may warrant greater protection being offered to this species.

- All clam species need the continued support of strong management controls, to ensure the hard work in protecting this rare resource is continued. In addition, continued community education programme and tourist visits may be encouraged to maintain awareness of the importance and 'uniqueness' of these stocks.

- BMR consider attempting to get most of the 'core' trochus fishery areas up to a threshold density of approximately 500–600 /ha before considering commercial fishing.

- BMR consider protecting a proportion of trochus within main aggregations so that broodstock (sizes ≥11 cm) can remain at higher density post fishing. This could also be accomplished by implementing a blanket measure, such as creating a 'gauntlet' fishery, with an upper as well as a lower size limit, and by 'resting' areas within the main fishing locations for longer periods between periods of commercial fishing.

- Careful management of fishing of sea cucumbers could allow commercial harvesting of a number of export species in Ngarchelong. Preferably, catches could be made using a pulse-harvest fishing strategy, similar to that currently employed for trochus, which allows a period of rest between fishing events and time to re-assess the stocks' response to fishing pressure.

Results of fieldwork in Ngatpang

Ngatpang is located in the west of Babeldaob Island, at the position: 7°29' N, 134°29' E. Its fishing area is 'open access', and delimited to the north by the Mlengui Pass and to the south by an east–west line at 7°31' N, 134°22' S. Its length is approximately 9.5 km and its width 6 km. A reserve is present at 7°30'5 N, 134°29'4 E, covering a total surface of 1.5 km². The four typically sampled habitat types were present. However the diveable back-reefs are only located in the northern part (~80% of back-reefs are sandy and not accessible to the divers). The lagoon is subject to a heavy terrigenous influence due to the many rivers. As a result of the high level of sediment in the water, a high abundance of filtrating sponges was noted.

Socioeconomics: Ngatpang

As compared to salaries, fisheries are not an important sector for income generation in Ngatpang. Only 8% of all households obtain first, and 20% second income from fisheries. Salaries provide 84% of all households with first income, and 8% with secondary income.

Agriculture plays the least important role and remittances do not play any role at all. Fresh-fish consumption is above the regional average and slightly below the consumption rate in all of Palau's CoFish sites. Invertebrate consumption is moderate (~8 kg/person/year).

Most fishing, especially for finfish, is done by males. Fewer females than males collect invertebrates. Finfish fishers mainly target the lagoon, but also the sheltered coastal reef and the outer reef. Various techniques are used to catch finfish. Handlines are used in all habitats, spear diving is particularly important at the outer reef, and gillnets are often used at the sheltered coastal reef. Pelagic fishing (trolling) may be combined with deep-bottom lining or any other technique targeting reef fish. Sheltered coastal reef fishing is done without any boat transport, but all other fishing depends on motorised boat transport.

Females mainly target the soft benthos (seagrass) for invertebrate collection while males are more diversified and also collect in mangroves and on reeftops. Invertebrate fisheries serve both subsistence and commercial purposes. Holothurians determine most of the reported total annual catch by wet weight. Giant clams, mainly collected from the reeftops by male fishers, also play a major role.

Finfish resources: Ngatpang

The status of finfish resources in Ngatpang was moderately good but already impacted. The site appeared naturally fairly rich in terms of substrate composition and fish biodiversity; however, it already showed a decline in resources (relative lack of carnivores and small average sizes), probably due to fishing. Reefs were generally healthy, with relatively high live-coral cover. Biodiversity of fish was among the highest recorded at the four country sites, and density the second-highest. However, sizes were fairly small compared to the other three sites and biomass was the lowest encountered. Only very few Scaridae of large size were present and apex predators (top of the food chain) were very rare. Remarkable differences were observed among the four reef types. In the coastal and back-reefs, corals were diverse and healthy; less coral cover was found at the intermediate reefs. Finfish resources also showed high variability. The coastal reef had the highest fish density and biomass of all habitats at the site and highest also of all country sites; in fact it appeared to be the richest coastal habitat in the region. The fish community was also diverse, with large-sized fish and dominance of carnivorous fish in terms of biomass. Fishing was the least intensive in this coastal habitat, and size ratios were below the 50% of maximum sizes only for Lethrinidae and Mullidae. In contrast, lagoon and back-reefs displayed the lowest values of density, biomass, size and biodiversity.

Trophic composition was dominated by herbivores, mostly Scaridae and Acanthuridae. Mullidae and Scaridae showed average size ratios much smaller than 50% of the maximum size, suggesting an impact from fishing. The outer reefs were still quite healthy but showed impact in terms of lower density, size and biomass compared to the less fished coastal reefs. Biodiversity was, however, very high, mirroring the rich quality of the habitat, and was the second-highest among the four sites. The trophic structure was dominated by herbivores, mainly Acanthuridae. Spear diving was often performed; the impact of this fishing method, which is highly selective on species and sizes, was evident in the smaller fish sizes; average size ratios were also low for Lethrinidae (38% of maximum sizes), which made up 33% of the total catches from this outer reef. In general, fish were very wary of the presence of divers. The reserve did not show any differences compared to outside areas, even though it had been established since 2003.

Invertebrate resources: Ngatpang

Reefs in Ngatpang provide extensive suitable areas for giant clams. A complete range of giant clam species was present, some of which are becoming rare in other parts of the Pacific. There were few management issues to consider for the smaller species of clams (*Tridacna maxima* and *T. crocea*), but larger clam species need greater protection from fishing. *T. gigas* and *T. derasa* were only recorded in small numbers compared to similar sites in other parts of Palau. Stocks of *T. squamosa*, although relatively well distributed around Ngatpang, were also at lower density than expected. In general, the status of giant clams at Ngatpang was reasonably healthy, especially for the most common species.

The distribution, density and length recordings give a mixed picture of MOP stock health. Despite the extensive habitat suitable for juveniles and adults, *Trochus niloticus*, the commercial topshell, was not common at Ngatpang. Commercial stocks were most common at easily accessible, shallow-water reefs closer to the ocean side of the lagoon, in the passage and on the reef slope. Size distribution reveals that no strong year-class is currently visible below the commercial size class range, and that past harvests have comprehensively fished the stock. The blacklip pearl oyster, *Pinctada margaritifera*, is more common at Ngatpang than at the more southerly and easterly CoFish sites in Palau.

Ngatpang has a diverse range of environments and depths suitable for sea cucumbers. The range of sea cucumber species recorded at Ngatpang was large, partially reflecting the varied environment, but also the fact that the export fishery is highly controlled in Palau. Sea cucumbers are not under significant fishing pressure and commercial export stocks are only lightly or moderately affected by past fishing. The species fished for subsistence are more impacted, and marine protected areas designated near Ngatpang need to be well managed to ensure these stocks are not depleted. This is especially true for the more easily targeted (and depleted) larger inshore species, such as sandfish, *Holothuria scabra*.

Recommendations for Ngatpang

- Spear diving be limited and regulated, especially in coastal and lagoon reefs.
- Restrictions in place for the existing marine reserves be observed and enforced.
- A regular monitoring system be established and implemented with community participation, to follow changes in resources, especially finfish in the intermediate and outer reefs and the few selected target invertebrate species.
- Groups of large, older clams be protected from fishing, to ensure there is sufficient breeding stock to create the next generation.
- All clam species need the support of further management measures, such as protected areas.
- No trochus harvests should proceed in Ngatpang, even if there is an opening in the fishery in the next year. Remaining stocks should be given time to build in number, to a point where the abundance is more certain to enable successful spawning and fertilisation.

- BMR consider attempting to get most of the 'core' trochus fishery areas up to a threshold density of 500–600 /ha, before considering commercial fishing.

- BMR consider protecting a portion of trochus broodstock (sizes $\geq$11 cm). This could be accomplished by creating a 'gauntlet' fishery, with an upper as well as a lower size limit, creating small no-fish areas within core areas of the fishery, or by 'resting' areas from commercial fishing within the main fishing locations for longer periods.

- Marine protected areas near Ngatpang be well managed to ensure that sea cucumber species fished by domestic fishers for subsistence, which are already impacted, are not further depleted.

- Careful management of fishing could allow commercial harvesting of a number of sea cucumber export species in Ngatpang. Preferably, catches could be made using a pulse-harvest fishing strategy, similar to that currently employed for trochus, which allows a period of rest between fishing events and time to re-assess the stocks response to fishing pressure.

Results of fieldwork in Airai

Airai is a village located in the south–southeast of Babeldaob island, situated at 07°21'N, 134°37'E. The fishing area is delimited to the north by the southern part of the Ngemelachel pass and to the south by a west–east line extending eastward from the southern channel of Babeldaob. The lagoon is relatively shallow (30–40 m) and contains few intermediate reefs, mostly found in the extreme northern and southern areas. The other three habitats (outer, back- and coastal reefs) are well represented. Two marine reserves are present, located at 7°23'2″N, 134°35'3″E (established in 1994, surface 1km^2) and at 7°20'3″N, 134°32'6″E (established in 1997, surface 1km^2).

Socioeconomics: Airai

Salaries are the most important source of income in Airai. Only 30% of all households reported fisheries as an income source; half of these as their first, and the other half as their second. Fresh-fish consumption (70 kg/person/year) is above the regional average and similar to the average consumption of all CoFish sites in Palau (68.8 kg/person/year). Invertebrate consumption is low (5 kg/person/year). The Airai community is more urbanised than in most other sites in Palau and spends more money than the average found across all sites investigated in Palau. Remittances do not play an important role.

Most finfish fishing is performed by males; females are more engaged in collecting invertebrates. Finfish fishers mainly target the lagoon and much less the outer reef. Most of the catch from the lagoon and outer reef is sold, presumably mainly to Koror. Various techniques are used for fishing finfish: handlining is the main method used in the sheltered coastal reef and outer reef; castnetting combined with other techniques in the lagoon. Other techniques include gillnetting, spear diving and rod fishing. Most fishing is done with motorised boat transport.

Invertebrate fishers focus on collecting bêche-de-mer and sea urchins from soft benthos (seagrass), and giant clams, crabs and lobsters from the reeftop. Invertebrate fisheries mainly serve the subsistence needs of the Airai community. Highest fishing pressure is observed for the soft-benthos (seagrass) and, to a lesser extent, for the reeftop fisheries. Bêche-de-mer species, giant clams and perhaps sea urchins, which are subject to seasonal harvesting, determine most of the total annual reported catch by wet weight. Present fishing pressure on these particular resources may be high and may need monitoring.

Finfish resources: Airai

The assessment indicated that the status of finfish resources in this site was rather meagre. The habitat was pretty poor and fish resources scarce, displaying parameters lower than at the other three country sites. Corals were rare and not healthy, especially the lagoon and back-reef, but were better on the outer reefs. Fish biodiversity, abundance and biomass were lower than at the other sites, and sizes were generally small. The finfish community was everywhere dominated by herbivores, especially Acanthuridae and Scaridae, which may be partially due to the type of substrate, mainly hard bottom, or to fishing. Carnivores (mainly Lethrinidae and Lutjanidae) were rare and apex predators even rarer. Average sizes were rather small and large-sized fish were almost absent. Larger species of Scaridae and Acanthuridae were recorded only rarely. Size ratios of carnivores were low. Fish were rather wary and distant from divers, which suggests spear diving may be over practised.

Coastal reefs were the healthiest of all the four habitats and the least fished, yet showed intermediate-to-low fish density and biomass, a dominance of herbivores, and some families with a very small size ratio. Lagoon resources, highly exploited in terms of fisheries and mainly for sale, showed small size ratios, particularly for Mullidae, Scaridae and Serranidae a sign of impact. Biomass and density were of intermediate-to-low value. Back-reefs were in similar condition to coastal reefs, however, biodiversity was higher. Outer reefs appeared to be the poorest and the most impacted of the four habitats, with lowest biomass and sizes, both at the site and country level. The overall analysis of the data suggests that Airai is relatively impacted.

Invertebrate resources: Airai

Airai presented extensive habitat suitable for giant clams. A complete range of giant clam species was present, some of which are becoming rare in other parts of the Pacific. There were few management issues to consider for the smaller species of clams (*Tridacna maxima* and *T. crocea*), but larger clam species need greater protection from fishing. The large true giant clam, *T. gigas*, and the smooth clam, *T. derasa*, were only recorded in small numbers compared to those at similar sites in other parts of Palau. Stocks of the fluted clam, *T. squamosa*, were also at lower density than expected. In general, the status of giant clams at Airai was reasonably healthy, especially for the most common species. Clam density and the 'full' range of clam size classes present support the assumption that, apart from some of the largest species, populations of giant clam are only partially impacted by fishing.

Data on distribution density and length recordings give a mixed picture of MOP stock health. *Trochus niloticus*, the commercial topshell, is common at Airai, and local reef conditions constitute excellent habitat for juvenile and adult trochus. Commercial stocks are most common at easily accessible shallow-water reefs inside the lagoon. The density of trochus suggests that stocks are healthy, but 'core' aggregations (where trochus are typically in greatest abundance) still have significant potential for growth in individual size and overall abundance, while 'non-core' areas (barrier reef) currently only hold limited densities of stock.

Size-class information reveals that past harvests have comprehensively fished the trochus stock. The blacklip pearl oyster, *Pinctada margaritifera*, is not common at Airai.

Airai has a diverse range of environments suitable for sea cucumbers. The range of sea cucumber species recorded at Airai was large, partially reflecting the varied environment, but also the fact that the export fishery is highly controlled in Palau. Presence and density data suggest that sea cucumbers are not under significant fishing pressure and commercial export stocks are only lightly or moderately affected by past fishing. The species fished for subsistence are more impacted relative to other sites around Palau, and fishers were already travelling to more remote sites on Babeldaob to access stocks at higher density.

Recommendations for Airai

- Fisheries management regulations that either temporarily or periodically limit locations, species and/or fishing techniques be implemented, in order to preserve reef and lagoon resources. Future fisheries management strategies need to take into account the high interest of the community in subsistence and leisure fisheries. Therefore, if restrictions are needed, measures must be identified in close cooperation with the community to ensure that these are acceptable and likely to be complied with.

- Use of gillnets and spear diving be regulated and limited, particularly in the lagoon.

- Conservation areas be patrolled and regulations enforced.

- No development or increase of fish marketing be allowed.

- Groups of large, older clams be protected from fishing, to ensure there is sufficient breeding stock to create future generations.

- BMR attempt to increase most of the 'core' trochus fishery areas up to a threshold density of ~500–600 /ha before considering commercial fishing.

- BMR protect a proportion of trochus broodstock (sizes ≥11cm) by creating a 'gauntlet' fishery, with an upper as well as a lower size limit, creating small no-fish areas within core areas of the fishery, and by 'resting' areas within the main fishing locations from commercial fishing for longer periods.

- Careful management of sea cucumber fishing could allow commercial harvesting of a number of export species in Palau. Preferably, catches could be made using a pulse-harvest fishing strategy, similar to that currently employed for trochus, which allows a period of rest between fishing events and time to re-assess the stocks' response to fishing pressure.

Results of fieldwork in Koror

Koror is one of the four largest islands in the country, located south of Babeldaob and north of Peleliu, around 07°10' N, 134°20' E. Here is where the main town and economic hub are found and where most of the Republic's population lives. A highway connects Koror to the main harbour on Malakal Island. The outer reef is shared with the larger island of Badelbaob, and several hundred small islands are included inside the large lagoon. The study area did not meet the normal standard CoFish design due to specific local requests that allowed only areas principally exploited by fishers to be assessed. Moreover, the sampled zones only partially correspond to the general fishing area, which extends from Koror in the north to Peleliu Island in the south.

Socioeconomics: Koror

Salaries are the most important source of income in Koror, complemented by other sources, such as retirement and social fees. Fisheries provide income for only 10% of all households. Fresh-fish consumption (77 kg/person/year) is above the regional average and also higher than the average consumption of all CoFish sites in Palau (68.8 kg/person/year). Invertebrate consumption is low (~4.5 kg/person/year). The average household expenditure level is slightly higher than found across all CoFish sites in Palau. This trend was to be expected considering that the two Koror communities surveyed (Meyuns, Ngermid) have adopted a more urban lifestyle than the northern rural communities. Although remittances do not play an important role, they contribute more here than at other Palau sites surveyed.

Most finfish fishing is performed by males, particularly if it is done exclusively. Very few females specialise in collecting invertebrates only; however, ~33% of male and female fishers fish for both finfish and invertebrates. Finfish fishers mainly target the lagoon and much less the outer reef; only a few fish the sheltered coastal reef. About half of the reported finfish annual catch is consumed, the other half is sold. Various techniques are used for fishing finfish; spear diving is the main method used in all habitats targeted. In most cases, spear diving is complemented by the use of handlines and, in the lagoon, also castnets and gillnets; at the outer reef, deep-bottom lines are employed. With the exception of some sheltered coastal reef fishing, all finfish fishing uses motorised boat transport.

Invertebrate fishers focus on collecting giant clams, bêche-de-mer and sea urchins from the reeftop and soft benthos (seagrass). Invertebrate collection is almost exclusively done only by walking. None of the invertebrate catch was reported for sale.

Finfish resources: Koror

Only back-, intermediate and outer reefs were surveyed, according to special local requests. The no-fishing areas were not accessible. The assessment indicated that the status of finfish resources in this site was good at the time of surveys. The reefs appeared generally healthy and fairly rich in coral cover, more so than the other country sites. Fish abundance and biomass were high placing Koror among the twenty richest sites in the region. Biodiversity was particularly high, and, as average value, the highest in the region. However, some signs of fishing impact were detectable as low average size ratios for certain families, especially Siganidae, Scaridae and Lethrinidae, which were recorded among the most-targeted families by fishers.

However, at the reef level, the three habitats varied considerably. Although intermediate and back-reefs displayed high coral cover, corals were often found in poor condition, either broken, diseased or attacked by crown-of-thorn starfish, still showing signs of the 2002 heavy bleaching events. Outer-reef corals were in a better state in terms of cover and health.

Finfish resources were also very variable among the three habitats. The outer reefs of Koror were absolutely the richest habitats among all sites. Fish abundance, biomass and diversity in the outer reefs were the highest among the habitats and among the highest in the region. The trophic community was dominated by carnivores (especially Lutjanidae), further suggesting the ecosystem is functioning well. However, large carnivores and top predators were rather rare in the outer reefs, possibly indicating a first sign of fishing impact. Size ratios were small for Scaridae, which made up the majority of catches from this habitat, where spear diving was the main method used; these low size ratios are probably the first indication of impact. In comparison, the intermediate reefs, the most fished of the three habitats, displayed less than half of the biomass of outer reefs. Lethrinidae, which constituted ~20% of the total biomass of catches, here displayed low size ratio, possibly as a consequence of frequent fishing. Back-reefs, with the lowest density, biomass (~25% of the biomass found on the outer reefs) and size among the three habitats, were the poorest habitat of the site. The trophic community was dominated by herbivores, suggesting an impoverishment of the ecosystem. Siganidae and Scaridae displayed low size ratios, indicating a possible impact from catches.

Some reserves established for tourism reasons were quite respected and displayed the highest biodiversity and biomass.

Invertebrate resources: Koror

Areas suitable for giant clams around Koror are extensive. A complete range of giant clam species was present, some of which are becoming rare in other parts of the Pacific. There were few management issues with the smaller species of clams (*Tridacna maxima* and *T. crocea*); however, the large true giant clam, *T. gigas*, was noticeably missing from many areas of Koror, compared to similar sites in other parts of Palau. Stocks of *T. squamosa* were common but at lower density than expected. This species, together with *Tridacna derasa* and *T. gigas*, needs the most support if further management measures are to be implemented. In general, the status of giant clams at Koror was reasonably healthy, especially for the most common species.

Distribution, density and length recordings give a mixed picture of MOP stock health. *Trochus niloticus* is common and local reef conditions constitute excellent habitat for adult and juvenile trochus. Commercial stocks are most common at easily accessible shallow-water reefs inside the lagoon; generally those fringing the mainland or influenced by passage water flows. The density of trochus suggests that stocks are healthy, but ‘core’ aggregations (where trochus are typically in greatest abundance) still have significant potential for growth in individual size and overall abundance, while ‘non-core’ areas are currently holding only limited densities of stock. Trochus size-class information reveals that previous harvests have comprehensively fished the stock, also that commercial-sized shells are still relatively small, and that no strong year-class is currently visible below the commercial size class range. On occasion, the three-year resting period currently adopted in Palau may be too short for continued successful management of the fishery. The blacklip pearl oyster, *Pinctada margaritifera*, is relatively uncommon at Koror.

Koror has a diverse range of environments and depths suitable for sea cucumbers. The range of sea cucumber species recorded at Koror was wide, partially reflecting the varied environment, but also the fact that the export fishery is highly controlled. Presence and density data suggest that sea cucumbers are not under significant fishing pressure and commercial export stocks are only lightly or moderately affected by past fishing. The species fished for subsistence are more impacted relative to other sites around Palau, and fishers were already travelling to Babeldaob to access stocks at higher density.

Recommendations for Koror

- Implementation of regulations and patrolling of reserves not be limited to dive sites.

- Spearfishing be controlled and regulated.

- A monitoring system be planned with community input to strictly observe changes in resources since even the healthiest sites showed first signs of a decrease in finfish resources.

- BMR consider attempting to get most of the ‘core’ trochus fishery areas up to a threshold density of approximately 500–600 /ha before considering commercial fishing.

- BMR consider protecting a proportion of trochus broodstock (sizes ≥11 cm) by creating a ‘gauntlet’ fishery, with an upper as well as a lower size limit, creating small no-fish areas within core areas of the fishery, and by ‘resting’ areas from commercial fishing within the main fishing locations for longer periods.

- Careful management of sea cucumber fishing could allow commercial harvesting of a number of export species in Palau. Preferably, the allowance of such a harvest would adopt a pulse-harvest fishing strategy, currently employed for trochus, which allows a period of rest between fishing events and time to re-assess the stocks’ response to fishing pressure.

RÉSUMÉ

D'avril à juin 2007, les agents du Projet de développement de la pêche côtière (CoFish) ont mené des travaux de terrain sur quatre sites à Palau. Palau est l'un des 17 États et Territoires insulaires océaniens ayant fait l'objet d'enquêtes, échelonnées sur 5 à 6 ans, conduites par les agents du projet CoFish ou de son projet associé PROCFish/C (composante côtière du Programme régional de développement des pêches océaniques et côtières dans les PTOM français et pays ACP du Pacifique)[3].

Le but de ces enquêtes était de recueillir des données de référence sur l'état des ressources récifales et de combler l'énorme déficit d'informations qui en entrave la gestion efficace.

Le projet visait en outre à obtenir les résultats suivants :

- première évaluation exhaustive et comparative des pêcheries récifales (poissons, invertébrés et paramètres socioéconomiques de leur exploitation) de plusieurs pays de la région océanienne, suivant une méthode normalisée, appliquée sur chaque site d'étude ;
- diffusion de rapports nationaux comprenant un ensemble de « 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'échelle locale et nationale, 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 à Palau comprenaient trois volets (poissons, invertébrés et aspects socioéconomiques) sur chaque site. L'équipe était composée de huit chercheurs du projet et de plusieurs agents du Bureau des ressources marines et du Ministère de l'environnement et de l'intérieur de Palau, ainsi que d'un agent de terrain de l'antenne de Conservation International à Alotau (Papouasie-Nouvelle-Guinée) détaché auprès du projet. Au cours des travaux de terrain, l'équipe a formé les agents de Palau aux méthodes d'enquête et d'inventaire utilisées dans chacune des trois composantes de son intervention, notamment la collecte de données et leur saisie dans la base de données du Projet.

À Palau, les quatre sites retenus étaient Ngarchelong, Ngatpang, Airai and Koror. Chaque site a été sélectionné selon les critères particuliers suivants :

- existence d'une pêche récifale active ;
- site représentatif du pays ;
- système relativement fermé (les habitants du site pêchent dans des zones bien définies) ;
- taille appropriée ;
- habitat diversifié ;

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

- absence de problèmes logistiques majeurs ;
- études déjà effectuées auparavant ;
- intérêt particulier du site pour le Bureau des ressources marines de Palau.

Résultats des travaux de terrain à Ngarchelong

Le village de Ngarchelong est situé à l'extrémité de la pointe nord-ouest de Babeldaob, île principale de l'archipel de Palau, par environ 07° 45' de latitude nord et 134° 37' de longitude est. Sa zone de pêche, qui s'étend entre 7° 53' et 8° 06' de latitude nord sur une longueur d'environ 13 milles nautiques, est d'accès libre. Une réserve marine protégée de 90 km², créée en 1994, se trouve au nord-ouest de cette zone par 7° 46' 4 de latitude nord et 134° 34' 5 de longitude est. Le lagon sud ne subit guère l'influence terrigène des rivières. Les récifs côtiers sont bordés pour la plupart de mangroves peu étendues. Les récifs intermédiaires sont plus abondants dans le nord. Les récifs situés à l'est et l'ensemble des arrière-récifs sont particulièrement sablonneux.

Données socioéconomiques : Ngarchelong

La pêche ne constitue pas une activité rémunératrice de premier plan à Ngarchelong. Seuls 12 pour cent des ménages y trouvent leur principale source de revenus, et 24 pour cent une source secondaire. A contrario, 56 pour cent des foyers tirent l'essentiel de leurs revenus des salaires, et 32 pour cent d'autres sources, au premier rang desquelles les prestations sociales, les pensions et l'artisanat. L'agriculture ne joue qu'un rôle mineur. Le taux de consommation de poisson frais (57 kg/personne/an) se situe au dessus de la moyenne régionale, tout en restant inférieur à la moyenne constatée sur l'ensemble des sites du projet CoFish à Palau (68,8 kg/personne/an). Le taux de consommation d'invertébrés est assez faible (environ 10 kg/personne/an).

Pour l'essentiel, la pêche de poissons est pratiquée par les hommes; rares sont les femmes qui se consacrent exclusivement à cette pêche, ramassent des invertébrés ou ciblent aussi bien des poissons que des invertébrés. La pêche de poissons s'effectue essentiellement dans le lagon, même si un quart des hommes pêcheurs se rend également sur le tombant récifal externe. Le récif côtier abrité est l'habitat le moins ciblé. Si plus de la moitié des prises de poissons réalisées à Ngarchelong est vendue à l'extérieur du village, vraisemblablement à Koror, la pression de pêche reste faible en raison de la grande étendue de la zone de pêche. Dans tous les habitats, la palangrotte est la technique la plus couramment utilisée. Elle peut cependant être associée à la pêche à la traîne sur l'extérieur du récif, pour cibler le poisson pélagique, et à la pêche au fusil-harpon et au filet maillant dans le lagon. Les sorties de pêche se font généralement en canot à moteur ou, beaucoup plus rarement, en pirogue.

La collecte d'invertébrés s'effectue principalement sur les fonds meubles (herbiers) pour les holothuries, et sur le sommet récifal pour les bénitiers. Ce sont avant tout les hommes qui ramassent ou pêchent la langouste en plongée dans la mangrove, même si la pratique reste épisodique. La pêche d'invertébrés répond surtout aux besoins de subsistance des habitants, tout en constituant également une source de revenus. La pression de pêche se fait le plus ressentir sur les fonds meubles (herbiers) et, dans une moindre mesure, sur le sommet récifal.

Ressources en poissons : Ngarchelong

Au moment de l'évaluation du site de Ngarchelong, l'état des ressources en poissons était relativement bon, l'habitat étant généralement sain, avec une bonne représentation des différents types de substrats et une bonne densité de coraux vivants. Le site est cependant considéré comme affecté par la pêche, en particulier sur le récif lagonaire intermédiaire, où se déroule l'essentiel des sorties. Les valeurs de densité, de biomasse et surtout de biodiversité sont à peine inférieures à celles du site de Koror, le plus riche du pays, et sont moyennes à élevées au regard des valeurs régionales. Cependant le rapport de tailles est faible par rapport à d'autres sites : les poissons se montrent méfiants en présence des plongeurs, et ce même à l'intérieur de la réserve, ce qui semble indiquer que la pêche au fusil-harpon s'y pratique très couramment; les équipes n'observent que très peu de spécimens de perroquets de grande taille; elles constatent également une absence totale de mérous, de napoléons et d'autres carnivores de grande taille. De même les superprédateurs (situés au sommet de la chaîne alimentaire) ne sont observés qu'en de très rares occasions.

En outre, des différences apparaissent dans la couverture corallienne des quatre habitats du récif : elle est généralement satisfaisante sur les récifs côtiers et intermédiaires, où l'on observe cependant par endroits des coraux en très mauvais état. La couverture corallienne est bonne dans les zones situées en face des îles du nord et sur le récif extérieur, mais médiocre sur les arrière-récifs. Les ressources en poissons varient également selon les habitats. Les récifs côtiers abritent une ichtyofaune particulièrement riche (abondance, biomasse, tailles et diversité des espèces) bien qu'elle soit dominée par les acanthuridés. En revanche le lagon et les arrière-récifs affichent les plus faibles taux de densité, biomasse, taille moyenne et diversité.

La taille moyenne des spécimens de plusieurs familles de poissons ciblées par les pêcheurs est bien inférieure à la moitié de la taille maximale observée, ce qui tend à démontrer l'incidence de la pêche. La pêche est pratiquée de manière plus intensive sur les récifs lagonaires et les familles les plus ciblées sont les lethrinidés, suivis des lutjanidés, des serranidés et des scaridés. L'état des récifs extérieurs se situe à un niveau intermédiaire entre celui des récifs côtiers et lagonaires de Ngarchelong, tout en étant relativement médiocre par rapport aux récifs extérieurs des autres sites du pays.

Ressources en invertébrés : Ngarchelong

On trouve à Ngarchelong une large gamme d'habitats récifaux de faible profondeur convenant bien aux bénitiers. Toute la gamme des espèces de bénitiers est représentée, y compris celles qui se raréfient ailleurs dans le Pacifique. La gestion des espèces de petite taille (*Tridacna maxima* et *T. crocea*) ne suscite pas de grosse inquiétude et quant aux espèces de bénitiers de plus grande dimension, si elles n'affichent pas une densité très élevée, elles n'en présentent pas moins un meilleur taux de couverture que celui constaté sur les autres sites étudiés dans le cadre du projet CoFish en Océanie. De manière générale, l'état des populations de bénitiers observées à Ngarchelong est satisfaisant, en particulier pour les espèces les plus communes, ce qui montre que cette ressource n'est que partiellement affectée par la pêche.

Les récifs de Ngarchelong constituent un vaste habitat propice aux juvéniles et aux adultes de *Trochus niloticus*, le troca d'intérêt commercial. Les stocks exploitables sont abondants sur les récifs de faible profondeur proches du port principal et faciles d'accès, ainsi que sur la barrière de l'arrière-récif donnant sur le lagon et près de la passe. On trouve également des trocas sur le tombant exposé du récif, mais sans que des concentrations à forte densité y soient constatées. La densité des trocas au sein des concentrations « fondamentales » (dont l'abondance est habituellement la plus élevée) ainsi que sur l'ensemble du récif laisse entrevoir un fort potentiel de croissance des populations. Dans la majorité des secteurs, la densité n'a pas encore atteint le seuil des 500 individus par hectare, valeur minimum requise pour envisager une exploitation commerciale de la ressource. L'huître perlière à lèvres noires (*Pinctada margaritifera*) est relativement commune à Ngarchelong, où elle est plus abondante que sur les autres sites du projet CoFish à Palau.

Ngarchelong comporte de vastes habitats propices à la croissance des holothuries. Les espèces observées présentent une grande diversité, ce qui témoigne en partie de la variété du milieu, mais aussi de la très stricte règlementation de leurs exportations à Palau (les exportations à des fins commerciales sont interdites depuis 15 ans). Les valeurs de présence et de densité mesurées donnent à penser que les holothuries ne sont pas soumises à une pression de pêche considérable et les stocks habituellement prélevés à des fins d'exportation ne sont aujourd'hui que faiblement ou modérément affectés par leur exploitation passée. Les espèces prélevées dans le cadre de la pêche vivrière sont plus touchées et une bonne gestion des aires marines protégées situées à proximité de Ngarchelong paraît nécessaire pour éviter l'épuisement de ces stocks.

Recommandations pour Ngarchelong

- Restriction et réglementation de la pêche au fusil-harpon.

- Mise en place d'un système de surveillance avec la participation des populations locales, afin de détecter toute modification de l'état des ressources halieutiques.

- Organisation de patrouilles dans la réserve marine afin de garantir le respect de la réglementation.

- Interdiction de la pêche des bénitiers plus âgés et de grande taille, afin de garantir la présence d'un stock de géniteurs suffisant pour produire une nouvelle génération. La présence de quelques spécimens *d'Hippopus porcellanus*, espèce rarement observée en Océanie, pourrait justifier des mesures de protection supplémentaires en sa faveur.

- Nécessité de continuer à gérer de façon rigoureuse l'ensemble des populations de bénitiers, afin de garantir la pérennité des efforts déployés pour protéger cette ressource peu commune. On pourrait également promouvoir les programmes d'éducation communautaire et les visites de touristes pour maintenir la prise de conscience sur l'importance et le caractère « exceptionnel » de ces stocks.

- Étude, par le Bureau des ressources marines, de la possibilité de relever la densité de la plupart des zones de pêche « fondamentales » des trocas au niveau de 500 à 600 individus par hectare, avant d'envisager une exploitation commerciale de la ressource.

- Étude, par le Bureau des ressources marines, de la possibilité de protéger une partie des trocas présents dans les concentrations principales, afin que la densité des stocks de géniteurs (taille $\geq$ 11 cm) se maintienne à un niveau supérieur après la pêche. Ce but pourrait également être atteint au moyen d'une mesure d'application globale, comme la limitation des prises selon une « fourchette » définie par une taille minimale et une taille maximale, ou en laissant « récupérer » plus longtemps certains secteurs des principales zones de pêche entre les périodes d'exploitation commerciale.

- Gestion rigoureuse de la pêche des holothuries, susceptible de permettre l'exploitation commerciale de plusieurs espèces recherchées à l'exportation. Il serait préférable d'adopter une stratégie de pêche ponctuelle intensive semblable à celle actuellement utilisée pour les trocas, qui prévoit une période de récupération entre les campagnes de pêche et donne le temps de réévaluer la réaction des stocks face à la pression de pêche.

Résultats des travaux de terrain à Ngatpang

Ngatpang se situe à l'ouest de l'île de Babeldaob, par 7° 29' de latitude nord et 134° 29' de longitude est. Sa zone de pêche est « en libre accès », limitée au nord par la passe de Mlengui et au sud par un axe est-ouest s'étendant entre 7° 31' de latitude nord et 134° 22' de latitude sud. Sa longueur est d'environ 9,5 km et sa largeur de 6 km. Ngatpang possède une réserve d'une superficie de 1,5 km² située à 7° 30' 5 de latitude nord et 134° 29' 4 de longitude est. Les quatre types d'habitat habituellement étudiés sont représentés sur le site. Cependant c'est uniquement dans le secteur septentrional que l'on trouve des arrière-récifs se prêtant à la plongée sous-marine (près de 80 pour cent des arrière-récifs sont sablonneux et l'on ne peut y plonger). Le lagon est soumis à une influence terrigène marquée due à la présence de nombreux cours d'eau. Le fort taux de sédiments présents dans l'eau explique l'abondance des éponges filtrantes.

Données socioéconomiques : Ngatpang

Par rapport aux salaires, la pêche ne constitue pas une source de revenus majeure à Ngatpang. Seuls 8 pour cent des ménages y trouvent leur première source de revenus et 20 pour cent une source secondaire. Les salaires constituent la principale source de revenus de 84 pour cent des foyers, et une deuxième source de revenus pour 8 pour cent des ménages. L'agriculture est l'activité génératrice de revenus la moins souvent citée et les envois de fonds sont inexistants. La consommation de poisson frais est supérieure à la moyenne régionale tout en restant légèrement inférieure à celle constatée sur les sites inventoriés dans le cadre du projet CoFish à Palau. Le taux de consommation d'invertébrés est modéré (environ 8 kg/personne/an).

Pour l'essentiel ce sont les hommes qui pratiquent la pêche, et en particulier celle du poisson. Les femmes sont moins nombreuses que les hommes à ramasser les invertébrés. Les pêcheurs de poisson explorent avant tout le lagon, mais interviennent également sur le récif côtier abrité et sur le récif extérieur. Les techniques de pêche employées sont variées. La palangrotte est utilisée dans tous les habitats, le fusil-harpon est une méthode privilégiée sur le récif extérieur, et le filet maillant est souvent employé sur le récif côtier abrité. La pêche de poisson pélagique (à la traîne) peut être associée à la pêche profonde à la palangre ou à une autre technique ciblant les espèces récifales. Si aucune embarcation n'est nécessaire pour pêcher sur le récif côtier abrité, le canot à moteur est en revanche indispensable pour tous les autres types de pêche.

C'est avant tout sur les fonds meubles (herbiers) que les femmes ramassent les invertébrés, alors que la pratique masculine est plus diversifiée puisque les hommes explorent également les mangroves et le sommet récifal. La collecte des invertébrés est pratiquée à des fins aussi bien vivrières que commerciales. Les holothuries constituent l'essentiel de la capture annuelle déclarée en poids humide, même si la part des bénitiers, ramassés le plus souvent par les hommes sur le sommet récifal, est également conséquente.

Ressources en poissons : Ngatpang

L'état des ressources en poissons de Ngatpang est relativement bon, bien que l'incidence de la pêche soit déjà visible. Le site semble naturellement assez riche, tant par la composition du substrat que par la biodiversité des poissons. On constate cependant déjà un déclin des ressources (absence relative de carnivores et tailles moyennes limitées), très probablement dû à la pêche. De manière générale, l'état de santé des récifs est bon, avec un taux de couverture corallienne vivante relativement élevé. Ngatpang affiche l'une des biodiversités de poissons parmi les plus élevées des quatre sites de Palau et se classe en deuxième position pour la densité. Mais la taille des poissons observés est inférieure à celle constatée sur les trois autres sites et la biomasse y est la plus faible. On n'observe qu'un nombre très réduit de scaridés de grande taille et les superprédateurs (situés au sommet de la chaîne alimentaire) sont très rares. Des différences notables apparaissent entre les quatre types de récif. Sur les récifs côtiers et les arrière-récifs, les coraux sont variés et en bonne santé, alors que la couverture corallienne est moins dense sur les récifs intermédiaires. L'état des ressources de poissons présente également une très grande variété. C'est le récif côtier qui affiche la plus forte densité de poissons et la biomasse la plus élevée de tous les habitats de Ngatpang et de tous les sites inventoriés à Palau : il semble même s'agir de l'habitat côtier le plus riche de toute la région. La population de poissons est également d'une grande diversité, avec des spécimens de grande taille et une biomasse où les carnivores se taillent la part du lion. C'est dans cet habitat côtier que la pêche est la moins intensive et seuls les lethrinidés et les mullidés présentent un rapport de tailles inférieur à 50 pour cent de la taille maximale. Le lagon et les arrière-récifs affichent en revanche les taux les plus faibles de densité, biomasse, taille et biodiversité.

La composition trophique est dominée par les herbivores, représentés pour l'essentiel par les scaridés et les acanthuridés. Les mullidés et les scaridés affichent des rapports de tailles moyens bien inférieurs à la moitié de la taille maximale, signe indicateur de l'incidence de la pêche. L'état des récifs extérieurs reste satisfaisant bien que l'incidence de la pêche s'y traduise par des valeurs de densité, taille et biomasse inférieures à celles constatées sur les récifs côtiers où la pêche est moins pratiquée. On constate cependant une très grande biodiversité qui reflète la grande richesse de l'habitat et le place au deuxième rang des quatre sites étudiés à Palau. La structure trophique est dominée par les herbivores, qui sont pour l'essentiel des acanthuridés. La pêche au fusil-harpon est de pratique courante et l'incidence de cette technique très sélective en termes d'espèces et de tailles, se traduit clairement par la petite taille des poissons observés; les rapports de tailles moyens sont également faibles pour les lethrinidés (38 pour cent de la taille maximale) qui représentent 33 pour cent des poissons capturés sur ce récif extérieur. De façon générale, les poissons se montrent très méfiants en présence de plongeurs. Bien qu'établie depuis 2003, la réserve ne se différencie en rien des autres secteurs.

Ressources en invertébrés : Ngatpang

Les récifs de Ngatpang renferment de vastes secteurs propices au bénitier. Toute la gamme des espèces y est représentée, y compris celles qui se raréfient ailleurs dans le Pacifique. La gestion des espèces de bénitiers de petite taille (*Tridacna maxima* et *T. crocea*) ne présente pas de carences particulières, mais il est nécessaire d'interdire plus strictement la pêche des espèces de grande taille. On n'observe qu'un petit nombre de *T. gigas* et de *T. derasa* par rapport à des sites semblables de Palau. Bien que relativement bien répartis sur le site de Ngatpang, les stocks de *T. squamosa* affichent également une densité moins élevée que prévue. Globalement, l'état des bénitiers de Ngatpang est relativement satisfaisant, en particulier pour les espèces les plus communes.

Les données relatives à la répartition, à la densité et à la longueur des nacres révèlent une image contrastée de l'état de santé de leurs stocks. En dépit de l'existence d'un habitat très étendu convenant aux juvéniles et adultes de *Trochus niloticus*, troca d'intérêt commercial, cette espèce est peu commune à Ngatpang. C'est sur les récifs de faible profondeur, faciles d'accès et proches de la façade océanique du lagon, dans la passe et sur le tombant récifal, que les stocks commercialisables sont présents en plus grand nombre. La ventilation par tailles des nacres observées montre qu'aucune classe d'âge n'est fortement représentée en dessous de la fourchette de tailles commercialisables et que les campagnes de pêche passées ont donné lieu à une exploitation intensive de la ressource. L'huître perlière à lèvres noires *Pinctada margaritifera* est plus courante à Ngatpang que sur les sites inventoriés par le projet CoFish plus au sud et à l'est de Palau.

Ngatpang présente une grande diversité de milieux et de profondeurs convenant bien aux holothuries. L'éventail d'espèces observé à Ngatpang est large, ce qui témoigne d'une part de la variété du milieu, mais aussi de la très stricte règlementation de leurs exportations à Palau. Les holothuries ne sont pas exposées à une pression de pêche importante et les stocks recherchés à l'exportation ne sont que faiblement ou modérément affectés par les campagnes de pêche antérieures. Les espèces prélevées à des fins de subsistance sont plus touchées et il convient d'instaurer une bonne gestion des aires marines protégées établies à proximité de Ngatpang pour empêcher l'épuisement de ces stocks. Ceci vaut tout particulièrement pour les espèces côtières les plus faciles à prélever (et à épuiser) comme l'holothurie de sable, *Holothuria scabra*.

Recommandations pour Ngatpang

- Restriction et réglementation de la pêche au fusil-harpon, en particulier sur les récifs côtiers et lagonaires.

- Respect des restrictions en vigueur dans les réserves marines et lutte contre les infractions.

- Mise en place d'un système de surveillance régulier avec la participation des populations locales afin de détecter toute modification de l'état des ressources, et en particulier des poissons sur les récifs intermédiaires et extérieurs et des quelques espèces d'invertébrés ciblées.

- Interdiction de la pêche des bénitiers plus âgés et de grande taille afin de garantir la présence d'un stock de géniteurs suffisant pour produire une nouvelle génération.

- Nécessité de mettre en place des mesures de gestion supplémentaire en faveur de l'ensemble des espèces de bénitiers, avec par exemple la création d'aires protégées.

- Pas de récolte de trocas à Ngatpang, même en cas d'ouverture de la pêche l'année prochaine à Palau. Il faut laisser aux stocks restants le temps de se multiplier et d'atteindre un niveau d'abondance tel qu'il offre une meilleure garantie de réussite de la ponte et de la fertilisation.

- Étude, par le Bureau des ressources marines, de la possibilité de relever la densité de la plupart des zones de pêche « fondamentales » des trocas au niveau d'environ 500 à 600 individus par hectare, avant d'envisager une exploitation commerciale de la ressource.

- Étude, par le Bureau des ressources marines, de la possibilité de protéger une partie des stocks de trocas géniteurs (taille ≥ 11 cm). Ceci pourrait être réalisé en réglementant les prises selon une « fourchette » définissant les taille minimale et maximale autorisées, en interdisant la pêche dans certains secteurs limités des principales zones de pêche, ou en « laissant récupérer » plus longtemps certaines parties des principales zones de pêche entre les périodes d'exploitation commerciale.

- Mise en place d'une gestion rigoureuse des aires marines protégées situées à proximité de Ngatpang afin de ne pas aggraver l'épuisement des espèces d'holothuries prélevées par les pêcheurs à des fins de subsistance, l'incidence de la pêche se faisant déjà sentir sur ces populations.

- Gestion rigoureuse de la pêche des holothuries susceptible de permettre l'exploitation commerciale de plusieurs espèces recherchées à l'exportation. Il serait préférable d'adopter une stratégie de pêche ponctuelle intensive semblable à celle actuellement utilisée pour les trocas, qui prévoit une période de récupération entre les campagnes de pêche et donne le temps de réévaluer la manière dont les stocks réagissent à la pression de pêche.

Résultats des travaux de terrain à Airai

Le village d'Airai se trouve au sud-sud-est de l'île de Babeldaob, par 07° 21' de latitude nord et 134° 37' de longitude est. Sa zone de pêche est délimitée au nord par la partie sud de la passe de Ngemelachel, et au sud par un axe est-ouest qui s'étend vers l'est depuis le chenal sud de Babeldaob. Le lagon est relativement peu profond (30-40 m) et compte quelques rares récifs intermédiaires, situés pour la plupart à l'extrême nord et à l'extrême sud de la zone. Les trois autres types d'habitat (récif extérieur, arrière-récif et récif côtier) sont bien représentés. Le site comporte deux réserves marines, la première située par 7° 23' 2″ de latitude nord et 134° 35' 3″ de longitude est (créée en 1994 et d'une superficie de 1 km²) et la deuxième située par 7° 20' 3″ de latitude nord et 134° 32' 6″ de longitude est (créée en 1997 et d'une superficie de 1 km²).

Données socioéconomiques : Airai

Les salaires constituent la principale ressource des habitants d'Airai. Seuls 30 pour cent des ménages tirent des revenus de la pêche : la moitié d'entre eux la citent comme première source de revenus, l'autre moitié comme deuxième source. Située au dessus de la moyenne régionale, la consommation de poisson frais (70 kg/personne/an) est proche de la consommation moyenne constatée sur les sites étudiés par le projet CoFish à Palau (68,8 kg/personne/an). La consommation d'invertébrés est faible (5 kg/personne/an). La population d'Airai est plus urbanisée que celle de la plupart des autres sites de Palau et ses dépenses sont plus élevées que la moyenne constatée sur les sites étudiés à Palau. Les envois de fonds ne jouent pas un rôle majeur.

La pêche des poissons est surtout pratiquée par les hommes; les femmes sont plus actives dans le ramassage des invertébrés. Les pêcheurs de poissons exploitent avant tout le lagon, ainsi que le récif extérieur, dans une moindre mesure. L'essentiel des prises effectuées sur le lagon et sur le récif extérieur est vendue, pour la plus grande part sans doute à Koror. Plusieurs techniques sont utilisées pour pêcher le poisson : la palangrotte est la méthode la plus couramment employée sur le récif côtier abrité et sur le récif extérieur, alors que dans le lagon les pêcheurs utilisent l'épervier associé à d'autres techniques, dont le filet maillant, le fusil-harpon et la canne à pêche. La plupart des sorties de pêche s'effectuent en canot à moteur.

Les pêcheurs d'invertébrés prélèvent avant tout les holothuries et les oursins sur les fonds meubles (herbiers) et les bénitiers, les crabes et les langoustes sur le sommet récifal. La pêche des invertébrés répond surtout aux besoins de subsistance des habitants d'Airai. C'est sur les fonds meubles (herbiers) et, dans une moindre mesure sur le sommet récifal, que la pression de pêche est la plus forte. Les diverses espèces d'holothuries, les bénitiers et les peut-être les oursins, qui font l'objet d'une récolte saisonnière, constituent l'essentiel des captures annuelles déclarées en poids humide. Il se peut que la pression de pêche qui s'exerce actuellement sur ces ressources soit élevée et qu'une surveillance soit nécessaire.

Ressources en poissons : Airai

Il ressort des résultats de l'évaluation que les ressources en poissons de ce site sont assez limitées. La qualité de l'habitat est médiocre et les poissons peu abondants, les paramètres étant moins bons que ceux des trois autres sites évalués à Palau. Les coraux sont rares et abimés, surtout dans le lagon et sur l'arrière-récif, car ils sont en meilleur santé sur les récifs extérieurs. Les valeurs de biodiversité, d'abondance et de biomasse des poissons sont moins bonnes que sur les autres sites, et les poissons observés sont généralement de petite taille. La population de poissons est partout dominée par les herbivores, notamment les acanthuridés et les scaridés, ce qui s'explique peut-être en partie par la nature du substrat constitué pour l'essentiel de fonds durs, ou par la pêche. Les carnivores (principalement les lethrinidés et les lutjanidés) sont peu nombreux et les superprédateurs encore plus rares. Les tailles moyennes des poissons sont assez petites et on note une absence quasi-totale de poissons de grande taille. Les espèces plus grandes de scaridés et d'acanthuridés ne sont que très peu représentées. Les rapports de tailles des carnivores sont faibles. En présence des plongeurs, les poissons sont méfiants et tendent à garder leurs distances, ce qui laisse supposer une pratique excessive de la pêche au fusil-harpon en plongée.

Des quatre habitats étudiés, le récif corallien est celui dont l'état de santé est le plus florissant et qui est le moins visité par les pêcheurs : pourtant la densité et la biomasse des poissons y sont moyennes à faibles, on y observe une prédominance des herbivores et un rapport de tailles très faible pour certaines familles. Les ressources lagonaires qui font l'objet d'une pêche intensive pratiquée essentiellement à des fins commerciales, présentent des rapports de tailles limités, notamment chez les mullidés, les scaridés et les serranidés, signe de l'incidence de la pêche sur ces populations. La biomasse et la densité affichent des valeurs intermédiaires à faibles. Bien que l'état des arrière-récifs soit semblable à celui des récifs côtiers, la biodiversité y est supérieure. Le récif extérieur semble être l'habitat le plus affecté des quatre puisqu'il affiche les paramètres de biomasse et de taille les plus médiocres du site et de l'ensemble de Palau. L'analyse globale des données laisse à penser que le site d'Airai est relativement affecté par la pêche.

Ressources en invertébrés : Airai

On trouve à Airai un habitat étendu convenant bien aux bénitiers. Toute la gamme des espèces de bénitiers est représentée, y compris celles qui se raréfient ailleurs dans le Pacifique. La gestion des espèces de petite taille (*Tridacna maxima* et *T. crocea*) ne présente pas de carences particulières, mais il est nécessaire d'interdire plus strictement la pêche des espèces de plus grande taille. Les bénitiers de grande taille tridacnes géants, *T. gigas,* et les grands tridacnes brillants, *T. derasa*, sont beaucoup moins abondants que sur des sites semblables situés dans d'autres régions de Palau. La densité des stocks de grands tridacnes gaufrés, *T. squamosa*, est également plus faible que prévu. Globalement, les bénitiers présents à Airai sont dans un état de santé satisfaisant, et ceci notamment pour les espèces les plus courantes. La densité des bénitiers et la présence d'une gamme « complète » de classes de tailles confirment l'hypothèse qu'en dehors de certaines espèces de grande taille, les populations de bénitiers ne sont que partiellement affectées par la pêche.

Les données relatives à la répartition, à la densité et à la longueur des nacres révèlent une image contrastée sur l'état de santé de leurs stocks. *Trochus niloticus*, le troca d'intérêt commercial, est une espèce commune à Airai, dont les récifs constituent un habitant convenant parfaitement aux trocas juvéniles et adultes. Les stocks d'intérêt commercial sont les plus abondants sur les récifs de faible profondeur faciles d'accès situés à l'intérieur du lagon. La densité des trocas laisse supposer que les stocks sont en bonne santé, mais les concentrations « fondamentales » de trocas (dont l'abondance est habituellement la plus élevée) ont encore un fort potentiel de croissance tant en terme de taille individuelle que d'abondance globale. En revanche les stocks présents dans les zones « non fondamentales » (récif barrière) n'affichent que des densités limitées. Les données relatives aux classes de taille montrent que les récoltes passées ont donné lieu à une exploitation intensive des stocks de trocas. L'huître perlière à lèvres noires, *Pinctada margaritifera* est rare à Airai.

Airai présente une grande diversité de milieux et de profondeurs convenant aux holothuries. L'éventail d'espèces d'holothuries observé à Arai est large, ce qui témoigne d'une part de la variété du milieu, mais aussi de la très stricte règlementation de leurs exportations à Palau. Les données de présence et de densité semblent indiquer que les holothuries ne sont pas soumises à une pression de pêche importante. Les stocks recherchés à l'exportation ne sont que faiblement ou modérément affectés par les campagnes de pêche antérieures. Les espèces prélevées à des fins de subsistance sont plus touchées que sur d'autres sites de Palau et les pêcheurs se rendent déjà sur des sites plus éloignés de Babeldaob pour trouver des stocks d'une plus grande densité.

Recommandations pour Airai

- Mise en place de restrictions temporaires ou périodiques concernant les zones de pêches, les espèces et/ou les techniques de pêche, afin de préserver les ressources récifales et lagonaires. Prise en compte dans les stratégies d'aménagement futures de l'importance pour la population de la pêche vivrière et de la pêche de loisir. En conséquence toute mesure restrictive jugée nécessaire doit être prise en concertation avec la population, pour garantir son acceptation et son respect.

- Règlementation et restriction de l'emploi des filets maillants et des fusils-harpons, en particulier dans le lagon.

- Organisation de patrouilles dans les aires protégées et lutte contre les infractions à la réglementation.

- Interdiction du développement ou du renforcement de la commercialisation du poisson.

- Interdiction de la pêche des bénitiers plus âgés et de grande taille, afin d'assurer un stock de géniteurs suffisant pour produire une nouvelle génération.

- Étude, par le Bureau des ressources marines, de la possibilité de relever la densité de la plupart des zones de pêche « fondamentales » des trocas au niveau d'environ 500 à 600 individus par hectare, avant d'envisager une exploitation commerciale de la ressource.

- Protection, par le Bureau des ressources marines, d'une partie des stocks de trocas géniteurs (taille ≥ 11 cm) en réglementant les prises selon une « fourchette » définissant les taille minimale et maximale autorisées, en interdisant la pêche dans certains secteurs limités situés dans les principales zones de pêche, et en « laissant récupérer » plus longtemps certaines parties des principales zones de pêche entre les périodes d'exploitation commerciale.

- Gestion rigoureuse de la pêche des holothuries, susceptible de permettre l'exploitation commerciale à Palau de plusieurs espèces recherchées à l'exportation. Il serait préférable d'adopter une stratégie de pêche ponctuelle intensive semblable à celle actuellement utilisée pour les trocas, qui prévoit une période de récupération entre les campagnes de pêche et donne le temps de réévaluer la manière dont les stocks réagissent à la pression de pêche.

Résultats des travaux de terrain à Koror

Située au sud de Babeldaob et au nord de Peleliu, par environ 07° 10' de latitude nord et 134° 20' de longitude est, Koror est l'une des quatre îles principales de Palau. On y trouve la plus grande ville du pays et son principal centre économique; c'est aussi là que réside la majorité des habitants de la République. Koror est relié au principal port de l'île de Malakal par une route surélevée. Koror partage son récif extérieur avec la grande île de Badelbaob et son vaste lagon renferme plusieurs centaines d'îlots. La zone étudiée ne répond pas aux critères normalement exigés dans le cadre du projet CoFish en raison de sollicitations locales qui n'ont permis d'inventorier que les zones surtout exploitées par les pêcheurs. En outre les zones étudiées ne coïncident que partiellement avec la zone de pêche la plus fréquentée, qui s'étend de Koror, au nord, à l'île de Peleliu, au sud.

Données socioéconomiques : Koror

À Koror, l'essentiel des revenus est constitué par les salaires, complétés par d'autres sources telles que les pensions et les prestations sociales. Seuls 10 pour cent des ménages tirent des revenus de la pêche. La consommation de poisson frais (77 kg/personne/an) est supérieure autant à la moyenne régionale qu'à la moyenne de l'ensemble des sites étudiés dans le cadre du projet CoFish à Palau (68,8 kg/personne/an). La consommation d'invertébrés est faible (environ 4,5 kg/personne/an). Le niveau moyen des dépenses des ménages est légèrement supérieur à celui relevé sur l'ensemble des sites visités à Palau par les agents du projet CoFish. Ce phénomène n'a rien de surprenant étant donné que les habitants des deux localités étudiées à Koror (Meyuns et Ngermid) ont adopté un mode de vie plus urbanisé que ceux des zones rurales du nord. La contribution des envois de fonds aux revenus des ménages est limitée, mais plus importante que dans les autres sites ciblés à Palau.

Les pêcheurs de poissons, et en particulier ceux qui se consacrent exclusivement à cette ressource, sont le plus souvent des hommes. Rares sont les femmes à se spécialiser dans le ramassage des invertébrés uniquement; en revanche, environ 33 pour cent des pêcheurs (hommes et femmes) ciblent aussi bien les poissons que les invertébrés. Les pêcheurs de poissons explorent surtout le lagon et se rendent beaucoup plus rarement sur le récif extérieur; seuls quelques uns d'entre eux exploitent le récif côtier abrité. Près de la moitié des prises de poissons annuelles déclarées est consommé, le reste étant commercialisé.

Plusieurs techniques sont utilisées pour pêcher le poisson : le fusil-harpon est la méthode la plus couramment employée dans l'ensemble des habitats ciblés. Le plus souvent elle est associée à la palangrotte, et dans le lagon, à l'épervier et au filet maillant; sur le récif extérieur on utilise des lignes pour la pêche profonde. L'usage du canot à moteur est systématique chez les pêcheurs de poissons, à l'exception de certaines sorties sur le récif côtier abrité.

Les pêcheurs d'invertébrés prélèvent surtout les bénitiers, les holothuries et les oursins sur le sommet récifal et les fonds meubles (herbiers). Le ramassage des invertébrés s'effectue presque exclusivement à pied. Aucun des pêcheurs interrogés ne déclare destiner ses prises à la vente.

Ressources en poissons : Koror

Conformément aux demandes formulées localement, l'enquête a porté uniquement sur les arrière-récifs, et les récifs intermédiaires et extérieurs. Les agents du projet n'ont pu avoir accès aux zones interdites aux pêcheurs. Il ressort des résultats obtenus qu'à l'époque de l'évaluation, l'état des ressources en poissons de ce site était bon. Les récifs semblent globalement en meilleure santé et plus riches en couverture corallienne que sur les autres sites du pays. Les valeurs d'abondance et de biomasse de poissons sont élevées, permettant à Koror de se classer parmi les 20 sites les plus riches de la région. La biodiversité est excellente puisque sa valeur moyenne est la plus élevée de la région. Certains éléments révèlent cependant une incidence de la pêche : ainsi les rapports de tailles moyens sont particulièrement faibles chez les siganidés, les scaridés et les lethrinidés, familles présentées par les pêcheurs comme faisant partie des plus ciblées.

S'agissant du récif, les trois habitats offrent des variations considérables. Sur les récifs intermédiaires et sur l'arrière-récif la couverture corallienne est dense, mais l'on constate que les coraux sont souvent en mauvais état : cassés, malades ou attaqués par des acanthasters, et portant encore les traces des graves épisodes de blanchissement de 2002. Sur les tombants récifaux externes, les coraux sont plus denses et en meilleure santé.

Les ressources en poissons des trois habitats sont également très différenciées. Les récifs extérieurs de Koror abritent sans conteste l'habitat le plus riche de tous les sites visités. Les valeurs d'abondance, de biomasse et de diversité des poissons y sont les plus élevées de tous les habitats et parmi les plus élevées de la région. La communauté trophique est dominée par les carnivores (en particulier les lutjanidés), indicateur supplémentaire du bon fonctionnement de l'écosystème. Cependant les grands carnivores et les grands prédateurs y sont plutôt rares, ce qui constitue peut-être le premier signe indicateur de l'incidence de la pêche. Les rapports de tailles sont faibles pour les scaridés, qui constituent la majorité des captures dans cet habitat où le fusil-harpon est la méthode la plus couramment utilisée; ces valeurs basses sont sans doute le premier signe indicateur de l'incidence de la pêche. Par comparaison, les récifs intermédiaires, qui constituent le plus exploité des trois habitats, abritent une biomasse inférieure de moitié à celle des récifs extérieurs. Les lethrinidés, qui représentent environ 20 pour cent de la biomasse totale des captures, affichent un rapport de tailles faible qui s'explique peut-être par la fréquence de la pêche. Les arrière-récifs sont l'habitat le moins riche du site, avec les valeurs de densité, de biomasse (environ 25 pour cent de la biomasse des récifs extérieurs) et de taille les plus basses de l'ensemble des trois habitats. La communauté trophique est dominée par les herbivores, ce qui laisse supposer un appauvrissement de l'écosystème. Les rapports de tailles des siganidés et des scaridés sont peu élevés, signe indicateur d'une possible incidence de la pêche.

On constate, dans certaines réserves créées à des fins touristiques, que la règlementation est bien respectée et on y enregistre les niveaux les plus élevés de biodiversité et de biomasse.

Ressources en invertébrés : Koror

Les zones convenant au bénitier sont très étendues autour de Koror. Toute la gamme des espèces de bénitiers y est représentée, y compris celles qui se raréfient ailleurs dans le Pacifique. La gestion des espèces de petite taille (*Tridacna maxima* et *T. crocea*) ne présente pas de carences particulières, mais le tridacne géant *T. gigas* brille par son absence dans de nombreux secteurs de Koror, contrairement à d'autres sites semblables à Palau. *T. squamosa* est courant mais en densité plus faible que prévu. C'est cette espèce qui, avec *Tridacna derasa* et *T. gigas*, devra être ciblée en priorité si de nouvelles mesures d'aménagement sont mises en œuvre. De manière générale l'état de santé des bénitiers de Koror est relativement satisfaisant, en particulier pour les espèces les plus communes.

Les données relatives à la répartition, à la densité et à la longueur des nacres révèlent une image contrastée sur l'état de santé de leurs stocks. *Trochus niloticus* est une espèce commune à Koror, dont les récifs constituent un habitant convenant parfaitement aux trocas juvéniles et adultes. Les stocks d'intérêt commercial sont les plus abondants sur les récifs de faible profondeur faciles d'accès situés à l'intérieur du lagon. Il s'agit généralement des récifs frangeants ou qui subissent l'influence de la circulation de l'eau dans les passes. La densité des trocas laisse supposer que les stocks sont en bonne santé, mais les concentrations « fondamentales » de trocas (dont l'abondance est habituellement la plus élevée) ont encore un fort potentiel de croissance tant en terme de taille individuelle que d'abondance globale. En revanche les stocks présents dans les zones « non fondamentales » n'affichent que des densités limitées. Les données relatives aux classes de taille montrent que les récoltes passées ont donné lieu à une exploitation intensive des stocks, que la taille des trocas commercialisables est encore relativement petite et qu'aucune classe d'âge n'est actuellement fortement représentée en dessous de la fourchette de tailles commercialisables. Dans certains cas il se peut que la période de trois ans d'interruption de la pêche actuellement en vigueur à Palau soit de trop courte durée pour une bonne gestion de la pêcherie. L'huître perlière à lèvres noires, *Pinctada margaritifera* est relativement peu commune à Koror.

Koror présente une grande diversité de milieux et de profondeurs convenant aux holothuries. L'éventail d'espèces d'holothuries observé à Koror est large, ce qui témoigne d'une part de la variété du milieu, mais aussi de la très stricte règlementation des exportations à Palau. Les données de présence et de densité semblent indiquer que les holothuries ne sont pas soumises à une pression de pêche importante. Les stocks recherchés à l'exportation ne sont que faiblement ou modérément affectés par les campagnes de pêche antérieures. Les espèces prélevées à des fins de subsistance sont plus touchées que sur d'autres sites de Palau et les pêcheurs se rendent déjà à Babeldaob pour trouver des stocks d'une plus grande densité.

Recommandations pour Koror

- Mise en place d'une réglementation des réserves et organisation de patrouilles ne se limitant pas aux sites de plongée.

- Restriction et réglementation de la pêche au fusil-harpon.

- Élaboration d'un système de surveillance avec la participation des populations locales afin de suivre au plus près toute modification de l'état des ressources, puisque les premiers signes indicateurs d'une diminution des ressources halieutiques apparaissent déjà, y compris sur les sites les plus riches.

- Étude, par le Bureau des ressources marines, de la possibilité de relever la densité de la plupart des zones de pêche « fondamentales » des trocas au niveau d'environ 500 à 600 individus par hectare, avant d'envisager une exploitation commerciale de la ressource.

- Étude, par le Bureau des ressources marines, de la possibilité de protéger une partie des stocks de trocas géniteurs (taille ≥ 11 cm) en réglementant les prises selon une « fourchette » définissant les taille minimale et maximale autorisées, en interdisant la pêche dans certains secteurs limités situés dans les principales zones de pêche, et en « laissant récupérer » plus longtemps certaines parties des principales zones de pêche entre les périodes d'exploitation commerciale.

- Gestion rigoureuse de la pêche des holothuries susceptible de permettre l'exploitation commerciale à Palau de plusieurs espèces recherchées à l'exportation. Il serait préférable d'adopter une stratégie de pêche ponctuelle intensive semblable à celle actuellement utilisée pour les trocas, qui prévoit une période de récupération entre les campagnes de pêche et donne le temps de réévaluer la manière dont les stocks réagissent à la pression de pêche.

ACRONYMS

ACP	African, Caribbean and Pacific Group of States
BdM	bêche-de-mer (or sea cucumber)
BMR	Bureau of Marine Resources/Ministry of Resources and Development
CoFish	Pacific Regional Coastal Fisheries Development Programme
CPUE	catch per unit effort
CTSA	Center for Tropical and Sub Tropical Aquaculture
Ds	day search
D-UVC	distance-sampling underwater visual census
EDF	European Development Fund
EEZ	exclusive economic zone
EU/EC	European Union/European Commission
FAO	Food and Agricultural Organization of the United Nations
FL	fork length
GDP	gross domestic product
GPS	global positioning system
ha	hectare
HH	household
KFC	Kuniyoshi Fishing Company
MCRMP	Millennium Coral Reef Mapping Project
MIRAB	Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations)
MRD	Marine Resource Division
MMDC	Micronesia Mariculture Demonstration Centre
MOP	mother-of-pearl
MOPt	mother-of-pearl transect
MPA	marine protected area
MRM	marine resource management
MSA	medium-scale approach
NCA	nongeniculate coralline algae
Ns	night search
NTFMP	Palau National Tuna Fishery Management Plan
OCT	Overseas Countries and Territories
PICTs	Pacific Island countries and territories
PITI	Palau International Traders Incorporated
PMDC	Palau Mariculture Demonstration Center
PMIC	Palau Marine Industries Corporation
PRC	Peoples Republic of China
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
RSW	refrigerated sea water
SBq	soft-benthos quadrat
SCUBA	self-contained underwater breathing apparatus
SE	standard error
SPC	Secretariat of the Pacific Community
USD	United States dollar(s)
WHO	World Health Organization

1. INTRODUCTION AND BACKGROUND

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

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

1.1 The PROCFish and CoFish programmes

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

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

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

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

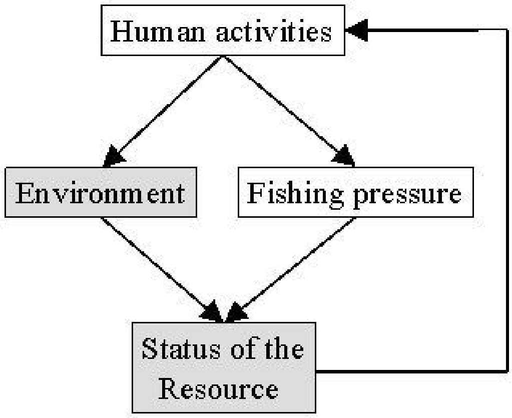

Figure 1.1: Synopsis of the CoFish multidisciplinary approach.
CoFish conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the basis for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

Expected outputs of the project include:

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

1.2 PROCFish/C and CoFish methodologies

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

1.2.1 Socioeconomic assessment

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

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

Socioeconomic assessments also relied on additional complementary data, including:

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

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

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

1.2.2 Finfish resource assessment

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

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

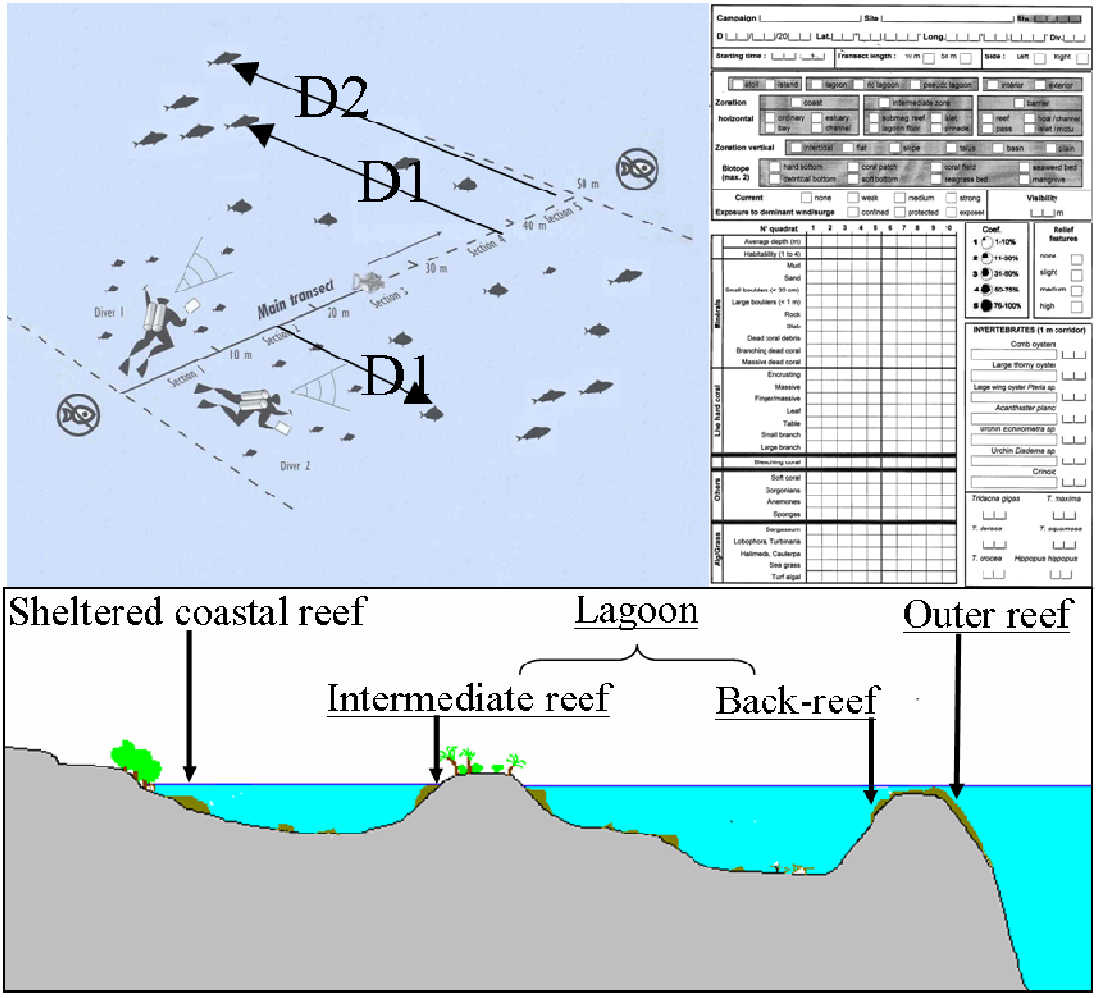

Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

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

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

1.2.3 Invertebrate resource assessment

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

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

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

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

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

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

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

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

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

1.3 Palau

1.3.1 General

The Republic of Palau lies in the western end of the region of Micronesia, 600 km equidistant east of the Philippines and north of Irian Jaya (Figure 1.4). The Palauan archipelago of around 386 islands and islets in 16 states is oriented in a northeast–southwest direction, with the islands lying between 2° and 8°N latitude, and 131° and 135°E longitude (Chapman 2004). Palau's 200-mile Exclusive Economic Zone (EEZ), totalling an area of 629,000 km^2, is the smallest EEZ in the western Pacific. Maritime borders are shared with Indonesia in the south, Philippines to the west, Federated States of Micronesia immediately east, and high-seas areas to the north and south-east, known as 'the Palau-FSM-PNG corridor' (Fitzpatrick and Donaldson 2007). The Palauan islands are mainly volcanic in origin (80%) with the rest made up of coral reef, atoll and limestone. Together they make up a total land mass of approximately 488 km^2. Babeldaob is the largest island, more than 330 km^2 in area; the other major islands are Meyuns and Malakal (Fitzpatrick and Donaldson 2007).

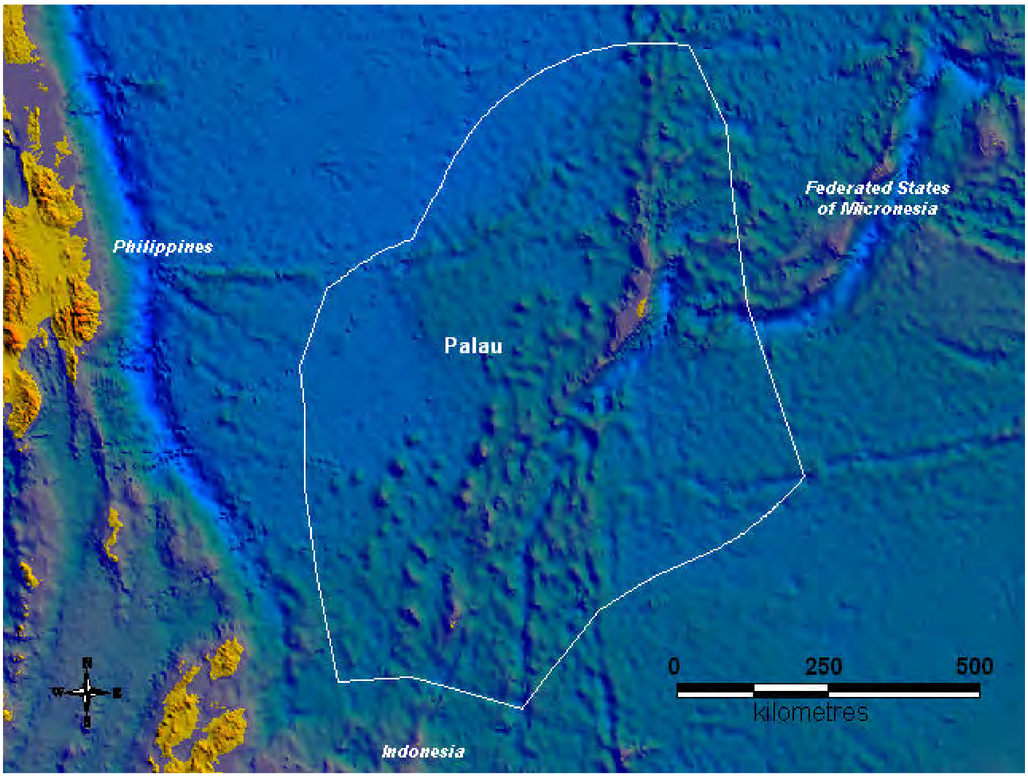

Figure 1.4 : Map of Palau.

The 'Rock Islands', as they are known locally, are the most abundant and unique island type and extend 30 km in length between Peleliu and Koror. They vary geologically from the high, mountainous largest island, Babeldaob, to low coral islands usually fringed by large barrier reefs. Fringing reefs border many of the individual islands, and reef ridges and mounds are abundant in the lagoon and passages between the islands and the barrier reef (Nichols 1991). Coastal marine habitat systems of Palau are dominated by lagoons, which make up a total area of 1034 km^2; outer reef is 265 km^2; inner reef is 187 km^2; and a mangrove system of 45 km^2. These systems support an extensive array of other habitats, including atolls, barrier reefs, fringing reefs, patch reefs, reef walls, lagoons, pinnacles, passes and channels, mangrove forests and seagrass bed. Climate is maritime tropical with little seasonal and daily variation. June and July are the wettest months (Nichols 1991).

The people of Palau are Micronesians of mixed Melanesian, Malay, Philipino and Polynesian ancestry. The recent population of Palau is around 19,907 people; 70% of these are native Palauans and 70% of the population live in the capital city of Koror on Koror Island (SPC 2006). Enumeration of native Palauan households in 2003 for the first time showed males outnumbered by females in all the 16 states at 92 males for 100 females (Government of the Republic of Palau 2003). A large proportion of the 15–44 year age groups (6000) had left to find work outside the Republic (Turner 2008), especially in the United States, and they were replaced by foreign workers, mainly Asians, who make up the second most important ethnic group in the country.

Historically, Palau had several colonial rulers: Spanish in the 1500s, Germany in 1889, and Japan in the 1920s. The United States of America seized the islands from the Japanese after World War II. Palau became a UN trusteeship in 1947, administered by USA as part of the Trust Territory of the Pacific Islands. In 1992, a Compact of Free Association was signed with USA, requiring USA to provide economic aid in exchange for the right to build and maintain US military facilities in Palau. Palau became a sovereign state in 1994, attaining a democratic republic status, headed by the president and two houses of National Congress similar to USA. Palau nationals, similar to other US-affiliated Pacific islands, enjoy free entry into the US Mainland and Territories such as Hawaii and Guam. A Council of Chiefs, comprising the highest traditional chiefs from each of the 16 states, is an advisory body to the president on matters concerning traditional laws and customs (Turner 2008).

Palauan economy is dominated by the service sector, which contributes over 50% of GDP and employs half of the work force. The government employs 25% of workers and accounts for 23% of the GDP (Wikipedia 2008). One of the government's main responsibilities is administering external assistance. Under the terms of the Compact of Free Association with the US, Palau is receiving a total of more than USD 450 million in assistance over 15 years and is eligible to participate in more than 40 federal programmes. The first grant of USD 142 million was received in 1994 and further payments in lesser amounts will be made annually through 2009. In 2006 Palau received a total of USD 23.7 million in grant income (Wikipedia 2008).

Tourism is Palau's main industry. Its major attractions are its diverse and pristine marine environment and its tropical island beauty. Visitor arrival in 2006 totalled 100,000, 15% more than the previous year, and 75% were from Taiwan, Japan, and the US The growing number of visitors is attributed to the reliable direct flights from Philippines, Taiwan and Guam. The value of tourism in 2002 was USD 66 million (Wikipedia 2008). The construction industry, including the new Compact Road development, relocation of the new capital, and new hotels, have boosted this sector's recent contribution to over 15% of GDP. The agriculture sector is represented by subsistence cultivation of coconuts, taro and bananas for food security and surplus for sale locally. The Compact of Free Association created a trust fund to provide perennial budget support when US direct assistance ends in 2009. The value of the trust fund in 2005 was approximately USD 150 million.

Fisheries contribution to the GDP of Palau was about 8% in 1998 (FAO 2008; Gillett 2002). However, Gillett and Lightfoot (2001) presented a drop in fisheries contribution to GDP for Palau from 4.1% in 1995 to 2.8% in 1999. Although substantial, this has declined dramatically in the last 10 years, partly due to a decline in the locally based longline fishery and strong growth in the tourism sector. The fisheries sector, however, still dominates commodity exports for Palau, mainly tuna and reef fisheries products. In 1995, Palau exported 2500 mt of tuna at an estimated value of USD 12.5 million. Coastal reef fisheries today are more important for food security. About 1100 Palauans are subsistence fishers and 200 are commercial fishers (FAO 2008).

1.3.2 The fisheries sector

The fisheries sector in Palau is divided into offshore fisheries for tuna and tuna-like species and the inshore fisheries (including aquaculture) comprising the deep-bottom fishery for snapper, shallow-reef finfish fisheries, invertebrates and ornamental collection. Tuna fisheries include both industrial-scale and small-scale recreational and artisanal activities in the coastal waters. The main challenge for the offshore fisheries is to achieve greater sustainable returns from locally based foreign fishing vessels' activities in its exclusive economic zone.

The inshore fishery is critical to Palau's domestic food supply. Traditional fishing methods included throwing spears, the use of sea cucumber skin, which emits a nerve toxin when rubbed (used to poison fish in shallow pools), a leaf sweep (rope or vine with leaves used to herd and capture fish), noose fishing for sharks, a gorge (piece of wood sharpened at both ends and attached to a line in the middle), and stone and wooden fish weirs built on the reef flats. These methods have now given way to more modern methods, such as stationary barrier nets or gillnets, underwater spearfishing (due to the introduction of goggles, and later waterproof torches for night spearfishing), cast nets, and portable fish traps (Johannes 1981). Paddling and sailing canoes have also been replaced in many parts of Palau by outboard-powered skiffs. The current challenge for inshore fisheries is centred around balancing exploitation rates of resources for subsistence and commercial activities with maintaining a healthy ecosystem and the fisheries resources.

Offshore tuna fishery

Industrial tuna fishing in the waters of Palau has been an important activity for over 80 years, although Palauans have not been very involved during this time (Chapman 2000). The Japanese were the pioneers, with pole-and-line activities for skipjack tuna (*Katsuwonus pelamis*) across the Micronesian region, which started in the late 1920s (SPC 1984). Early production peaked in the Micronesian areas at 33,000 mt in 1937, with 75% of this coming from Palau and Chuuk (Rothschild and Uchida 1968). Fishing, however, declined during World War II and did not resume in Palauan waters until the US Van Camp Seafood Company transhipment base was established in 1964 in Koror, supported by up to 15 locally based pole-and-line vessels (SPC 1984, Chapman 2000). Landings peaked from 1978 to 1981, when an average of 6600 mt of skipjack were caught annually (SPC 1984). The pole-and-line activity was later replaced by the more cost-effective and competitive purse-seining method of tuna fishing, forcing the Van Camp operation to close down in 1982 (Chapman 2000).

Japanese distant-water tuna longlining activity also started in the waters around Palau in the 1960s, although effort was sporadic during the 1970s and 1980s (Chapman 2000). The initial target species was the larger yellowfin tuna (*Thunnus albacares*). This changed over time with vessels setting their gear deeper to target the high-value bigeye tuna (*Thunnus obesus*). The 1980s also saw Korea and Taiwan develop their distant-water longline fleets to supply fish to the Japanese market (Chapman 2000). Changes in Japanese consumer preference for fresh tuna over frozen tuna in the 1980s led to changes in the longline fleets, with smaller vessels making shorter trips and using ice, refrigerated sea water (RSW) or brine for chilling the catch. The fish was landed to shore facilities for airfreight to Japan. Two companies established themselves in Palau: Palau International Traders Incorporated (PITI) in the late 1980s, and Palau Marine Industries Corporation (PMIC) in the early 1990s (PSC 1999). Both companies commenced their fishing operations by bringing in foreign vessels, mainly from the Peoples Republic of China (PRC). A third company, Kuniyoshi Fishing Company (KFC) was established in the mid-1990s, and mainly brought in Taiwanese or PRC vessels to supply them with fish (PCS 1999, Chapman 2000).

The tuna industry in Palau today involves transhipment of fresh and frozen fish by airfreight to Japan and Asia. The same three companies are involved in this venture: two with shore-based facilities for processing and packing (PITI and PMIC) and the third one (KFC), which operates from the wharf. The shore-based activities provide jobs for Palauans. A total of 95 small longliners mainly from PRC and Taiwan were involved in this venture in 2003 (Gillett 2003). Production from these three companies in 2001 was 1893 mt of fresh tuna and 234 mt of frozen tuna all exported to Japan (Gillett 2003). A japanese fleet of longliners, purse seiners and pole-and-line vessels was also active in Palau waters under a bilateral access agreement with the Japan Fisheries Association.

Tuna fishing activity in Palau declined in fleet structure and landings from 1993 to 2003 as a result of the migratory nature of the tuna stocks (Fitzpatrick and Donaldson 2007). This decline was due to the tuna moving eastward as a result of El Niño conditions, causing fleets to move east to FSM to follow the fish (Sisior 2004). As the fish moved westward again with la Niña conditions, the Japanese tuna fleet increased to 53 vessels in 2006 although the biggest increase was in the Taiwanese fleet. Altogether, a total of 266 longline vessels were licensed to fish in the Palau EEZ in 2006, as well as 29 Japanese purse seiners (Sisior 2007). Licence fees are one of the government's main revenue sources from the fisheries sector. Recent increases in landings are attributed to an increase in the bigeye tuna catch. Total catch in 2006 from the Palau EEZ was estimated at 5370 mt (Sisior 2007). Palau is a strong party to the US Multi lateral Treaty with the FFA member countries, which allows US purse seiners to fish in FFA member-country waters. From this FFA countries derive benefit from treaty allocation and from catch composition from each country's EEZ waters.

National involvement in the tuna fishery in Palau, as in other smaller Pacific Island countries, is limited to a single locally based pole-and-line vessel, which lands around 100 mt of skipjack tuna annually (Chapman 2004). In addition, in the early 2000s, eight Philipino-design pump-boats (6–9 m trimarans) worked with a mother ship around some fish aggregating devices (FADs) on a trial basis, although no catch records are available (Chapman 2004).

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

Traditionally, some areas of Palau used sailing canoes and feather lures to troll for tunas and other pelagic fish outside the reef (Chapman 2004). Outboard-powered skiffs and artificial or synthetic lures were introduced to the fishery in the 1960s. In support of the small-scale tuna fishery, the Palau Marine Resources Division (MRD) initiated a FAD programme in 1980, with six deep-water FADs deployed (Watt and Chapman 1998). A second FAD programme was initiated in 1990 and 1991 and a joint activity with MRD and the Palau Community Action Association, with seven FADs deployed (Anon. 1991). Also at this time, SPC was requested to provide technical assistance with FAD site surveys and mid-water fishing methods used in association with FADs. This assistance was provided in late 1991 and 1992, with 10 site surveys identifying six suitable locations, the deployment of two FADs, and the training of local fishers and MRD staff in vertical longline fishing activities (Watt and Chapman 1998).

In 1999 it was reported that around 20–30 boats fished part-time for tuna and other pelagic species outside the reef (Chapman 2004). Several FADs were deployed in 1998 and 1999; however, their lifespan was less than 12 months. SPC received a second request for technical assistance in 2002, to further promote mid-water fishing methods used in association with FADs. This assistance was provided in the same year, with 17 MRD staff and interested fishers trained in the construction and use of vertical longlines and *palu-ahi* mid-water handlining (Beverly 2003).

MRD conducted a study on sportsfishing and gamefishing in 1994–1996, which generated a lot of interest in these activities, and a sportsfishing association was established (Idechong and Graham 1998). In the late 1990s, there were three charter fishing vessels engaged in sportfishing, although several other dive boats also provided this service to tourists (Gillett 1999, Idechong and Graham 1998). A few dozen semi-commercial fishing operators targeted coastal tuna and other pelagic species by trolling close to the reef. Sportsfishing in Palau includes offshore or nearshore trolling and casting, spinning and fly-fishing in the lagoon for reef species. Sportsfishing operators are members of a Sport Fishing Association. Association members are concerned that tuna longlining may affect the number of tuna and marlin available for sportsfishing in Palau (Chapman 2000, Idechong and Graham 1998, Gillett 1999). There are two sports fishing or gamefishing tournaments per year in Palau, one in April and the other in November (Whitelaw 2001).

Deep-water snapper fishery

Deep-water snapper fishing is relatively new to the fishers of Palau. Prior to the 1980s, handlining was conducted to a depth of around 80 m (Taumaia and Crossland 1980). In late 1979 and early 1980, SPC's Deep Sea Fisheries Development Project introduced deep-water fishing techniques and trained local fishers in making up the gear and the fishing technique (Taumaia and Crossland 1980). This was followed by a second visit by SPC in 1983, when a survey of deep-bottom fishing grounds was undertaken to assess the economic potential for a deep-bottom fishery. Training local fishers and a government demonstration team was also an important part of the project (Taumaia and Cusack 1997). SPC provided additional assistance in 1987/1988, with the objectives of looking for offshore seamounts using deep-water echo-sounding equipment, and trial fishing in areas previously fished. One seamount was located during this visit and fishing trials recorded low catch rates (1.84 kg/reel-hour) compared to those of the 1983 trials (4.2 kg/reel-hour), which indicated a fragile and limited deep-water snapper resource in Palau (Chapman 1997).

The deep-water fish resource of Palau is dominated by 13 species of Lutjanidae, Lethrinidae and Serranidae (Nichols 1991). The best fishing grounds are in the areas of the north northeast and south southwest reefs (Taumaia and Crossland 1980). Dalzell and Preston (1992) made an assessment of the deep-water snapper stocks based on the three fishing trials conducted by SPC in the 1980s. They concluded that the maximum sustainable yield for deep-water snappers was between 16.2 and 48.7 mt/year, and that the catches in 1988 were already approaching this figure (Dalzell and Preston 1992). In 2003, there were no fishing vessels in Palau targeting deep-water snappers, with some fishers working on an *ad hoc* basis only, and their catch sold on the local market (Chapman 2004).

Deep-water shrimp survey

A deep-water shrimp survey was funded by the US Department of Commerce to determine the potential of a deep-water shrimp fishery in Palau waters. The project was in two phases. Phase I (June to August 1987) was to evaluate the depth distribution of the deep-water shrimp, and different trapping techniques at various sites. Phase II (June to August 1988) used underwater camera gear to learn more about deep-water shrimp feeding habits, acceptance to different baits, and the general behaviour of the commercial-value species, *Heterocarpus leavigatus* and *H. hensifer* (Anon. 1989).

Aquaculture and mariculture

The Micronesia Mariculture Demonstration Centre (MMDC) was established in 1973 to serve the US-affiliated Pacific Islands by developing, demonstrating and promoting mariculture technology. MMDC later became the Palau Mariculture Demonstration Center (PMDC), and was used for mariculture training in the region as well as a marine science research laboratory (Gillett 2002). Trochus and soft corals were cultured for reseeding research but also giant clams and soft corals were sold to the aquarium market (Graham 1996). The facility also supported a handful of giant clam grow-out sites around Palau in the 1990s (Gillett 2002). The hawksbill turtle hatchery and ranching project that started in the early 1980s was terminated in the early 1990s and replaced with turtle research and a public education programme (Anon. 1989, Anon. 1991).

Trials in seaweed, milkfish, crocodiles, oysters, shrimps and sponges have been carried out by the Center, but have yet to be proven potentially viable (Evans *et al.* 2003). Recent research is focused on spawning marine fishes of the grouper family, *Epinephlus fuscoguttatus,* coral trout *Plectropomus leopardus* and *P. areolatus* and Napoleon wrasse *Chelinus undulatus.* Grouper fingerlings are transferred to Ngatpang where they are raised in net-cages in the lagoon (Ponia 2006). A major milkfish farm is also being developed at Ngatpang with milkfish fry imported from the Philippines and using Philippine labour and expertise. In addition, a mud crab (*Scylla serata*) ranch is trialling at the possibility of fattening baby crabs for the market (Kalo Pakoa pers. obs. April 2007).

Reef fisheries (finfish and invertebrates)

Shallow-water finfish

Finfish from reefs and lagoons comprise a large portion of the catch of the subsistence and semi-commercial reef-fishery sector in Palau (Maragos *et al.* 1994b). As is the case with other island countries in the region, the reef-fish fishery of Palau is a multi-species and multi-gear fishery. About 80 species of reef fish from 13 families are involved in the fishery including snappers (Lutjanidae), emperors (Lethrinidae), groupers (Serranidae), parrotfish (Scaridae), wrasses (Labridae), rabbitfish (Siganidae), surgeonfish (Acanthuridae), trevallies (Carangidae) and herrings (Clupeidae) (Nichols 1991). Dominant individual species that support reef fish fisheries in the 1980s included *Siganus canaliculatus*, *Epinephelus fuscoguttatus*, *E. microdon*, *Plectropomus areolatus*, *P. leopardus*, *Cetoscarus bicolor*, *Hipposcarus longiceps*, *Scarus spinus*, *S. ghobban*, *Bolbometopon muricatum* and *Chelinus undulates* (Nichols 1991, Kitalong 1991). In the 1990s, most reef fishing occured around the states of Koror, Peleliu and Angaur.

The reef-fish production estimate for Palau for 1988 was about 1814 t, of which 65% was consumed by the subsistence sector for food security and the rest sold locally and exported mainly to Guam (Shimada cited in Maragos *et al.* 1994b). Estimates of reef-fish production in Palau are available (Kitalong and Dalzell 1991, Kelty *et al.* 2004), but more recent estimates (Birkeland *et al.* 2000) set an average harvest levels at 1800 mt of reef fish per year. Rabbitfish (*Siganus canaliculatus*), found throughout the archipelago, is a significant species in landings, and is a culturally important fish in the Palauan diet. About 11 mt of rabbitfish was landed in 1990, valued at around USD 25,000 (Nichols 1991). Parrotfish are an important component of the artisanal sector and the four species (*Cetoscarus bicolor*, *Hipposcarus longiceps*, *Scarus spinus* and *Scarus ghobban*) were among the top ten reef fish landed at the local fish markets in Koror in the 1990s (Nichols 1991).

Commercial fishers landed over 250 mt of inshore fish, lobsters and mangrove crabs in 1990, with 155 mt of this being finfish exported to mainly Guam and Saipan (Anon. 1991).

Although only a part of the commercial landings, purchase records from major fish retailers put the landings and dockside value for 1991, 1992, and 1993 at 350.5 mt (USD 1032,000), 599.1 mt (USD 1624,000), and 418.9 mt (USD 1077,000) respectively (Anon. 1996).

Groupers and humphead wrasses were important in the subsistence and semi-commercial fishery in Palau. Exploitation of these species increased in the 1990s due to the live reef food fish trade development trials. Production at Helen Reef during a two-year experimental fishing trial yielded 50 mt of humphead wrasse (*Chelinus undulates*) and groupers (*Epinephelus* spp. and *Plectropomus* spp.). Production for the main archipelago over a 10-year period in the 1990s yielded 127 mt of live reef food fish and aquarium fish (Graham 2001). Live reef food fish fishing ceased in Palau at the end of the 1990s due to overexploitation of stocks.

A survey at Helen Reef in 2000 failed to detect humphead wrasse and grouper, which suggests both species may have been overfished during the LRFFT trial (Birkeland *et al.* 2000). Other surveys (Kitalong and Oiterang 1992, Davis and Kearns 2003) have documented low populations of grouper at aggregation sites and dive sites. Groupers are now protected in Palau with a sale ban between May and August to protect spawning aggregation (Sadovy and Domeier 2005). Humphead wrasses are also protected from commercial export. Bumphead parrotfish (*Bolbometopon muricatum*) is still harvested in spite of a serious decline in stocks (The Environment Inc. 2003). In general, fish populations off the main islands of Palau are showing signs of overfishing compared to the southwestern islands where there is less fishing pressure. Around the main islands of Palau, highly desired species of fish are either absent, or present only in low numbers (Turgeon *et al.* 2002).

Aquarium fishery (pet fish or ornamental reef fishery)

The marine aquarium trade started in 1991 with one company being involved in the trade. The national government's Palau Mariculture Demonstration Centre was also involved in the trade, but its business was limited to cultured giant clams and soft corals. In 1993, a total of 38,553 live fish were exported for a value of USD 48,600 (Anon. 1996). In 1994 Palau exported 100,000 fish from 200 species and 40,000 invertebrates from 100 species at a total value of USD 200,000, making this trade Palau's second-most important export activity (Graham 1996). Current production in this trade is not exactly known but export status extracted from UNEP databases in early 2008 put Palau's exports at around 20,000 pieces worth around USD 50,000 (Anon. 2008).

Invertebrates

Molluscs

Trochus (*Trochus niloticus*) is native to Palau and occurs throughout the archipelago; however, trochus are more abundant along eastern and north-eastern reefs and in the shallow west-facing reefs (Maragos *et al.* 1994b). Fishing for trochus is an old fishery in the Pacific region; in Palau it began in 1899 under the German occupation. Sale of trochus shells by local inhabitants of the Pacific Islands marks the initial commercialisation of fisheries resources that communities were involved in. As in other places in the region, Palauans started to earn money by selling their trochus shells and sea cucumbers to obtain money to buy imported products during the early trading years. Trochus remains an important resource in Palau, generating significant incomes for rural populations (Matthews 2003).

Harvests of trochus in the 1920s ranged from 200 to 360 mt; from the late 1920s to the 1970s, harvests fell to around 100 mt. This early fall in production resulted in the establishment of management systems of 'resting' stock between harvests since the 1980s. However, continued harvesting over the years has resulted in stock depletion (Nichols 1991). In 1992, following a three-year moratorium, fishers landed a total of 265.1 mt, with a dockside value of USD 645,000. This equated to 251.9 mt of cleaned and dried shell, which, when exported to Asian markets, brought in USD 1.1 million (Anon. 1996). The 1995 harvest was 428 mt with a dockside vale of USD 1.8 million (Anon. 1996).

At Helen Reef, trochus stocks have been virtually eliminated by poachers (Birkeland *et al.* 2000). A stock assessment to allocate harvestable quantity in 2002 (Kitalong 2002) reported higher densities on the western reefs of Babeldaob and estimated total tonnage of harvestable sizes for Kayagel to Peleliu of around 2400 mt. The actual quantity taken out of this estimate is unknown and recent production data are not available. However, harvest production was reported to fall by 47 mt from 1989 (257 mt) to 2000 (210 mt) (Fitzpatrick and Donaldson 2007).

Giant clams (Tridacnidae) are represented in Palau by seven species (*Tridacna gigas*, *T. derasa*, *T. squamosa*, *T. maxima*, *T. crocea*, *Hippopus hippopus*, and *H. porcellanus*) distributed in shallow waters of the Palauan islands (Maragos *et al.* 1994a, 1994b). Giant clam meat is an important traditional food source in Palau. Fishing is mainly for subsistence, although surplus is often sold at the local market. Export of clam meat or whole shell collected from the wild is illegal. Assessment of the resource conducted around the main archipelago and the southwest islands revealed a declining population due to over-exploitation (Maragos *et al.* 1994b; Birkeland *et al.* 2000). Palau was one of the first Pacific Island countries to develop a mariculture sector through the Micronesia Mariculture Demonstration Center, which was set up in 1973. Giant clam and trochus were the main species cultured by the centre for research into the potential of mariculture in the management of these resources. The centre has been producing thousands of giant clam seeds since the 1980s for restocking back on to the reefs of Palau. The main species cultured are *T. gigas*, *T. derasa*, *T. squamosa* and *H. hippopus*.

The pearl oyster (*Pinctada margaritifera*) fishery was important in the past during the Japanese administration, but fishing of wild stocks ceased as the stocks became overfished (Maragos *et al.* 1994b). Other bivalves of importance in the subsistence fishery are mangrove clams (genera *Anodonita*, *Polymeseda* and *Terebralia*), and oysters (*Crassostrea* spp.) (Fitzpatrick and Donaldson 2007).

Crustaceans

Two species of spiny rock lobster (*Panulirus penicillatus* and *P. versicolor*) are important in the subsistence and commercial fishery; other species are present but are of lesser importance. Commercial fishing of lobsters began in 1966 to supply the local market and resource assessment in the 1990s indicated the resource had suffered from overexploitation (Kitalong and Oiterong 1992). Production over a ten-year period from 1989 to 1998 varied from 9 to 25 mt (The Environment Inc. 2003) and recent data on stocks and landings are needed to verify existing information. Mud crab or mangrove crab (*Scylla serata*) is an important catch of the semi-commercial sector and is mainly produced from the mangrove habitats of the main island of Babeldaob. The state of Ngatpang is the main supplier of crab, accounting for 40% of the country's harvest in the 1990s (Maragos *et al.* 1994b). Three species of land crab important in the subsistence fisheries are *Cardiosoma hirtipes*, *C. cornifex* and *Gecorcoidea lalandii* (Matthews 2003).

Sea cucumbers and sea urchins

There are 12 commercially important species of sea cucumber in Palau waters and the most important species are *Holothuria scabra*, *H. fuscogilva*, *H. nobilis*[5], *Actinopyga mauritiana*, *A. miliaris*, *A.* spp., *Bohadschia argus* and *Thelenota ananas* (Fitzpatrick and Donaldson 2007). Trade in dried sea cucumber goes mainly to Hong Kong, Taiwan and China. In addition, sea cucumber is featured in the subsistence fishery as food items in Palau. Local edible species include *Stichopus vastus* (*ngimes*), *Actinopyga* spp. (*cheremrum*), *H. scabra* (*molech*) and *H. impatiens* (*sekesakel*) (Lambeth 1999). The intestines of these species are eaten raw or sold in bottles, and the body wall of *Actinopyga* spp. is prepared in a special traditional way. Figures on export production of bêche-de-mer from Palau were not exactly known but total landings between 1989 and 1998 were estimated at 11.8 mt, of which half (5.5 mt) was sold locally, 0.5 mt exported and the rest (5.8 mt) was consumed by the subsistence sector. Palau has imposed a moratorium on the export of sea cucumbers with the ban currently in place for more than 15 years. Exploitation of sea cucumbers for domestic use, though, is allowed, with more than ten species known to be harvested by local coastal communities. The sea urchin *Tripneustes gratilla* is harvested in Palau but no data are available.

Tourism

Tourism is the single most important industry in Palau and eco-tourism is a major part of that industry. A unique part of Palau's attraction is the area known as 'rock islands', spectacular world-class dive sites and the diversity of marine species, such as the photosynthetic jellyfish and the 'jellyfish lake'. The government realises the importance of tourism and provides strong support for the sector with hopes that it will provide a stimulus for other economic activities in Palau. The industry derived USD 67 million or 47% of the Gross Domestic Product (GDP) in 1996 (ADB 2005).

Tourist arrival fluctuated during the 1990s until 2001 in the range of 30,000 to 60,000 visitors. Various factors, including the Asian economic crisis, the SARS epidemic and the September 11 event in USA, but arrivals have since returned to normal with substantial growth in visitor numbers. The number of visitors was 95,000 in 2004 (ADB 2005). Future growth in the tourism sector is going to be a challenge for Palau if environmental health is to be maintained.

1.3.3 Fisheries research activities

Palau's reefs and resources are relatively well studied compared to the other island countries in the region. A comprehensive ecological survey (Maragos *et al.* 1994a, 1994b) provided a good documentation of the status of reef resources (fish and invertebrates) of Palau. A more recent assessment of the resource status of Helen Reef by Birkeland *et al.* (2000) documents the recent status of resources in the area. A review of the results of modern biological surveys

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

of different reef resources, the environment and fisheries production in Palau is provided by Fitzpatrick and Donaldson (2007). Sea cucumbers and echinoderms are documented by Maragos *et al.* (1994b) and the invertebrates of Airai State were surveyed by Kitalong (2003).

Many research activities in Palau are conducted by the Palau Conservation Society (PCS) with funding from PCS corporate partners. Many of these are local businesses who have shown their dedication to protecting the environment by becoming a Corporate Partner to PCS. PCS Corporate Partners commit funds by making annual donations to PCS, usually a certain percentage of their annual profits. Corporate Partnership allows the same benefits as membership.

Research in the aquaculture sector, especially for clams and trochus, has been supported by the Center for Tropical and Sub Tropical Aquaculture (CTSA) including technical support and capacity building. The Palau Community College is involved in research of various types of aquaculture.

Socioeconomic issues

Palau is experiencing an aging population, low fertility and a large presence of foreign workers. Despite weak economic growth, the country enjoyed a 4.7% annual growth in the employment sector from 1994 to 2003. Temporary residents, mainly foreign workers, represent 28% of the country's population, and outnumber the local Palauan workers (ADB 2005). Palau is enjoying one of the region's lowest unemployment rate (2.3% in 2000), a high standard of government services, and a relatively high standard of education and health. However, a changing lifestyle as a result of a high dependence on imported food is creating a potential epidemic of non-communicable diseases, which undermine people's quality of life. Palau is rated as having the seventh-fattest people in the world according to World Health Organization figures. Poor diet, western-style junk food, and a lack of exercise have put Palauans at risk of premature death from weight-related illnesses (Encyclopaedia Britannica 2008). A large part of the population (6500) lives abroad, mainly in the US. With a high emigration rate of young people, future development of the local workforce is uncertain. Reliance on foreign workers is, therefore, likely to remain for many years yet.

The Palau socio-cultural system is matrilineal, i.e. matrilineal descent determines social position, inheritance, kinship structure, residence patterns and land tenure. Women in Palau maintain an important presence in the national government today. Although investment is promoted in the country, access to land is seen as a key obstacle to secure business development as land in Palau remains the birthright of the native community.

Inshore fisheries are an important source of food security in Palau and women's contribution to securing food for the family is an important part of subsistence reef fisheries (Lambeth 1999).

1.3.4 Fisheries management

National government agencies charged with marine resources development and management are the Ministry of Natural Resources and the Ministry of State. The Palau Maritime Authority in the Ministry of State is responsible for issuing fishing licences for activities within the 12–200-mile fisheries zone. Territorial waters are managed under the State Governments. The Bureau of Marine Resources (BMR) under the Ministry of Resources and

Development is responsible for research and development activities and monitoring, advices and trainings. The BMR works under the Fisheries Act 1975 and its supporting regulations, which fall under the Palau National Code, Title 27 (Sisior 2007). In addition, the Marine Protection Act enacted in 1994 enabled Palau to adopt more stringent restrictions on sale, harvest and export of marine resources, including: giant clams, lobsters, trochus, mangrove crabs, coconut crabs, sea cucumbers, napoleon wrasse, humphead parrotfish, groupers, aquarium fish and hard corals. Gear restriction includes the use of SCUBA and small-mesh nets for fishing (Chapman 2004). Harvesting of trochus is regulated by short open seasons and the sea cucumber fishery has been closed for the last 10 years. Palau has been a regional leader in giant clam (*Tridacna gigas and T. derasa*) farming for stock rehabilitation and for the aquarium market (Graham 1996). Palau is also a leader in conservation activities with 21 sites all over the country established as conservation areas. These include: grouper spawning aggregation sites, the rock islands and the jellyfish lake. Palau Conservation Society has been an instrumental force in consolidating support in this initiative. These conservation sites have contributed to eco-tourism development in Palau.

The Palau National Tuna Fishery Management Plan (NTFMP) developed in 1999 was ratified in 2002. The overall objectives of NTFMP is to derive greater benefits from Palau's tuna resources through effective management, increased revenue, local industry development, capacity building and regional cooperation in tuna fisheries management. Despite not yet being fully implemented, management measures stipulated in the plan have been implemented since 2003 (Lewis 2004). Palau is a strong member of FFA and has participated effectively in greater regional cooperation in tuna management effort (IW:LEARN 2008). One of Palau's recent efforts is a national ban on live reef food fishery and joint agreement by PNA countries to enforce a high-seas fishing ban in the Palau-FSM-PNG corridor (Sasako 2008).

Palau also has an active traditional management system that is being used to manage resources. However, the traditional system is changing as a result of the strong centralised national government system, and traditional chiefs are now being integrated into the state government system to retain influence (Ridep-Morris 2004).

1.4 Selection of sites in Palau

Four CoFish sites were selected in Palau: Ngarchelong in the north–northwest, Ngatpang in the west, Airai in the south–southeast, and Koror in the southwest. These sites were selected for two reasons. First, these sites shared most of the required characteristics for our study: they had active reef fisheries, were representative of the country, were relatively closed systems[6], 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 Palau's Bureau of Marine Resources. Second, there was a mix of marketing arrangements for the non-subsistence catch, road-side sales, exports to Koror, the capital and main urban centre for sale, and export of some species, such as trochus, to overseas markets.

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

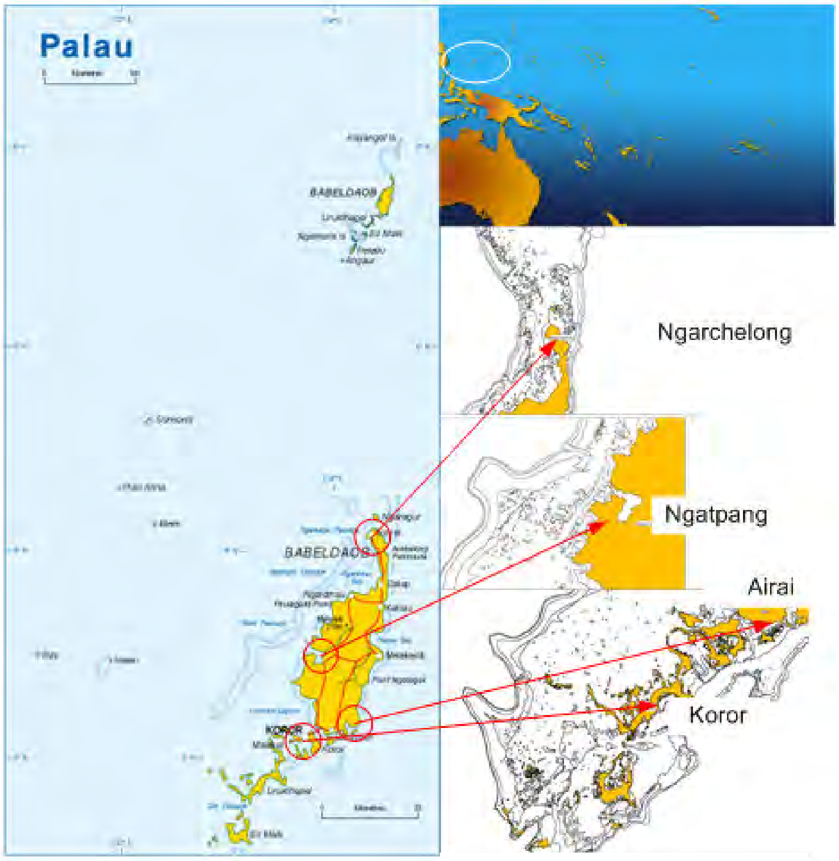

Figure 1.5: Map of the four sites selected in Palau.

2. PROFILE AND RESULTS FOR NGARCHELONG

2.1 Site characteristics

Ngarchelong is a village located at the extreme north–northwest tip of the island of Babeldaob, the main island of the Palau archipelago (Figure 2.1). The approximate position is 07°45'N, 134°37'E. The fishing area extends between 7°53'N and 8°06'N over a length of about 13 nautical miles. It is an open-access area. A marine conservation area is located in the northwest of this area, positioned at 7°46'4N, 134°34'5E, with a total surface of 90 km². This reserve has been effective since 1994. The southern lagoon receives a little terrigenous influence from the rivers. The coastal reefs are bordered in many places by small mangroves. Intermediate reefs are more abundant in the northern area. The eastern reefs and all back-reefs are very sandy.

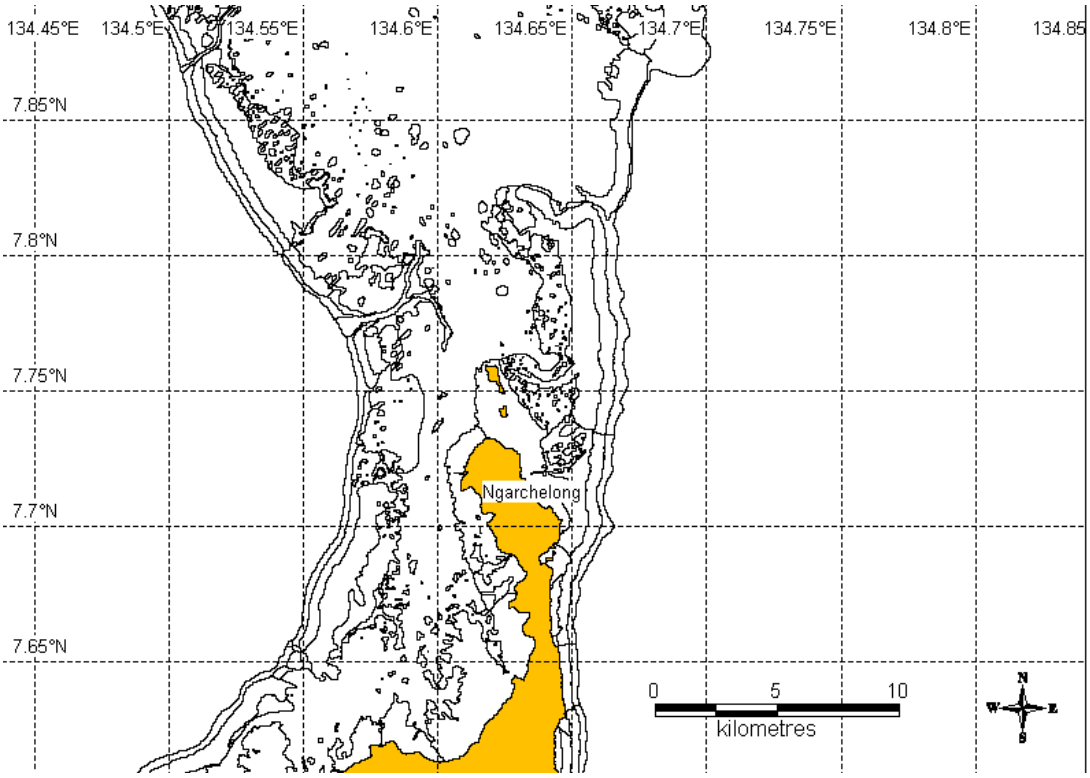

Figure 2.1: Map of Ngarchelong.

2.2 Socioeconomic surveys: Ngarchelong

Socioeconomic fieldwork was carried out in the Desbedall and Ollei communities (in the following referred to as 'Ngarchelong') located on the northern part of Palau's main island in May – June 2007. The survey covered a total of 25 households (14 in Desbedall, 11 in Ollei) including 87 people. Thus, the survey represents about 47% of the community's households (53) and total population (184).

Household interviews aimed at the collection of general demographic, socioeconomic and consumption parameters. A total of 23 individual interviews of finfish fishers (16 males, 7 females) and 15 invertebrate fishers (5 males, 10 females) were conducted. These fishers belonged to one of the 25 households surveyed. Sometimes, the same person was interviewed for both finfish fishing and invertebrate fishing.

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

Our survey results (Table 2.1) suggest an average of one fisher per household. If we extrapolate our survey results, we arrive at a total of 61 fishers in Ngarchelong. Applying our household survey data concerning the type of fisher (finfish fisher or invertebrate fisher) by gender, we can project a total of 38 fishers who only fish for finfish (males, females), a total of six fishers who only fish for invertebrates (females) and 17 fishers who fish for both finfish and invertebrates (males, females).

More than half, i.e. 60% of all households in Ngarchelong own a boat, and most (87%) are motorised; the remaining 13% are non-motorised (canoes, hulls not fitted with an outboard engine).

Ranked income sources (Figure 2.2) suggest that fisheries are not an important sector as compared to salaries. Only 12% of the households indicated that fisheries are their first source of income, and another 24% quoted fisheries as a complementary secondary income source. Salaries provide 56% of all households with first income; other sources, including retirement payments, welfare and handicrafts, provide 32% of all households with first and 4% of all households with second income. Agriculture does not play any important role, accounting for 12% only: 4% as first and 8% as second source of revenue.

The importance of fisheries, however, shows in the fact that all households consume fresh fish, and the majority (80%) also consume invertebrates. The fish that is consumed is mostly caught by a member of the household (84%), rarely bought (16%) but often received as a gift (60%). The proportion of invertebrates caught by a member of the household where consumed is lower (52%). Invertebrates are also much less often bought (16%) or received as a gift (12%) in comparison to finfish. Finfish and invertebrates that are marketed mainly target the Koror and other urban markets rather than the Ngarchelong community itself.

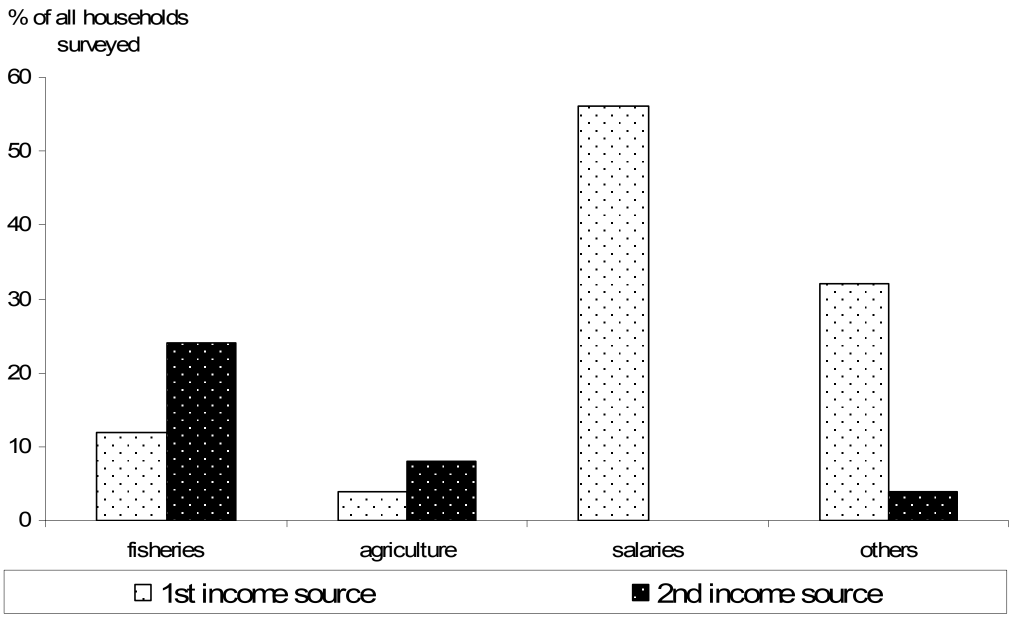

Figure 2.2: Ranked sources of income (%) in Ngarchelong.
Total number of households = 25 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly represented by retirement payments, welfare and handicraft.

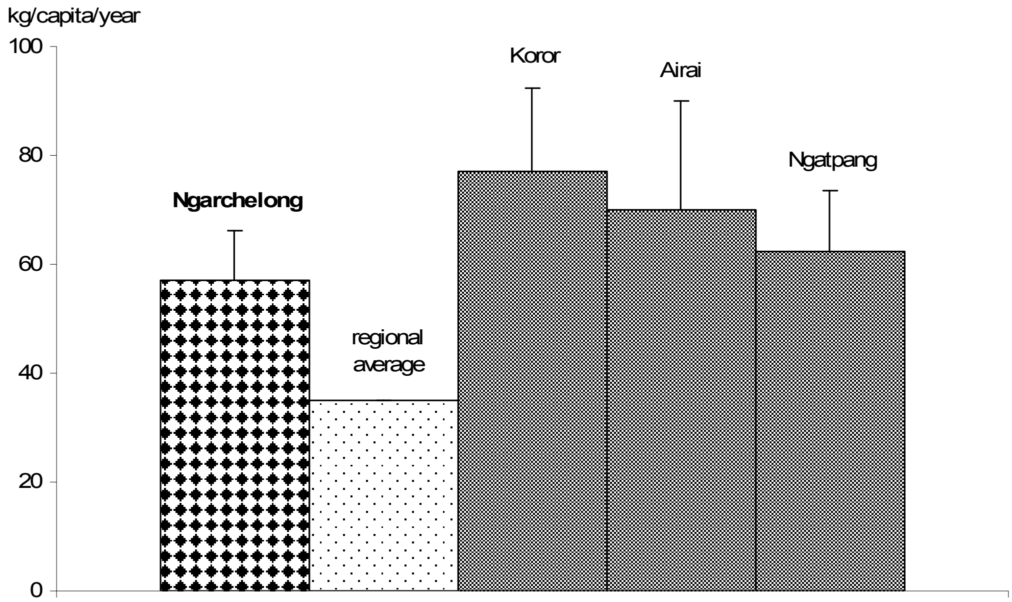

Figure 2.3: Per capita consumption (kg/year) of fresh fish in Ngarchelong (n = 25) compared to the regional average (FAO 2008) and the other three CoFish sites in Palau.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent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

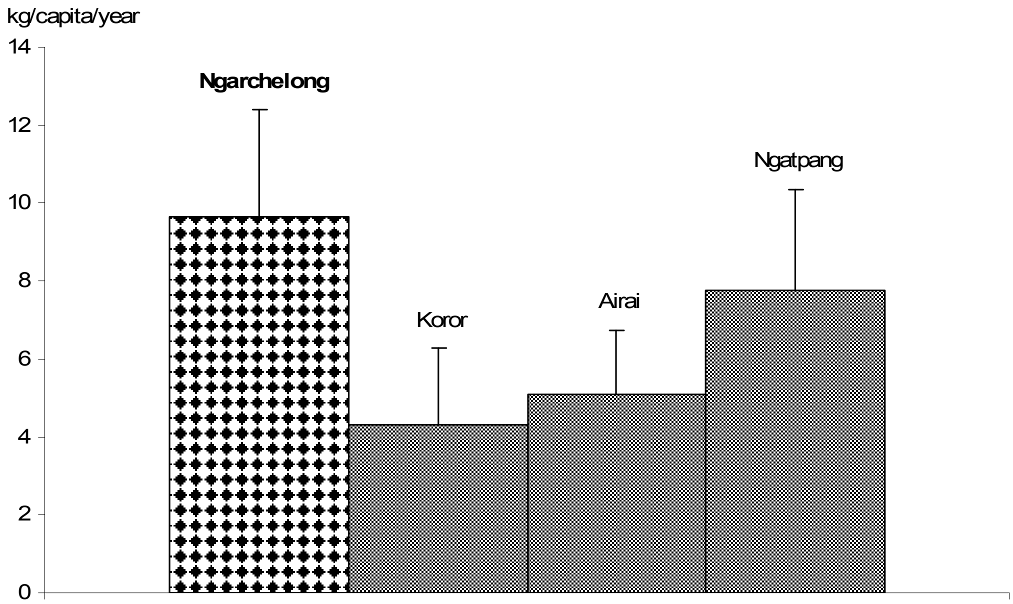

Figure 2.4: Per capita consumption (kg/year) of invertebrates (meat only) in Ngarchelong (n = 25) compared to the other three CoFish sites in Palau.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

The per capita consumption of fresh fish is ~57 ±9.2 kg/year in Ngarchelong, which is above the regional average (FAO 2008) (Figure 2.3), but lower than the consumption across all CoFish sites investigated in Palau. The per capita consumption of invertebrates (meat only) is ~10 kg/year (Figure 2.4) and significantly lower compared to finfish but higher than the average invertebrate consumption found for all CoFish sites in Palau. Canned fish consumption is low at ~6.5 kg/person/year and similar to the average consumption level found for all CoFish sites in Palau (~6 ±7.91 kg/person/year) (Table 2.1).

Comparing results among all sites investigated in Palau (Table 2.1), the people of Ngarchelong province are similarly not very dependent on fisheries for income generation. Ngarchelong people eat less fresh fish in a year, but more invertebrates and about the same amount of canned fish. The average household expenditure level is significantly lower than the average but, overall, remittances are not important in Ngarchelong, as elsewhere.

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

Survey coverage	Site (n = 25 HH)	Average across sites (n = 128 HH)
Demography		
HH involved in reef fisheries (%)	80.0	74.2
Number of fishers per HH	1.16 (±0.16)	1.12 (±0.08)
Male finfish fishers per HH (%)	48.3	53.8
Female finfish fishers per HH (%)	13.8	4.2
Male invertebrate fishers per HH (%)	0.0	0.7
Female invertebrate fishers per HH (%)	10.3	9.1
Male finfish and invertebrate fishers per HH (%)	10.3	16.1
Female finfish and invertebrate fishers per HH (%)	17.2	16.1
Income		
HH with fisheries as 1st income (%)	12.0	9.4
HH with fisheries as 2nd income (%)	24.0	13.3
HH with agriculture as 1st income (%)	4.0	3.9
HH with agriculture as 2nd income (%)	8.0	3.1
HH with salary as 1st income (%)	56.0	67.2
HH with salary as 2nd income (%)	0.0	4.7
HH with other sources as 1st income (%)	32.0	23.4
HH with other sources as 2nd income (%)	4.0	14.1
Expenditure (USD/year/HH)	4464 (±435.5)	6365.28 (±392.62)
Remittance (USD/year/HH) (1)	1425 (±862.5)	1830.00 (±575.82)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	57.09 (±9.21)	68.79 (±7.91)
Frequency fresh fish consumed (times/week)	4.27 (±0.46)	4.25 (±0.17)
Quantity fresh invertebrate consumed (kg/capita/year)	9.65 (±2.76)	6.20 (±7.91)
Frequency fresh invertebrate consumed (times/week)	0.65 (±0.12)	0.80 (±0.09)
Quantity canned fish consumed (kg/capita/year)	6.45 (±1.53)	5.92 (±0.62)
Frequency canned fish consumed (times/week)	1.62 (±0.31)	1.94 (±0.15)
HH eat fresh fish (%)	100.0	99.2
HH eat invertebrates (%)	80.0	68.0
HH eat canned fish (%)	76.0	85.2
HH eat fresh fish they catch (%)	84.0	77.8
HH eat fresh fish they buy (%)	16.0	33.3
HH eat fresh fish they are given (%)	60.0	59.3
HH eat fresh invertebrates they catch (%)	52.0	40.7
HH eat fresh invertebrates they buy (%)	16.0	29.6
HH eat fresh invertebrates they are given (%)	12.0	14.8

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

2.2.2 Fishing strategies and gear: Ngarchelong

Degree of specialisation in fishing

Fishing in Ngarchelong is performed by both genders (Figure 2.5). However, 62% of all fishers target exclusively finfish and 48% of these fishers are males, and only 14% females. Few females also collect invertebrates (~10%). No males specialise in collecting invertebrates only, but 10% of male fishers and 17% of female fishers target both finfish and invertebrates.

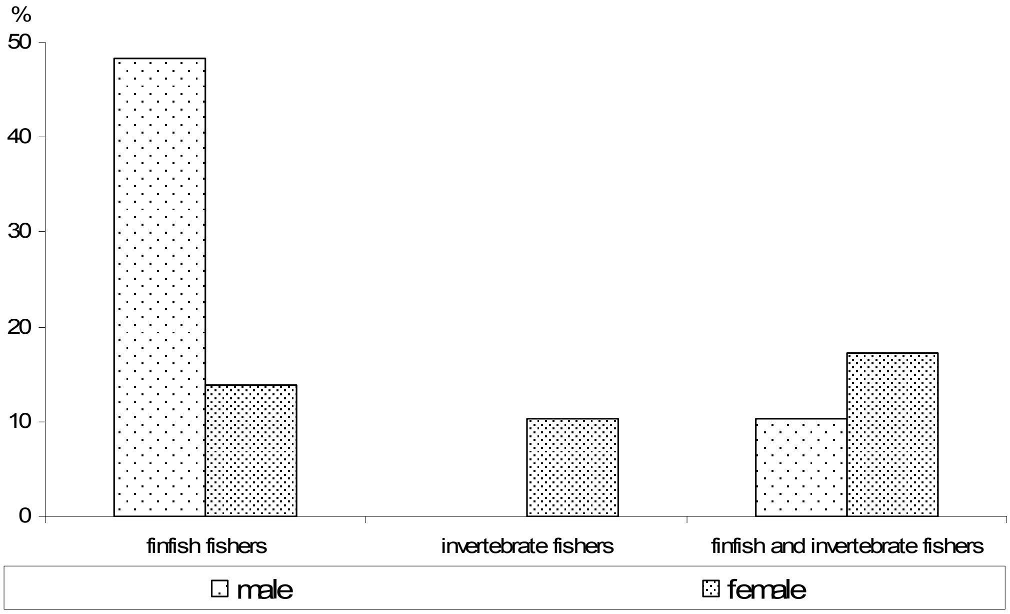

Figure 2.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Ngarchelong.
All fishers = 100%.

Targeted stocks/habitat

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

Resource	Fishery / Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	0.0	14.3
	Lagoon	87.5	85.7
	Lagoon & outer reef	6.3	0.0
	Outer reef	25.0	14.3
Invertebrates	Reeftop	60.0	50.0
	Soft benthos (seagrass)	80.0	80.0
	Mangrove	20.0	10.0
	Lobster	20.0	0.0

Finfish fisher interviews, males: n = 16; females: n = 7. Invertebrate fisher interviews, males: n = 5; females, n = 10.

Fishing patterns and strategies

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

Our survey sample suggests that fishers in Ngarchelong can choose from sheltered coastal reef, lagoon and the outer-reef habitats. Some combine the lagoon and the outer reef in one fishing trip. Most fishers, males and females, however, target the lagoon. Only 14% of all female fishers target either the sheltered coastal reef or the outer reef, and 31% of all male fishers target the outer reef alone or in combination with the lagoon.

Invertebrate fisheries in Ngarchelong include reeftop, soft-benthos (seagrass), mangrove gleaning and, to some extent, diving for lobster. The latter is done by male fishers only and applicable to 20% of all fishers surveyed. Soft-benthos and reeftop gleaning are the main fisheries; 80% of males and females target the soft benthos and 60% and 50% of males and females respectively collect from the reeftop. Mangrove fishing is rare and practised by 20% of all male and only 10% of female fishers interviewed. If considering overall participation (Figure 2.6), soft-benthos collection represents 52% and reeftop gleaning another 35% of all fishing. As shown in Figure 2.7, females' and males' participation is not much different among fisheries. Only diving for lobsters is exclusively performed by males.

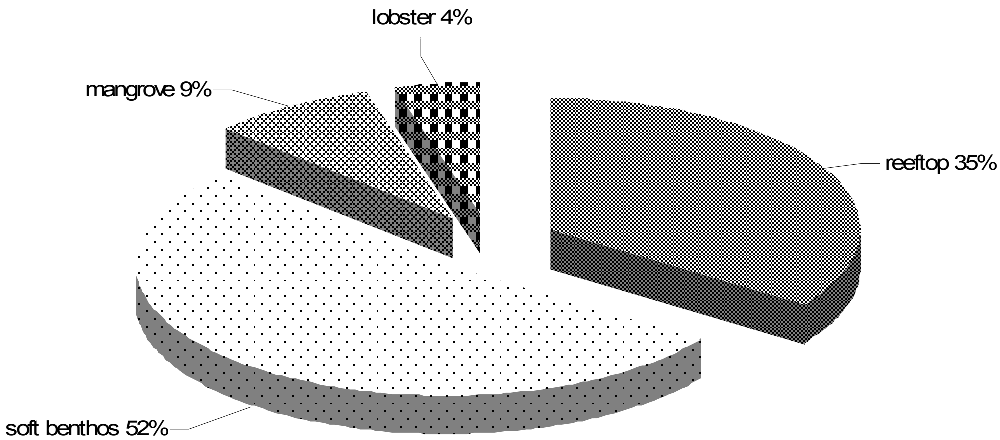

Figure 2.6: Proportion (%) of fishers targeting the four primary invertebrate habitats found in Ngarchelong.
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

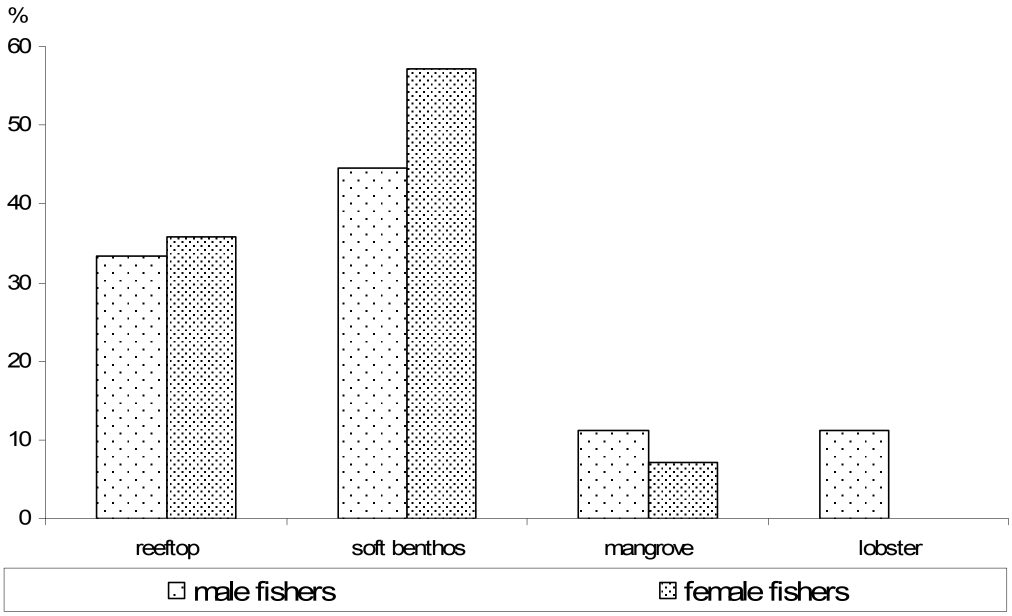

Figure 2.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Ngarchelong.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 5 for males, n = 10 for females.

Gear

Figure 2.8 shows that handlining is the main technique used in any of the habitats fished. At the outer reef, fishers combine handlining with trolling, thus also targeting pelagic species. In the lagoon area, spear diving and gillnetting may also be used. However, these techniques are not dominant. All male and most female finfish fishers (~86%) use boat transport, mainly motorised boats. Only 6% of male and 29% of female finfish fishers use a canoe to reach their fishing grounds.

Gleaning and free diving for invertebrates are done using very simple tools only. Lobsters are picked up with spears, and equipment also includes masks, snorkels and fins. Reeftop, soft-benthos (seagrass) and mangrove gleaning are done by hand, mainly using plastic containers to collect molluscs, holothurians, sea urchins and clams. Lobster and mangrove fishing always requires boat transport. Lobster diving is completely dependent on motorised boat transport, while mangroves may be reached with either motorised boats or canoes. Boat transport is also mainly used for any of the other gleaning activities (reeftop, soft benthos); however, a quarter of all trips to the reeftops and half of all trips targeting the soft benthos (seagrass) are done by walking only.

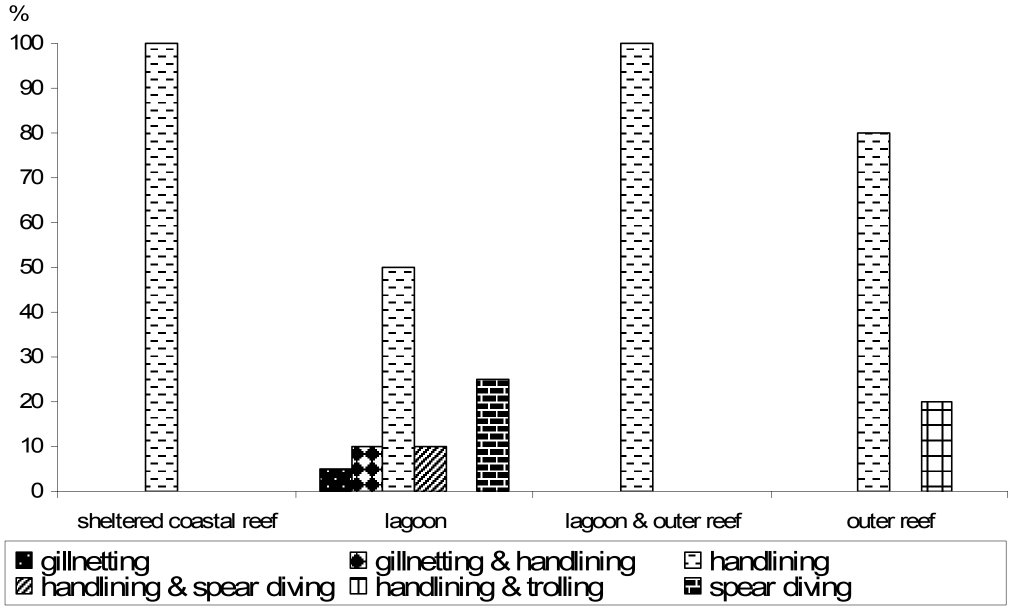

Figure 2.8: Fishing methods commonly used in different habitat types in Ngarchelong. Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Frequency and duration of fishing trips

As shown in Table 2.3 the most frequent fishing trips are those to the lagoon and the lagoon and outer reef combined. Female and male finfish fishers targeting these habitats do so 1.5–2 times per week. The outer reef is less frequently visited (<1/week by males). Females fishing at the sheltered coastal reef go out about twice a month only. Trips to the lagoon usually take the longest (6 hours/trip). However, fishing at the outer reef requires longer time (7 hours/trip). Fishing the sheltered coastal reef, which is mainly done by females, is the shortest activity (2 hours/trip).

Finfish are usually caught during the day; however, fishing at the outer reef may also be done at night or according to the tides (day or night). Night fishing in the lagoon is rare either for male or female fishers. Finfish fishing is done throughout the year; the same applies for invertebrate collection. All fishers collect invertebrates during the day time, regardless of which habitat is targeted.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef		0.46 (n/a)		2.00 (n/a)
	Lagoon	1.37 (±0.26)	2.15 (±0.80)	5.82 (±0.57)	5.92 (±0.78)
	Lagoon & outer reef	2.00 (n/a)	0	4.00 (n/a)	0
	Outer reef	0.81 (±0.19)	0.23 (n/a)	7.00 (±1.08)	4.00 (n/a)
Invertebrates	Reeftop	1.00 (±0.00)	0.32 (±0.06)	1.33 (±0.33)	4.60 (±1.21)
	Soft benthos (seagrass)	0.78 (±0.22)	1.03 (±0.25)	1.25 (±0.25)	2.81 (±0.72)
	Mangrove	1.00 (n/a)	0.23 (n/a)	1.00 (n/a)	6.00 (n/a)
	Lobster	0.46 (n/a)	0	4.00 (n/a)	0

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 16; females: n = 7. Invertebrate fisher interviews, males: n = 5; females: n = 10.

2.2.3 Catch composition and volume – finfish: Ngarchelong

Catches from the lagoon, the main habitat targeted, include the greatest variety of different fish species and species groups, with Lethrinidae (*Lethrinus* spp., *L. olivaceus*, *L. rubrioperculatus*, *L. xanthothochilus* and *L. harak*) determining 28%, and Lutjanidae (*Lutjanus gibbus*, *L. virescens*, *L. bohar*, *Symphorichthys spirulus*) accounting for another 17%, followed by Serranidae (10%), Siganidae (>7%) and Scaridae (13%). Outer-reef catches mainly include Lethrinidae (39%), Carangidae (29%), Serranidae (21%) and Lutjanidae (13%). If the lagoon and the outer reef are jointly targeted in one fishing trip, *Epinephelus* spp. (33%) and *Lutjanus gibbus* (27%) determine most of the catch, with the remaining proportion due to *Lutjanus bohar* and other Lethrinidae. Reported catches from the sheltered coastal reef are the least diversified and include only a very few species, such as *Lethrinus olivaceus* and *Lethrinus harak* (Detailed data are provided in Appendix 2.1.1.).

Our survey sample of finfish fishers interviewed represents about 38% of the projected total number of finfish fishers in Ngarchelong. Due to the sample size, it is highly likely that the sample is representative of the whole community. Hence, we have extrapolated our results to estimate the total annual fishing pressure imposed by the people of Ngarchelong on their fishing ground. This estimate does not include any possible impact from any external fishers.

As shown in Figure 2.9, the major share of the impact is due to commercial reef fishing; i.e. catches that are sold outside the Ngarchelong community account for 78% of the total annual estimated catch or 37.4 t/year. Subsistence need determines about 22% of all catches, corresponding to a total annual consumption of about 10.5 t. Most of the catch is done by male fishers, females play a much lesser role (~21%). Highest pressure is imposed on the lagoon, with a minor impact on the outer reef (13%) and negligible fishing impact on the sheltered coastal reef or the combined fishing of the lagoon and the outer reef (~3%).

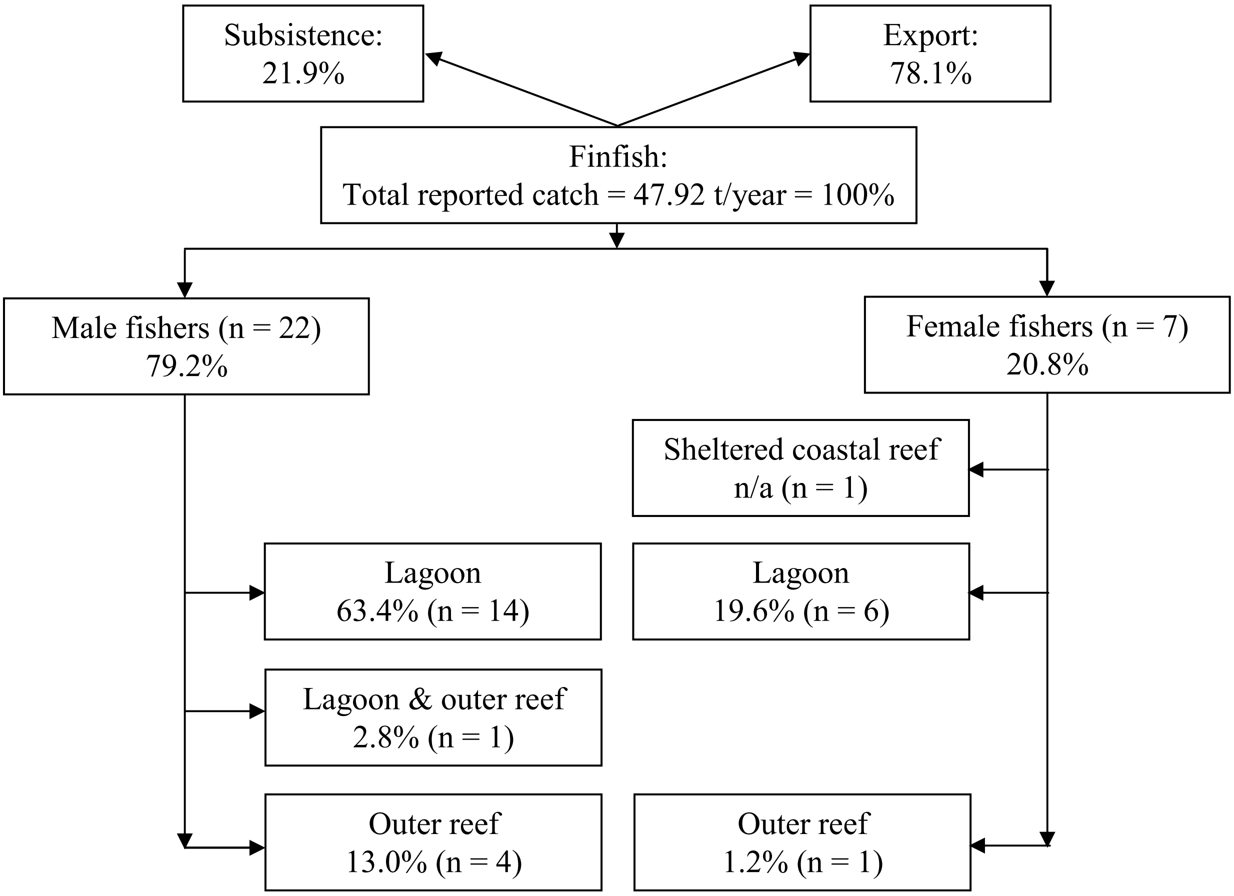

Figure 2.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Ngarchelong.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. n/a = no information available.

The high impact on the lagoon habitat resources is a function of the number of fishers targeting this area as well as the high average annual catch rate. As shown in Figure 2.10, average annual catches range between 300 and >1000 kg/year/fisher and the highest catch rates are achieved by female and male fishers fishing the lagoon, i.e. 800 and >1000 kg/fisher/year. The catch rates of male fishers targeting the outer reef alone or in combination with the lagoon area are less and range from ~600 to 800 kg/fisher/year. Female fishers targeting the outer reef are much less productive (200–300 kg/fisher/year) and catches taken by females fishing the sheltered coastal reef are insignificant.

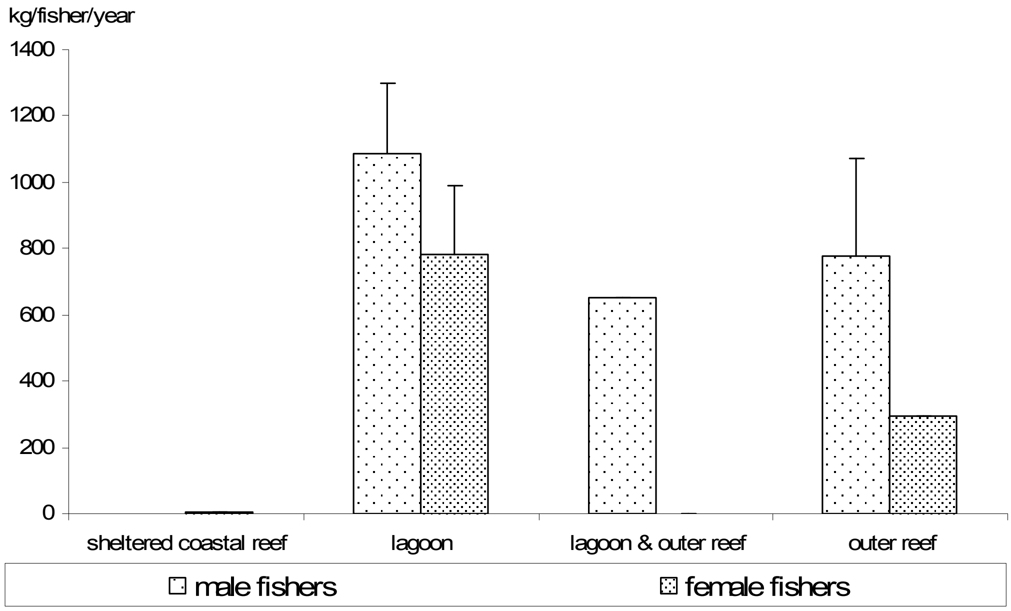

Figure 2.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Ngarchelong.
Bars represent standard error (+SE).

However, comparing CPUEs calculated for the different habitats fished (Figure 2.11), the efficiency achieved by both female and male finfish fishers at the outer reef is surprisingly high, with 4–7 kg/hour fished. However, the sample size of respondents who target the outer reef is small and, therefore, figures may not be representative. In fact, CPUEs reached by lagoon fishers reach 3–3.5 kg/hour fishing trip, and are higher than the CPUE determined for the combined fishing of the outer reef and lagoon (~2 kg/hour fishing trip). Again, the efficiency of female fishers targeting the sheltered coastal reef is very low.

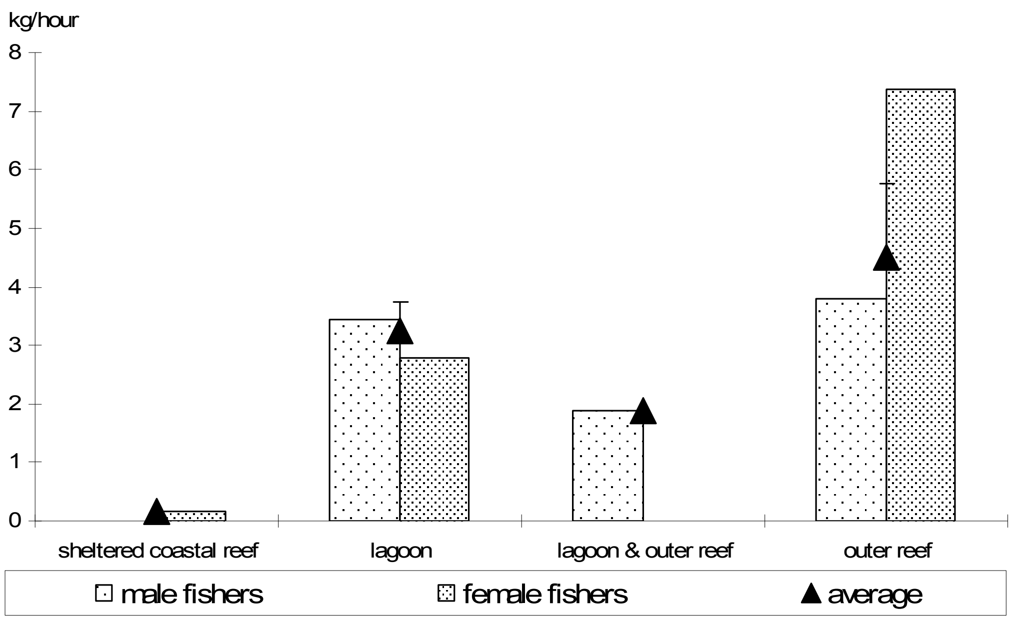

Figure 2.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Ngarchelong.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data show that most catch from any of the habitats fished is intended for subsistence needs and non-monetary exchange among community members. However, the share of the catch intended for sale is highest if the outer reef is targeted, and also important if the lagoon is fished. Sheltered coastal reef fishing is exclusively for subsistence needs, and fishers who combine lagoon and outer-reef habitats in one fishing trip also do not fish commercially (Figure 2.12).

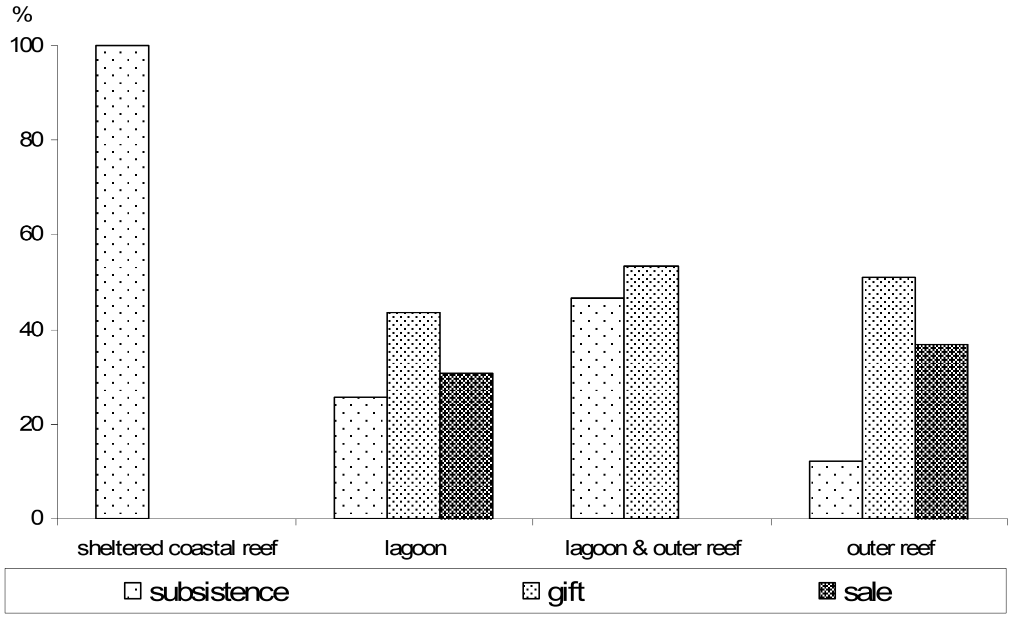

Figure 2.12: The use of finish catches for subsistence, gift and sale, by habitat in Ngarchelong.
Proportions are expressed in % of the total number of trips per habitat.

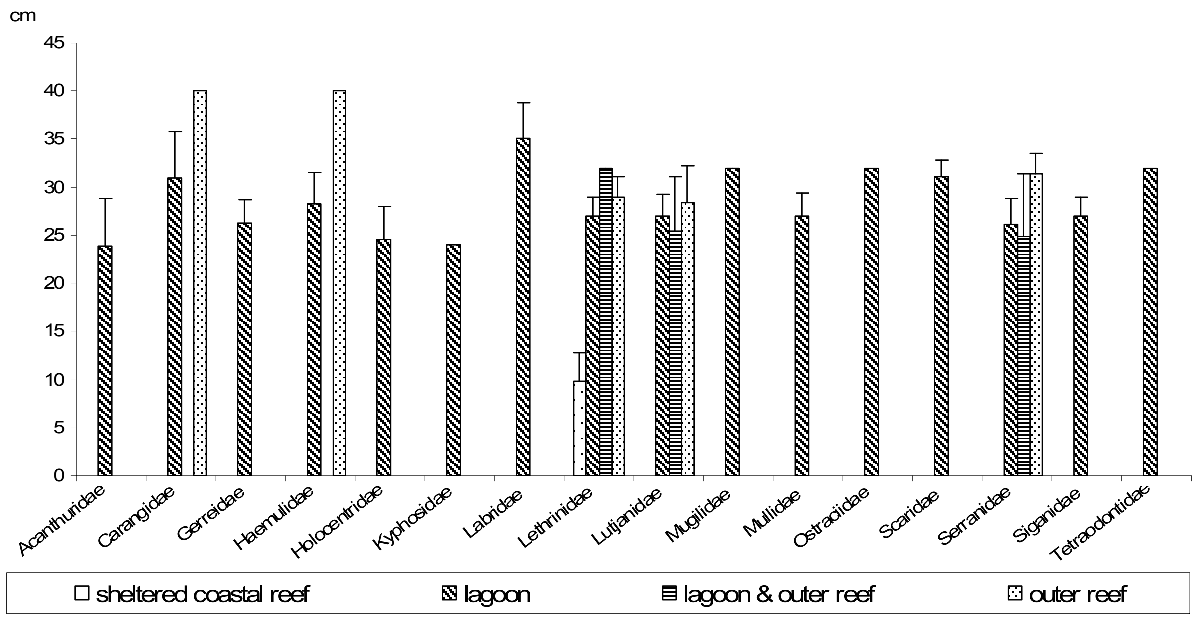

Figure 2.13: Average sizes (cm fork length) of fish caught by family and habitat in Ngarchelong.
Bars represent standard error (+SE).

Data on the average reported finfish sizes by family and habitat (Figure 2.13) show that the smallest fish sizes are reported for catch from the sheltered coastal reef. This is consistent with the low reported productivity (CPUE) and the fact that catch serves subsistence needs only. Although there are far fewer families represented in catches reported from the outer reef as compared to lagoon catches, there seems to be a trend that average fish sizes increase from the lagoon to the outer reef. This is particularly prominent for Carangidae and Haemulidae and, to a lesser extent, for Serranidae. However, for the two families of Lethrinidae and Lutjanidae, no real differences in average reported size can be observed. In general, the average reported fish sizes for lagoon and outer-reef catches are relatively large, and range between 25 and >30 cm for the lagoon, and from 30 to 40 cm for the outer reef.

Some parameters selected to assess the current fishing pressure on Ngarchelong's living reef resources are shown in Table 2.4. The comparison of habitat surfaces that are included in Ngarchelong's fishing ground show that the lagoon determines most, while reef surfaces are small, with ~18 km^2 for the sheltered coastal reef and ~35 km^2 for the outer-reef area only (Figure 2.14). Considering that most fishers in Ngarchelong target the lagoon, a very low fisher density results. Because relatively few fishers target either the sheltered coastal or the outer reef, the fisher density in both habitats is low despite the fact that the surface areas are much smaller than the lagoon. Given the small size of the Ngarchelong community (total of 184 people), and the size of the reef and the total fishing ground, population and fisher density are both very low, and so is the calculated fishing pressure in terms of annual subsistence catch per unit area. This ratio may still remain low even when taking into consideration the extrapolated total annual catch (47.92 t/year), which includes catch for external sale. In summary, current fishing pressure seems to be very low.

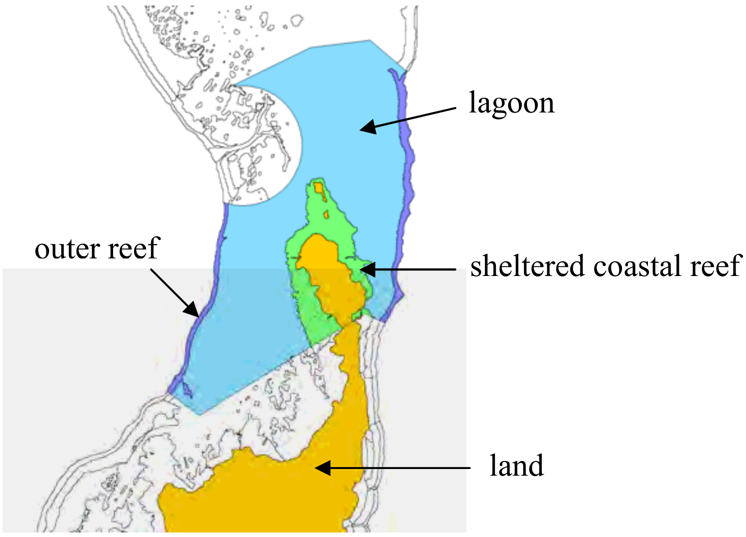

Figure 2.14: Fishing ground and habitat classification of Ngarchelong.

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

Parameters	Habitat					
	Sheltered coastal reef	**Lagoon**	**Lagoon & outer reef**	**Outer reef**	**Total reef area**	**Total fishing ground**
Fishing ground area (km^2)	18.09	133.26		34.61	85.72	185.95
Density of fishers (number of fishers/km^2 fishing ground) (1)	<1	<1		<1	<1	<1
Population density (people/km^2) (2)					2	1
Average annual finfish catch (kg/fisher/year) (3)	6.74 (n/a)	995.31 (±160.41)	651.43 (n/a)	682.47 (±247.65)		
Total fishing pressure of subsistence catches (t/km^2)					0.12	0.06

Figures in brackets denote standard error; n/a = standard error not calculated; (1) total number of fishers (= 55) is extrapolated from household surveys; (2) total population = 184; total subsistence demand = 10.50 t/year; (3) catch figures are based on recorded data from survey respondents only.

2.2.4 Catch composition and volume – invertebrates: Ngarchelong

Calculations of the recorded annual catch rates per species groups are shown in Figure 2.15. The graph shows that the major impact by wet weight is mainly due to bêche-de-mer species, including *Holothuria* spp*.*, *H. scabra, Stichopus* spp. and *Actinopyga* spp. The shares of total annual catches reported for giant clams, sea urchins and others are small or insignificant. (Detailed data are provided in Appendices 2.1.2 and 2.1.3.).

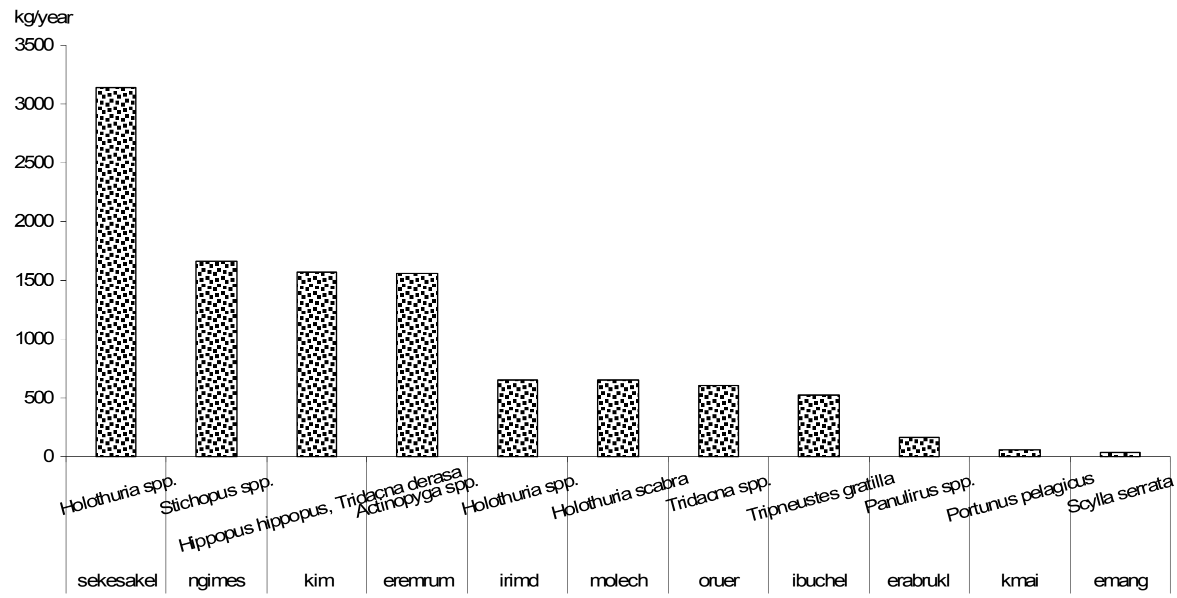

Figure 2.15: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Ngarchelong.

Overall, the diversity of vernacular names reported for any of the habitats targeted is low. Soft benthos (seagrass) is the main habitat where people from Ngarchelong collect bêche-de-mer that they eat or sell elsewhere. Thus, it is not surprising that the highest number of vernacular names is found for this fishery. Catches from mangroves and lobster dives are represented by 1–2 and reeftop by only three vernacular names (Figure 2.16).

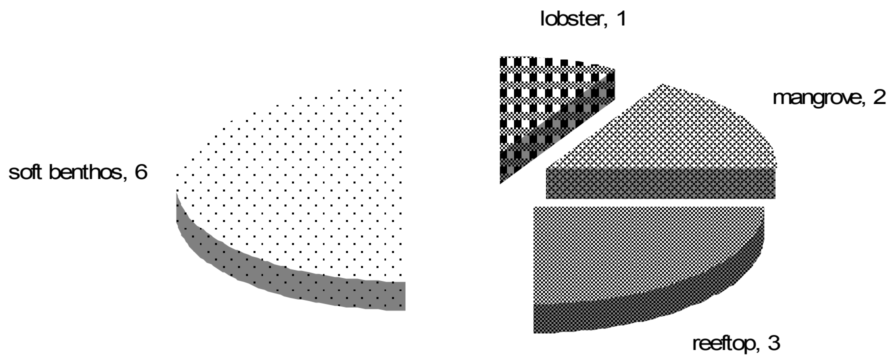

Figure 2.16: Number of vernacular names recorded for each invertebrate fishery in Ngarchelong.

Figure 2.17 shows again that the highest figures, here for average annual catches (650–700 kg/fisher/year) by wet weight occur for soft-benthos (seagrass) harvesting, the main habitat for bêche-de-mer, one of the major target species for subsistence or local sale. The reeftop fishery provides 200–350 kg/fisher/year, while lobster diving produces 150 kg/fisher/year wet weight. Overall, catch rates from mangrove areas are insignificant.

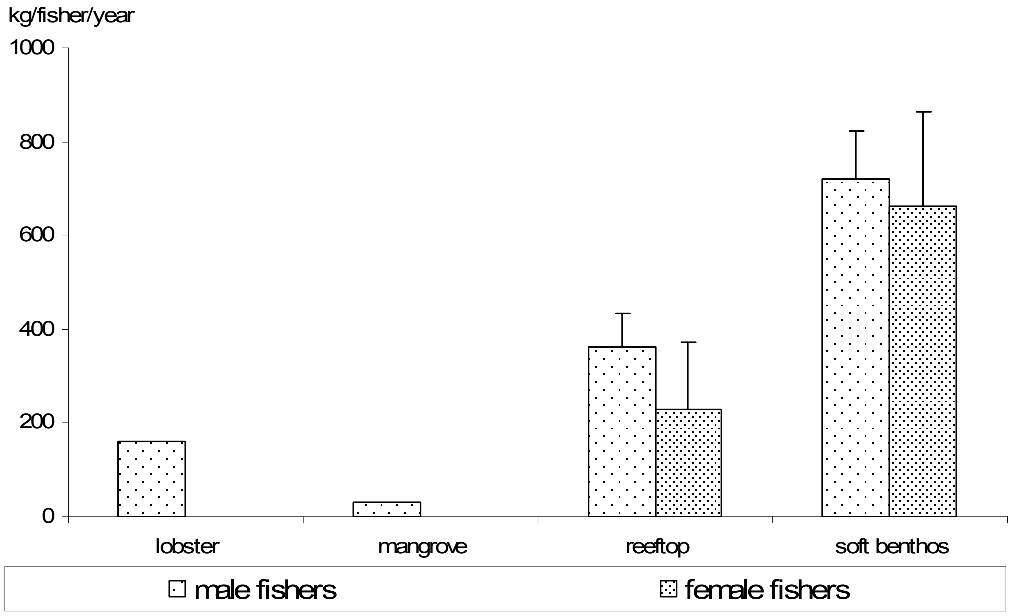

Figure 2.17: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Ngarchelong.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 5 for males, n = 10 for females). Bars represent standard error (+SE).

As demonstrated in Figure 2.18, most invertebrate fisheries serve subsistence purposes. However, the share of invertebrate catch sold is substantial and reaches about half of the subsistence demand. Bearing in mind that most invertebrates consumed, offered on a non-monetary basis, or given away by any of the households surveyed in Ngarchelong are caught by a family member, it is argued that commercialisation mainly targets external markets in Palau. Thus, it is concluded that the current impact of fishing on Ngarchelong's invertebrate resources is determined by both the consumption needs of the community and the need to generate income by serving external demand. In addition, it should be borne in mind that external and visiting fishers may add further pressure.

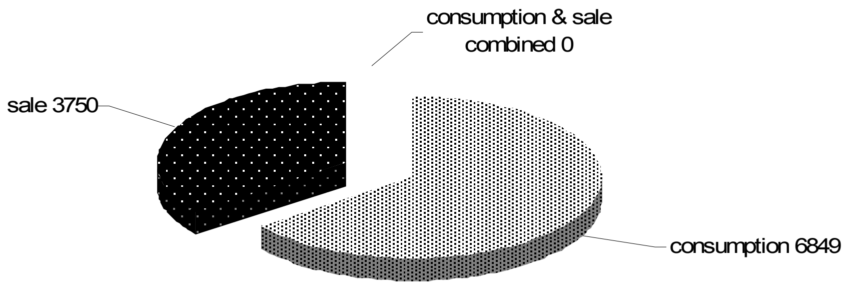

Figure 2.18: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Ngarchelong.

The total annual catch volume expressed in wet weight based on recorded data from all respondents interviewed amounts to 10.60 t/year (Figure 2.19). As reported earlier, catches from the soft benthos (seagrass) and, to a lesser extent, reeftop are significant, representing ~77% and 21% of the total reported annual catch respectively. Other catches (mangrove collection and lobster diving) determine the remaining 2%. While catches from soft benthos (seagrass) are mainly taken by female fishers, males' and females' contributions to annual catches reported for reeftop gleaning are similar.

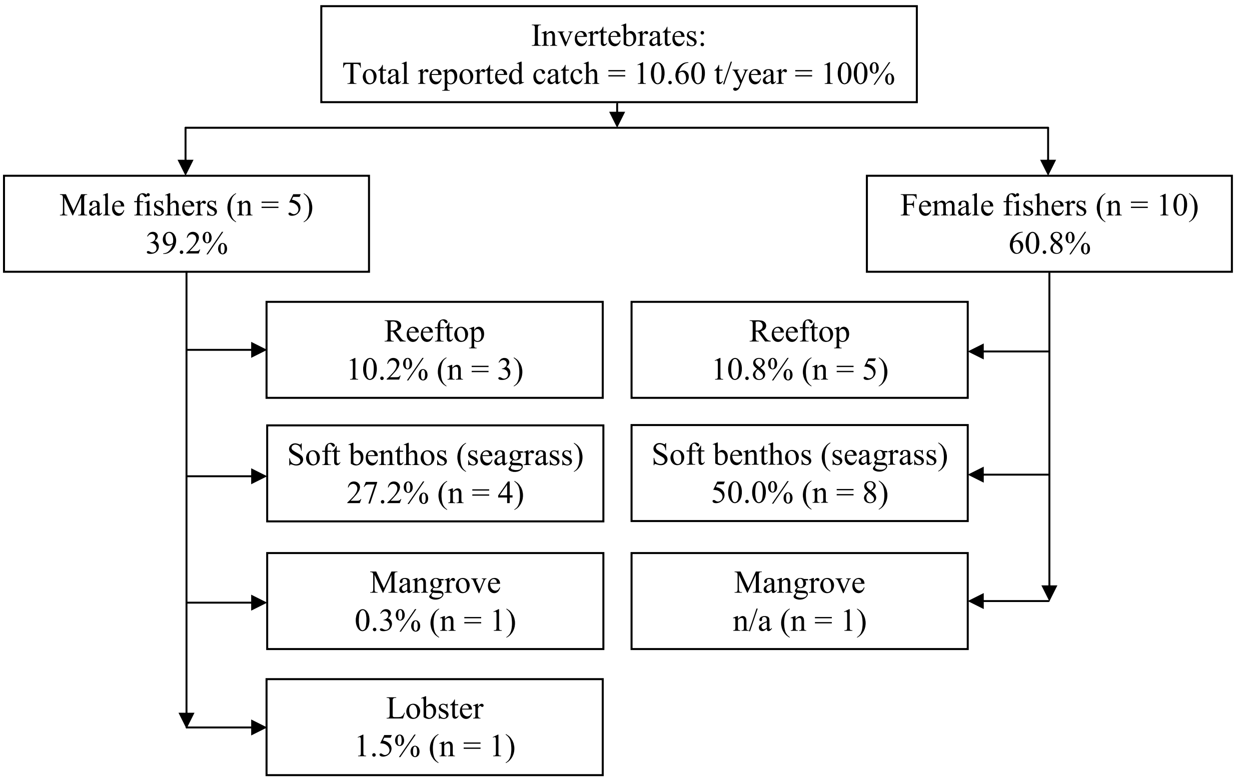

Figure 2.19: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Ngarchelong.
n is the total number of interviews conducted per each fishery; n/a = no information available; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

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

Parameters	Fishery / Habitat			
	Lobster	Mangrove	Reeftop	Soft benthos
Fishing ground area (km^2)	12.29 [3]	n/a	25.63	n/a
Number of fishers (per fishery) [1]	1	3	12	19
Density of fishers (number of fishers/km^2 fishing ground)	<1		<1	
Average annual invertebrate catch (kg/fisher/year) [2]	159.91 (n/a)	30.40 (n/a)	278.69 (±92.83)	681.63 (±135.28)

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

Not many fishers from the Ngarchelong community collect invertebrates. As a result, fisher densities are low, as shown in the case of reeftop fishery, for which the habitat area is known. Also, the few fishers who dive for lobsters do not pose any threat if the available reef length that supports lobster fishery is taken into consideration. As in other sites surveyed in Palau, overall catches are low, except perhaps soft-benthos gleaning, which provides a catch of >680 kg/fisher/year. However, none of the figures suggest that the current fishing pressure poses a major risk to any of the community's invertebrate resources.

2.2.5 Discussion and conclusions: socioeconomics in Ngarchelong

- As compared to salaries, fisheries are not an important sector for income generation in Ngarchelong. Only 12% of all households obtain primary income from fisheries, and another 24% obtain secondary income. In contrast, salaries are most important, providing 56% of all households with first income. Other income sources, mainly welfare, retirement payments and handicrafts, make up 32% of first-income sources. Agriculture is of minor importance.

- All households regularly consume fresh fish and the majority also invertebrates. Fresh fish consumption is above the regional average but lower than the average over all CoFish sites in Palau. Invertebrate consumption is moderate (~10 kg/person/year).

- The low average household expenditure level suggests that people in Ngarchelong enjoy a rather traditional lifestyle, which is supported to a great extent by subsistence production and non-monetary exchange of services and goods among community members. Remittances do not play any role.

- Most finfish fishing is done by males; only a few females exclusively fish for finfish, collect invertebrates or target both finfish and invertebrates. Finfish fishers mainly target the lagoon, but one quarter of all male fishers also fish the outer reef. The sheltered coastal reef is the least targeted habitat. Invertebrate collection focuses on soft benthos (seagrass) for bêche-de-mer and reeftop for giant clams. Mangrove gleaning and diving for lobsters are rarely done, and mainly performed by males.

- Handlining is the main fishing technique used in all habitats. However, handlining may be combined with trolling for pelagic fish at the outer reef, and with spear diving and gillnetting in the lagoon. Most fishing is done using motorised boats and, in rare cases, non-motorised boats.

- Highest fishing pressure exists on the lagoon, due to high fisher density and high catch rate. However, given the large surface area, a low fishing pressure figure per unit area results. Also, overall, population density, fisher density and catch per km^2 of reef area or of total fishing ground are all very low. CPUEs are highest for the outer reef and not much lower for lagoon fishing. A trend of increasing average fish sizes from the sheltered coastal reef towards the outer reef was observed, which suggests that resources on the outer reef are fished less than on the sheltered coastal reef and in the lagoon.

- Invertebrate fisheries mainly serve the community's subsistence needs, but are also used to generate income. Highest fishing pressure is observed for the soft benthos (seagrass) and to a lesser extent for the reeftop fisheries. Impact in terms of reported annual catch (wet weight) is negligible for the lobster and mangrove fisheries.

The above observations show that fishing is not the major basis for the livelihood of people in Ngarchelong from a commercial point of view. However, the community's subsistence needs are substantial: ~57 kg/person/year of finfish and ~10 kg/person/year of invertebrates. While more than half of finfish catches in Ngarchelong are sold outside the community, presumably to Koror, fishing pressure remains low due to the large area of fishing ground. Invertebrate exploitation is relatively low with a reported annual catch of 10.6 t wet weight. However, very few species are targeted and therefore these may be under some pressure. On the other hand, if taking into account that most of the invertebrate catch is locally consumed, and given the small population size, fishing pressure cannot have reached any alarming level even though collection may be very selective. Assuming that the previous exploitation level of Ngarchelong's reef and lagoon resources was similar to that of today, it is concluded that, overall, the status of reef and lagoon resources is healthy.

2.3 Finfish resource surveys: Ngarchelong

Finfish resources and associated habitats were assessed between 17 and 20 April 2007, from a total of 24 transects (6 coastal-reef, 4 intermediate-reef, 9 back-reef, and 5 outer-reef transects, see Figure 2.20 for transect locations and Appendix 3.1.1 for coordinates).

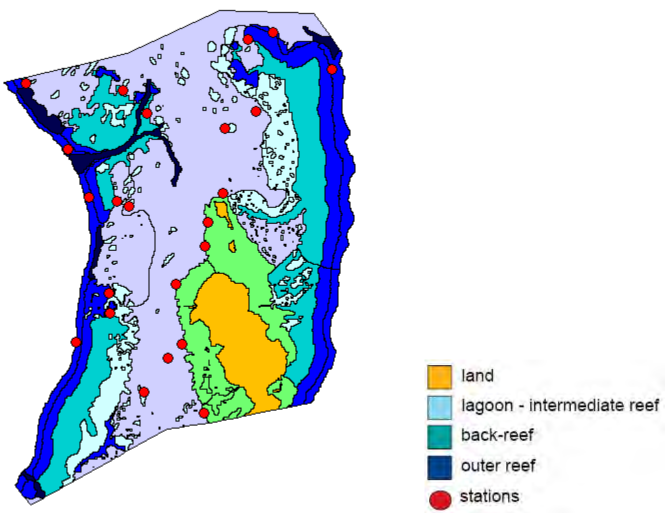

Figure 2.20: Habitat types and transect locations for finfish assessment in Ngarchelong.

2.3.1 Finfish assessment results: Ngarchelong

A total of 21 families, 57 genera, 191 species and 9995 fish were recorded in the 24 transects (See Appendix 3.1.2 for list of species.). Only data on the 15 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 47 genera, 171 species and 9702 individuals.

Finfish resources varied greatly among the four reef environments found in Ngarchelong (Table 2.6). The coastal reef contained a greater number of fish (0.8 fish/m^2), larger average fish size (19 cm FL) and biomass (173 g/m^2) and the highest biodiversity (56 species/transect), but the second-highest size ratio (58%) at the site. Back- and intermediate reefs displayed similar values of density (0.4 fish/m^2), biomass (43 g/m^2) and biodiversity (48 and 46 species/transect respectively), but intermediate reefs had higher average size (15 cm FL) and size ratio (49%) than back-reefs. Outer reefs had less density and biomass, smaller average sizes and biodiversity, but higher size ratio (as high as 60%) when compared to coastal reefs.

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

Parameters	Habitat				
	Sheltered coastal reef (1)	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	4	9	5	24
Total habitat area (km^2)	18.1	22.3	33.0	29.9	103.3
Depth (m)	3 (1–5) (3)	3 (1–5) (3)	2 (1–8) (3)	6 (2–10) (3)	4 (1–10) (3)
Soft bottom (% cover)	8 ±3	16 ±5	14 ±5	2 ±1	10
Rubble & boulders (% cover)	35 ±9	30 ±6	26 ±6	12 ±8	24
Hard bottom (% cover)	34 ±8	30 ±3	24 ±8	52 ±8	35
Live coral (% cover)	18 ±0	20 ±0	31 ±0	25 ±0	25
Soft coral (% cover)	0 ±0	0 ±0	0 ±0	0 ±0	3
Biodiversity (species/transect)	56 ±5	46 ±4	48 ±4	54 ±5	51±2
Density (fish/m^2)	0.8 ±0.2	0.4 ±0.1	13.2 ±0.6	0.6 ±0.1	0.5
Biomass (g/m^2)	173.1 ±65.5	43.4 ±2.2	43.5 ±16.2	102.8 ±42.9	83.3
Size (cm FL) (4)	19 ±1	15 ±1	12 ±0	18 ±1	16
Size ratio (%)	58 ±2	49 ±2	44 ±2	60 ±2	52

(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.

Coastal-reef environment: Ngarchelong

The coastal-reef environment of Ngarchelong was dominated by two major families: Acanthuridae and Scaridae and, to a much less extent, the carnivores: Mullidae, Lutjanidae and Lethrinidae (Figure 2.21, Table 2.7). These five families were represented by 52 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Acanthurus lineatus*, *Hipposcarus longiceps*, *Chlorurus sordidus*, *Naso lituratus*, *Monotaxis grandoculis*, *Lutjanus gibbus*, *Mulloidichthys flavolineatus*, *M. vanicolensis*, *Scarus psittacus* and *Zebrasoma scopas* (Table 2.7). This reef environment was dominated by rubble (35%) and hard bottom (34%), with relatively low live-coral cover (18%), and little soft bottom (8%) (Table 2.6, Figure 2.21).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.21 ±0.06	27.3 ±7.3
	Acanthurus lineatus	Lined surgeonfish	0.07 ±0.05	18.2 ±11.6
	Naso lituratus	Orangespine unicornfish	0.02 ±0.01	8.6 ±5.2
	Zebrasoma scopas	Twotone tang	0.04 ±0.02	2.0 ±1.0
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.02 ±0.01	8.0 ±4.8
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.02 ±0.02	8.0 ±7.7
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.02 ±0.01	4.9 ±4.1
	Mulloidichthys vanicolensis	Yellowfin goatfish	0.02 ±0.02	2.6 ±2.6
Scaridae	*Hipposcarus longiceps*	Pacific longnose parrotfish	0.02 ±0.02	15.7 ±14.8
	Chlorurus sordidus	Daisy parrotfish	0.08 ±0.02	14.8 ±6.1
	Scarus psittacus	Common parrotfish	0.02 ±0.01	2.4 ±1.2

The density, size, biomass and diversity of finfish in the coastal reefs of Ngarchelong were the highest at the site. Size ratio (58%) was the second-highest. When compared to the other two sites in the country with coastal reefs, Ngarchelong coastal reefs still displayed highest density and biodiversity. However, size and biomass were lower than Ngatpang values. The trophic structure was dominated by herbivorous fish, mainly represented by Acanthuridae and Scaridae. Mullidae was the most abundant carnivorous family, with two species being the most significant. Lutjanidae and Lethrinidae were similarly important in the biomass composition, and mainly represented by *Lutjanus gibbus* and *Monotaxis grandoculis.* Size ratio was slightly below 50% for Lethrinidae and Lutjanidae. These are the only families targeted by male fishers. The coastal reefs of Ngarchelong displayed a dominance of rubble and hard bottom (69%) with a limited cover of live coral (18%). The rather high complexity of the substrate composition, including also a part of soft bottom, can explain the high diversity of fish and the complex composition of the main species, including both herbivores (associated with hard bottom) and carnivores (with species related to both hard and soft bottom). The sheltered coastal reef is the least fished of the four reef habitats.

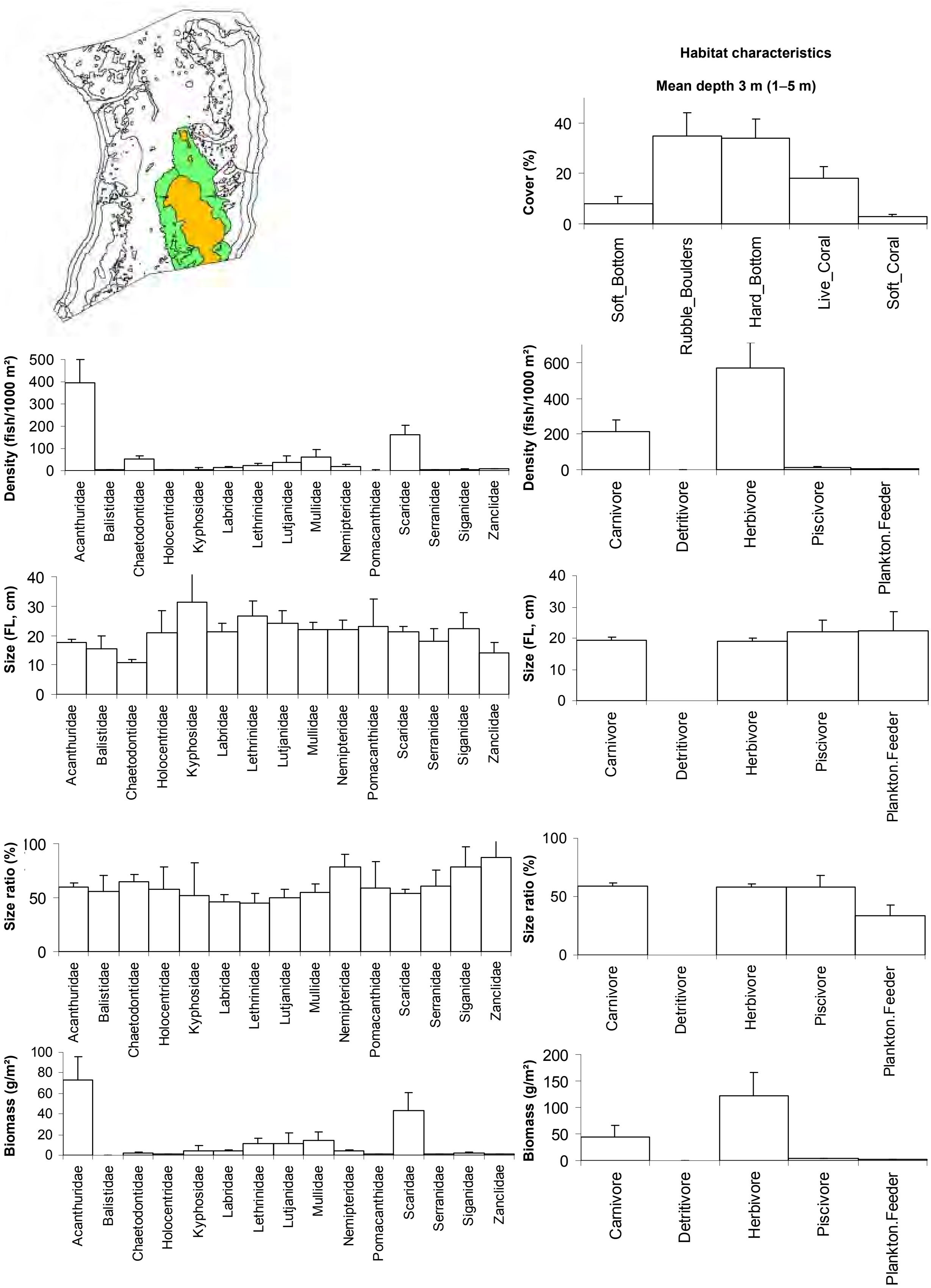

Figure 2.21: Profile of finfish resources in the coastal-reef environment of Ngarchelong.
Bars represent standard error (+SE); FL = fork length.

Intermediate-reef environment: Ngarchelong

The intermediate reef of Ngarchelong was dominated, both in terms of density and biomass, by herbivorous Acanthuridae and Scaridae (Figure 2.22). These two families were present with 30 species, with the most important in terms of biomass and abundance being: *Ctenochaetus striatus*, *Chlorurus sordidus*, *Scarus dimidiatus*, *S. psittacus*, *Acanthurus lineatus*, *A. nigricauda* and *A. nigricans* (Table 2.8). Similar to coastal reef, the substrate was equally composed of rubble and hard bottom (30%), live coral was present in fairly good amount (20%) and soft bottom, although limited, was also present (16% Table 2.6, Figure 2.22).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.133 ±0.017	13.8 ±3.0
	Acanthurus lineatus	Lined surgeonfish	0.013 ±0.007	1.1 ±0.7
	Acanthurus nigricauda	Epaulette surgeonfish	0.007 ±0.004	1.0 ±0.8
	Acanthurus nigricans	Whitecheek surgeonfish	0.014 ±0.013	1.0 ±0.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.053 ±0.014	5.2 ±0.2
	Scarus dimidiatus	Yellow-barred parrotfish	0.014 ±0.004	1.6 ±0.6
	Scarus psittacus	Common parrotfish	0.020 ±0.014	1.2 ±0.5

The density and biomass at this reef were the lowest at the site and similar to back-reefs. Size and size ratios were slightly higher than at back-reefs. However, biodiversity was the overall lowest of the site (46 species/transect). When compared to the intermediate reefs of the other three country sites, density and biomass at Ngarchelong were higher only than at Ngatpang, while size and size ratio were the absolute lowest but biodiversity the second-highest among back-reefs (Table 2.6). Lutjanidae, Mullidae and Serranidae and especially Lethrinidae (25%) and Scaridae (42%) displayed low size ratios, suggesting a possible impact from fishing. In fact, all these families were the most fished in this habitat, which was the most frequently visited by male fishers. The trophic composition was highly dominated by herbivores, where Acanthuridae and Scaridae represented the largest bulk of biomass, with several small-sized species. Carnivores were present in very limited abundance. The substrate was equally composed of rubble and hard bottom, with little soft coral and a fairly good cover of live coral; such composition usually advantages herbivores, as was the case here.

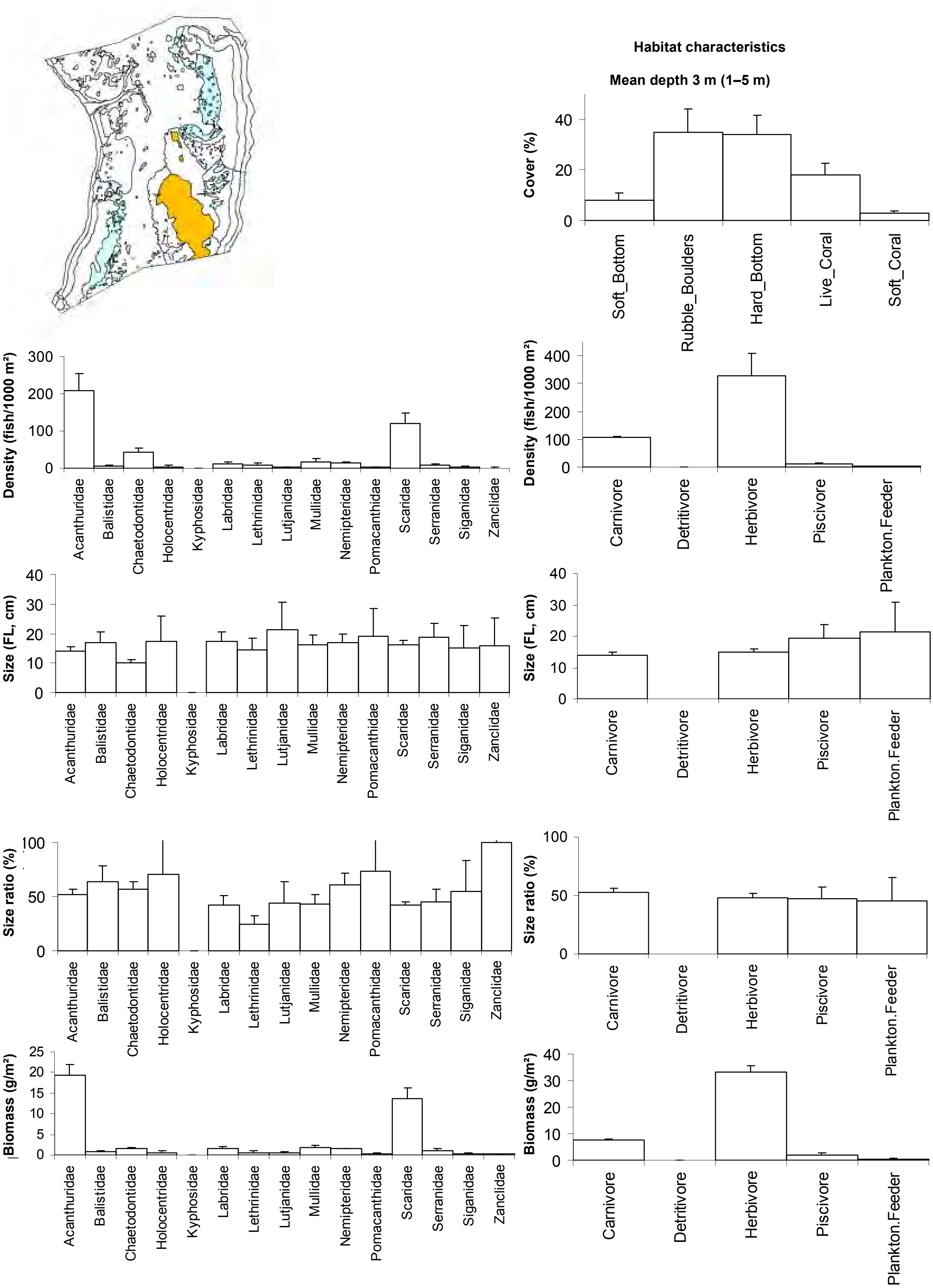

Figure 2.22: Profile of finfish resources in the intermediate-reef environment of Ngarchelong. Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Ngarchelong

The back-reef of Ngarchelong was dominated, in terms of density and biomass, by herbivores Acanthuridae and Scaridae (Figure 2.23). These two families were represented by a total of 32 species dominated by *Ctenochaetus striatus*, *Acanthurus nigricauda*, *Chlorurus sordidus*, *Scarus schlegeli* and *S. dimidiatus* (Table 2.9). Live coral dominated the habitat (31%), rubble and hard bottom presented similar percentage cover (24 and 26%), while soft bottom was limited to 14% of the total substrate (Table 2.6 and Figure 2.23).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.136 ±0.041	18.4 ±6.4
	Acanthurus nigricauda	Epaulette surgeonfish	0.010 ±0.002	3.3 ±1.4
	Chlorurus sordidus	Daisy parrotfish	0.033 ±0.016	2.2 ±0.5
	Scarus schlegeli	Schlegel's parrotfish	0.007 ±0.004	1.6 ±1.0
Scaridae	*Scarus dimidiatus*	Yellow-barred parrotfish	0.007 ±0.003	1.4 ±0.7

The density and biomass, as well as size, size ratio and biodiversity of this reef were comparable to the intermediate reef and inferior to both coastal and outer reefs. However, size, size ratio and biodiversity were the lowest at the site. When compared to the other back-reefs, Ngarchelong displayed the lowest values in the country for all biological parameters. Size ratio was below 50% for Scaridae and especially Lethrinidae, suggesting an impact from fishing. The trophic structure was strongly dominated by herbivores in terms of both abundance and biomass. Both Acanthuridae and Scaridae were represented by small-sized species. The habitat composition, dominated by live coral, with hard bottom and rubble was the type favouring herbivores, such as Acanthuridae.

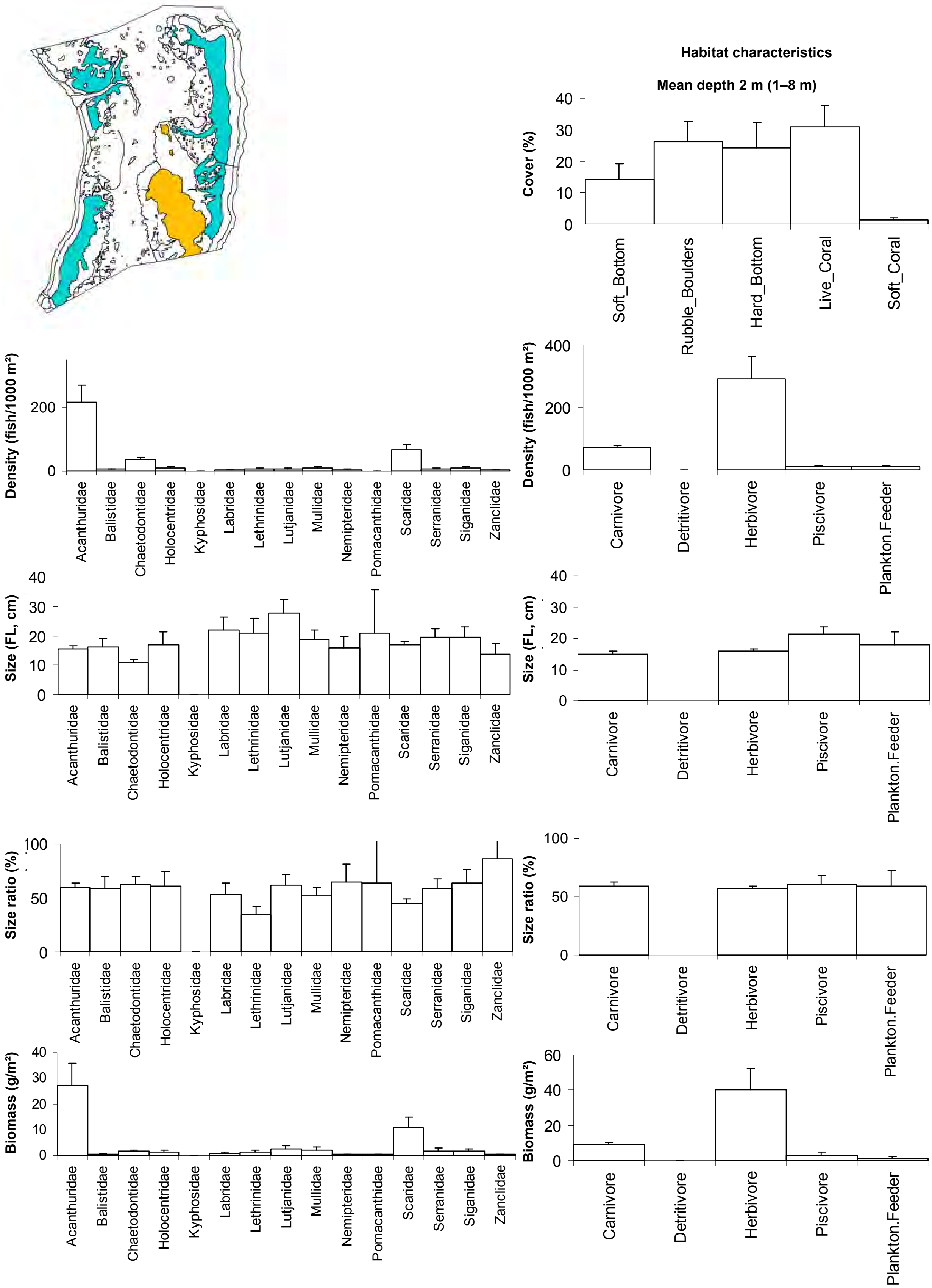

Figure 2.23: Profile of finfish resources in the back-reef environment of Ngarchelong.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Ngarchelong

The outer reef of Ngarchelong was dominated in terms of density by herbivores Acanthuridae and Scaridae and, particularly in terms of biomass, by carnivore Lutjanidae (Figure 2.24). These three families were represented by a total of 35 species dominated by *Ctenochaetus striatus*, *Lutjanus gibbus*, *Chlorurus sordidus*, *Acanthurus nigricans*, *A. nigricauda*, *Naso lituratus*, *Scarus dimidiatus* and *Acanthurus lineatus* (Table 2.10). Hard bottom (52%) highly dominated the habitat and cover of live coral was high (25%, Table 2.6 and Figure 2.24). As common for an outer reef, soft bottom was rare, occupying less than 10% of total substrate.

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.200 ±0.063	34.8 ±17.2
	Acanthurus nigricans	Whitecheek surgeonfish	0.024 ±0.019	3.7 ±3.4
	Acanthurus nigricauda	Epaulette surgeonfish	0.011 ±0.010	3.4 ±3.1
	Naso lituratus	Orangespine unicornfish	0.006 ±0.003	2.3 ±1.5
	Acanthurus lineatus	Lined surgeonfish	0.014 ±0.014	2.0 ±2.0
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.050 ±0.050	20.6 ±20.2
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.048 ±0.025	4.8 ±1.8
	Scarus dimidiatus	Yellow-barred parrotfish	0.006 ±0.004	2.2 ±1.9

The density, size, biomass and biodiversity of this reef were high but lower than in coastal reefs. Size ratio was the highest at this habitat. When compared to the outer reefs of the other sites, density and biomass were only higher than Airai values but lower than at the other two sites, while size and size ratio were the second-lowest and biodiversity the lowest among the four sites. All families displayed high average size ratios, above the 50% maximum recorded for the respective species. The trophic structure was dominated by herbivores, mainly represented by average-sized species of Acanthuridae and small-sized species of Scaridae. Carnivores were mostly represented by Lutjanidae, with *L. gibbus* displaying very high biomass. Composition of habitat, mostly made up of live coral and hard bottom (92%), was the kind that normally favours herbivores, such as Acanthuridae, here clearly dominant. Fishing in such a habitat was rarer than in the lagoon and mainly done by handlining and trolling, therefore impacting resources the least.

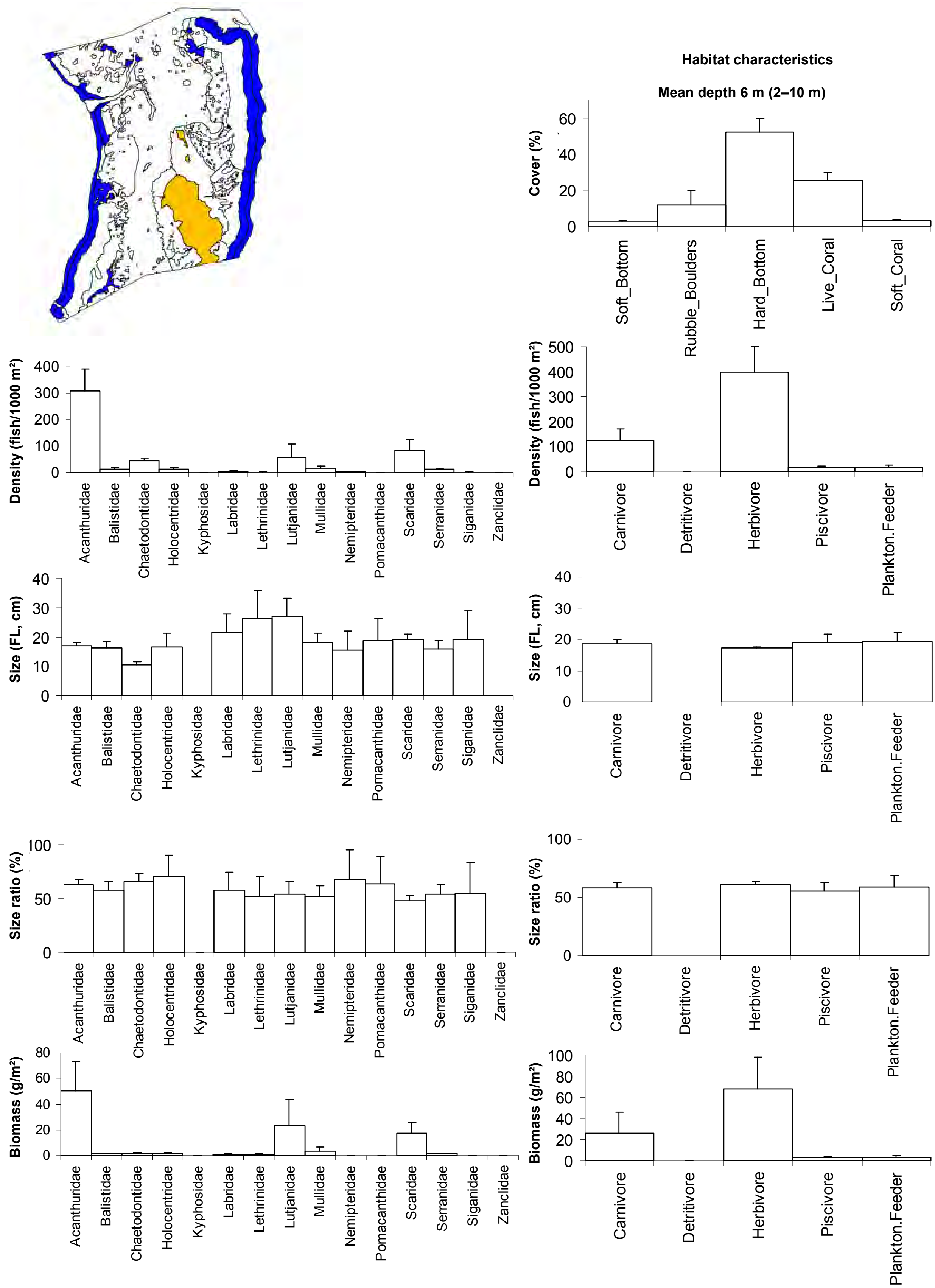

Figure 2.24: Profile of finfish resources in the outer-reef environment of Ngarchelong.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Ngarchelong

Overall, the reefs of Ngarchelong were heavily dominated by two main herbivorous families: Acanthuridae and Scaridae (Figure 2.25). These two families were represented by a total of 48 species dominated by *Ctenochaetus striatus*, *Lutjanus gibbus*, *Chlorurus sordidus*, *Acanthurus lineatus*, *A. nigricauda*, *Hipposcarus longiceps*, *Naso lituratus* and *Scarus dimidiatus* (Table 2.11). Hard bottom dominated the overall habitat cover (35%), and live coral and rubble displayed high cover (25 and 24% respectively, Table 2.6 and Figure 2.25). Soft bottom occupied only 10% of total substrate. The overall fish assemblage in Ngarchelong shared characteristics of primarily back- and outer reefs (32% and 29% of total habitat respectively), then of intermediate reefs (22%) and to a lower extent coastal reefs (18% of habitat).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus lineatus*	Lined surgeonfish	0.02	4.1
	Acanthurus nigricauda	Epaulette surgeonfish	0.01	3.6
	Ctenochaetus striatus	Striated surgeonfish	0.17	23.7
	Naso lituratus	Orangespine unicornfish	0.01	2.7
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.02	7.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.05	5.8
	Hipposcarus longiceps	Pacific longnose parrotfish	0.01	3.3
	Scarus dimidiatus	Yellow-barred parrotfish	0.01	2.1

Overall, Ngarchelong appeared to support a relatively good finfish resource, with second-highest density, biomass, average size and biodiversity among the four sites, where recorded values were surpassed only by Koror reefs. Size ratio was however the lowest recorded. These results suggest that the overall finfish resource in Ngarchelong was in good condition. Detailed assessment at family level revealed a dominance of Acanthuridae and Scaridae in terms of density and biomass of the fish community. A general lack or serious poverty of carnivores was the dominant profile among all reefs. However, in the analysis of the overall reef habitat, Lutjanidae were revealed as the most important carnivorous family in terms of biomass, with a slightly lower value than Scaridae. The dominance of herbivores can be explained by the composition of the habitat, mostly composed of hard rock and live coral, with very little soft substrate, which normally favours most invertebrate-feeding carnivores, such as Mullidae and Lethrinidae. The study of size and size ratio trends disclosed the presence of smaller-than-average fish, indicating a first impact on some selected families of both herbivores and carnivores: Scaridae, Mullidae, Serranidae and especially Lethrinidae displayed overall small size ratios. Catches of such carnivores could be another cause of the composition of the fish community, being heavily skewed towards few herbivores.

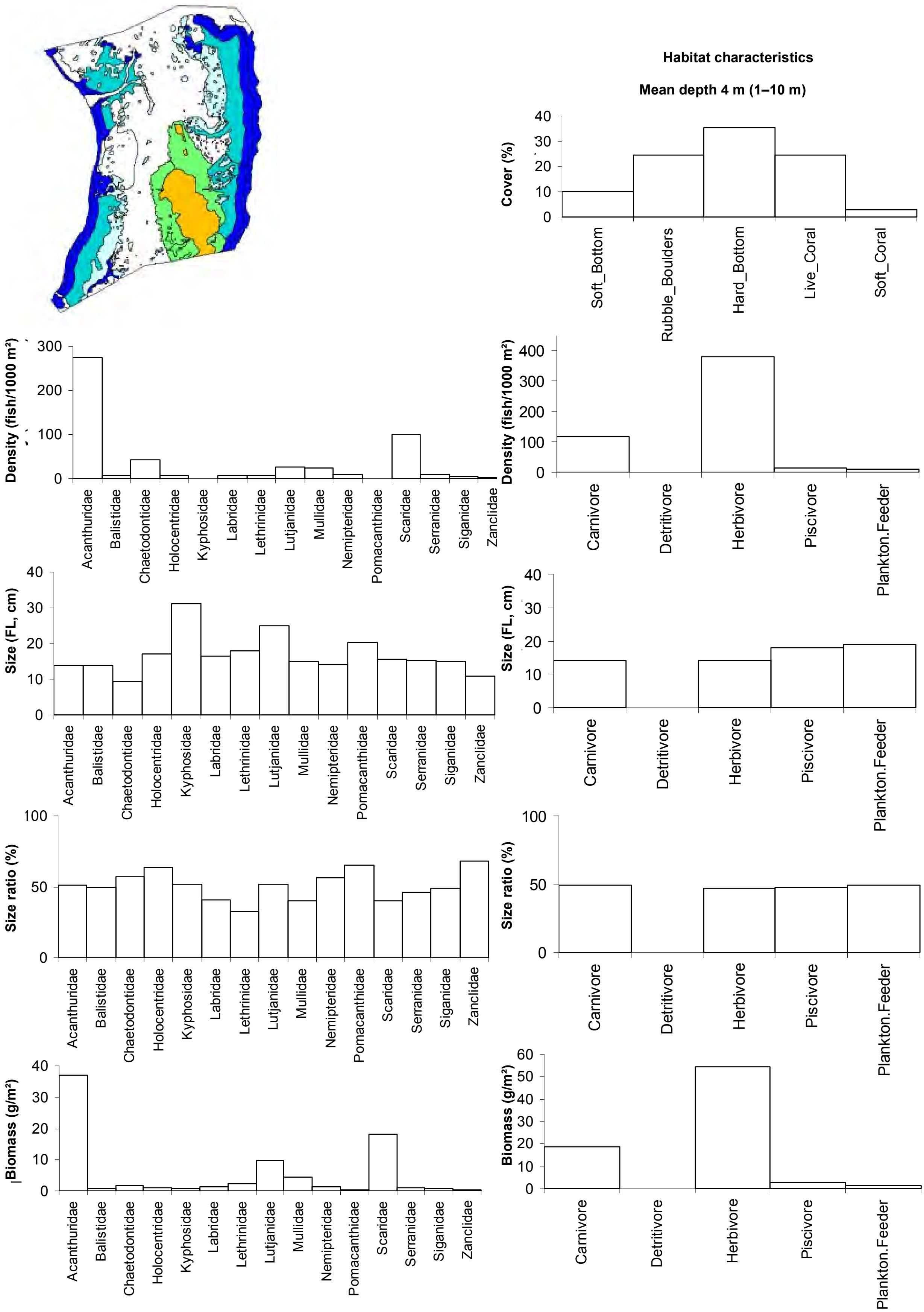

Figure 2.25: Profile of finfish resources in the combined reef habitats of Ngarchelong (weighted average).
FL = fork length.

2.3.2 Discussion and conclusions: finfish resources in Ngarchelong

- The assessment indicated that the status of finfish resources in Ngarchelong at the time of surveys was average.

- The habitat was found to be generally healthy, with good representation of different substrate types and live coral.

- Fish density, biomass, and especially biodiversity displayed values only slightly lower than the richest site in the country, Koror, and average to high compared to regional values.

However:

  - size ratios were at the lower end of the country range;
  - fish everywhere reacted warily to the presence of divers, even inside the reserve, suggesting that spearfishing is a very common practice;
  - large-sized species of parrotfish (*Scarus altipinnis*, *Chlorurus microrhinos*, *Hipposcarus longiceps*) were only rarely observed;
  - A total absence of large groupers and napoleon wrasses, as well as other carnivores was also noted: *Lutjanus gibbus* was present but very wary, and Lethrinidae (*Lethrinus harak*, *L. xanthochilus*, *L. olivaceus*) were present only in small numbers. Apex (top of the food chain) predators were also extremely rare.

- Moreover, differences were detected among the four reef habitats. At both coastal and intermediate reefs, the general status of corals was on average fairly good, however very poor at some sites, with coral rubbles covered in encrusting brown sponges, algae and turfs. Better coral coverage was found in front of the northern islands, with many table and branching corals. Back-reef slope was poor in corals, degrading into sandy depths. On the outer reef, coral coverage was rather high in the shallow-reef-flat, with many soft corals (*Lemnalia*), branching *Pocillopora* and tabulate *Acropora*. However, at this habitat coral cover varied, with areas of barren bedrock and rock boulders covered with turfs and encrusting algae mixed with areas with higher coral cover of massive and submassive *Porites* and tabulate, encrusting and digitate corals abundant, especially below 20 m.

- Similar to habitat conditions, finfish resources showed variability among the four reef types. The coastal reefs, although representing only less than 20% of the total reef area in Ngarchelong, were particularly rich in fish fauna (abundance, biomass, size and species diversity), although community composition was dominated by Acanthuridae. Reef fishing was done mainly for subsistence goals in this habitat. In contrast, the lagoon and back-reefs displayed the lowest values of density, biomass, average size and diversity. Average sizes of several families (Lethrinidae, Scaridae, Mullidae, Serranidae and Labridae) were much lower than the 50% of their maximum recorded value, indicating an impact from fishing on these targeted families. Fishing was in fact more intense on lagoon reefs and the mostly targeted families were Lethrinidae, followed by Lutjanidae, Serranidae and Scaridae. The outer reefs displayed intermediate conditions between coastal and lagoon reefs in Ngarchelong, but were relatively poor when compared to the outer reefs of the other country sites.

- Male fishers already exploited the reserve area as well as areas located much further to the north.

2.4 Invertebrate resource surveys: Ngarchelong

The diversity and abundance of invertebrate species at Ngarchelong were independently determined using a range of survey techniques (Table 2.12), broad-scale assessment (using the 'manta tow'; locations shown in Figure 2.26) and finer-scale assessment of specific reef and benthic habitats (Figures 2.27 and 2.28).

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

Table 2.12. Number of stations and replicates completed at Ngarchelong

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	22	132 transects
Soft-benthos transects (SBt)	13	78 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	1	36 transects
Mother-of-pearl searches (MOPs)	6	36 search periods
Reef-front searches (RFs)	9	54 search periods
Reef-front search by walking (RFs_w)	0	0 search period
Sea cucumber day searches (Ds)	6	36 search periods
Sea cucumber night searches (Ns)	2	12 search periods

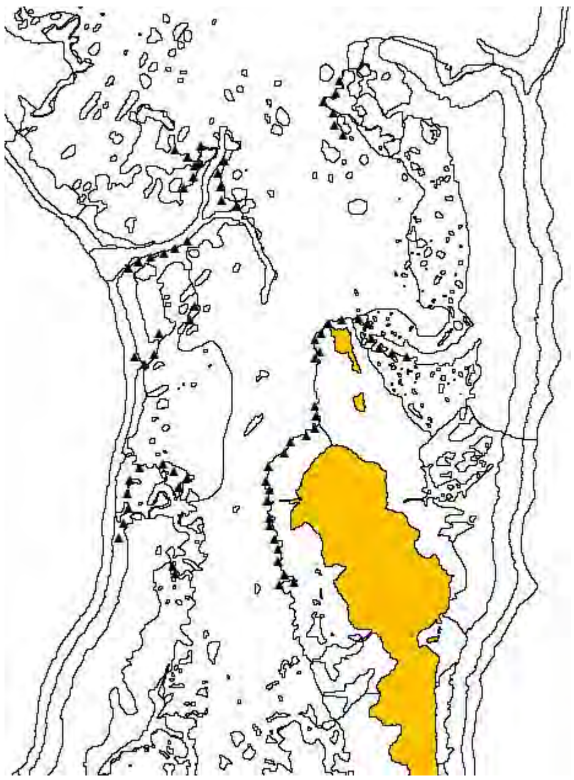

Figure 2.26: Broad-scale survey stations for invertebrates in Ngarchelong.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

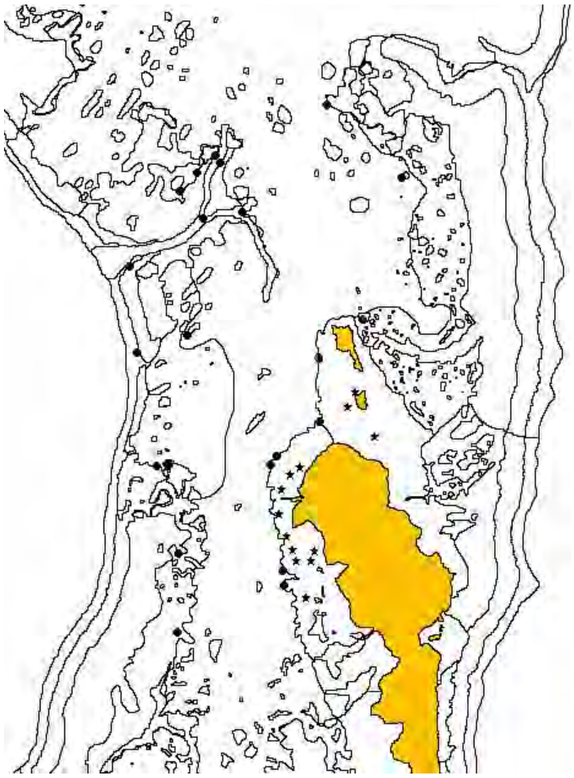

Figure 2.27: Fine-scale reef-benthos transect survey stations and soft-benthos transect survey stations in Ngarchelong.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

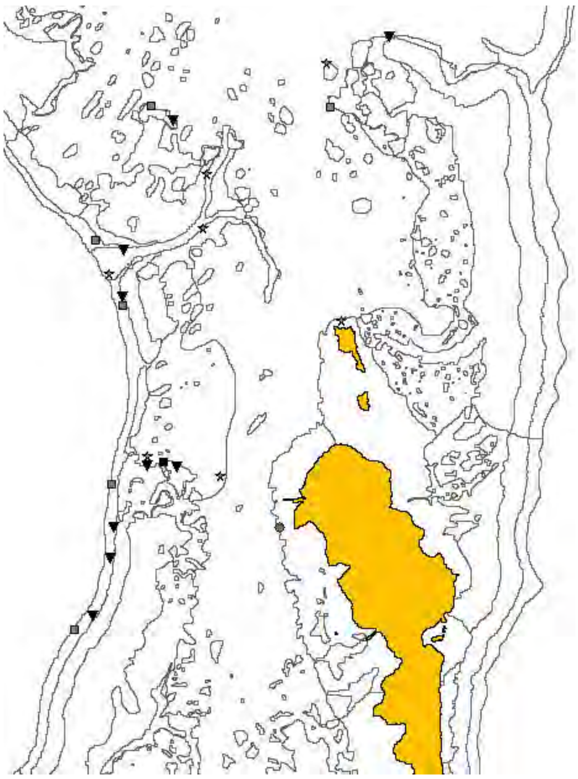

Figure 2.28: Fine-scale survey stations for invertebrates in Ngarchelong.
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
black squares: mother-of-pearl transct stations (MOPt);
grey stars: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Eighty-one species or species groupings (groups of species within a genus) were recorded in the Ngarchelong invertebrate surveys: 16 bivalves, 25 gastropods, 23 sea cucumbers, 6 urchins, 6 sea stars, 2 cnidarians and 3 lobsters (Appendix 4.1.1). Information on key families and species is detailed below.

2.4.1 Giant clams: Ngarchelong

Shallow-reef habitat that is suitable for giant clams was extensive at Ngarchelong (37.9 km^2: approximately 25.6 km^2 within the lagoon and 12.3 km^2 on the reef front or slope of the barrier). The main lagoon was very extensive at ~149.8 km^2, and stretched west and north from Babeldaob across a full range of reef structures before reaching a reef complex at the barrier.

At Ngarchelong, the coastline was less characterised by bays than extended shallow coastal reef flats with seagrass and fringing coral reef. Some true embayments with mangrove existed along the coastline just south of Ngarchelong where conditions were more protected from seasonal northeast winds (June to September). This relatively open lagoon (with barrier passages to the west, north and northeast) was subject to a higher level of oceanic influence, the barrier reef having a complex broad structure and a shallow reef slope (shoals extending seawards). In general a complete range of habitats was available for giant clams.

Using all techniques, seven species of giant clam were noted. Broad-scale sampling provided a good overview of giant clam distribution and density of the seven clam species recorded: the elongate clam *Tridacna maxima*, the boring clam *T. crocea*, the fluted clam *T. squamosa*, the smooth clam *T. derasa*, the true giant clam *T. gigas*, the horse-hoof or bear's paw clam *Hippopus hippopus* and the china clam *H. porcellanus*. *H. porcellanus* has a limited distribution (Philippines to western Irian Jaya), and has not been recorded before in CoFish surveys of other Pacific Island countries.

Records from broad-scale sampling revealed that *T. crocea* had the widest occurrence (found in 12 stations and 68 transects) followed by *T. maxima* (12 stations and 57 transects), *T. squamosa* (8 stations and 10 transects), *T. gigas* (7 stations and 10 transects) and *T. derasa* (6 stations and 10 transects). *H. hippopus,* which is well camouflaged and usually relatively sparsely distributed, was recorded in 11 stations (28 transects in total). This was the first time for our researchers to see *H. porcellanus* (5 stations and 6 transects), a less common species than *H. hippopus* (Figure 2.29).

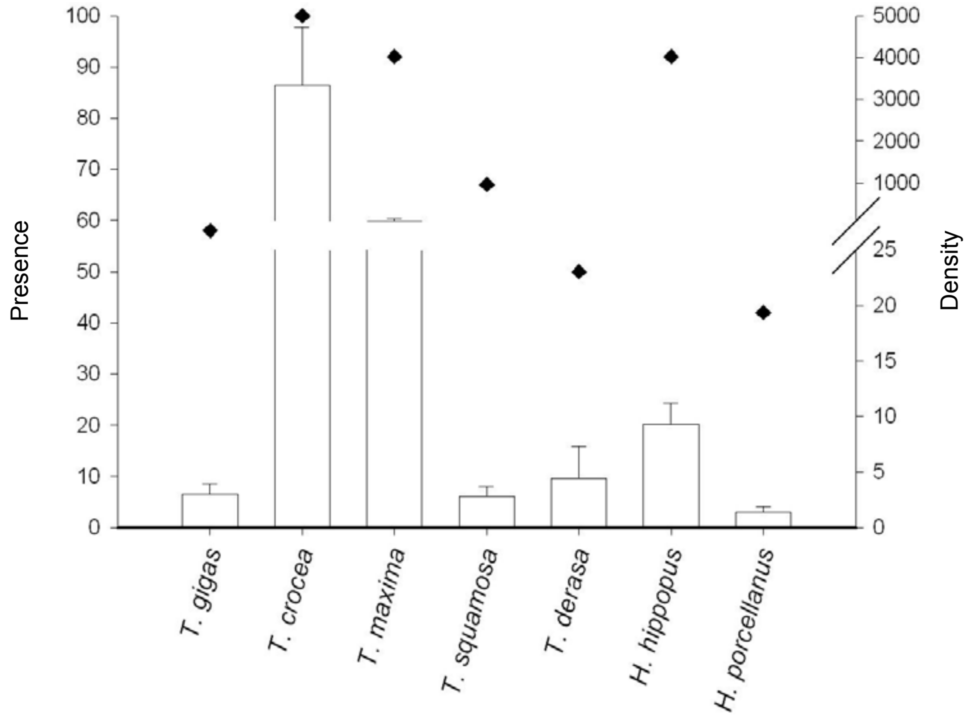

Figure 2.29: Presence and mean density of giant clam species at Ngarchelong based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 2.30). In these reef-benthos assessments (RBt), *T. crocea* was present in 100% of stations, the highest station density being 11,458.3 /ha ±1168.0. *T. maxima* was also relatively common (82% of stations), with moderately high density. Distribution (32% of stations) and density of *H. hippopus* were moderate and *T. squamosa* was less common and at lower density than in neighbouring CoFish sites. No high-density patches of *H. hippopus*, *T. squamosa*, or *H. porcellanus* clams were located in survey.

Outstanding results were obtained for the two large giant clam species. Firstly *T. derasa*, which is usually only rarely recorded in RBt surveys, was recorded in four stations at reasonable density (7.6 /ha ±3.5), whereas *T. gigas* was also numerous in comparison to elsewhere in the Pacific. *T. gigas* was noted in numerous areas of reef at Ngarchelong and 15 individuals were recorded in survey, but only once in RBT transects (Figure 2.30).

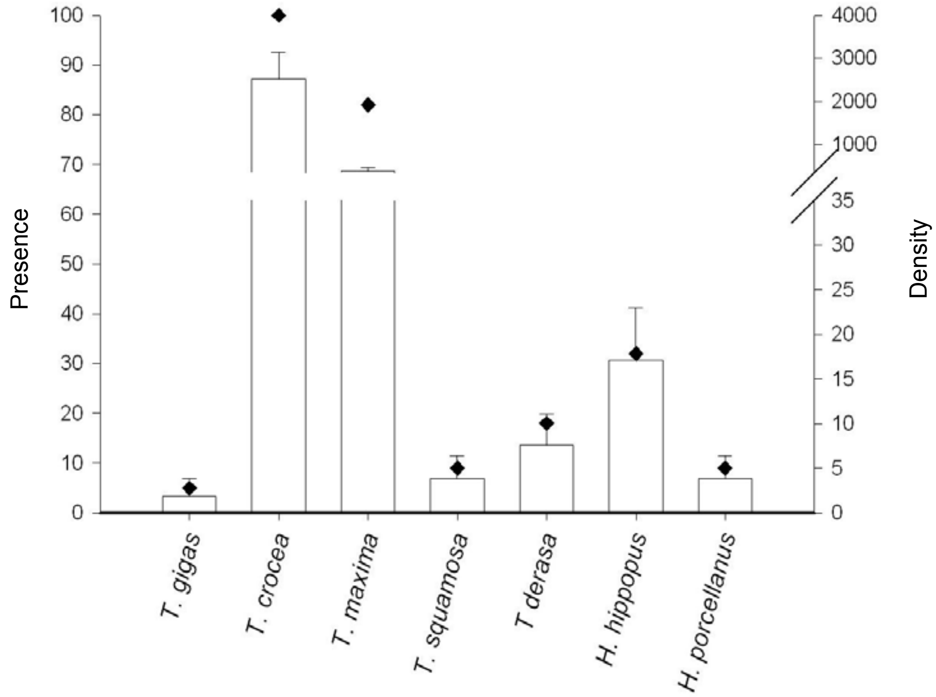

Figure 2.30: Presence and mean density of giant clam species at Ngarchelong based on reef-benthos transect survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

A full range of *T. crocea* lengths were noted although the largest sizes were not common (mean 7.0 cm ±0.1). The mean size of *T. maxima* was 12.9 cm ±0.4, whereas *T. maxima* from reef-benthos transects alone (shallow-water reefs) had a slightly smaller mean length (12.4 cm ±0.4, which represents a clam of about 5–6 years old).

A full range of sizes were recorded for the faster growing *T. squamosa* (which grows to an asymptotic length L_∞ of 40 cm). This species averaged 24.2 cm shell length ±1.7 (which equates to a clam of approximately 6 years of age). *H. hippopus* (mean length 25.9 cm ±0.7) are generally well camouflaged, especially clams below 14 cm, but the size-class distribution indicates that recruitment was occurring and a full range of adult sizes, although small in number, was present. *H. porcellanus* was relatively common at Ngarchelong but, as in other sites, always less common than *H. hippopus*. *H. porcellanus* had a mean length of 25.7 cm ±1.3, and was mostly noted in middle and outer zones of the lagoon. Twenty-four *T. derasa* were recorded in this survey, which is a large number in comparison to CoFish records elsewhere in the Pacific. *T. derasa* had a mean length of 34.7 cm ±1.8, and the smallest was 10 cm (Figure 2.31). The fifteen *T. gigas* (which can reach adult lengths >1.3 m) recorded in Ngarchelong had a mean length of 65.5 cm; the largest clam was >110 cm in length.

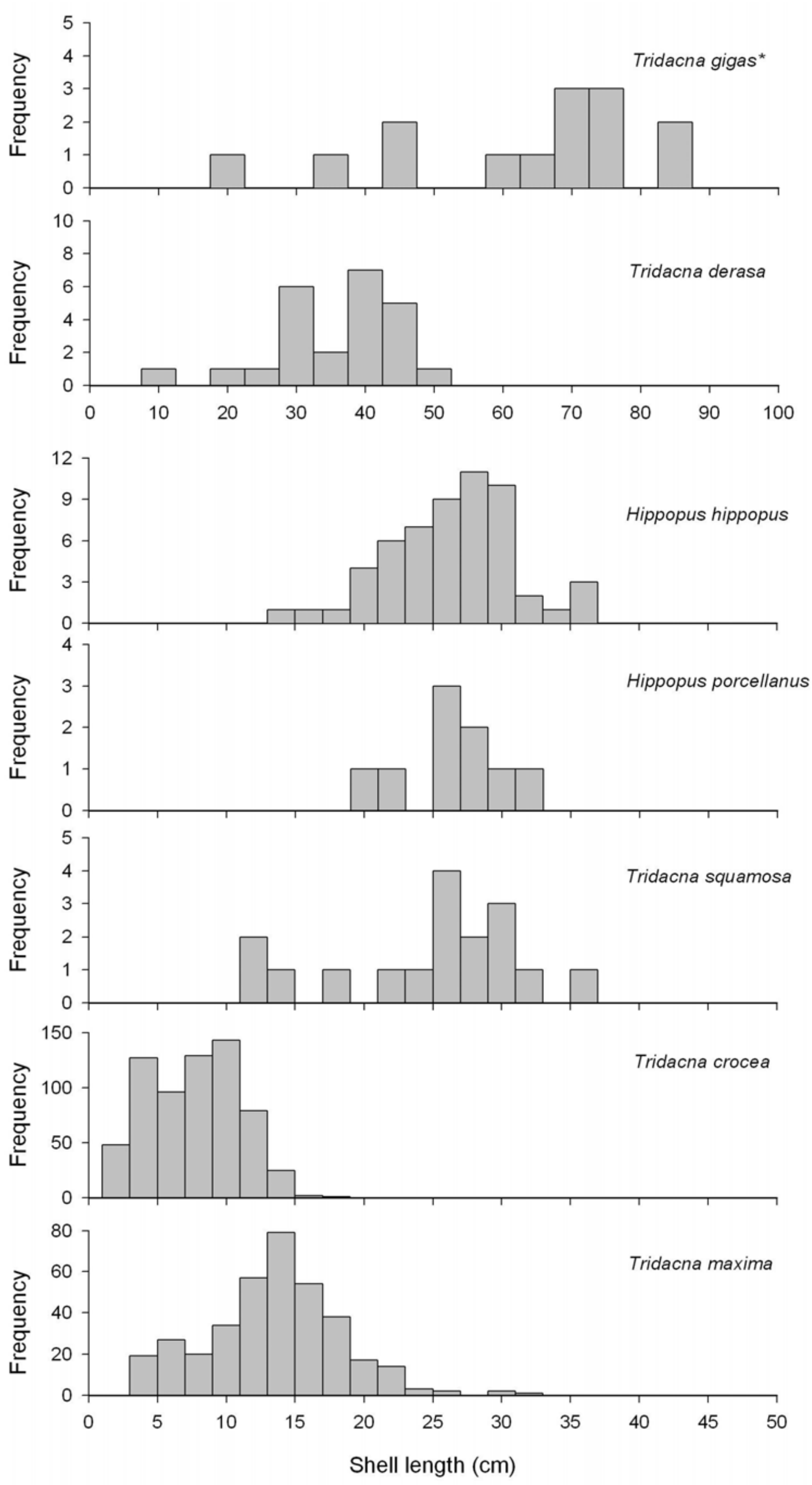

Figure 2.31: Size frequency histograms of giant clam shell length (cm) for Ngarchelong.
* One large *T. gigas* of 115 cm was also recorded.

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

Palau is within the natural distribution of the commercial topshell, *Trochus niloticus*, and Ngarchelong has both inshore, intermediate and barrier reef suitable for both juveniles and adults of this commercial species. The CoFish survey work revealed that *T. niloticus* was relatively commonly distributed around the reefs at Ngarchelong (total lineal distance of exposed reef perimeter 33.3 km). The most significant trochus aggregations were localised within coastal reefs located to the north of the main Ngarchelong harbour and midshore reefs receiving both oceanic and lagoonal influence near passages. The reef slope and shoals found outside the barrier reef were extensive, with a more exposed aspect and water movement regime. Although *T. niloticus* was commonly recorded in this area as well, densities were generally low (<20 /ha per station).

The management of the trochus fishery in Palau restricts commercial fishing to one harvest every 3–4 years, with subsequent rest periods for stock recovery. The last commercial harvest in Palau was in 2005.

CoFish work surveyed all reef zones to ascertain the distribution and density of trochus. Usually, in addition to standard broad-scale and shallow-reef surveys, trochus information is collected using reef-front searches and mother-of-pearl transects (MOPt). If too few trochus are present, the dive team resorts to mother-of-pearl searches (MOPs), which allow a more comprehensive coverage of the bottom, without the need to conform to the linearity of strip transects (See Methods and Table 2.13).

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

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
B-S	10.8	1.3	10/12 = 83	21/72 = 29
RBt	458.3	215.8	15/22 = 68	47/132 = 36
RFs	22.2	10.6	7/9 = 78	17/54 = 31
MOPs	32.8	13.4	5/6 = 83	11/36 = 31
MOPt	979.2		1/1 = 100	6/6 = 100
Tectus pyramis				
B-S	8.0	1.5	9/12 = 75	25/72 = 35
RBt	204.5	66.7	18/22 = 82	53/132 = 40
RFs	14.4	3.5	8/9 = 89	19/54 = 35
MOPs	34.1	13.7	5/6 = 83	15/36 = 42
MOPt	20.8		1/1= 100	1/6 = 17
Pinctada margaritifera				
B-S	4.6	1.2	9/12 = 75	16/72 = 22
RBt	15.2	5.2	7/22 = 32	8/132 = 6
RFs	0.4	0.4	1/9 = 11	1/54 = 2
MOPs	1.3	1.3	1/6 = 17	1/36 = 3
MOPt	0	0	0/1 = 0	0/6 = 0

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

A total of 414 trochus were recorded (n = 268 were measured) during the survey, which was 24% of the trochus noted in the four sites surveyed in Palau. The majority of the stock was on shallow reef (~1.5–2 m deep) that was easily accessible to fishers working with a mask and snorkel. By far the majority of broad-scale and reef-benthos transect stations held trochus, and those stations that returned a positive result yielded a density range of 3–4167 trochus/ha. As mentioned previously, trochus were common, yet not in dense aggregations, on the exposed reef fronts (range of station densities, 4–94 /ha). In MOP surveys, only a single station was positioned above a reasonable aggregation, and in this location the abundance was high (Table 2.13). Most MOP surveys were searches, with the highest station density recorded at 91 trochus/ha.

If we adopt the threshold of 500 shells/ha as an indication of the threshold density required before main aggregations can be considered for commercial fishing, trochus density records from Ngarchelong generally indicate that aggregations still have significant potential for growth in overall abundance.

Shell size also gives an important indication of the status of stocks by highlighting new recruitment into the fishery, or the lack of a recruitment signal, which could have implications for the numbers of trochus entering the capture size classes in the next two years.

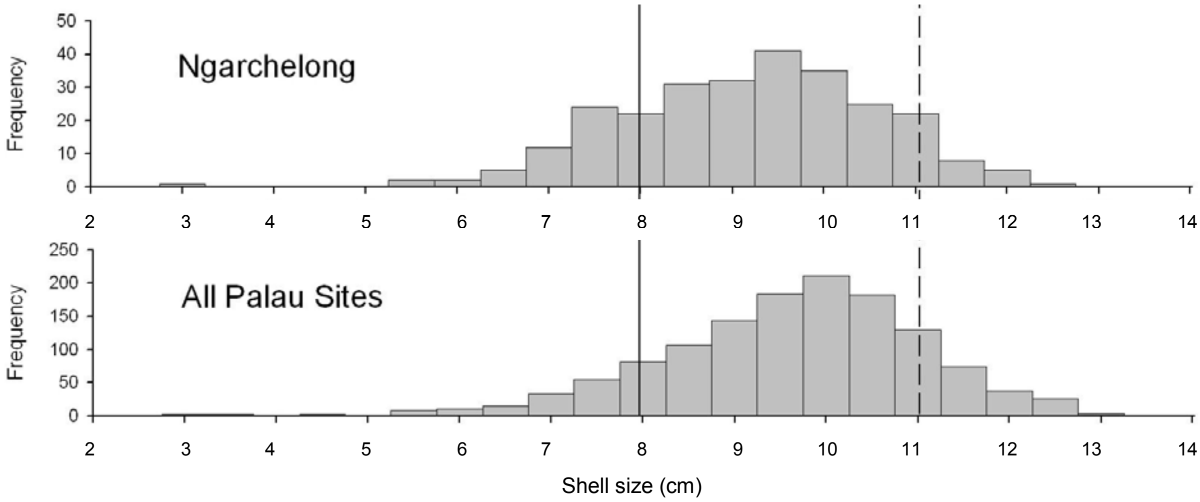

Figure 2.32: Size frequency histograms of *Trochus niloticus* shell length (cm) in Ngarchelong and all Palau sites.

The mean basal width of trochus at Ngarchelong was 9.0 cm ±0.1 (Figure 2.32). The length frequency graph reveals that the bulk of stock at Ngarchelong are within the capture size classes (first maturity of trochus is at 7–8 cm or ~3 years old). For this cryptic species, younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic style of life and joining the main stock. As can be seen from the length frequency graph, a small recruitment pulse of younger trochus is evident from size records collected at Ngarchelong. In this case younger shells, probably a result of a moderately successful spawning in summer 2004, are entering the fishery size classes. There is no clear evidence of large successful recruitment from 2005 or 2006 spawnings.

In addition, only 4% of the stock were larger than 11 cm basal width, which is relatively low for the mature proportion of a population. In some other trochus fisheries, where stock has not been fished for an extended period or there is a maximum basal width for commercial sale (of >11 cm), this portion of the stock makes up 20–50% of the population. The result from Ngarchelong can be interpreted as an indication of the level of fishing in previous harvests. Low numbers of large trochus can indicate that trochus stocks were comprehensively targeted during the previous two fishing periods (in 2000 and 2005).

The level of suitability of reefs for grazing gastropods was also highlighted by results for false trochus or green topshell (*Tectus pyramis*). This related, but less valuable species of topshell (an algal-grazing gastropod with a similar life history to trochus) was common and at relatively high density at Ngarchelong (n = 205 recorded in survey). The mean size (basal width) of *T. pyramis* was 5.8 cm ±0.1 and, again, no large recruitment pulse was identified, which may suggest that conditions for spawning and/or settlement of these gastropods were not especially favourable in recent years (Figure 2.33).

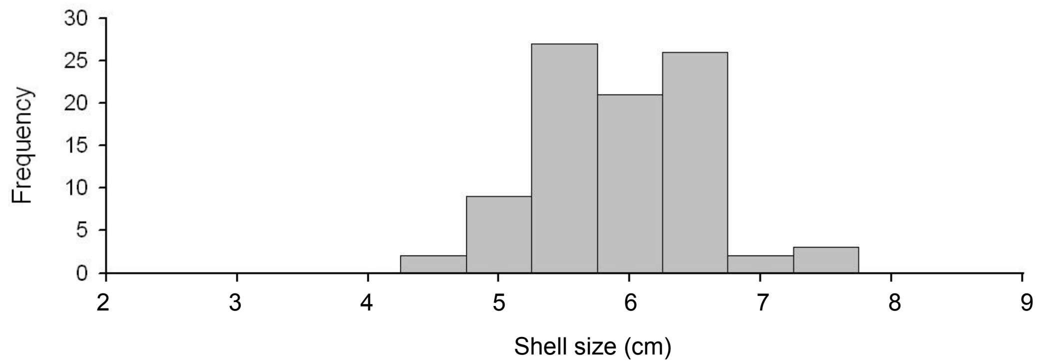

Figure 2.33: Size frequency histogram of *Tectus pyramis* shell base diameter (cm) for Ngarchelong.

Another mother-of-pearl species, the blacklip pearl oyster, *Pinctada margaritifera*, is cryptic and normally sparsely distributed in open lagoon systems (such as found at Ngarchelong). In survey, the number of blacklip seen during assessments was moderately high (n = 32), and higher than for other CoFish sites in Palau. The mean shell length (anterior–posterior measure) of these pearl oysters was 11.3 cm ±1.2.

2.4.3 Infaunal species and groups: Ngarchelong

Soft benthos at the coastal margins of Ngarchelong was generally suitable for seagrass, but the plan for surveys in Palau was to concentrate resources and time on questions relating to the important trochus fishery. As no obvious or reported concentrations of in-ground resources (shell 'beds') were noted, we did not complete infaunal 'digging' surveys (quadrat surveys).

2.4.4 Other gastropods and bivalves: Ngarchelong

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs) was not recorded in survey, but two smaller species were noted. *L. lambis* was recorded in broad-scale and reef- and soft-benthos transect stations at low-to-moderate density (n = 25, average of 2–53 /ha). The only other *Lambis* species recorded was *Lambis chiragra* (n = 8). The strawberry or red-lipped conch, *Strombus luhuanus*, was also not common, with no dense patches recorded (Appendices 4.1.2 to 4.1.9).

Three species of turban shell, *Turbo argyrostomus*, *T. chrysostomus* and *T. setosus*, were recorded during surveys. The larger, silver-mouthed turban, *T. argyrostomus*, was recorded at moderate rates (in 33% of reef-front search periods) and density (4.4 /ha ±2.7). The density was higher for reef-benthos transect stations (47.3 /ha ±29.6). Other resource species targeted by fishers (e.g. *Astralium*, *Bursa*, *Cerithium*, *Chicoreus*, *Conus*, *Cypraea*, *Dolabella*, *Haliotis*, *Latirolagena*, *Ovula*, *Pleuroploca*, *Tectus*, *Thais* and *Vasum*) were also recorded during independent survey (Appendices 4.1.2 to 4.1.9).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Anadara*, *Atrina*, *Chama*, *Lopha*, *Pinctada*, *Pinna*, *Pteria* and *Spondylus*, are also in Appendices 4.1.2 to 4.1.9. No creel survey was conducted at Ngarchelong.

2.4.5 Lobsters: Ngarchelong

There was no dedicated night reef-front assessment of lobsters (See Methods.), although night-time assessments (Ns) for nocturnal sea cucumber species offered a small extra opportunity to record lobster species. Lobster records (*Panulirus versicolor* and *P.* spp.) were not common (n = 7) in surveys at Ngarchelong. Five prawn killers (*Lysiosquillina maculata*) and two mud lobsters, *Thalassina* spp. (locally known as *cheramrou*), were also recorded.

2.4.6 Sea cucumbers[7]: Ngarchelong

Around Ngarchelong there were extensive areas of shallow- and deep-water sheltered lagoon bordering the elevated land mass of Babeldaob and extending north (part of the total lagoon area, 149.8 km^2). Coastal areas around Ngarchelong were very suitable for supporting sea cucumbers, which feed on detritus and other organic matter in the upper few mm of bottom substrates. Extensive reef margins and areas of shallow, mixed hard and soft benthos provided a range of suitable habitats for sea cucumbers.

The presence and density of sea cucumber species were determined through broad-scale, fine-scale and dedicated survey methods (Table 2.14; Appendices 4.1.2 to 4.1.9; see also Methods). Results from the full range of assessments yielded 22 commercial species of sea cucumber (plus one indicator species; see Table 2.14).

Sea cucumber species associated with shallow-reef areas, such as the medium-value leopardfish (*Bohadschia argus*), was common in distribution (40% of broad-scale transects) and recorded at moderately high density (24.3 /ha ±5.3). The high-value black teatfish (*Holothuria nobilis*), which is easily targeted by commercial fishers, was quite common (17% of broad-scale transects), but not recorded at very high density in broad-scale or shallow-reef transect stations (<4 /ha). The fast growing and medium/high-value greenfish (*Stichopus chloronotus*) was present (33–36% of broad-scale and reef-benthos transects), and was at reasonably high densities in RBt stations (109.8 /ha ±40.7; see Appendix 4.1.3).

Surf redfish (*Actinopyga mauritiana*) were recorded in reef-front searches (RFs) and shallow-water reef transects (RBt). As this species is mostly found, where its name suggests, on reef fronts, RFs provide a valuable signal on its status. In Ngarchelong, 44% of reef-front searches

[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.

held *A. mauritiana*, but in these and in RBts the density was not high (<10 /ha). In other locations in the Pacific, this species is recorded in densities above 400–500 /ha.

More protected areas of reef and soft benthos in the enclosed, relatively embayed areas of the lagoon also returned good distribution and density values for sea cucumbers. Curryfish (*Stichopus hermanni*) were recorded in 22% of broad-scale assessments at moderately low density (7.2 /ha). Blackfish (*Actinopyga miliaris*) and stonefish (*A. lecanora*) were also recorded, but the species group of most local interest would probably be the currently unnamed *A.* sp. nov. (currently being described by Kris Netchy, University of Guam), the brown curryfish, *Stichopus vastus* and *Holothuria impatiens*. *Actinopyga* spp. and the brown curryfish (*S. vastus*) were recorded in some exceptionally high-density patches at soft-benthos transect stations (Figure 2.34).

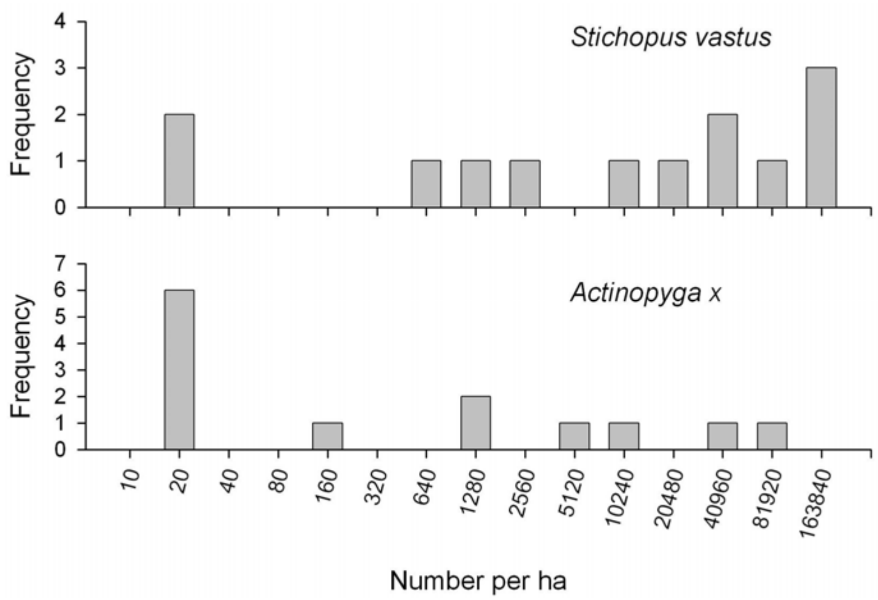

Figure 2.34: Histogram of sea cucumber inshore species abundance data by soft-benthos station in Ngarchelong.

In Palau, these three species (or species groups) of sea cucumbers are exploited by the subsistence fishery and traditionally used as food. *Actinopyga* spp. has three colour morphs and is prepared by gutting and cleaning the animal before the body wall is finely chopped up and mixed with lime juice and sauce for use as a sashimi.

In Palau, a lower-value species of sea cucumber, lollyfish (*Holothuria atra*), is sometimes used as a neurotoxin for catching octopus. This species was still at high density in soft-benthos transects. Pinkfish (*H. edulis*) was also present at reasonable coverage and density.

The high-value sandfish, *H. scabra*, was found in 31% of soft-benthos stations at Ngarchelong. Although mangrove and seagrass shoreline areas were common along shorelines, this species was mostly recorded on those in the southwest, which possibly received more shelter from northeasterlies (June to September). No comprehensive search was completed to the east of the Babeldaob mainland and it would be good if this area could be assessed in the future to see if seagrass areas support this valuable species. In the four stations where sandfish was recorded, the density was high (792–1792 individuals/ha), and a full range of size classes was noted (mean length of 16.5 cm ±0.3, n = 142; Figure 2.35).

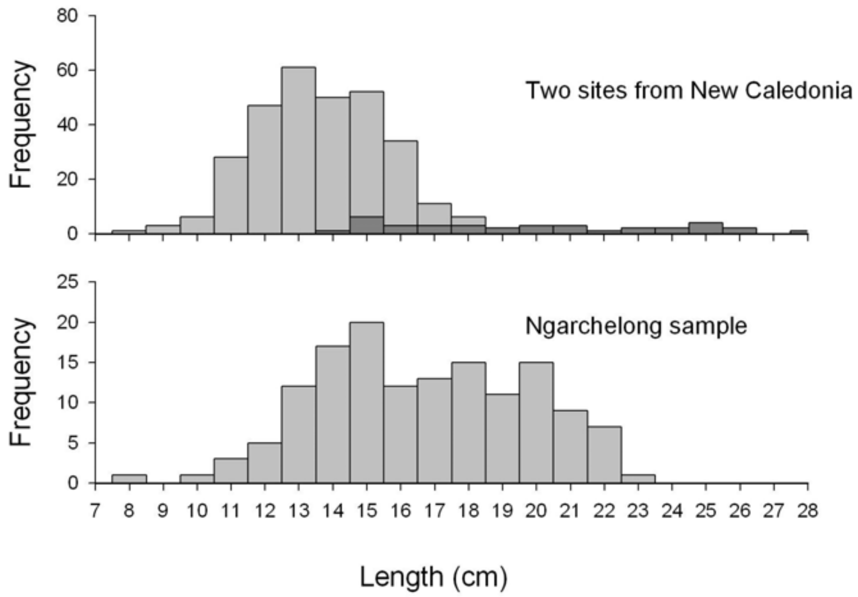

Figure 2.35: Histogram of sandfish, *Holothuria scabra*, length frequencies from Ngarchelong (lower graph), and two other western Pacific samples for comparison (upper graph).

The lower-value false sandfish (*Bohadschia similis*), which is usually recorded in a similar habitat as sandfish, was not ubiquitous across soft-benthos transect sites either, only being recorded in 38% of stations (with moderate-to-high average density 496.8 /ha ±384.9).

Deep-water assessments (30 x 5-min searches, average depth 21.8 m, maximum depth 31 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the narrow and wide passages had suitably dynamic water movement for these species, and *H. fuscogilva* was recorded in four of the six stations surveyed. At these stations, the average station density for *H. fuscogilva* was low to moderate (7.7 /ha ±4.6) and, in general, the density of other deepwater species was also low to moderate.

2.4.7 Other echinoderms: Ngarchelong

At Ngarchelong, a small number of edible collector urchins, *Tripneustes gratilla* (n = 4), and a single slate urchin, *Heterocentrotus mammillatus*, were recorded in survey. Urchins, such as *Diadema* spp. and *Echinothrix* spp., can be used within assessments as potential indicators of habitat condition. Unusually, *Diadema* spp. were not noted and *Echinothrix* spp. were rare in survey. *Echinometra mathaei* were recorded at low levels across the site (Appendices 4.1.1 to 4.1.7).

Starfish (e.g. *Linckia laevigata*, the blue starfish, and *L. guildingi*) were very common in broad-scale surveys (92% of broad-scale transects) and at moderate-to-high density (183.8 /ha ±35.0). Pincushion stars, *Culcita novaeguineae*, were also common (n = 32), but the most destructive corallivore (coral eating) starfish, the crown of thorns (*Acanthaster planci*), was moderately rare (n = 12, mean density in broad-scale transects = 2.3 /ha).

The horned or chocolate chip star (*Protoreaster nodosus*) was recorded at moderate density in inshore seagrass, and the doughboy sea star (*Choriaster granulatus*) was at low density, mostly at depth on the lagoon floor.

Table 2.14. Sea cucumber species records for Ngarchelong

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 22; SBt = 13			Other Stations RFs = 9; MOPs = 6; MOPt = 1			Other Stations Ds = 6; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinities	Deepwater redfish	M/H				16.0	52.1	31 SBt						
Actinopyga lecanora	Stonefish	M/H				1.9 3.2	41.7 41.7	5 RBt 8 SBt						
Actinopyga mauritiana	Surf redfish	M/H				3.8	41.7	9 RBt	5.2	11.8	44 RFs			
Actinopyga miliaris	Blackfish	M/H	0.4	15.7	3				0.4	3.9	11 RFs	0.4	2.4	17 Ds
Actinopyga sp. nov.	Undescribed species	M				3682.7	6839.3	54 SBt				1204.4	2408.9	50 Ns
Bohadschia argus	Leopardfish	M	24.3	60.3	40	41.7 12.8	183.3 166.7	23 RBt 8 SBt	0.9 5.1	3.9 30.3	22 RFs 17 MOPs	0.8 13.3	4.8 26.7	17 Ds 50 Ns
Bohadschia graeffei	Flowerfish	L	3.9	21.8	18				2.2 2.5 104.2	9.8 15.2 104.2	22 RFs 17 MOPs 100 MOPt			
Bohadschia similis	False sandfish	L				496.8	1291.7	38 SBt				75.6	151.1	50 Ns
Bohadschia vitiensis	Brown sandfish	L				439.1	815.5	54 SBt				1528.9	1528.9	100 Ns
Holothuria atra	Lollyfish	L	24.1	49.5	49	125.0 897.4	171.9 897.4	73 RBt 100 SBt	3.9 11.4	8.8 13.6	44 RFs 83 MOPs	44.4	44.4	100 Ns
Holothuria coluber	Snakefish	L				5.7 67.3	62.5 175.0	9 RBt 38 SBt				13.3	26.7	50 Ns
Holothuria edulis	Pinkfish	L	19.4	66.5	29	30.3 105.8	133.3 343.8	23 RBt 31 SBt						
Holothuria flavomaculata		L												
Holothuria fuscogilva[4]	White teatfish	H										5.2	7.7	67 Ds
Holothuria fuscopunctata	Elephant trunkfish	M	0.2	16.7	1				1.7	15.7	11 RFs	3.6	21.4	17 Ds
Holothuria nobilis [4]	Black teatfish	H	3.9	23.6	17	3.8	41.7	9 RBt	1.3 7.6	5.9 22.7	22 RFs 33 MOPs	1.6	4.8	33 Ds
Holothuria scabra	Sandfish	H				455.1	1479.2	31 SBt						
Holothuria pervicax		L												
Stichopus chloronotus	Greenfish	H/M	23.6	70.8	33	109.8 25.6	302.1 111.1	36 RBt 23 SBt	2.2	6.5	33 RFs			
Stichopus hermanni	Curryfish	H/M	7.2	32.3	22				1.3	7.6	17 MOPs	0.4	2.4	17 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; MOPt = mother-of-pearl transect; Ds = day search; Ns = night search.

Table 2.14. Sea cucumber species records for Ngarchelong (continued)

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 22; SBt = 13			Other Stations RFs = 9; MOPs = 6; MOPt = 1			Other Stations Ds = 6; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Stichopus horrens	Peanutfish	M/L				1.9 19.2	41.7 83.3	5 RBt 23 SBt						
Stichopus vastus	Brown curryfish	H/M				17445.5	20617.4	85 SBt				1471.1	2942.2	50 Ns
Synapta spp.	-	-				22.4	58.3	38 SBt				4.4	8.9	50 Ns
Thelenota ananas	Prickly redfish	H	5.6	30.8	13	1.9	41.7	5 RBt	3.5 3.8	10.5 7.6	33 RFs 50 MOPs	4.8	9.6	50 Ds
Thelenota anax	Amberfish	M	0.2	16.7	1							3.2	6.3	50 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; MOPt = mother-of-pearl transect; Ds = day search; Ns = night search.

2.4.8 Discussion and conclusions: invertebrate resources in Ngarchelong

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

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

- There is a wide range of shallow-water reef habitats that are suitable for giant clams. Inshore, midshore and barrier reef was extensive around Ngarchelong and water movement was generally dynamic.

- A complete range of giant clam species was present, some of which are becoming rare in other parts of the Pacific. There were few management issues to consider for the smaller species of clams (*Tridacna maxima* and *T. crocea*), and the larger clam species, although not at high density, have a better coverage here than at most other CoFish sites around the Pacific.

- In general, the status of giant clams at Ngarchelong was healthy, especially for the most common species. Clam density and the 'full' range of clam size classes present, support the assumption that, apart from some of the largest species, populations of giant clam are only partially impacted by fishing.

In summary, the distribution, density and length recordings of the commercial topshell *Trochus niloticus* give the following picture:

- Local reef conditions at Ngarchelong constitute an extensive and good habitat for juvenile and adult trochus. Commercial stock was common at easily accessible shallow-water reefs close to the main harbour, and on the lagoon-side back-reef at the barrier and near the passage. The exposed reef slope also held trochus, but no high-density aggregations were recorded.

- *Trochus niloticus* was relatively common at Ngarchelong. The density of trochus within the 'core' aggregations (where trochus are typically in greatest abundance) and across reefs in general suggests there is still significant potential for stocks to increase in number. The majority of areas had not reached the 500 shells/ha that is considered to be the minimum threshold for considering commercial harvests.

- Size-class information also reveals that no strong year-class is currently visible below the commercial size-class range, and that past harvests have comprehensively fished the stock, as aggregations are holding very small numbers of large old shells (>11 cm basal width).

Management considerations for trochus

- On occasion, the resting period adopted in Palau may be too short for continued successful management of the trochus fishery. Firstly, this approach relies on there being regular recruitment (no recruitment failures), which is uncommon with mollusc fisheries in general (Strong recruitment year-classes only generally arrive every 3–5 years.). Secondly, most egg production originates from the largest individuals of the population, and trochus only reach these size classes at >6 years of age (from shells that would need to survive up to two harvest rotations under the current management scenario).

- Some areas, which are located in less-than-optimal habitat, such as the exposed reef-front shoals at Ngarchelong, might take longer to recover from fishing and therefore might require extra management of fishing to ensure stocks are not too heavily depleted, or longer periods of rest between fishing periods.

The blacklip pearl oyster, *Pinctada margaritifera*, was relatively common at Ngarchelong, and at greater numbers than at other CoFish sites in Palau.

Data collected on sea cucumbers at Ngarchelong suggest the following:

- Ngarchelong has an extensive and diverse range of environments and depths suitable for sea cucumbers. Bordering Ngarchelong, especially to the south, are extensive inshore reef flats and embayments with seagrass beds and mangrove-lined shorelines (suitable for inshore species). In addition, a full range of oceanic-influenced reefs extends seawards to the barrier reef and northwards.

- The range of sea cucumber species recorded at Ngarchelong was large, partially reflecting the varied environment, but also the fact that the export fishery is highly controlled in Palau (Commercial export has been banned for 15 years.)

- The general indication from presence and density data collected in survey suggests that sea cucumbers are not under significant fishing pressure and stocks typically taken for commercial export are only lightly or moderately affected by past fishing. The species fished by domestic fishers for subsistence are more impacted, and marine protected areas designated near Ngarchelong need to be well managed to ensure these stocks are not depleted. This is especially true for the more easily targeted (and depleted) species of local importance that are under higher pressure at sites in the south of Babeldaob, and the larger inshore species of high value, such as sandfish, *Holothuria scabra*.

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

2.5 Overall recommendations for Ngarchelong

- Spearfishing be controlled and regulated.

- A monitoring system be set up and implemented with community input to follow any further changes in finfish resources.

- The existing marine reserve be patrolled in order to ensure compliance with regulations.

- Groups of large, older clams are protected from fishing to ensure there is sufficient breeding stock to create the next generation. The presence in small numbers of *Hippopus* *porcellanus*, which is not recorded in many other places in the Pacific, may warrant greater protection being offered to this species.

- All clam species need the continued support of strong management controls, to ensure the hard work in protecting this rare resource is continued. In addition, continued community education programme and tourist visits may be encouraged to maintain awareness of the importance and 'uniqueness' of these stocks.

- BMR consider attempting to get most of the 'core' trochus fishery areas up to a threshold density of approximately 500–600 /ha before considering commercial fishing.

- BMR consider protecting a proportion of trochus within main aggregations so that broodstock (sizes ≥11 cm) can remain at higher density post fishing. This could also be accomplished by implementing a blanket measure, such as creating a 'gauntlet' fishery, with an upper as well as a lower size limit, and by 'resting' areas within the main fishing locations for longer periods between periods of commercial fishing.

- Careful management of fishing of sea cucumbers could allow commercial harvesting of a number of export species in Ngarchelong. Preferably, catches could be made using a pulse-harvest fishing strategy, similar to that currently employed for trochus, which allows a period of rest between fishing events and time to re-assess the stocks' response to fishing pressure.

3. PROFILE AND RESULTS FOR NGATPANG

3.1 Site characteristics

Ngatpang is located in the west of Babeldaob Island, at the position 7°29' N, 134°29' E (Figure 3.1). Its fishing area is 'open access', and delimited to the north by the Mlengui Pass and to the south by an east–west line at 7°31' N, 134°22' S. Its length is approximately 9.5 km and its width 6 km. A reserve is present at 7°30'5 N, 134°29'4 E, covering a total surface of 1.5 km². The four typically sampled habitat types were present. However the diveable back-reefs are only located in the northern part (~80% of back-reefs are sandy and not accessible to the divers.). The lagoon is subject to a heavy terrigenous influence due to the many rivers. As a result of the high level of sediment in the water, a high abundance of filtrating sponges was noted.

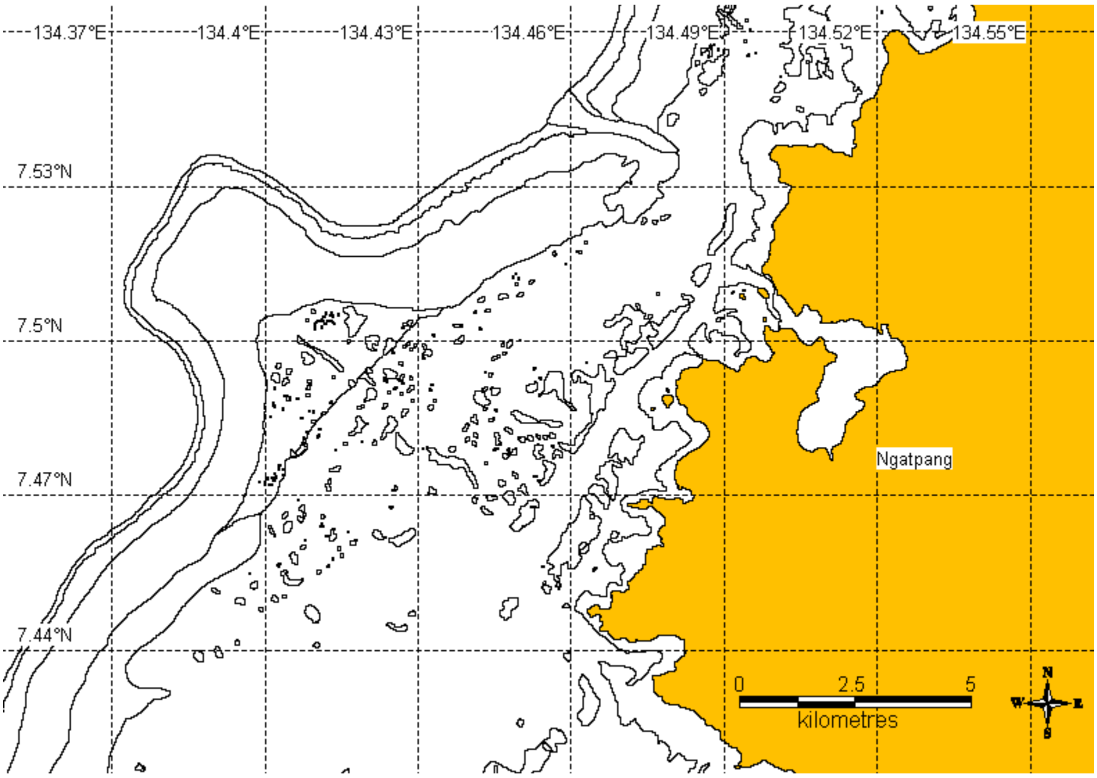

Figure 3.1: Map of Ngatpang.

3.2 Socioeconomic surveys: Ngatpang

Socioeconomic fieldwork was carried out in the Ibobang and Mechebechubl communities (in the following referred to as 'Ngatpang') located on the northwest coast of Palau's main island in May – June 2007. The survey covered a total of 25 households (12 in Ibobang; 13 in Mechebechubl) including 116 people. Thus, the survey represents about 57% of the community's households (44) and total population (204).

Household interviews aimed at the collection of general demographic, socioeconomic and consumption parameters. A total of 23 individual interviews of finfish fishers (19 males, 4 females) and 16 invertebrate fishers (10 males, 6 females) were conducted. These fishers belonged to one of the 25 households surveyed. Sometimes, the same person was interviewed for both finfish and invertebrate fishing.

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

Our survey results (Table 3.1) suggest an average of one fisher per household. If we extrapolate these results, we arrive at a total of 58 fishers in Ngatpang. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher, finfish and invertebrate fisher) by gender, we project a total of 35 fishers who only fish for finfish (all males), a total of 9 fishers who only fish for invertebrates (mostly females, few males) and 14 fishers (males, females) who fish for both finfish and invertebrates.

The majority (88%) of all households in Ngatpang are engaged in fisheries and 80% of all households own a boat. Most boats are motorised (95%); only ~5% are paddle canoes.

Ranked income sources (Figure 3.2) suggest that fisheries are not important compared to salaries. Only 8% of the households indicated that fisheries provide their first source of income, and another 20% quoted fisheries as their second income source. Salaries provide 84% of all households with first income, 8% with second income. Other sources, mainly retirement or pension payments, are also less important, providing 4% households with first and 16% with second income. Agriculture plays the least important role, providing either first or second income to only 4% of all households.

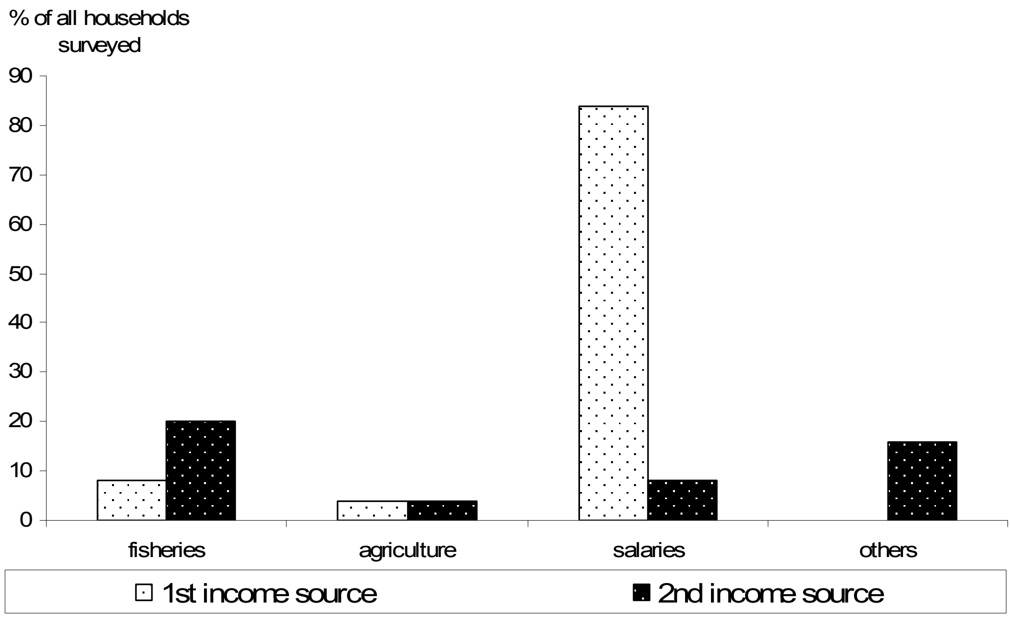

Figure 3.2: Ranked sources of income (%) in Ngatpang.
Total number of households = 25 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly retirement payments, welfare and handicrafts.

The importance of fisheries, however, shows in the fact that all households consume fresh fish, and more than half (60%) also consume invertebrates. The fish that is consumed is mostly caught by a member of the household (88%), sometimes also bought (40%) but often received as a gift (56%). The proportion of invertebrates caught by a member of the household where consumed is lower (44%). Invertebrates are also much less frequently bought (16%) or received as a gift (16%) in comparison to finfish. These results suggest that finfish are not only sold at an external market, i.e. Koror, but also sold in the Ngatpang community. However, the share of invertebrates marketed within the local community is assumed to be small, and if invertebrates are harvested for commercial purposes they are mainly sold at external markets.

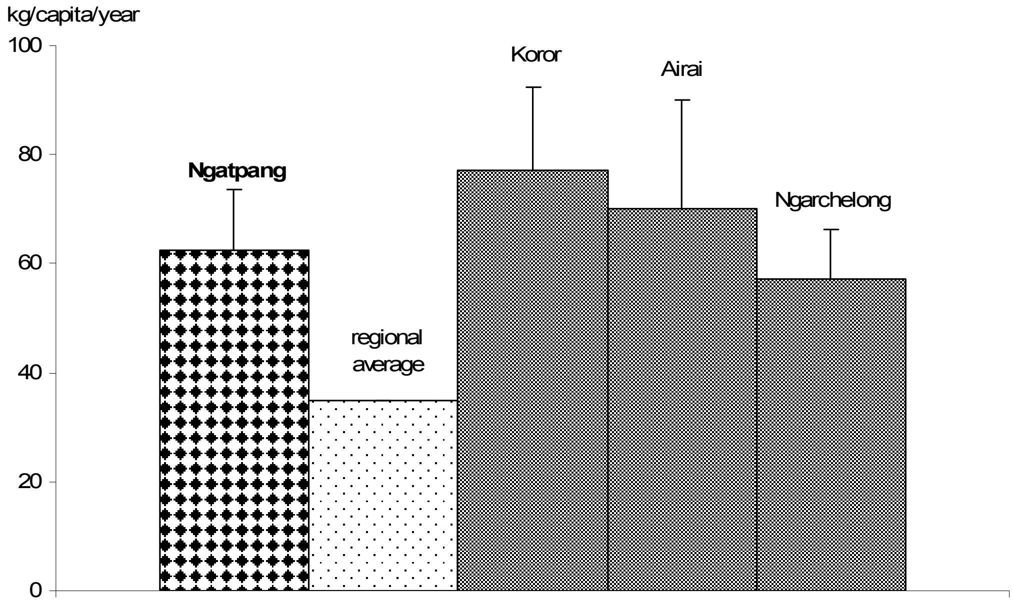

Figure 3.3: Per capita consumption (kg/year) of fresh fish in Ngatpang (n = 25) compared to the regional average (FAO 2008) and the other three CoFish sites in Palau.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

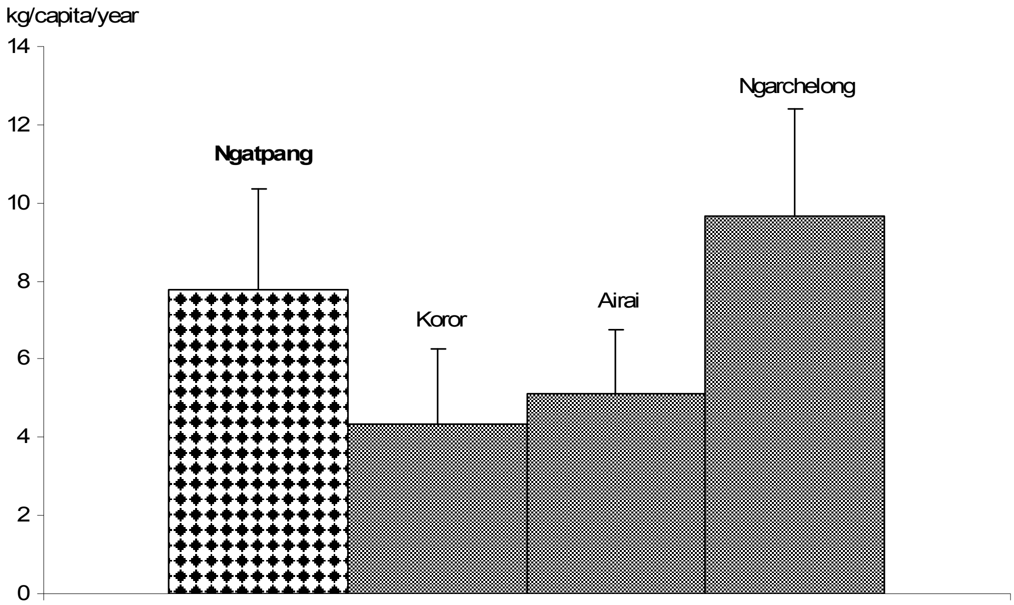

Figure 3.4: Per capita consumption (kg/year) of invertebrates (meat only) in Ngatpang (n = 25) compared to the other the three CoFish sites in Palau.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

Fresh fish consumption (~63 kg/person/year ±11.07) in Ngatpang is above the regional average (FAO 2008) (Figure 3.3), but slightly lower than the average consumption across all

CoFish sites investigated in Palau. Invertebrate consumption (meat only) is ~8 kg/person/year (Figure 3.4), significantly lower than fresh fish but the second-highest value compared to all CoFish sites in Palau. Canned-fish consumption is low with ~5.5 kg/person/year and about average across all CoFish sites in Palau (~6 kg/person/year ±7.91) (Table 3.1).

Comparing results among all sites investigated in Palau (Table 3.1), the Ngatpang community is similar to the other communities in its lack of dependence on fisheries for income generation. Ngatpang people eat slightly less fresh fish and slightly more invertebrates than the country average, and about the same amount of canned fish. Household expenditure and remittances are less than average.

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

Survey coverage	Site (n = 25 HH)	Average across sites (n = 128 HH)
Demography		
HH involved in reef fisheries (%)	88.0	74.2
Number of fishers per HH	1.32 (±0.15)	1.12 (±0.08)
Male finfish fishers per HH (%)	60.6	53.8
Female finfish fishers per HH (%)	0.0	4.2
Male invertebrate fishers per HH (%)	3.0	0.7
Female invertebrate fishers per HH (%)	12.1	9.1
Male finfish and invertebrate fishers per HH (%)	12.1	16.1
Female finfish and invertebrate fishers per HH (%)	12.1	16.1
Income		
HH with fisheries as 1st income (%)	8.0	9.4
HH with fisheries as 2nd income (%)	20.0	13.3
HH with agriculture as 1st income (%)	4.0	3.9
HH with agriculture as 2nd income (%)	4.0	3.1
HH with salary as 1st income (%)	84.0	67.2
HH with salary as 2nd income (%)	8.0	4.7
HH with other source as 1st income (%)	4.0	23.4
HH with other source as 2nd income (%)	16.0	14.1
Expenditure (USD/year/HH)	5412.50 (±675.23)	6365.28 (±392.62)
Remittance (USD/year/HH) (1)	800.00 (n/a)	1830.00 (±575.82)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	62.48 (±11.07)	68.79 (±7.91)
Frequency fresh fish consumed (times/week)	4.08 (±0.31)	4.25 (±0.17)
Quantity fresh invertebrate consumed (kg/capita/year)	7.78 (±2.56)	6.20 (±7.91)
Frequency fresh invertebrate consumed (times/week)	0.64 (±0.15)	0.80 (±0.09)
Quantity canned fish consumed (kg/capita/year)	5.54 (±1.02)	5.92 (±0.62)
Frequency canned fish consumed (times/week)	1.72 (±0.24)	1.94 (±0.15)
HH eat fresh fish (%)	100.0	99.2
HH eat invertebrates (%)	60.0	68.0
HH eat canned fish (%)	88.0	85.2
HH eat fresh fish they catch (%)	88.0	77.8
HH eat fresh fish they buy (%)	40.0	33.3
HH eat fresh fish they are given (%)	56.0	59.3
HH eat fresh invertebrates they catch (%)	44.0	40.7
HH eat fresh invertebrates they buy (%)	16.0	29.6
HH eat fresh invertebrates they are given (%)	16.0	14.8

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

3.2.2 Fishing strategies and gear: Ngatpang

Degree of specialisation in fishing

Fishing in Ngatpang is performed by both genders (Figure 3.5) but, overall, participation by females is low (24%). The majority (>60%) of all fishers (males only) exclusively target finfish. Very few fishers target only invertebrates (12% females, 3% males). A few fishers (12% males, 12% females) target both invertebrates and finfish.

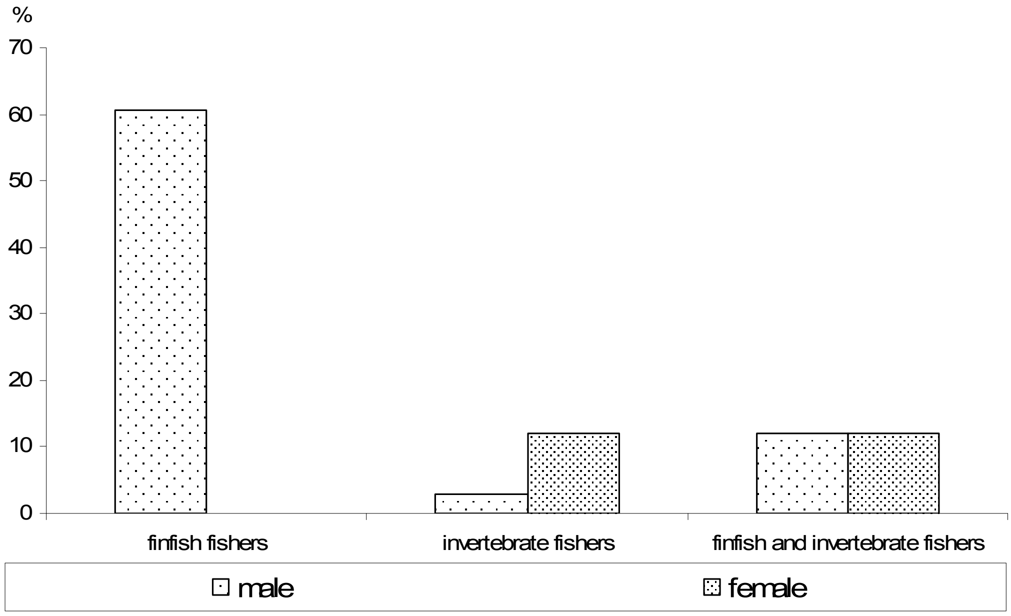

Figure 3.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Ngatpang.
All fishers = 100%.

Targeted stocks/habitat

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

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

Resource	Fishery / Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	21.1	25.0
	Lagoon	57.9	50.0
	Lagoon & outer reef	10.5	0.0
	Outer reef	36.8	25.0
Invertebrates	Reeftop	40.0	0.0
	Soft benthos (seagrass)	60.0	100.0
	Mangrove	50.0	16.7

Finfish fisher interviews, males: n = 19; females: n = 4. Invertebrate fisher interviews, males: n = 10; females, n = 6.

Fishing patterns and strategies

Our survey sample suggests that fishers in Ngatpang can choose among the sheltered coastal reef, lagoon and outer-reef habitats. Some fishers combine the lagoon and the outer reef in one fishing trip. Most fishers, both males and females, target the lagoon; however, quite a number of fishers also target the outer reef or the sheltered coastal reef. Only 10–11% of all fishers combine the lagoon and outer reef in one fishing trip.

Invertebrate fisheries in Ngatpang include reeftop, soft-benthos (seagrass) and mangrove gleaning (Figure 3.6). Most invertebrate fishers (males and females) engage in soft-benthos (seagrass) gleaning. As shown in Figure 3.7, participation by female and male fishers differs among fisheries. While females mainly target the soft benthos (seagrass), males are more diversified and also target reeftop and mangrove habitats. No females target the reeftop. More males than females participate in mangrove gleaning.

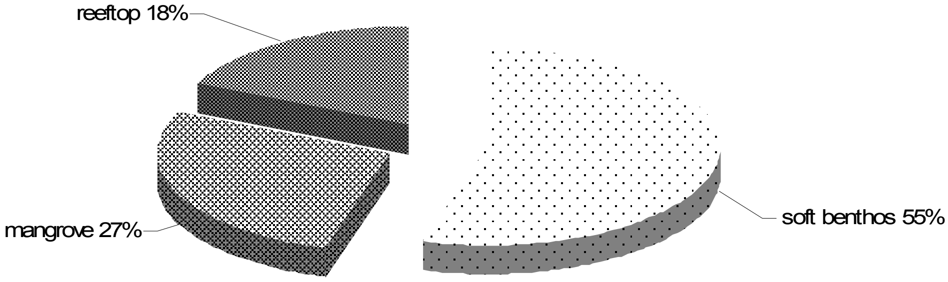

Figure 3.6: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Ngatpang.
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

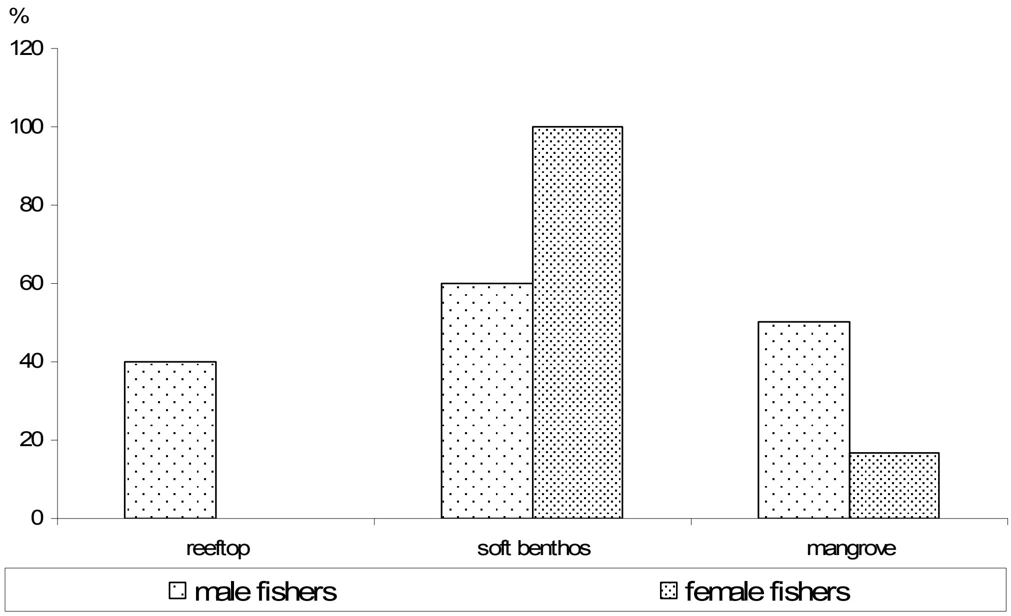

Figure 3.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Ngatpang.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 19 for males, n = 4 for females.

Gear

Figure 3.8 shows that there are quite a number of techniques used exclusively or in combination during one fishing trip. Handlines are used in all habitats; spear diving is mainly performed at the outer reef but sometimes also at the sheltered coastal reef and in the lagoon. Gillnets are mainly used at the sheltered coastal reef and techniques targeting pelagic species, including trolling and deep-bottom fishing, are used by fishers targeting the outer reef. Fishers targeting the sheltered coastal reef do not use boats; however, those targeting the lagoon, outer reef and lagoon and outer reef combined all use motorised boats.

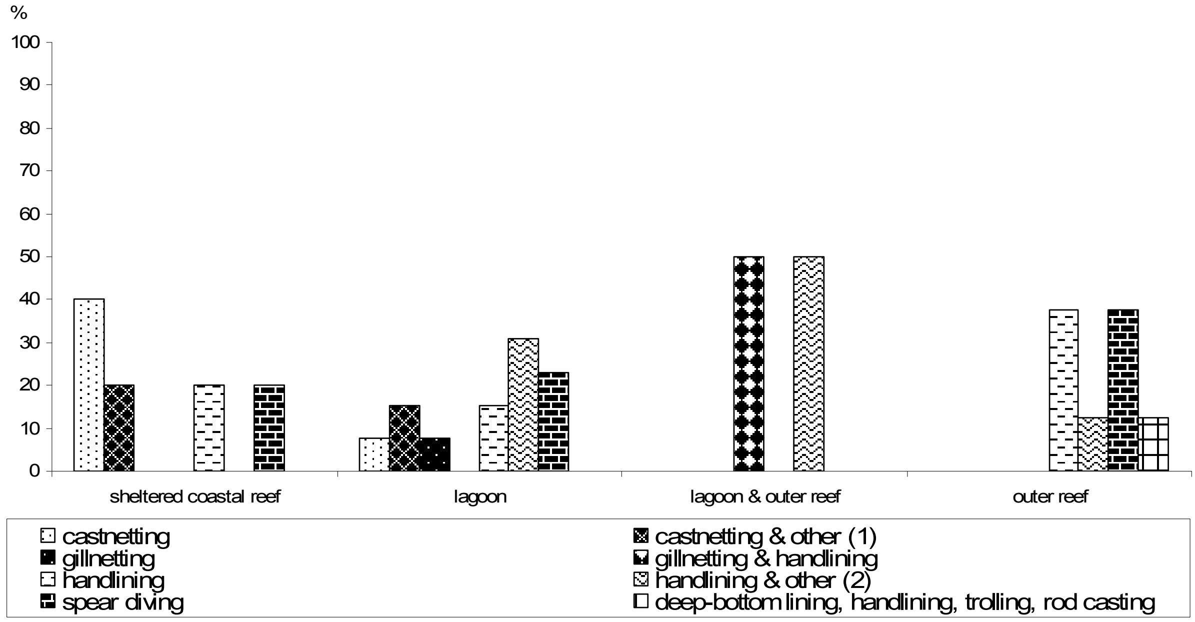

Figure 3.8: Fishing methods commonly used in different habitat types in Ngatpang.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip. 'Other (1)' refers to gillnetting, handlining and spear diving; 'other (2)' refers to rod casting and spear diving.

Invertebrate fishing is done using very simple tools only. Reeftop, soft-benthos (seagrass) and mangrove gleaning are done by hand, mainly using plastic containers to collect molluscs, holothurians, sea urchins and clams. Motorised boats are mostly used by invertebrate fishers especially for gleaning the reeftop but also soft benthos (seagrass). This fact may explain why reeftop gleaning is predominantly performed by males. Mangroves are usually reached by walking, and only on rare occasions are motorised boats used to access the mangrove fishing grounds.

Frequency and duration of fishing trips

As shown in Table 3.3, the frequency of fishing trips is highly variable: on average 3–4 times/week to the sheltered coastal reef, 1–2 times/week to the lagoon, and once a fortnight to the outer reef. This pattern is similar for both male and female finfish fishers. However, the reverse pattern was found in the duration of fishing trips. On average, the more often people fish, the less time they spend fishing. Thus, the most frequent trips (to the sheltered coastal reef) are short (1–2 hours/trip). Trips to the lagoon and to the lagoon and outer reef combined are the longest (7–8 hours/trip). Trips to the outer reef are also time consuming (5–6, or sometimes 8 hours/trip).

Finfish fishers go out throughout the entire year. There is no clear preference for fishing during the day, at night or according to the tides (i.e. day or night). However, data suggest that fishers targeting the sheltered coastal reef do so during the day or according to the tides (either day or night). Lagoon fishers either fish at night or according to the tides. Outer-reef fishers have no clear preference: some fish during the day, others at night, and some according to the tides.

For invertebrate collection, frequencies of trips are similar among the three major habitats targeted, on average once a week for male fishers and once a fortnight for females. Trips take 2–3.5 hours/trip. Invertebrates are usually collected throughout the year and only mangrove fishers stop during certain months. Most invertebrate fishing is done during the day, but for reeftop collection, a quarter of all fishers prefer to collect according to the tides, i.e. either during day or night.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	3.75 (±0.75)	3.00 (n/a)	1.00 (±0.20)	1.50 (n/a)
	Lagoon	1.56 (±0.24)	1.12 (±0.88)	5.27 (±0.54)	8.00 (±0.00)
	Lagoon & outer reef	1.00 (±0.00)	0	7.00 (±1.00)	0
	Outer reef	0.48 (±0.14)	0.23 (n/a)	5.43 (±0.74)	8.00 (n/a)
Invertebrates	Reeftop	1.00 (±0.00)	0	3.25 (±1.25)	0
	Soft benthos	1.00 (±0.00)	0.65 (±0.16)	2.33 (±0.25)	2.83 (±0.49)
	Mangrove	1.54 (±0.88)	0.58 (n/a)	3.00 (±0.89)	4.00 (n/a)

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 19; females: n = 4. Invertebrate fisher interviews, males: n = 10; females: n = 6.

3.2.3 Catch composition and volume – finfish: Ngatpang

Catches from the lagoon, the main habitat targeted, include the greatest variety of fish species. Lethrinidae alone determine >33% of the reported annual catch, Siganidae 19%, and Lutjanidae >10%. Catches from the sheltered coastal reef are less diverse and mainly comprise Serranidae (27%), Acanthuridae (26%), Siganidae (15%) and Scaridae (11%). Outer-reef catches mainly include Lethrinidae (31%), Serranidae (21%), Lutjanidae (15%) and Scaridae (13%) (Detailed data are provided in Appendix 2.2.1.).

Our survey sample of finfish fishers interviewed represents about 47% of the projected total number of finfish fishers in Ngatpang, and is thus assumed to be a representative sample. Hence we have extrapolated our results to estimate the total annual fishing pressure imposed by the people of Ngatpang on their fishing ground. This estimate does not include any possible impact that is imposed by external fishers.

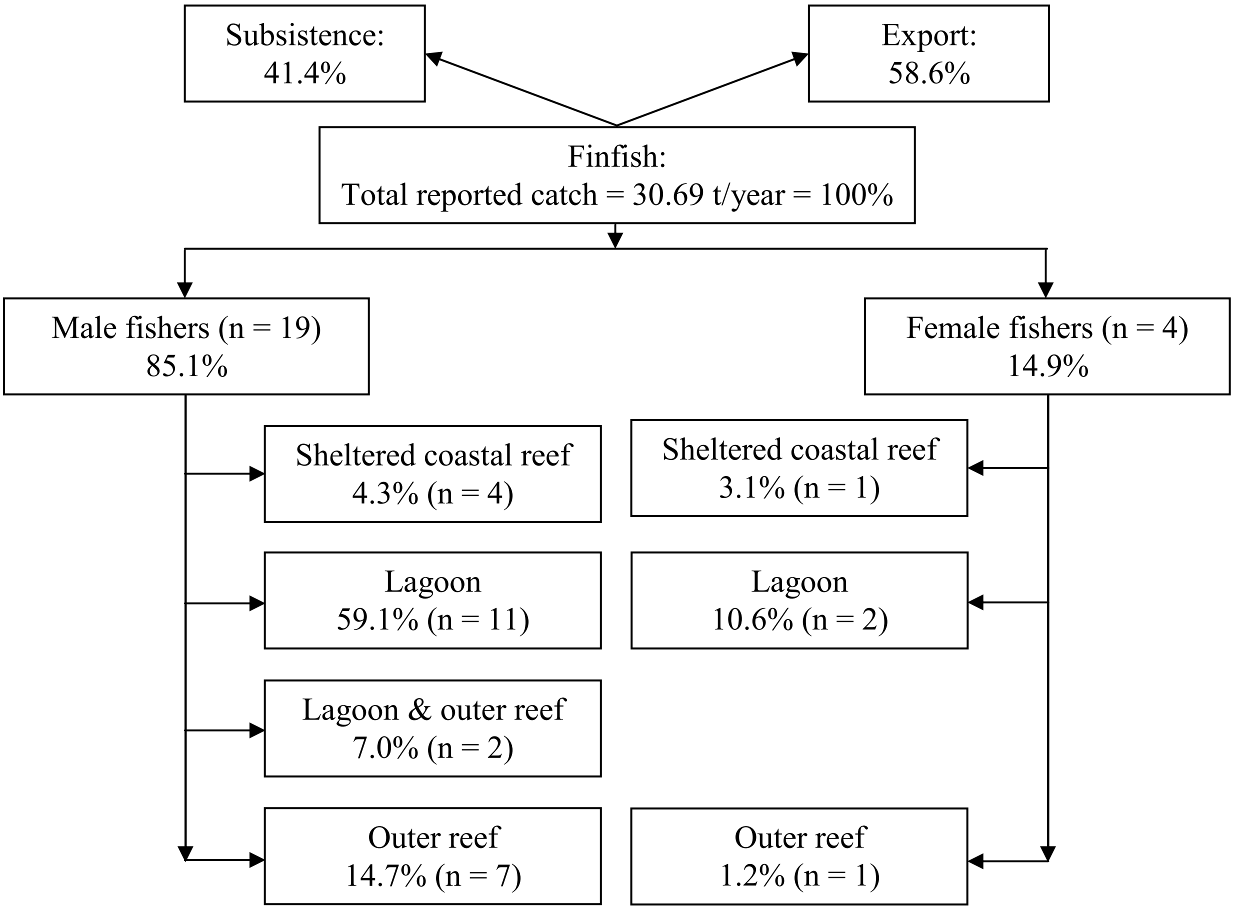

Figure 3.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Ngatpang.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

As shown in Figure 3.9, more than half of the impact is due to commercial reef fishing, i.e. catches that are sold outside the Ngatpang community account for 59% of the total annual estimated catch or ~18 t/year. Subsistence need determines about 41% of all catches, corresponding to a total annual consumption of about 12.5 t. Most of the catch is by male fishers, females play only an insignificant role (<15%). Highest pressure is imposed on the lagoon, with a minor impact on the sheltered coastal reef (~7%) and the outer reef (16%). The impact of the combined fishing of the lagoon and outer-reef areas represents only ~7% of the total annual catch.

The high impact on lagoon resources is due to the number of fishers targeting this habitat as well as the large catch. As shown in Figure 3.10, catches are ~900 kg/fisher/year with no difference between male and female fishers. However, the variability (SE) of the reported catch data is considerable for the female finfish fishers in the lagoon. The annual productivity of any of the other fisher groups is much less and reaches about 600 kg/fisher/year if lagoon and outer reef are fished in one trip, and almost 400 kg/fisher/year at the outer reef. The annual reported catches for the sheltered coastal reef are 200 kg/fisher/year by male finfish fishers and slightly higher for female fishers. Due to the small sample size of female finfish fishers targeting the sheltered coastal reef, these results are inconclusive.

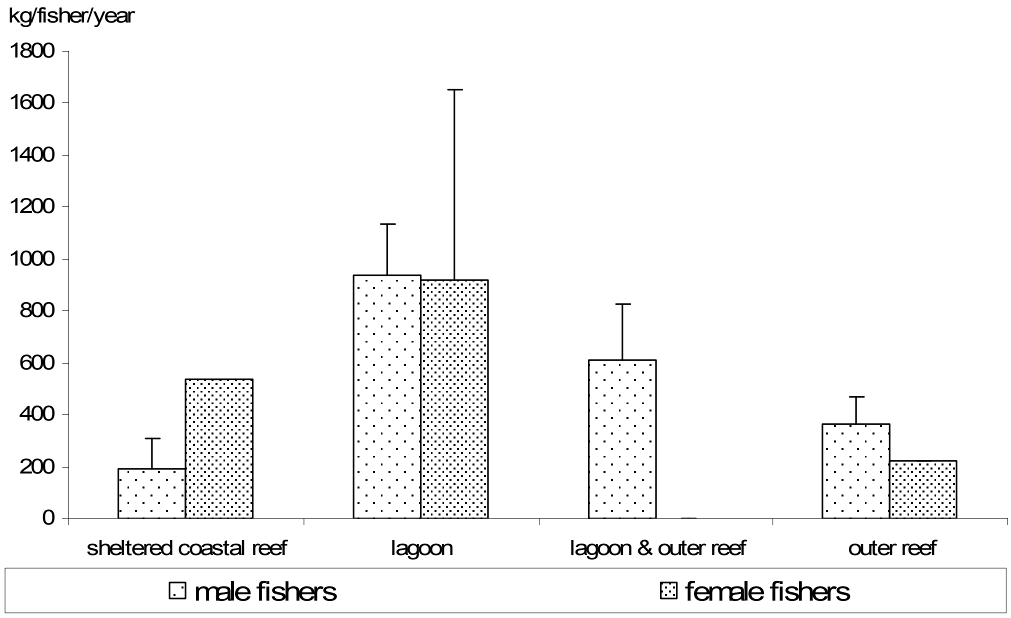

Figure 3.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Ngatpang.
Bars represent standard error (+SE).

However, comparing the CPUE calculated for the different habitats fished (Figure 3.11), three major observations accrue. Firstly, there are slight differences between male and female finfish fishers in terms of productivity. Males are more efficient when targeting the lagoon and the outer reef, while females are more efficient than males at the sheltered coastal reef (Note, however, the small sample size of female fishers at the sheltered coastal reef.). Secondly, highest CPUEs are reported for the outer reef, with ~4 kg/hour fished for male fishers, followed by male fishers in the lagoon (3 kg/hour). CPUE by male fishers at the sheltered coastal reef is least with about 1 kg/hour fished. Thirdly, female finfish fishers seem to perform at the same level regardless of where they fish, on average ~2.5 kg/hour fished.

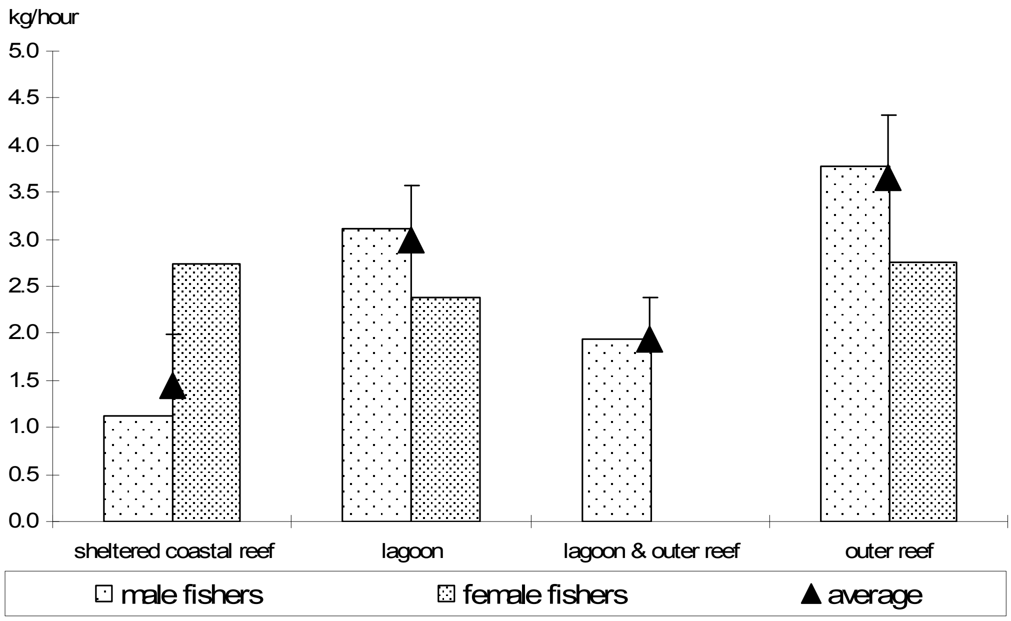

Figure 3.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Ngatpang.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data shows that most catch from any of the habitats fished is intended for subsistence needs and non-monetary exchange among community members. However, the share of the catch intended for sale is highest if the outer reef is targeted, and also the lagoon. Sheltered coastal reef fishing is exclusively for subsistence needs, as is most fishing in the lagoon and outer-reef habitats combined (Figure 3.12).

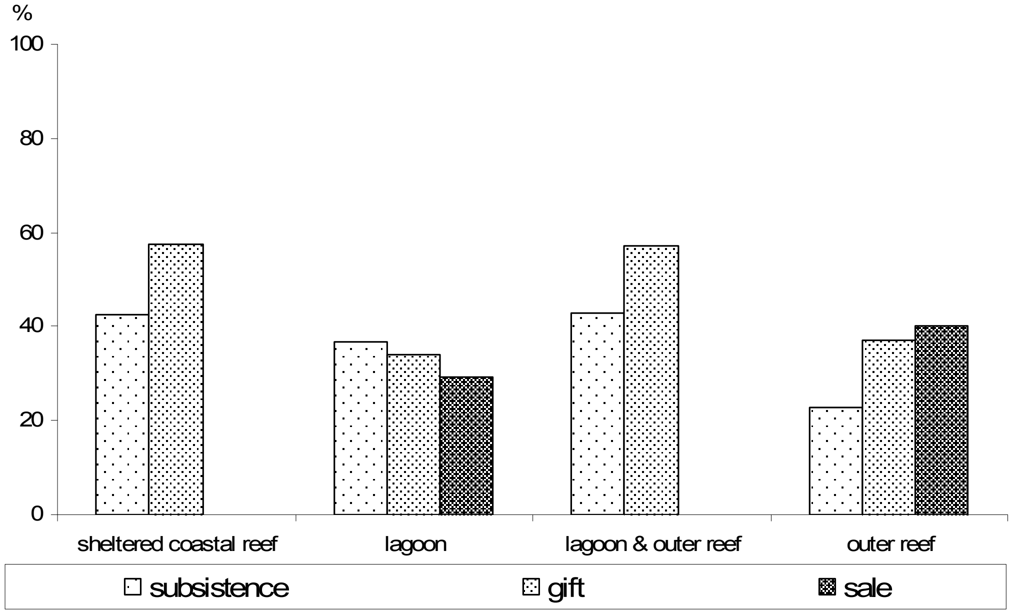

Figure 3.12: The use of finish catches for subsistence, gift and sale, by habitat in Ngatpang. Proportions are expressed in % of the total number of trips per habitat.

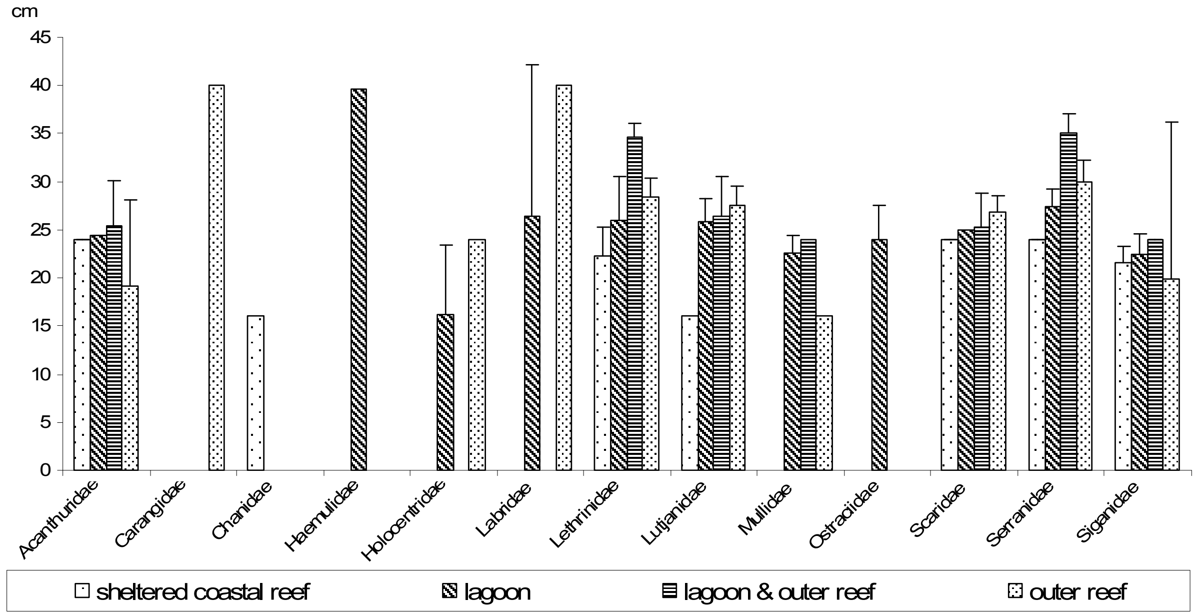

Figure 3.13: Average sizes (cm fork length) of fish caught by family and habitat in Ngatpang. Bars represent standard error (+SE).

Data on the average reported finfish sizes by family and habitat (Figure 3.13) show that, generally, average reported fish size slightly increases from sheltered coastal reef to outer-reef catches. Sometimes, the sizes reported for catches from the combined fishing of lagoon and outer reef seem to be larger than from the outer reef; however, this may be due to the small sample size of respondents representing this fisher group. However, the data also show some surprises, e.g. the high variability in fish sizes of Siganidae caught at the outer reef and of Labridae caught in the lagoon. Some families, e.g. Acanthuridae and Mullidae, even appear to decrease in fish size from the nearshore to the outer reef. Overall, average fish sizes range between 25 and 30 cm, with smaller sizes (as expected) reported from the sheltered coastal reef, and exceptionally large sizes reported for catches from the outer reef. In some cases, large average fish sizes were also reported from lagoon catches.

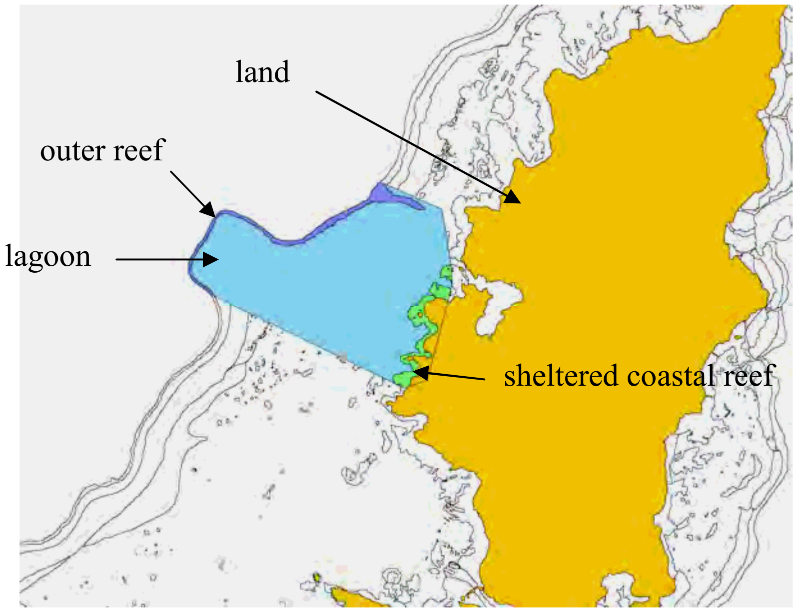

Figure 3.14: Fishing ground and habitat classification of Ngatpang.

Some parameters selected to assess the current fishing pressure on Ngatpang's living reef resources are shown in Table 3.4. The comparison of habitat surfaces (Figure 3.14) that are included in Ngatpang's fishing ground show that the lagoon area determines most of the total fishing ground. Total reef areas, including the sheltered coastal, back- and outer reef, account for less than half of the total fishing ground. Considering that most fishers in Ngatpang target the lagoon, a very low fisher density results from the large size of this habitat. Consequently, although the numbers of fishers targeting the sheltered coastal and the outer reef are much lower, fisher densities are higher (although still relatively low), due to the limited areas of these habitats. The lagoon also provides the highest annual catches. Average annual catches from the outer and the sheltered coastal reefs reach only 65% and 27% of the lagoon catch. Overall, fisher density per reef unit area is low. Also, population density is low (~6 people/km²) if accounting for the reef area only, and even less (~3 people/km²) if calculated per total fishing ground.

Again, if calculating the actual fishing pressure in terms of the annual total subsistence demand per reef and total fishing ground unit areas, very low pressure values result, i.e. ~0.4 t/km² of reef area and ~0.2 t/km² of total fishing ground area.

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

Parameters	Habitat					
	Sheltered coastal reef	Lagoon	Lagoon & outer reef	Outer reef	Total reef area	Total fishing ground
Fishing ground area (km^2)	3.73	72.53		4.00	35.46	80.26
Density of fishers (number of fishers/km^2 fishing ground) (1)	2	<1		4	1	<1
Population density (people/km^2) (2)					6	3
Average annual finfish catch (kg/fisher/year) (3)	259.26 (±114.78)	934.33 (±184.35)	608.00 (±217.14)	347.11 (±91.73)		
Total fishing pressure of subsistence catches (t/km^2)					0.36	0.16

Figures in brackets denote standard error; (1) total number of fishers (= 49) is extrapolated from household surveys; (2) total population = 204; total subsistence demand = 12.7 t/year; (3) catch figures are based on recorded data from survey respondents only.

3.2.4 Catch composition and volume – invertebrates: Ngatpang

Calculations of the recorded annual catch rates per species group are shown in Figure 3.15. The graph shows that the major impact by wet weight is mainly due to one bêche-de-mer species, *Actinopyga* spp. Giant clams (*Tridacna* spp. and *Hippopus* spp.), other holothurians, including *Stichopus* spp. and *Holothuria* spp., as well as the crab *Scylla serrata*, also contribute. The annual catches of the four remaining species groups, including lobsters and sea urchins, are insignificant (Detailed data are provided in Appendices 2.2.2 and 2.2.3.).

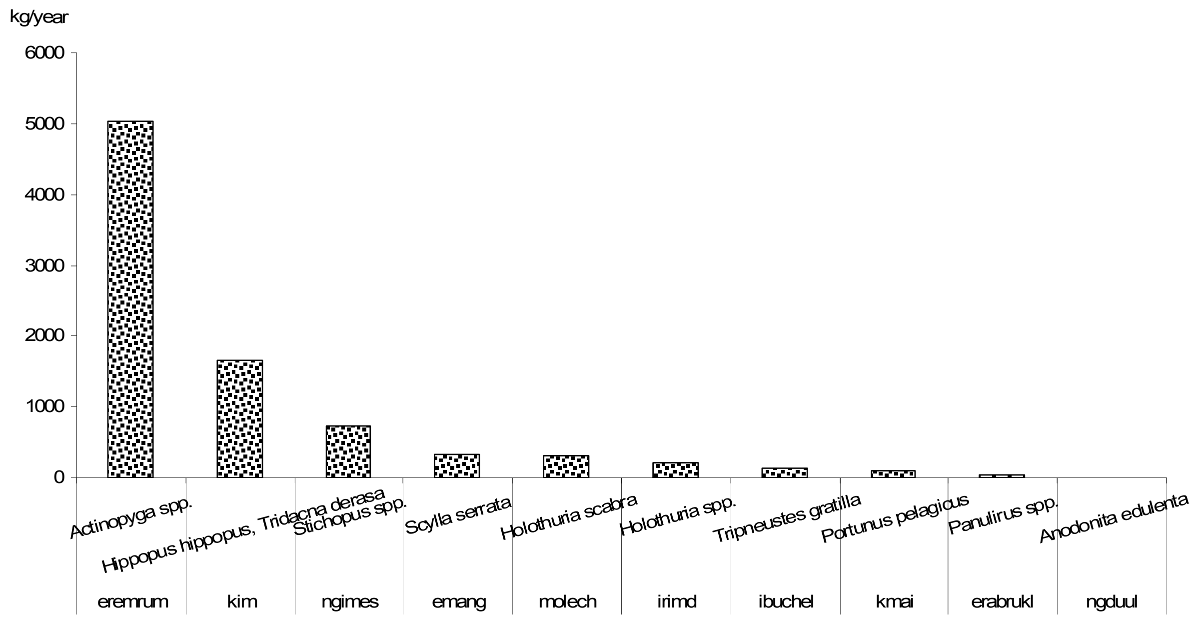

Figure 3.15: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Ngatpang.

Overall, the diversity of vernacular names reported for any of the habitats targeted is low. Soft benthos (seagrass) is the main habitat where people from Ngatpang collect bêche-de-mer that they eat or sell elsewhere. Thus, it is not surprising that the highest number of vernacular names (6) is reported for this fishery. Catches from mangroves are known by three vernacular names and catches from reeftops by only two (Figure 3.16).

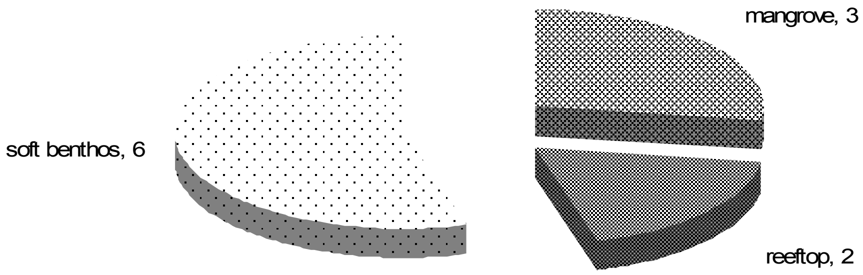

Figure 3.16: Number of vernacular names recorded for each invertebrate fishery in Ngatpang.

Figure 3.17 shows again that the highest figures for average annual catches (600 kg/fisher/year) by wet weight occur for soft-benthos (seagrass) harvesting, the main habitat for bêche-de-mer, one of the major target species for subsistence or local sale. The reeftop fishery scores second, with only about half the catch of bêche-de-mer (~300 kg/fisher/year), while mangrove fishers have the lowest catch rates, i.e. <100 kg/fisher/year.

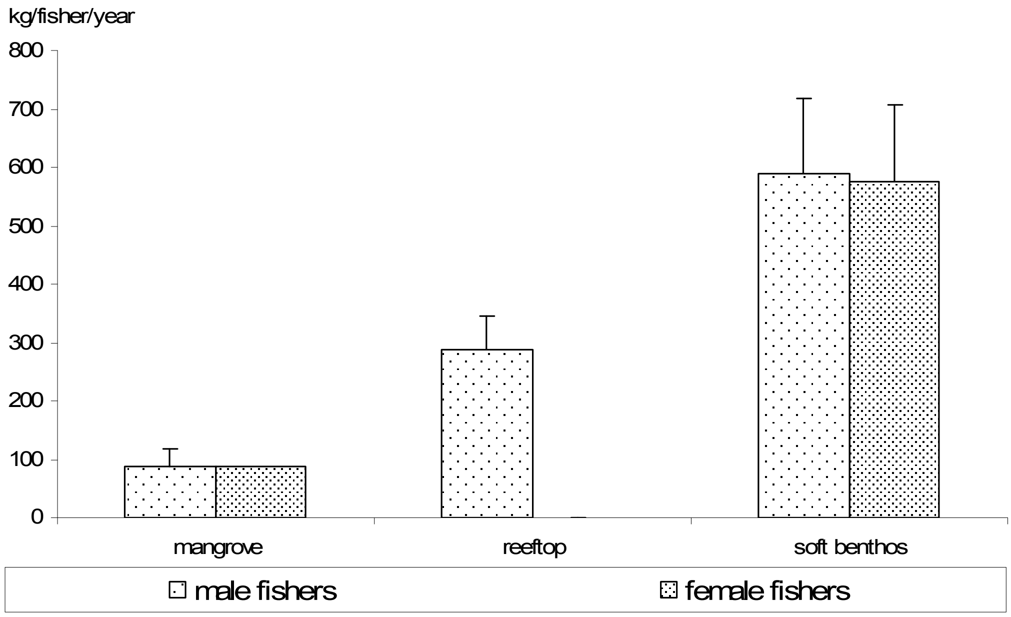

Figure 3.17: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Ngatpang.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 10 for males, n = 6 for females). Bars represent standard error (+SE).

Invertebrate catches serve both subsistence and income generation purposes (Figure 3.18), with a slightly higher subsistence demand. Thus, it can be concluded that the current impact of fishing on invertebrate resources in Ngatpang is determined by both the subsistence needs of the community and the need to generate income by serving external demand. In addition, external and visiting fishers may add further pressure.

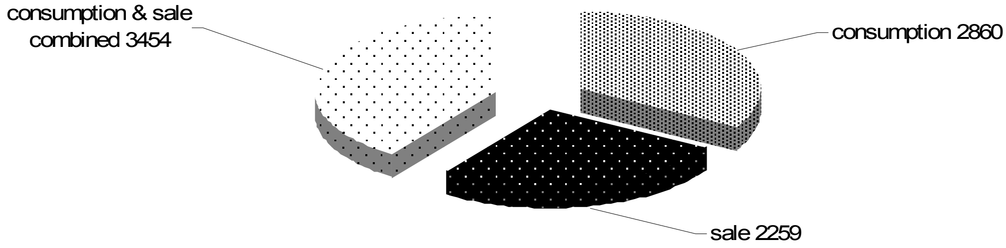

Figure 3.18: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Ngatpang.

The total annual catch volume expressed in wet weight based on recorded data from all respondents interviewed amounts to 8.6 t/year (Figure 3.19). As reported earlier, catches from the soft benthos (seagrass) are the prominent catch, representing >80% of the total annual reported catch by wet weight. Reeftop determines most of the remaining shares, while mangrove fishers do not contribute much to the annual impact by wet weight (~5%).

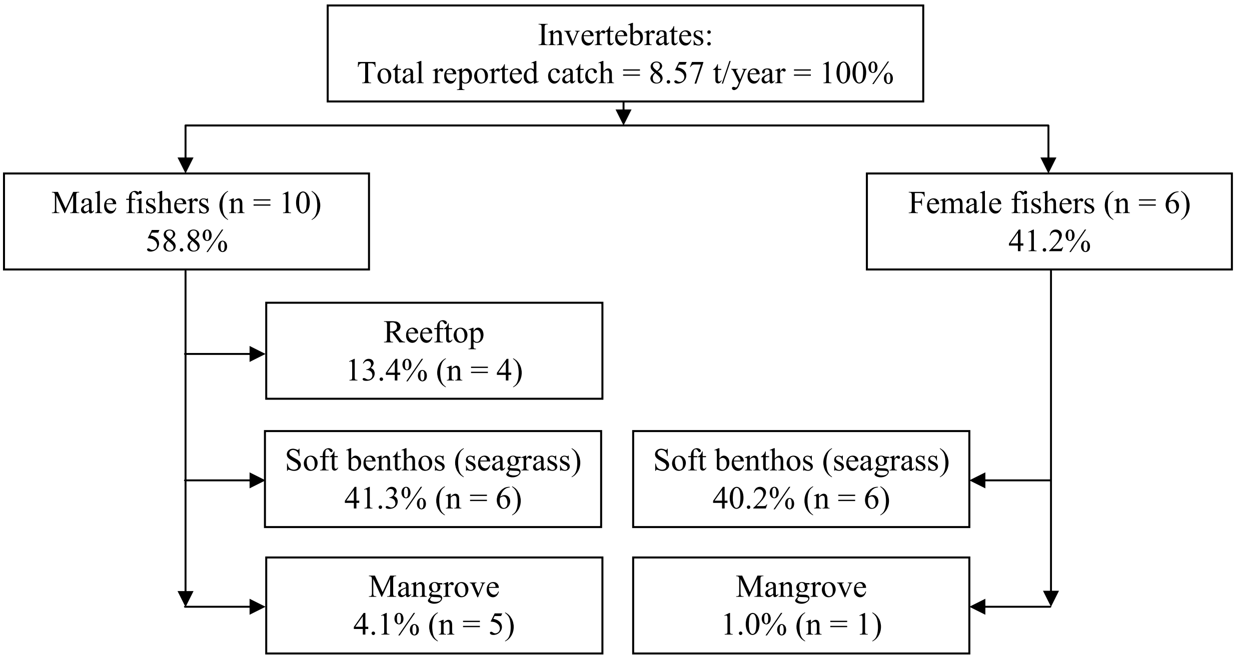

Figure 3.19: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Ngatpang.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

Table 3.5: Selected parameters (±SE) used to characterise the current level of fishing pressure of invertebrate fisheries in Ngatpang

Parameters	Fishery / Habitat		
	Mangrove	Reeftop	Soft benthos
Fishing ground area (km^2)		12	
Number of fishers (per fishery) (1)	7	4	19
Density of fishers (number of fishers/km^2 fishing ground)		<1	
Average annual invertebrate catch (kg/fisher/year) (2)	87.22 (±24.05)	287.71 (±58.38)	582.17 (±88.34)

Figures in brackets denote standard error; (1) number of fishers extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only.

The invertebrate fishery in Ngatpang is similar to other sites surveyed in Palau. Firstly, only a few fishers target any of the available habitats, i.e. mangrove, reeftop and soft benthos; secondly, the average annual catches are rather low. As observed in Ngarchelong, soft-benthos fishers have the highest catch rates, >580 kg/fisher/year. However, none of the parameters suggest any major problem in the invertebrate fishery resources in Ngatpang.

3.2.5 Discussion and conclusions: socioeconomics in Ngatpang

- As compared to salaries, fisheries are not an important sector for income generation in Ngatpang. Only 8% of all households reported to obtain first, and another 20% second income from fisheries. In contrast, salaries furnish 84% of all households with first, and yet another 8% with secondary income. Agriculture plays the least important role. Other sources, mainly retirement or pension payments, are also low in importance.

- All households eat fresh fish regularly and more than half also consume invertebrates. Fresh fish consumption is above the regional average and slightly below the average consumption rate in all of Palau's CoFish sites. Invertebrate consumption is moderate (~8 kg/person/year.

- The average household expenditure level is not of particular note, other than to mention that people in Ngatpang enjoy a rather traditional and rural lifestyle and hence spend less on average than households in the more urbanised communities surveyed. Remittances do not play any role.

- Most fishing, especially for finfish, is done by males. Fewer females than males collect invertebrates. Finfish fishers mainly target the lagoon, but also the sheltered coastal reef and the outer reef. Females mainly target the soft benthos (seagrass) for invertebrate collection while males are more diversified and also collect in mangroves and on reeftops.

- Various techniques are used to catch finfish. Handlines are used in all habitats, spear diving is particularly important at the outer reef, and gillnets are often used at the sheltered coastal reef. Pelagic fishing (trolling) may be combined with deep-bottom lining or any other technique targeting reef fish. Sheltered coastal reef fishing is done without any boat transport, but all other fishing depends on motorised boat transport.

- Highest fishing pressure is on the lagoon, with highest number of fishers, highest average annual catch rates, and almost 70% of the total annual reported catch. However, overall fisher density (<1–4 fishers/km²), population density (3–6 people/km²) and fishing pressure as expressed in annual subsistence catch per reef and fishing ground (0.2–0.4 t/km²) area are all low.

- Highest CPUE is reached at the outer reef with ~4 kg/hour fished, which drops to ~3 kg/hour fished in the lagoon. Overall, average fish sizes are ~25–30 cm. Average sizes reported for catches from the sheltered coastal reef are represented more at the lower, and sizes reported for catches at the outer reef at the higher end of this scale.

- Invertebrate fisheries serve both subsistence and commercial purposes. Highest fishing pressure is observed for the soft-benthos (seagrass) fisheries, accounting for >80% of the total annual reported catch (wet weight). Holothurians determine most of the reported total annual catch by wet weight. Giant clams, mainly collected from the reeftops by male fishers, also play a major role.

- The above observations result in two major conclusions. Firstly, current pressure on finfish resources in Ngatpang is low if taking into account fisher density and subsistence catch per unit area. Even when taking into consideration the extrapolated total annual catch, including commercial catches for external demand, fishing pressure still remains low (a maximum of ~4 t/km² per reef area and an average of 0.4 t/km² per total fishing ground). The fact that most fishers target the lagoon and that lagoon fishers have the highest catches is counteracted by the large surface area of this habitat. The reported CPUE is highest for the outer reef, where the average reported fish sizes are the largest. Both observations suggest that the resource status in Ngatpang fishing grounds follows the expected trend, i.e. biomass and sizes increase from the coastal reef to the outer reef. Considering invertebrate fisheries, fisher densities seem to be low. The reported total annual catch of 8.6 t does not give reason to assume detrimental impact. However, care should be taken regarding the fact that most reported catch is accounted for by a very few selected species. Thus, the resource status of these species may need monitoring.

- Considering the population density of Palau, the distance to the country's major market in Koror, and the consumption pattern of the Ngatpang community itself, there is no reason to assume any major change of fishing pressure in the near future. However, the selection of a few target species in invertebrate fisheries calls for a monitoring programme concerning the few species concerned.

3.3 Finfish resource surveys: Ngatpang

Finfish resources and associated habitats were assessed in Ngatpang between 23 and 25 April 2007, from a total of 22 transects (6 sheltered coastal, 6 intermediate, 4 back-reef and 6 outer-reef transects; see Figure 3.20 and Appendix 3.2.1 for transect locations and coordinates respectively).

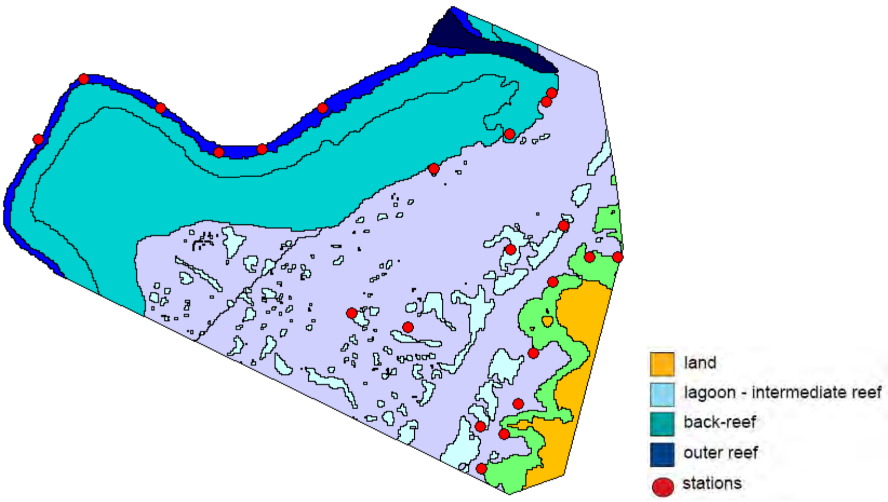

Figure 3.20: Habitat types and transect locations for finfish assessment in Ngatapang.

3.3.1 Finfish assessment results: Ngatpang

A total of 23 families, 63 genera, 214 species and 15,902 fish were recorded in the 22 transects (See Appendix 3.2.2 for list of species.). Only data on the 15 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 50 genera, 190 species and 13,982 individuals.

Finfish resources differed slightly among the four reef environments found in Ngatpang. The coastal reef contained the highest density (0.8 fish/m²), largest size (21 cm FL), largest biomass (191 g/m²) and second-highest size ratio (60%) and biodiversity (48 species/transect) among the four habitats. Intermediate reefs displayed the lowest values of such parameters (except for size, the second-lowest). Back-reefs displayed second-lowest values of density (0.5 fish/m²), biomass (43 g/m²), size ratio (52%) and biodiversity (48 species/ transect, as in the coastal reef), only higher than intermediate-reef values. The outer reef displayed density equal to coastal reef, but size and biomass were lower than the high values recorded at that habitat. Size ratio and biodiversity at the outer reef were, however, the far highest of the site.

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

Parameters	Habitat				
	Sheltered coastal reef (1)	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	6	4	6	22
Total habitat area (km^2)	3.7	5.8	27.7	2.9	40.2
Depth (m)	2 (1–4) (3)	6 (2–12) (3)	6 (1–14) (3)	10 (6–14) (3)	6 (1–14) (3)
Soft bottom (% cover)	19 ±4	9 ±3	11 ±5	1 ±1	11
Rubble & boulders (% cover)	25 ±4	22 ±7	24 ±6	1 ±1	22
Hard bottom (% cover)	27 ±7	26 ±8	26 ±5	52 ±11	28
Live coral (% cover)	22 ±2	36 ±11	29 ±8	40 ±9	30
Soft coral (% cover)	1 ±0	2 ±1	7 ±4	3 ±1	5
Biodiversity (species/transect)	48 ±4	41 ±4	48 ±5	65 ±3	51 ±2
Density ($fish/m^2$)	0.8 ±0.2	0.3 ±0.0	0.5 ±0.1	0.8 ±0.1	0.5
Biomass (g/m^2)	191.4 ±82.7	35.7 ±8.9	43.1 ±6.8	124.7 ±17.1	61.7
Size (cm FL) (4)	21 ±1	15 ±1	14 ±1	17 ±1	15
Size ratio (%)	60 ±2	51 ±2	52 ±3	63 ±3	53

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

Sheltered coastal reef environment: Ngatpang

The sheltered coastal reef environment of Ngatpang was dominated by one carnivorous family: Lutjanidae, and three major herbivorous families: Siganidae, Acanthuridae and Scaridae (Figure 3.21). These four families were represented by 45 species; particularly high abundance and biomass were recorded for *Lutjanus fulviflamma*, *Siganus argenteus*, *Ctenochaetus striatus*, *Lutjanus gibbus*, *Hipposcarus longiceps*, *Siganus fuscescens*, *Scarus dimidiatus* and *Lutjanus fulvus* (Table 3.7). This reef environment presented a diverse habitat with similar percentage of hard bottom and rubble (27% and 25%), high cover of live corals (22%), and 19% of soft bottom (Table 3.6 and Figure 3.21).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Lutjanidae	*Lutjanus fulviflamma*	Longspot snapper	0.19 ±0.19	67.3 ±67.0
	Lutjanus gibbus	Humpback snapper	0.02 ±0.01	11.0 ±6.1
	Lutjanus fulvus	Flametail snapper	0.01 ±0.01	4.5 ±2.6
Siganidae	*Siganus argenteus*	Forktail rabbitfish	0.09 ±0.08	18.1 ±14.6
	Siganus fuscescens	Mottled spinefoot	0.09 ±0.09	8.2 ±8.2
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.10 ±0.05	15.7 ±5.0
Scaridae	*Hipposcarus longiceps*	Pacific longnose parrotfish	0.02 ±0.01	8.4 ±4.9

The density, size and biomass of finfish in the sheltered coastal reefs of Ngatpang were the highest at the site. However, size ratio (60%) and biodiversity (48 species/transect) were lower than values recorded at outer reefs. When compared to the other country sites with coastal reefs, Ngatpang still displayed the highest density, size and biomass, but size ratio was second to Airai (62%) and biodiversity second to Ngarchelong (56 species/transect). Lethrinidae and Mullidae presented very low size ratio (45%), probably indicating heavy exploitation of such resources. Fishing in the coastal reef displayed the lowest fishing pressure in terms of total annual catches. However, among the mostly caught families were Acanthuridae (26% of total catches) and Scaridae (11%). Trophic structure in this coastal reef was slightly dominated by herbivorous fish in terms of density, but by carnivorous fish in terms of biomass, suggesting that resources are still relatively healthy. The complex substrate is probably providing good niches for this diversity of trophic guilds and families.

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

Intermediate-reef environment: Ngatpang

The intermediate-reef environment of Ngatpang was dominated by two herbivorous families: Acanthuridae and Scaridae and, to a lesser extent, by Labridae and, in terms of density only, Chaetodontidae (Figure 3.22). These four families were represented by 48 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Scarus schlegeli*, *Cheilinus undulatus* and *Chlorurus sordidus* (Table 3.8). This reef environment presented a diverse habitat with similar percentage of hard bottom and rubble (26% and 22% respectively), average cover of live corals (36%), and 9% cover of soft bottom (Table 3.6 and Figure 3.22).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.105 ±0.033	13.0 ±5.0
Labridae	*Cheilinus undulatus*	Napoleon wrasse	0.001 ±0.001	2.3 ±2.1
Scaridae	*Scarus schlegeli*	Schlegel's parrotfish	0.011 ±0.006	2.6 ±2.0
	Chlorurus sordidus	Daisy parrotfish	0.030 ±0.010	2.3 ±0.9

The density, size ratio, biomass and biodiversity of finfish in the intermediate reefs of Ngatpang were the lowest of all the habitats at the site. Average size was only higher than back-reef values (15 cm versus 14 cm FL). When compared to the same type of habitat from the other sites, Ngatpang intermediate reefs still displayed lowest density, biomass, size and biodiversity of all sites. Only average size ratio was higher than the Ngarchelong value (51% versus 49%). Trophic composition was dominated by herbivores in terms of both density and biomass. Scaridae and Acanthuridae, both herbivore families, strongly dominated the fish community, and the relatively high biomass of carnivore Labridae was mostly due to the presence of napoleon wrasses. Labridae, Mullidae and Scaridae showed average size ratios much lower than 50% of the maximum size, probably suggesting an impact from fishing. Lethrinidae were found to be the most frequently caught fish family, although catches were generally very diverse. Fishing in this habitat was the most intense, showing the highest catches per year of all habitats.

The intermediate-reef habitat of Ngatpang displayed a quite diverse composition of hard and soft bottom, with an average cover of live corals: this diverse habitat, rich in corals, hosted a high diversity and abundance of Chaetodontidae. However, one would expect a better representation of carnivore families, which are here very rare, probably due to fishing.

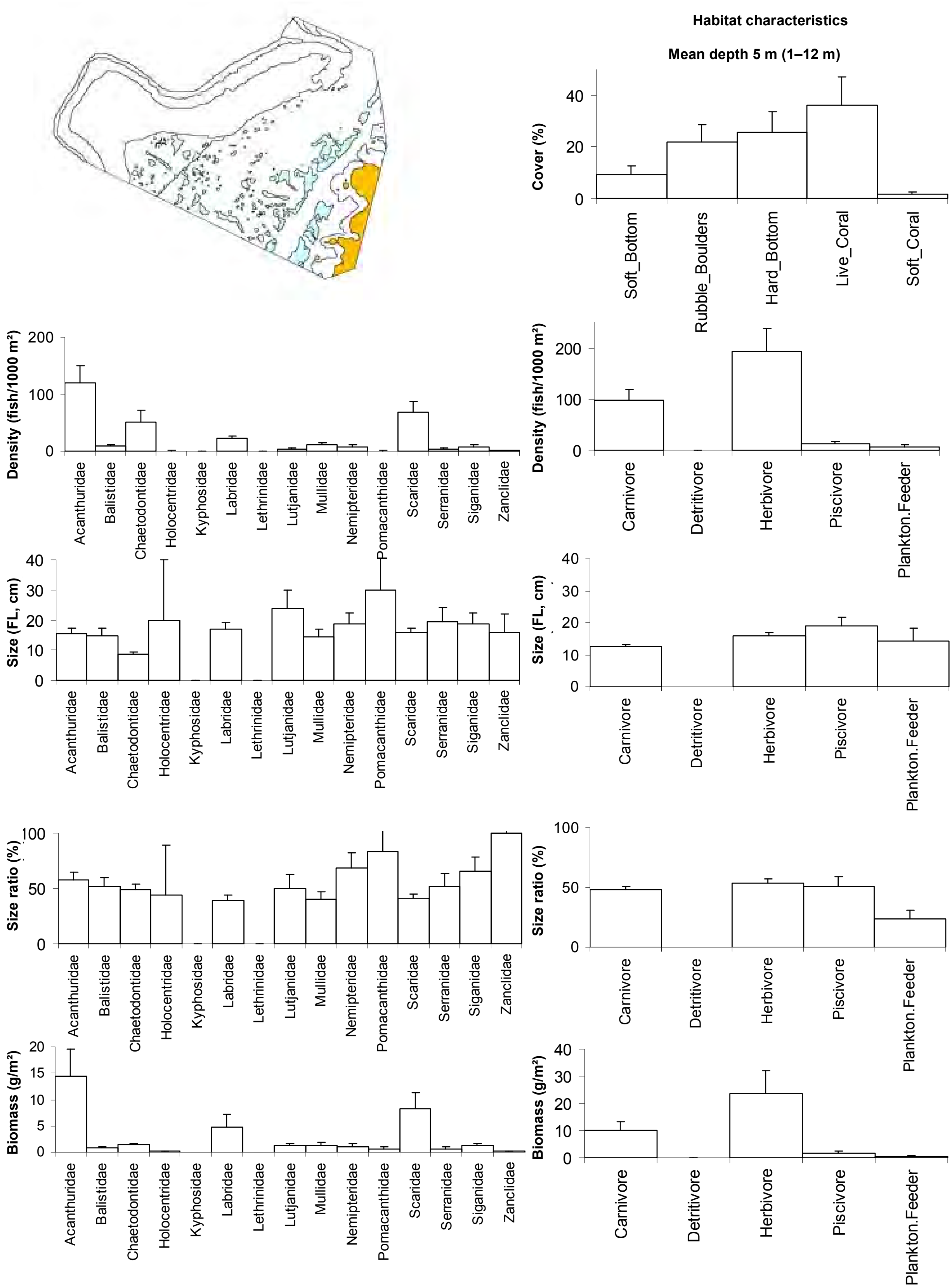

Figure 3.22: Profile of finfish resources in the intermediate-reef environment of Ngatpang.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Ngatpang

The back-reef environment of Ngatpang was dominated by five major families: herbivorous Acanthuridae and Scaridae and, in terms of biomass, carnivorous Lutjanidae, Holocentridae, and, to a lesser extent and, only in terms of density, Chaetodontidae (Figure 3.23). These were represented by 45 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Lutjanus fulvus*, *L. fulviflamma*, *Myripristis murdjan*, *Chlorurus sordidus* and *Zebrasoma scopas* (Table 3.9). This reef environment presented a dominance of live coral (29%), similar proportion of hard bottom (26%) and rubble (24%), and very little soft bottom cover (11%, Table 3.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.16 ±0.04	14.4 ±1.3
	Zebrasoma scopas	Twotone tang	0.05 ±0.03	1.6 ±1.1
Holocentridae	*Myripristis murdjan*	Pinecone soldierfish	0.01 ±0.01	1.8 ±1.0
Lutjanidae	*Lutjanus fulvus*	Flametail snapper	0.02 ±0.01	5.1 ±2.5
	Lutjanus fulviflamma	Longspot snapper	0.01 ±0.01	2.6 ±2.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.02 ±0.01	1.8 ±1.1

The density, size, biomass and biodiversity of finfish in the back-reefs of Ngatpnag were slightly higher than in the intermediate reefs and lower than in the outer and coastal reefs. Size ratio was the only lowest value recorded at the site. By comparing these parameters to values recorded in the back-reefs of the other three sites, Ngatpang appeared to have the second-lowest biomass, size, size ratio and biodiversity, better only than Ngarchelong values (Table 3.6). The trophic structure of this back-reef was dominated by herbivores in terms of density, but carnivores were almost as important in terms of biomass. Lutjanidae were the mostly represented carnivores, followed by Holocentridae. Average size ratio was low for Labridae (29% of maximum size), Scaridae (36%) and Siganidae (34%), probably suggesting an impact from fishing. The back-reefs of Ngatpang had a rich substrate, with high cover of live coral, and little soft bottom. The high abundance and diversity of Chaetodontidae (14 species present in the total of stations) was the result of such a healthy reef habitat.

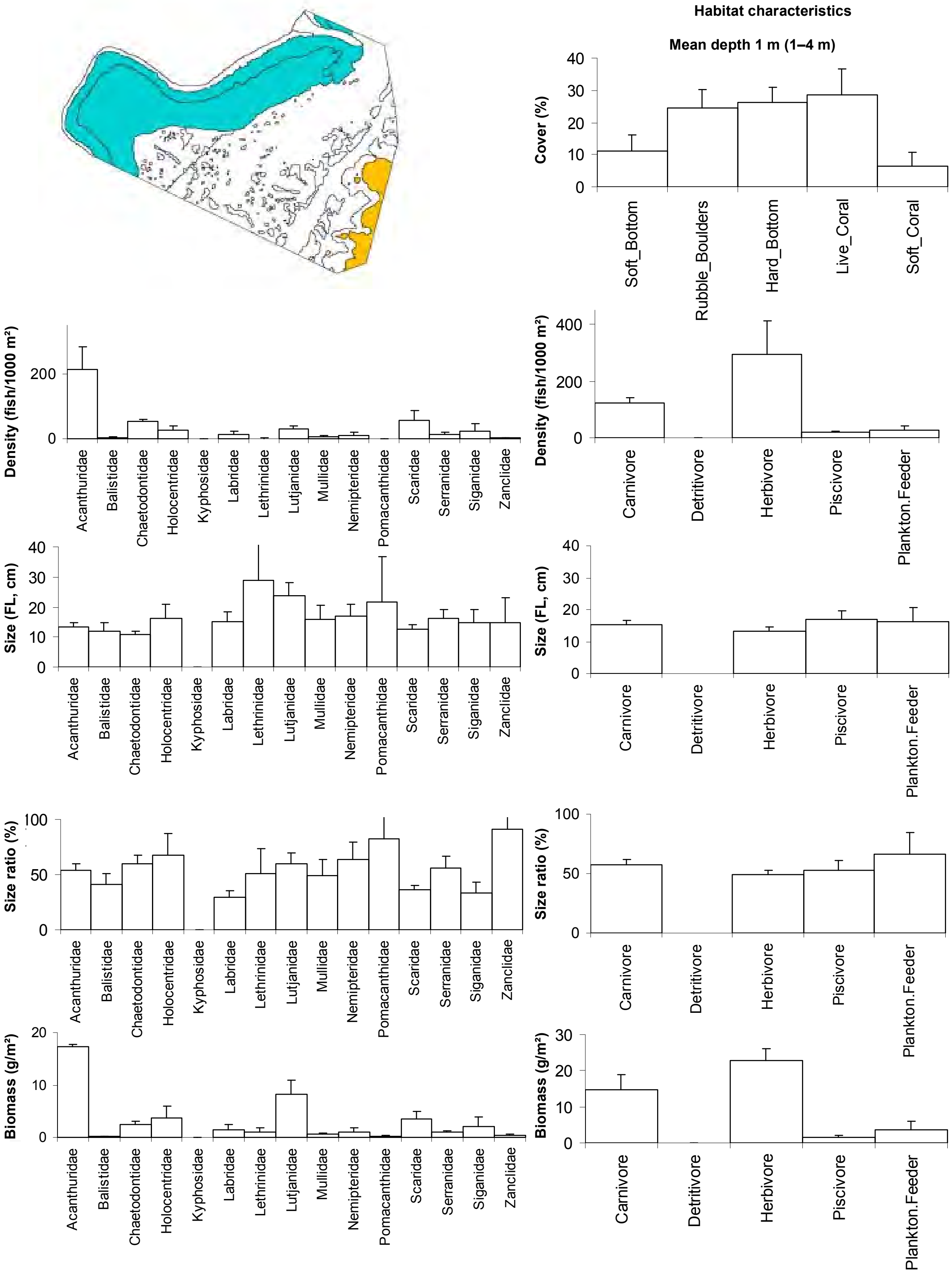

Figure 3.23: Profile of finfish resources in the back-reef environment of Ngatpang.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Ngatpang

The outer-reef environment of Ngatpang was strongly dominated by one family, Acanthuridae (Figure 3.24) in extremely high numbers. Mullidae, Lutjanidae, Lethrinidae, Holocentridae and Scaridae were also important, although in comparatively much lower density. Moreover, Chaetodontidae were important in terms of abundance. These seven families were represented by 69 species; particularly high biomass and abundance were recorded especially for *Ctenochaetus striatus*, followed by *Acanthurus nigricans*, *A. lineatus*, *Macolor niger*, *Lutjanus gibbus*, *Parupeneus pleurostigma*, *Myripristis adusta*, *Monotaxis grandoculis*, *Naso lituratus*, *P. barberinus*, *A. nigricauda* and *Chlorurus sordidus* (Table 3.10). This reef environment presented a dominance of hard bottom (52%), high coral cover 40%, and very little rubble (1%) and soft bottom (1%, Table 3.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.32 ±0.07	41.7 ±9.1
	Acanthurus nigricans	Whitecheek surgeonfish	0.10 ±0.04	9.2 ±3.2
	Acanthurus lineatus	Lined surgeonfish	0.03 ±0.01	7.2 ±3.4
	Naso lituratus	Orangespine unicornfish	0.01 ±0.00	3.6 ±1.5
	Acanthurus nigricauda	Epaulette surgeonfish	0.01 ±0.01	3.3 ±3.1
Holocentridae	*Myripristis adusta*	Shadowfin soldierfish	0.02 ±0.01	4.2 ±3.0
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.01 ±0.01	4.0 ±2.1
Lutjanidae	*Macolor niger*	Black and white snapper	0.01 ±0.01	5.2 ±5.1
	Lutjanus gibbus	Humpback snapper	0.01 ±0.01	4.6 ±3.2
Mullidae	*Parupeneus pleurostigma*	Sidespot goatfish	0.02 ±0.02	4.6 ±4.6
	Parupeneus barberinus	Dash-and-dot goatfish	0.01 ±0.01	3.6 ±3.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.01 ±0.01	2.6 ±2.0

The density, size, biomass and biodiversity of finfish in the outer reefs of Ngatpang were lower than in the coastal-reef habitat. Only size ratio was the highest recorded at the site. When compared to the outer reefs of other sites, density and biomass values were higher only than in Airai, while size registered the second-highest value and size ratio the highest of all outer reefs. However, biodiversity was the lowest among the four sites (Table 3.6). The trophic structure of this outer reef was clearly dominated by herbivores, mainly represented by the high density of Acanthuridae, mostly the small, ubiquitous *Ctenochaetus striatus,* followed by Scaridae in much lower importance. Mullidae, Lutjanidae, Holocentridae and Lethrinidae were the most represented carnivores. Average size ratio was low for Lethrinidae (38% of maximum size), suggesting a possible impact from fishing. Emperor species in fact represent some of the highest catches from this reef (33% of total catches) along with snappers (15%). The outer reefs of Ngatpang displayed a rich substrate with very high cover of live coral, and almost non-existent soft bottom. The extremely high abundance and diversity of Chaetodontidae (23 species recorded in the total number of survey stations) were related to this large amount of live-coral cover.

Figure 3.24: Profile of finfish resources in the outer-reef environment of Ngatpang.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Ngatpang

Overall, the fish assemblage of Ngatpang was dominated by the herbivorous family Acanthuridae, followed by Scaridae and Siganidae, and the carnivorous family Lutjanidae. Chaetodontidae were important in terms of density only (Figure 3.25). These three families were represented by a total of 83 species, dominated (in terms of biomass and density) by *Ctenochaetus striatus*, *Lutjanus fulviflamma*, *L. fulvus*, *Chlorurus sordidus*, *Siganus argenteus* and *Zebrasoma scopas* (Table 3.11). Overall, the substrate was dominated by live coral (30%) and hard bottom (28%), with an average amount of rubble (22%) and soft bottom (11%). The overall substrate composition and fish assemblage in Ngatpang shared characteristics primarily of back-reef (69% of the total reef habitat), then intermediate reef (15%) and, to lesser extent, coastal reef (9%) and outer reef (7%).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.16	16.3
	Zebrasoma scopas	Twotone tang	0.04	1.5
Lutjanidae	*Lutjanus fulviflamma*	Longspot snapper	0.02	8.1
	Lutjanus fulvus	Flametail snapper	0.02	3.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.02	2.2
Siganidae	*Siganus argenteus*	Forktail rabbitfish	0.01	1.7

Overall, Ngatpang appeared to support a rather average finfish resource, with second-lowest value of density (0.5 fish/m²), lowest value of biomass (62 g/m²) and average-to-low size ratio (53%). Average fish size was the smallest in the country (15 cm FL versus the maximum value of 18 cm FL). However, biodiversity was particularly high and of the same value as Koror (51 species/transect, a very high value when compared to the regional average). These results suggest that the finfish resource in Ngatpang was in rather average condition, especially considering the healthy condition of finfish in the coastal reefs, where values of density and biomass were among the highest in the region for the same type of habitat. Overall, size ratios were low for Lethrinidae (48%), Mullidae (49%), Labridae (33%), Scaridae (40%) and Siganidae (44%), suggesting an impact from fishing on these families. The more detailed assessment at the trophic and family level revealed a dominance of herbivores over carnivores, especially in terms of density. This trend could be partially explained by the composition of the habitat, where hard bottom and corals were dominant. This type of substrate favours herbivores and a few families of carnivores, mainly Lutjanidae, that are normally associated with hard bottom. However, selective fishing (targeting mainly Lethrinidae in most habitats, along with Lutjanidae and some herbivore families) might have caused this particular fish composition. In conclusion, Ngatpang appeared to be naturally rich in terms of substrate composition and fish biodiversity, but already showing declining resources (poverty of carnivores and small average sizes) probably due to fishing.

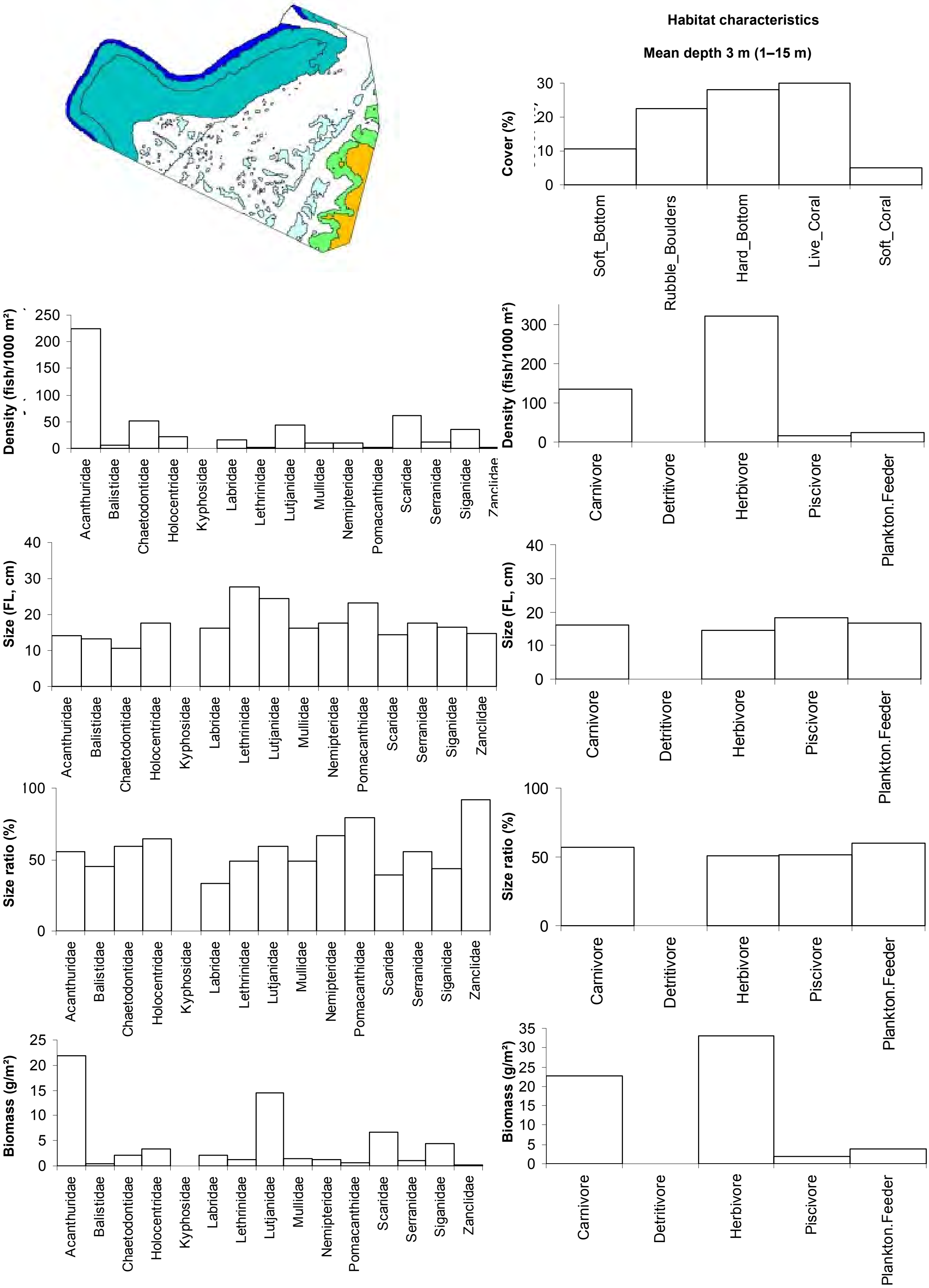

Figure 3.25: Profile of finfish resources in the combined reef habitats of Ngatpang (weighted average).
FL = fork length.

3.3.2 Discussion and conclusions: finfish resources in Ngatpang

The assessment indicated that the status of finfish resources in this site was moderately good but already impacted: Ngatpang appeared to be naturally fairly rich in terms of substrate composition and fish biodiversity; however, it already showed a decline in resources (relative lack of carnivores and small average sizes), probably due to fishing.

- The good general conditions were due to the general health of the reefs, with their relatively high coverage of live corals.

- Biodiversity of fish averaged over the four habitats was among the highest recorded at the four sites, and density the second-highest. However, sizes were fairly small compared to the other three sites and biomass was the lowest encountered. In general, fish were very wary of the presence of divers. The reserve did not show any differences compared to outside areas, even though it had been established since 2003.

- We noted only very few Scaridae of large size (*Scarus altipinnis*, *Chlorurus microrhinos*, *Hipposcarus longiceps*). *Bolbometopon muricatum* was almost non-existent.

- Apex (top of the food chain) predators were very rare.

- Remarkable differences were observed among the four reef types. Corals were fairly diverse and healthy, especially on the coastal and back-reefs, with many life forms present (submassive, digitate, foliose, encrusting and branching) as well as several soft corals (*Lemnalia* and *Dendronephtya*). On the outer reefs, the coral cover was high at depths higher than 10 m, with many tabulate, massive, branching, encrusting as well as some soft corals. Less coral cover was found at the intermediate reefs, especially on the reef flat.

- Finfish resources also showed high variability. The coastal reef had the highest fish density and biomass of all habitats at the site and highest also of all country sites; in fact it appeared to be the richest coastal habitat in the region. The fish community was also diverse, with large-sized fish; its trophic structure was dominated by carnivorous fish in terms of biomass. Fishing was the least intensive in this habitat, and size ratios were below the 50% of maximum sizes only for Lethrinidae and Mullidae. Lagoon and back-reefs displayed the lowest values of density, biomass, size and biodiversity. Fishing pressure was high in these habitats, with high number of fishers, and highest catches per year. Handlining, spear diving and gillnetting were the main methods used. Trophic composition was dominated by herbivores, mostly represented by Scaridae and Acanthuridae. Mullidae and Scaridae showed average size ratios much smaller than 50% of the maximum size, probably suggesting an impact from fishing. The outer reefs were still quite healthy but showed impact in terms of lower density, size and biomass compared to the less fished coastal reefs. Biodiversity was, however, very high, mirroring the rich quality of the habitat, and was the second-highest among the four sites. The trophic structure was dominated by herbivores, mainly Acanthuridae, which were in turn dominated by the small, ubiquitous *Ctenochaetus striatus*. Fishing was frequently done by spear diving, which is usually very selective on species and sizes. The impact of this selective fishing method was evident in the smaller sizes; average size ratios were also low for Lethrinidae (38% of maximum sizes), which made up 33% of the total catches from this outer reef.

3.4 Invertebrate resource surveys: Ngatpang

The diversity and abundance of invertebrate species at Ngatpang were independently determined using a range of survey techniques (Table 3.12): broad-scale assessment (using the 'manta tow'; locations shown in Figure 3.26) and finer-scale assessment of specific reef and benthic habitats (Figures 3.27 and 3.28).

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

Table 3.12: Number of stations and replicates completed at Ngatpang

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	19	114 transects
Soft-benthos transects (SBt)	15	90 transects
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 (RFs)	5	30 search periods
Reef-front search by walking (RFs_w)	0	0 search period
Sea cucumber day searches (Ds)	6	36 search periods
Sea cucumber night searches (Ns)	2	12 search periods

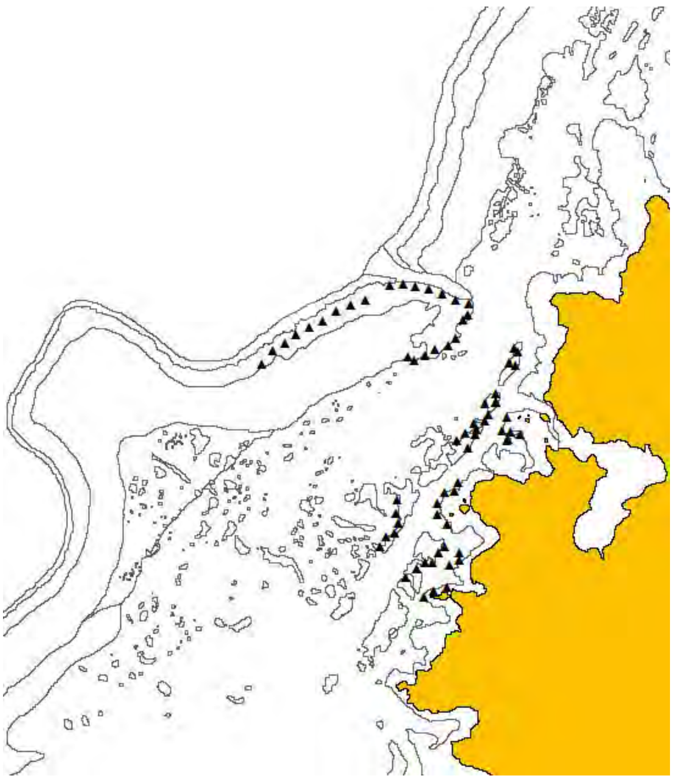

Figure 3.26: Broad-scale survey stations for invertebrates in Ngatpang.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

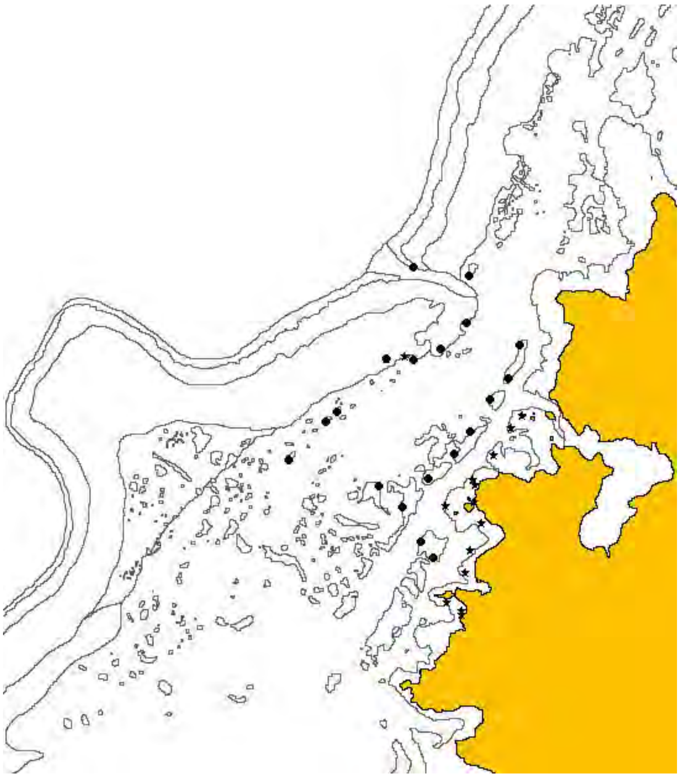

Figure 3.27: Fine-scale reef-benthos transect survey stations and soft-benthos transect survey stations in Ngatpang.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

Figure 3.28: Fine-scale survey stations for invertebrates in Ngatpang.
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey stars: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Eighty-one species or species groupings (groups of species within a genus) were recorded in the Ngatpang invertebrate surveys: 18 bivalves, 22 gastropods, 25 sea cucumbers, 5 urchins, 5 sea stars, 2 cnidarians and 3 lobsters (Appendix 4.2.1). Information on key families and species is detailed below.

3.4.1 Giant clams: Ngatpang

Shallow-reef habitat that is suitable for giant clams was present at moderate levels at Ngatpang (14.6 km^2: ~12.0 km^2 within the lagoon and 2.6 km^2 on the reef front or slope of the barrier). The main lagoon area was ~72.8 km^2, and stretched east from Babeldaob across lines of reef (or pseudo barriers) before finishing in a broad, shallow, sandy back-reef and barrier.

This relatively enclosed section of the lagoon (a barrier-reef passage to the north) was subject to a higher level of influence from land (allochthonous inputs) compared to other CoFish sites in Palau. In addition, seasonal winds from the northeast and southwest seem to funnel through this area. Hard reef substrate was available at the fringes of the deepwater shoreline embayments within the pseudo barrier reef, in the patch reefs in the lagoon, and at the barrier reef.

Large, shallow-water embayments on the coast to the north and south of Ngatpang were relatively depositional in nature, and the survey team did not attempt to enter the brackish water lagoon that extended landwards from its narrow entrance to the north of Ngatpang. The barrier reef, on the other hand, was mostly oceanic-influenced, and had a broad and shallow reef slope, with shallow-water reef (shoals) extending in some sections more than 100 m seawards from the front of the barrier reef. Despite the high-island environment close to shore, the range of habitats available was broad and did not generally limit the distribution of clams.

Using all survey techniques, seven species of giant clam were noted. Broad-scale sampling provided a good overview of giant clam distribution and density of the seven species: the elongate clam *Tridacna maxima*, the boring clam *T. crocea*, the fluted clam *T. squamosa*, the smooth clam *T. derasa*, the true giant clam *T. gigas*, the horse-hoof or bear's paw clam *Hippopus hippopus*, and the china clam *H. porcellanus*. *H. porcellanus* species has a limited distribution (Philippines to western Irian Jaya), and has not been recorded before in CoFish surveys of other Pacific Island countries.

Records from broad-scale sampling revealed that *T. crocea* had the widest occurrence (found in 12 stations and 64 transects), followed by *T. maxima* (in 11 stations and 48 transects), *T. squamosa* (in 9 stations and 24 transects) and *T. derasa* (in 3 stations and 3 transects). *H. hippopus*, which is well camouflaged and usually relatively sparsely distributed, was recorded in 9 stations (15 transects in total). This was the first time for our researchers to see *H. porcellanus* (found in 3 stations and 3 transects), a less common species than *H. hippopus* (Figure 3.29).

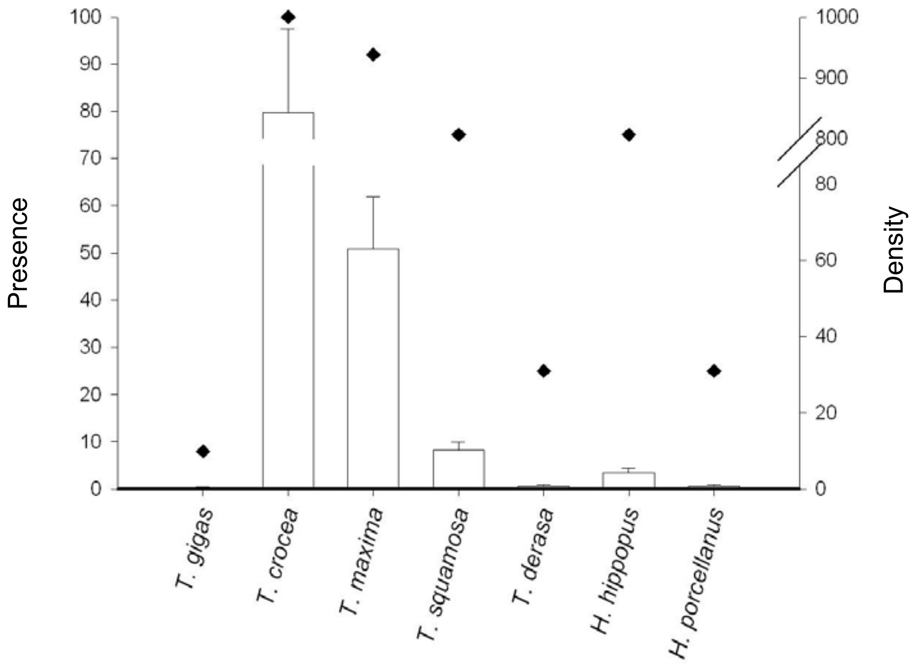

Figure 3.29: Presence and mean density of giant clam species at Ngatpang based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 3.30). In these reef-benthos assessments (RBt), *T. crocea* was present in 100% of stations, the highest station density being 9375 clams/ha ±993.2. *T. maxima* was also relatively common (in 74% of stations), with moderately high density. *T. squamosa* was less common here than in neighbouring Koror, but still reasonably common (in 32% of stations) and at moderate density. No high-density patches of *T. squamosa* were located in survey, but densities of *H. hippopus* reached 291.7 clams/ha in a station on the lagoon side of the barrier reef, near the southern arm of the passage. Although two *T. gigas* individuals were recorded in RBt assessments, *T. derasa* was only noted in broad-scale and deep-water day searches (Ds) for sea cucumbers (Figure 3.30).

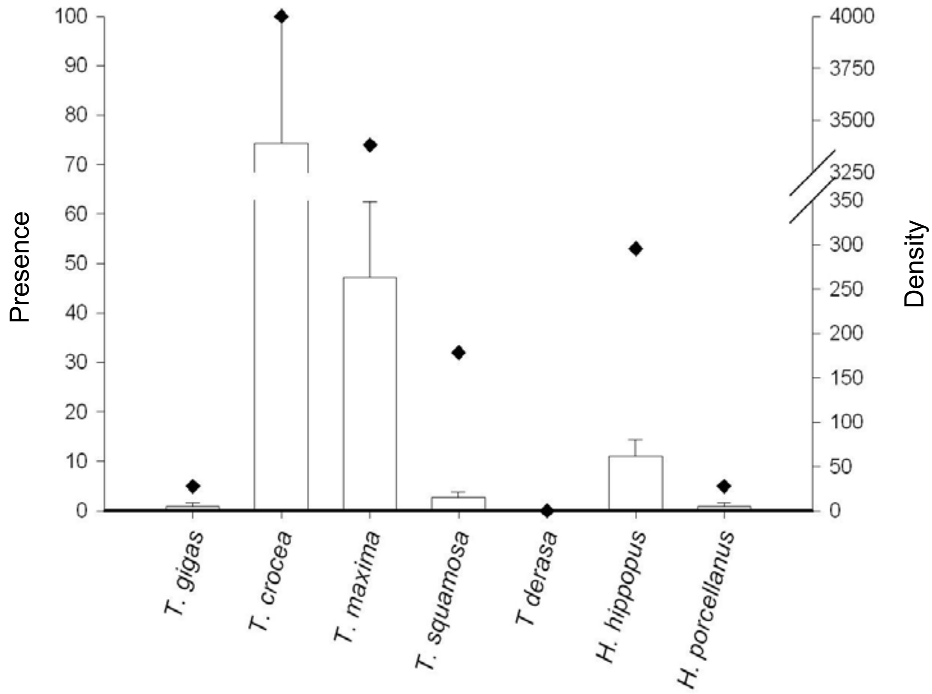

Figure 3.30: Presence and mean density of giant clam species at Ngatpang based on all reef-benthos transect assessments.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

A full range of sizes was noted for *T. crocea*, although the largest sizes were not common (mean 5.9 cm ±0.1). *T. maxima* were also smaller on average than in other CoFish sites in Palau (mean 12.2 cm ±0.4). *T. maxima* from reef-benthos transects alone (shallow-water reefs) had a slightly smaller mean length (10.8 cm ±0.5), which is the size reached by a clam of about 5 years old). A full range of sizes was recorded for the faster-growing *T. squamosa* (which grows to an asymptotic length L_∞ of 40 cm). This species averaged a rather large 27.9 cm shell length ±1.2 (which equates to a clam of ~7 years of age). *H. hippopus* (mean length 24.2 cm ±0.9) is generally well camouflaged, but the distribution of size classes indicates that recruitment was occurring and a full range of adult sizes was noted. Two specimens of the less common species *H. porcellanus* (mean length 25.2 cm ±1.3) were noted in shallow reef-benthos transect surveys, both on back-reefs near the passage. The four *T. derasa* individuals had a mean shell length of 41.0 cm ±5.4; the smallest was 31 cm (Figure 3.31). Five *T. gigas* (which can reach adult lengths in excess of 1.3 m) were recorded in Ngatpang (mean length 51.6 cm), the largest of which was in excess of 65 cm in length.

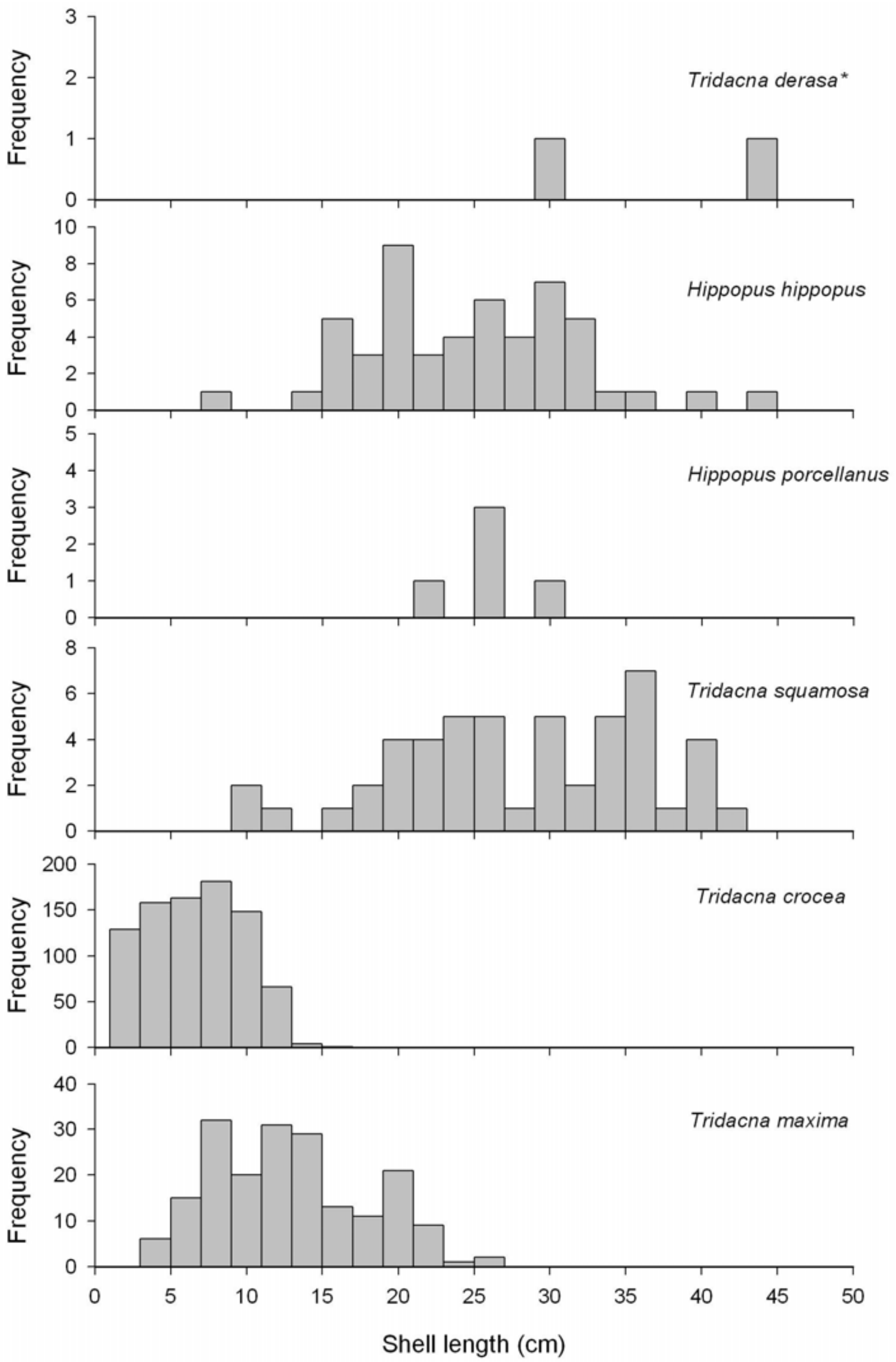

Figure 3.31: Size frequency histograms of giant clam shell length (cm) for Ngatpang.
* One individual *T. derasa* with a shell length of 55 cm was also recorded.

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

Palau is within the natural distribution range of the commercial topshell, *Trochus niloticus*, and Ngatpang has both intermediate lagoon reefs and barrier reefs suitable for this species. The CoFish survey results revealed that *T. niloticus* was not common at Ngatpang, despite the moderately extensive coastal, lagoon and barrier reef area (with lineal distance of exposed reef perimeter of 14.4 km). The lack of large numbers of trochus was partially a result of environmental constraints, as the water in the lagoon was more depositional, and lagoon reefs more embayed with less oceanic influence.

The most significant trochus aggregations were very localised, in reefs generally located in more oceanic-influenced areas with dynamic water flow, e.g. passage reef. The reef slope and shoals found outside the barrier reef also were more exposed and the water movement more dynamic but, although *T. niloticus* was common in distribution, densities were low. The management of the trochus fishery in Palau allows commercial fishing only once every three or four years, with subsequent rest periods for stock recovery. The last commercial harvest in Palau was in 2005.

The CoFish work surveys all the reef zones to ascertain the distribution and density of trochus. Usually mother-of-pearl transects (MOPt) form an important part of this work but, due to the low density of trochus found, only mother-of-pearl searches (MOPs) could be completed (See Methods and Table 3.13.).

Table 3.13: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Ngatpang

Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
B-S	0.2	0.2	1/12 = 8	1/72 = 1
RBt	17.5	11.6	3/19 = 16	6/114 = 5
RFs	8.6	3.1	4/5 = 80	9/30 = 30
MOPs	19.73	11.6	3/5 = 60	8/30 = 27
Tectus pyramis				
B-S	0	0	0/12 = 0	0/72 = 0
RBt	21.9	13.7	4/19 = 21	8/114 = 7
RFs	5.5	2.0	4/5 = 80	6/30 = 20
MOPs	12.1	3.9	4/5 = 80	7/30 = 23
Pinctada margaritifera				
B-S	3.7	0.9	8/12 = 67	14/72 = 19
RBt	8.8	5.1	3/19 = 16	4/114 = 4
RFs	1.6	1.0	2/5 = 40	2/30 = 7
MOPs	1.5	1.5	1/5 = 20	1/30 = 3

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

A total of 33 trochus individuals were recorded during the survey (n = 30 were measured), which was 2% of the trochus noted in the four sites surveyed in Palau. The majority of the stock was on shallow reef (~1.5–2 m deep), which was easily accessible to fishers using mask and snorkel. Only 16% of reef-benthos transect stations held trochus, and these yielded densities of 42–208 trochus/ha. In MOPs, three of the five stations held trochus, and the density was 8–61 trochus/ha. At Ngatpang, trochus were not recorded at densities greater than 500 /ha, the minimum threshold density that main aggregations need to reach before commercial fishing can commence.

Shell size also gives important information on the status of stocks by highlighting new recruitment into the fishery, or the lack of recruitment, which could have implications for the numbers of trochus entering the capture size classes in the following two years.

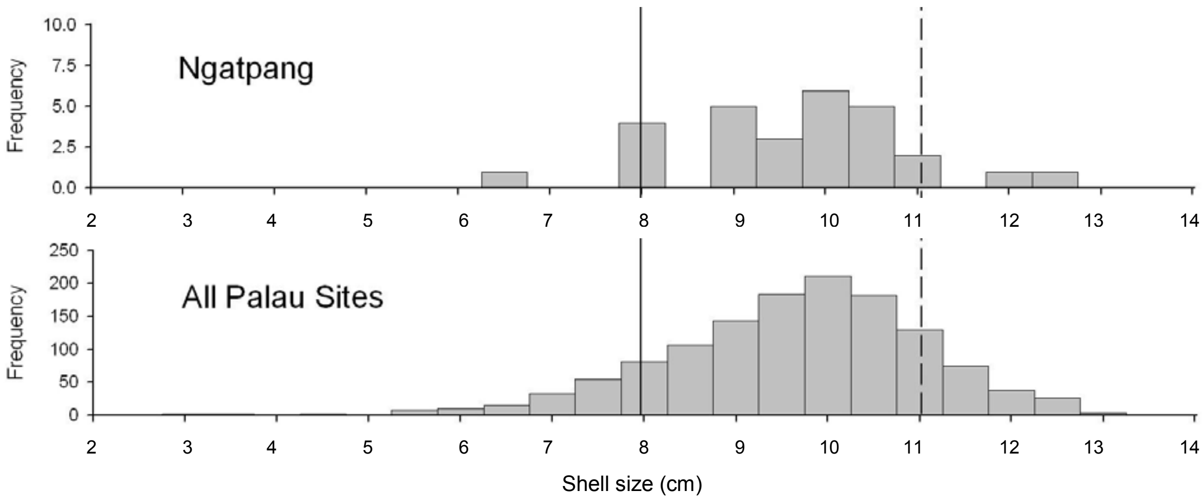

Figure 3.32: Size frequency histograms of *Trochus niloticus* shell base diameter (cm) for Ngatpang and all Palau sites.

The mean basal width of trochus at Ngatpang was 9.5 cm ±0.2 (Figure 3.32). A shell of 9.6 cm basal width weighs approximately 250 g. The length-frequency graph reveals that most trochus at Ngatpang are within the capture size classes (Trochus reach first maturity at three years of age, i.e. ~7–8 cm in shell size.). For this cryptic species, younger shells are normally only picked up in surveys from the size of ~5.5 cm, when small trochus are emerging from a cryptic style of life and joining the main stock. As can be seen from the length-frequency graph, no large recruitment pulse of young trochus was evident from records collected at Ngatpang.

In addition, only 7% of the stock was from size classes >11 cm basal width, which is a relatively small proportion of mature shells for a population. In some other trochus fisheries, where stock has not been fished for an extended period or where there is a maximum basal width for commercial sale (shells >11 cm are protected from fishing), this portion of the stock makes up between 20–50% of the population. The result from Ngatpang can be interpreted as an indication of the level of fishing in previous harvests. Low numbers of large shells may indicate that trochus stocks were comprehensively targeted during the previous two fishing periods (in 2000 and 2005).

The level of suitability of reefs for grazing gastropods was also highlighted by results for the false trochus or green topshell (*Tectus pyramis*). This related, but less valuable species of topshell (an algal-grazing gastropod with a similar life history to trochus) was also not at high density at Ngatpang (n = 25 recorded in survey). The mean size (basal width) of *T. pyramis* was 6.2 cm ±0.2. A single small individual (<5.5 cm) was recorded in survey, but again no large recruitment pulse was identified, which may suggest that conditions for recent spawning and/or settlement of these gastropods may not have been especially favourable in recent years.

Another mother-of-pearl species, the blacklip pearl oyster *Pinctada margaritifera*, is cryptic and normally sparsely distributed in open lagoon systems (such as those found at Ngatpang). In survey, the number of blacklip seen during assessments was moderately high (n = 23), and higher than for the more southerly and easterly CoFish sites in Palau. The mean shell length (anterior–posterior measure) of these pearl oysters was 13.5 cm ±1.2.

3.4.3 Infaunal species and groups: Ngatpang

Soft benthos at the coastal margins of Ngatpang was generally suitable for seagrass but, in general, assessments in Palau concentrated mainly on the important trochus fishery. As no concentrations of in-ground resources (shell 'beds') were noted, we did not complete an infaunal 'digging' survey (quadrat surveys).

3.4.4 Other gastropods and bivalves: Ngatpang

Seba's spider conch *Lambis truncata* (the larger of the two common spider conchs) was rare in survey (n = 1) and *Lambis lambis* was also only moderately common in shallow-water reef transects assessments (n = 25). Interestingly, only two were seen during broad-scale survey and none were noted in transects on soft benthos. The only other *Lambis* species recorded were *Strombus lentiginosus* (n = 1) and *Lambis chiragra* (n = 2). The strawberry or red-lipped conch *Strombus luhuanus* was also not common, with no dense patches recorded (Appendices 4.2.2 to 4.2.8).

Three species of turban shell: *Turbo agyrostomus*, *T. chrysostomus* and *T. crassus* were recorded during surveys. The larger silver-mouthed turban, *T. argyrostomus*, was only recorded at low-to-moderate rates (in 23% of reef-front searches) and density (5.5 /ha ±2.4). The density recorded in reef-benthos transects was even lower. Other resource species targeted by fishers (e.g. *Astralium*, *Cerithium*, *Charonia*, *Chicoreus*, *Conus*, *Cypraea*, *Haliotis*, *Latirolagena*, *Ovula*, *Tectus* and *Vasum*) were also recorded during independent surveys (Appendices 4.2.2 to 4.2.8).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Anadara*, *Atrina*, *Chama*, *Gafrarium*, *Hyotissa*, *Malleus*, *Pinna*, *Pteria* and *Spondylus*, are also in Appendices 4.2.2 to 4.2.8. No creel survey was conducted at Ngatpang.

3.4.5 Lobsters: Ngatpang

There was no dedicated night reef-front assessment of lobsters (See Methods.) although night-time assessments (Ns) for nocturnal sea cucumber species offered a small extra opportunity to record lobster species. Lobster records (*Panulirus versicolor* and *P.* spp.) were uncommon (n = 4) in surveys at Ngatpang. A single prawn killer (*Lysiosquillina maculata*) and two mud lobsters, *Thalassina* spp. (known as *cheramrou* in Palau), were also recorded.

3.4.6 Sea cucumbers[8]: Ngatpang

Around Ngatpang there were extensive areas of shallow and deepwater sheltered lagoon bordering the elevated land mass of Babeldaob (lagoon area 72.8 km²). Coastal areas around Ngatpang were very suitable for supporting sea cucumbers, which feed on detritus and other organic matter in the upper few mm of bottom substrates. Extensive reef margins and areas of shallow, mixed hard- and soft-benthos habitat provided a range of suitable habitats for sea cucumbers. Despite the site and inshore lagoon having a major influence from the land, there was a complete range of conditions present, with more dynamic water movement and

[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.

flushing of oceanic water on the back-reef, the passage and the relatively extensive reef-front slope.

The presence and density of sea cucumber species were determined through broad-scale, fine-scale and dedicated survey methods (Table 3.13, Appendices 4.2.2 to 4.2.8; see also Methods). Results from the full range of assessments yielded 24 commercial species of sea cucumber (plus one indicator species, see Table 3.13).

Sea cucumber species associated with shallow-reef areas, such as the medium-value leopardfish (*Bohadschia argus*) was common in distribution (found in 47% of reef-benthos transects) and recorded at relatively high density (81.1 /ha. ±26.4). The high-value black teatfish (*Holothuria nobilis*) was also very common for a species easily targeted by industry (found in 15% of broad-scale transects and 32% of RBt stations) and was recorded at high density in shallow reef transect stations (26.3 /ha. ±12.0). The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was present (in 19% of broad-scale transects and 16% of reef-benthos transects) but not at high density in reef-benthos transect stations (19.7 /ha. ±12.1; see Appendices 4.2.2 to 4.2.8).

Surf redfish (*Actinopyga mauritiana*) were recorded in a range of assessments. As this species is mostly found, where its name suggests, on reef fronts, reef-front searches provide a valuable signal on its status. In Ngatpang, 60% of reef-front searches held *A. mauritiana* but not in high density (generally <20 /ha.). In other locations in the Pacific, this species is recorded in densities >400–500 /ha.

In more protected areas of reef and soft benthos in the enclosed, relatively embayed areas of the lagoon, good indications of the distribution and density of sea cucumbers were obtained. Curryfish (*Stichopus hermanni*) were recorded in 35% of broad-scale assessments at moderate density (11.8 /ha.). Blackfish (*Actinopyga miliaris*) and stonefish (*A. lecanora*) were also recorded. However, the species group of most local interest would probably be the currently unnamed *Actinopyga* sp. nov. (currently being described by Kris Netchy, University of Guam), the *Holothuria pervicax*/*Holothuria impatiens* group and the brown curryfish, *Stichopus vastus*. *Actinopyga* sp. nov. and *S. vastus* were recorded in some very high-density patches (>1000 /ha in SBt) on soft benthos. In Palau, these three species (or species groups) of sea cucumbers are exploited by the subsistence fishery and traditionally eaten. *Actinopyga* sp. nov. has three colour morphs and is prepared by gutting and cleaning the animal before the body wall is finely chopped up and mixed with lime juice and sauce for use as a sashimi.

In Ngatpang, the low-value lollyfish (*Holothuria atra*) (sometimes used as a neurotoxin for catching octopus) was recorded at high density in soft-benthos transects. Pinkfish (*H. edulis*) was also present at reasonable coverage and density.

The high-value sandfish (*H. scabra*) was found in only 20% of soft-benthos stations at Ngatpang, despite mangrove and seagrass shoreline areas being common (This species generally prefers this type of 'richer', soft-benthos depositional shoreline.). In these three stations, the density of sandfish was high (1875–4708 /ha.) and a full range of size classes was noted (mean length 16.1 cm ±0.2; Figure 3.33).

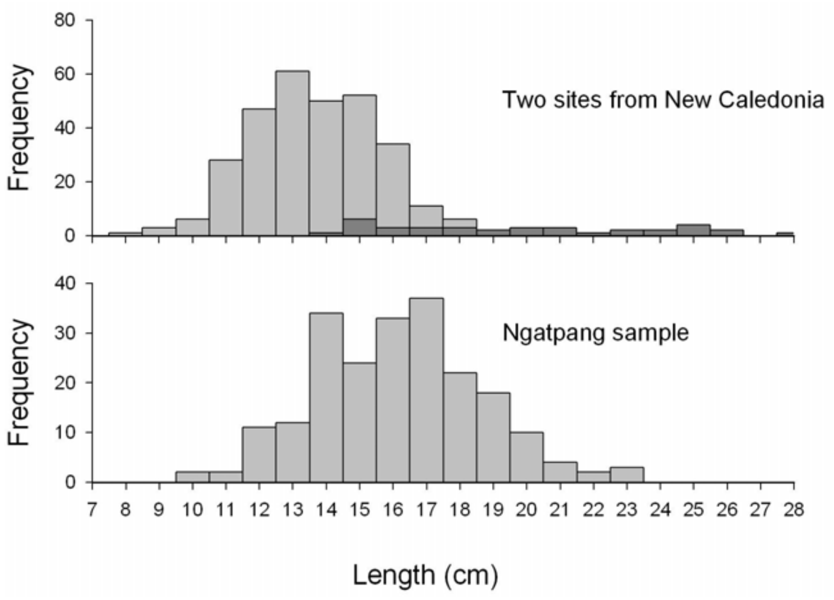

Figure 3.33: Length frequency histograms of sandfish *Holothuria scabra* from Ngatpang (lower graph) and two other western Pacific samples for comparison (upper graph).

It was interesting to note that the lower-value false sandfish (*Bohadschia similis*), which uses the same habitat as sandfish, was only present at low density in 7% of the soft-benthos transect stations.

Deep-water assessments were completed (30 five-minute searches, average depth 21.6 m, maximum depth 32 m) to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the passage and in the 'races' between the bars of reef that lay parallel with the shore had suitably dynamic water movement at Ngatpang, and *H. fuscogilva* was recorded in three of the six stations surveyed. At these stations, the average density of *H. fuscogilva* was low (2 /ha. ±1.1) and, in general, the density of other deepwater species was not high, apart from amberfish *T. anax* (a low-value species).

3.4.7 Other echinoderms: Ngatpang

At Ngatpang, a small number (n = 4) of edible collector urchins *Tripneustes gratilla* but no slate urchins *Heterocentrotus mammillatus* were recorded in surveys. Urchins, such as *Diadema* spp. and *Echinothrix* spp., can be used within assessments as potential indicators of habitat condition. Unusually, *Echinothrix* spp. were not recorded, but *Diadema* spp. and *Echinometra mathaei* were recorded at low levels (Appendices 4.2.2 to 4.2.8).

Starfish (e.g. the blue starfish *Linckia laevigata* and *L. guildingi*) were common in broad-scale surveys (61% of broad-scale transects) and at moderate density (103.1 /ha. ±20.5). Coralivore (coral eating) starfish were common in the form of pincushion stars *Culcita novaeguineae* (n = 42), but crown of thorns starfish *Acanthaster planci* were moderately rare in survey (n = 13 noted, mean density in broad-scale transects 0.2 /ha.).

The horned or chocolate chip star (*Protoreaster nodosus*) was recorded at moderate density in inshore seagrass, and the doughboy sea star (*Choriaster granulatus*) was at low density, mostly at depth on the lagoon floor.

Table 3.13: Sea cucumber species records for Ngatpang

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 19; SBt = 15			Other stations RFs = 5; MOPs = 5			Other stations Ds = 6; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinities	Deepwater redfish	M/H	0	0	0	2.8	41.7	7 SBt						
Actinopyga lecanora	Stonefish	M/H				2.2	41.7	5 RBt	1.5	7.6	20 MOPs			
Actinopyga mauritiana	Surf redfish	M/H	0.2	16.7	1	2.2	41.7	5 RBt	14.1 1.5	23.5 7.6	60 RFs 20 MOPs			
Actinopyga miliaris	Blackfish	M/H	0.7	16.7	4	108.3	541.7	20 SBt	0.8	3.9	20 RFs	0.8	2.4	33 Ds
Actinopyga sp. nov.	Undescribed species	M				4494.4	7490.7	60 SBt						
Bohadschia argus	Leopardfish	M	18.1	46.4	39	81.1 5.6	171.3 41.7	47 RBt 13 SBt				2.4 22.2	7.1 22.2	33 Ds 100 Ns
Bohadschia graeffei	Flowerfish	L	10.9	30.1	36	17.5	83.3	21 RBt	0.8	3.9	20 RFs			
Bohadschia similis	False sandfish	L				2.8	41.7	7 SBt				22.2	44.4	50 Ns
Bohadschia vitiensis	Brown sandfish	L	0.2	16.7	1	16.7	62.5	27 SBt				702.2	702.2	100 Ns
Holothuria atra	Lollyfish	L	17.7	57.9	31	87.7 3247.2	208.3 3746.8	42 RBt 87 SBt	1.6 4.5	7.8 11.4	20 RFs 40 MOPs	62.2	124.4	50 Ns
Holothuria coluber	Snakefish	L	0.9	22.2	4	11.0 55.6	104.2 208.3	11 RBt 27 SBt						
Holothuria edulis	Pinkfish	L	23.1	49	47	105.3 2.8	153.8 41.7	68 RBt 7 SBt	1.5	7.6	20 MOPs	8.9	17.8	50 Ns
Holothuria flavomaculata		L	1.6	38.9	4	13.2 2.8	250.0 41.7	5 RBt 7 SBt						
Holothuria fuscogilva [4]	White teatfish	H				30.7	291.7	11RBt	1.6	7.8	20 RFs	2.0	4.0	50 Ds
Holothuria fuscopunctata	Elephant trunkfish	M	13.1	58.9	22	2.2	41.7	5 RBt	3.1	15.7	40 RFs	2.8	5.6	50 Ds
Holothuria nobilis [4]	Black teatfish	H	6.2	40.4	15	26.3 2.8	83.3 41.7	32 RBt 7SBt	3.1 16.7	7.8 20.8	20 RFs 80 MOPs	0.8 22.2	4.8 44.4	17 Ds 50 Ns
Holothuria scabra	Sandfish	H				594.4	2972.2	20 SBt						
Holothuria pervicax		L												
Stichopus chloronotus	Greenfish	H/M	13.2	67.9	19	19.7	125	16 RBt						
Stichopus hermanni	Curryfish	H/M	11.8	33.9	35	6.6	62.5	11 RBt	7.8 1.5	39.2 7.6	20 RFs 20 MOPs	2.8	8.3	33 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; Ds = day search; Ns = night search.

Table 3.13: Sea cucumber species records for Ngatpang (continued)

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 19; SBt = 15			Other stations RFs = 5; MOPs = 5			Other stations Ds = 6; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Stichopus horrens	Peanutfish	M/L				2.2	41.7	5 RBt						
Stichopus vastus	Brown curryfish	H/M				2.2 783.3	41.7 1175.0	5 RBt 67 SBt						
Synapta spp.	-	-				5.6	41.7	13 SBt						
Thelenota ananas	Prickly redfish	H	9.9	51.1	19	26.3	166.7	16 RBt	15.7 9.1	26.1 15.2	60 RFs 60 MOPs	2.4 4.4	4.8 8.9	50 Ds 50 Ns
Thelenota anax	Amberfish	M	4.4	45.2	10	2.2	41.7	5 RBt	0.8	3.9	20 RFs	8.7	13.1	66 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; Ds = day search; Ns = night search.

3.4.8 Discussion and conclusions: invertebrate resources in Ngatpang

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

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

- The wide range of shallow-water reef habitats, and the extensive intermediate and patch reef around Ngatpang provide extensive suitable areas for giant clams.

- A complete range of giant clam species was present, some of which are becoming rare in other parts of the Pacific. There were few management issues to consider for the smaller species of clams (*Tridacna maxima* and *T. crocea*), but larger clam species need greater protection from fishing. As giant clams only mature to produce eggs at a large size (This can take up to 10 years in *T. gigas*.), it is important that groups of large, older clams are protected from fishing, to ensure there is sufficient production of gametes (especially eggs) to create the next generation and therefore maintain sustainability of the resource.

- The large true giant clam, *T. gigas*, and the smooth clam, *T. derasa*, were only recorded in small numbers compared to similar sites in other parts of Palau. Stocks of the fluted clam, *T. squamosa*, although relatively well distributed around Ngatpang, were also at lower density than expected.

- In general, the status of giant clams at Ngatpang was reasonably healthy, especially for the most common species. Clam density and the 'full' range of clam size classes present support the assumption that, apart from some of the largest species, populations of giant clam are only partially impacted by fishing.

Data on mother-of-pearl shell (MOP) species suggest that:

- The blacklip pearl oyster, *Pinctada margaritifera*, is more common at Ngatpang than at the more southerly and easterly CoFish sites in Palau.

- The distribution, density and length recordings give a mixed picture of MOP stock health.

- Local reef conditions constitute extensive and moderately good habitat for juvenile and adult *Trochus niloticus*, the commercial topshell, although the site is more enclosed than is optimal. Trochus, however, were not common at Ngatpang, and their low density suggests that stocks are marginal, and 'core' aggregations (where trochus are typically in greatest abundance) still have significant potential for growth in overall abundance. Commercial stocks were most common at easily accessible, shallow-water reefs closer to the ocean side of the lagoon, in the passage and on the reef slope.

- Trochus size-class information also reveals that no strong year-class is currently visible below the commercial size class range, and that past harvests have comprehensively fished the stock, as aggregations are not dominated by old shells.

- It is difficult in such a situation to determine how much of the current poor status of trochus is driven by harvesting and how much by environmental constraints, but what is obvious is that no harvests should proceed in this area, even if there is an opening in the fishery in the next year. Remaining stocks should be given time to build in number, to a point where the abundance is more certain to enable successful spawning and fertilisation (In this single-sex species, individuals need to be at high density to ensure spawning success.) Without this there is no chance for the fishery to develop its potential, and the stock will further decline.

Considerations for future management of trochus include the following:

- On occasion, the resting period adopted in Palau may be too short for continued successful management of the trochus fishery. Firstly, this approach relies on there being regular recruitment (no recruitment failures), which is uncommon with mollusc fisheries in general (Strong recruitment year-classes only generally arrive every 3–5 years.). Secondly, most egg production originates from the largest individuals of the population, and trochus only reach these size classes at ≥6 years of age (from shells that would need to survive up to two harvest rotations under the current management scenario).

- Some areas that are located in less than optimal habitat, such as Ngatpang, might take the longest to recover from fishing, and therefore may require extra management of fishing to ensure trochus stocks are not too heavily depleted, or longer periods of rest between fishing periods.

Data collected on the presence and density of sea cucumbers suggest the following:

- Ngatpang has a diverse range of environments and depths suitable for sea cucumbers. Bordering Ngatpang are seagrass and mangrove shorelines, suitable for inshore species, and large areas of inshore and midshore reefs have embayments of protected shallow water. In addition, a full range of oceanic-influenced reefs extends seawards to the barrier reef.

- The range of sea cucumber species recorded at Ngatpang was large, partially reflecting the varied environment, but also the fact that the export fishery is highly controlled in Palau.

- Sea cucumbers are not under significant fishing pressure and commercial export stocks are only lightly or moderately affected by past fishing. The species fished by domestic fishers for subsistence are more impacted, and marine protected areas designated near Ngatpang need to be well managed to ensure these stocks are not depleted. This is especially true for the more easily targeted (and depleted) larger inshore species, such as sandfish, *Holothuria scabra*.

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

3.5 Overall recommendations for Ngatpang

- Spear diving be limited and regulated, especially in coastal and lagoon reefs.

- Restrictions in place for the existing marine reserves be observed and enforced.

- A regular monitoring system be established and implemented with community participation, to follow changes in resources, especially finfish in the intermediate and outer reefs and the few selected target invertebrate species.

- Groups of large, older clams be protected from fishing, to ensure there is sufficient breeding stock to create the next generation.

- All clam species need the support of further management measures, such as protected areas.

- No trochus harvests should proceed in Ngatpang, even if there is an opening in the fishery in the next year. Remaining stocks should be given time to build in number, to a point where the abundance is more certain to enable successful spawning and fertilisation.

- BMR consider attempting to get most of the 'core' trochus fishery areas up to a threshold density of 500–600 /ha, before considering commercial fishing.

- BMR consider protecting a portion of trochus broodstock (sizes ≥11 cm). This could be accomplished by creating a 'gauntlet' fishery, with an upper as well as a lower size limit, creating small no-fish areas within core areas of the fishery, or by 'resting' areas from commercial fishing within the main fishing locations for longer periods.

- Marine protected areas near Ngatpang be well managed to ensure that sea cucumber species fished by domestic fishers for subsistence, which are already impacted, are not further depleted.

- Careful management of fishing could allow commercial harvesting of a number of sea cucumber export species in Ngatpang. Preferably, catches could be made using a pulse-harvest fishing strategy, similar to that currently employed for trochus, which allows a period of rest between fishing events and time to re-assess the stocks response to fishing pressure.

4. PROFILE AND RESULTS FOR AIRAI

4.1 Site characteristics

Airai is a village located in the south–southeast of Babeldaob island, situated at 07°21'N, 134°37'E (Figure 4.1). The fishing area is delimited to the north by the southern part of the Ngemelachel pass and to the south by a west–east line extending eastward from the southern channel of Babeldaob. The lagoon is relatively shallow (30–40 m) and contains few intermediate reefs, mostly found in the extreme northern and southern areas. The other three habitats (outer, back- and coastal reefs) are well represented. Two marine reserves are present, located at 7°23'2″N, 134°35'3″E (established in 1994, surface 1km²) and at 7°20'3″N, 134°32'6″E (established in 1997, surface 1km²).

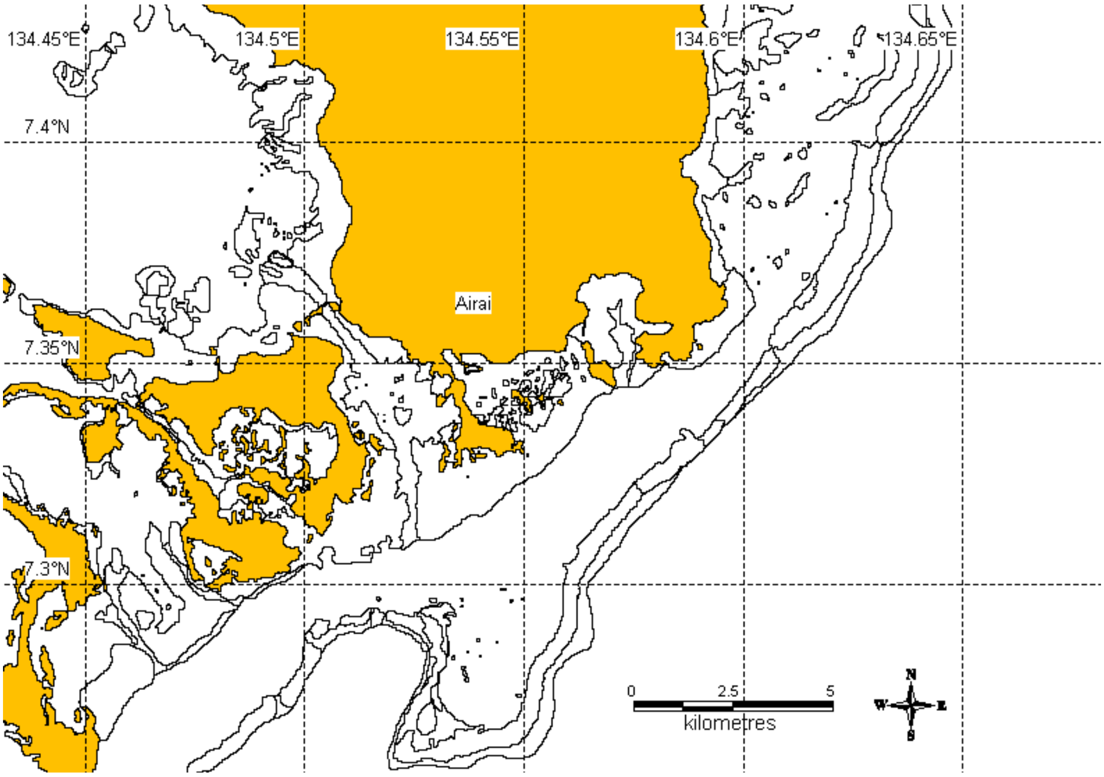

Figure 4.1: Map of Airai.

4.2 Socioeconomic surveys: Airai

Socioeconomic fieldwork was carried out in the Airai community north of Koror on Palau's main island in May – June 2007. The survey covered a total of 27 households, including 134 people. Thus, the survey represents about 6% of the community's households (470) and total population (2333). Further to the fact that the sample size is limited, the selected households may not be representative of the entire community because they were selected according to two major criteria. First, about one-third of the interviews focused on households with known male fishers. Second, the remaining two-thirds of the interviews focused on the part of the community where the females form part of an informal invertebrate research and monitoring group. This group is being supported by a local researcher, who actively supports the monitoring of invertebrate resources and the status of its supporting habitats and fishing grounds. Consequently, the results presented here characterise only the parts of the Airai community that are composed of households with very active finfish fishers and invertebrate collectors; therefore any resulting bias may be taken into account.

Household interviews aimed at the collection of general demographic, socioeconomic and consumption parameters. A total of 25 individual interviews of finfish fishers (17 males, 8 females) and 14 invertebrate fishers (5 males, 9 females) were conducted. These fishers belonged to one of the 27 households surveyed. Sometimes, the same person was interviewed for both finfish and invertebrate fishing.

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

Our survey results (Table 4.1) suggest an average of one fisher per household. If we extrapolate these results, we arrive at a total of 611 fishers in Airai. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 296 fishers who only fish for finfish (mostly males, a few females), a total of 53 fishers who only collect invertebrates (all females) and 262 fishers (males and females) who fish for both finfish and invertebrates.

The majority of all households surveyed in Airai are involved in fisheries (~78%). More than half, i.e. ~59% of all households in Airai own a boat; most are motorised (81%), the remaining 19% are non-motorised (canoes).

Ranked income sources (Figure 4.2) suggest that fisheries is not an important sector compared to salaries. Only ~15% of households indicated that fisheries is their first source of income, and another ~15% quoted fisheries as their second income source. Salaries, in contrast, provide 52% of all households with first and an additional 11% with second income. Other sources, including retirement payments, welfare and handicrafts, provide 33% of all households with first and 15% of all households with second income. Agriculture does not play an important role, providing ~7% households with first, and ~4% with second source of revenue.

The importance of fisheries, however, shows in the fact that all households eat fresh fish, and more than half (67%) also eat invertebrates. The fish that is consumed is mostly caught by a member of the household (78%), but also bought (33%) and often received as a gift (60%). The proportion of invertebrates caught by a member of the household where consumed is much lower (41%). Invertebrates are bought as often as fish (30%) but much less often received as a gift (15%). These results suggest that finfish and invertebrates sold do not only target the market in Koror but are also sold locally in Airai.

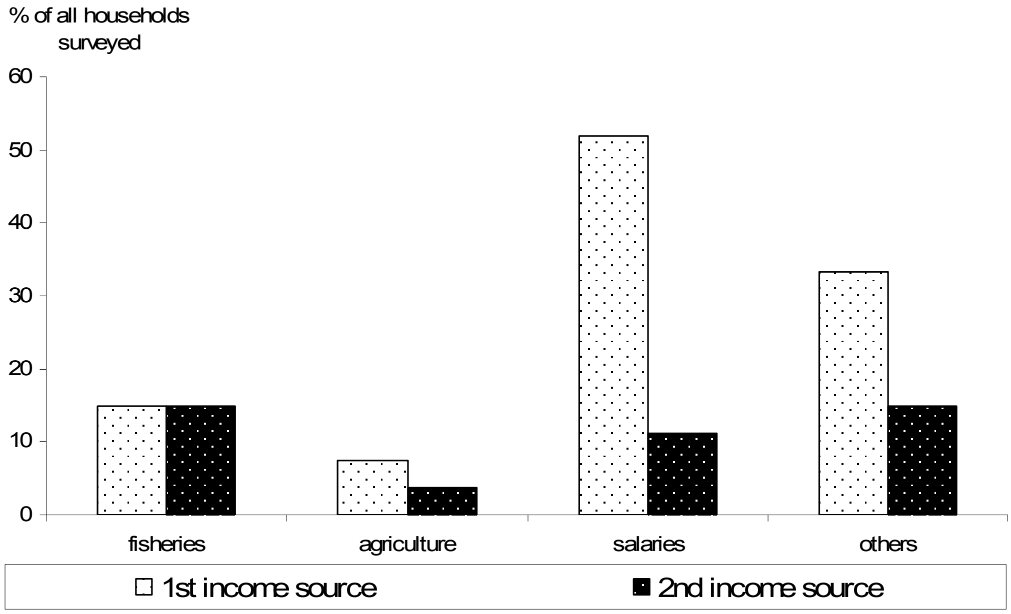

Figure 4.2: Ranked sources of income (%) in Airai.
Total number of households = 27 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly retirement payments, welfare and handicrafts.

Fresh fish consumption in Airai (~70 kg/person/year ±20.18) is above the regional average (FAO 2008) (Figure 4.3), and as high as the average consumption across all CoFish sites investigated in Palau. It should be noted that the data variability (SE) among Airai households is large and may be explained by the selection of households as explained above.

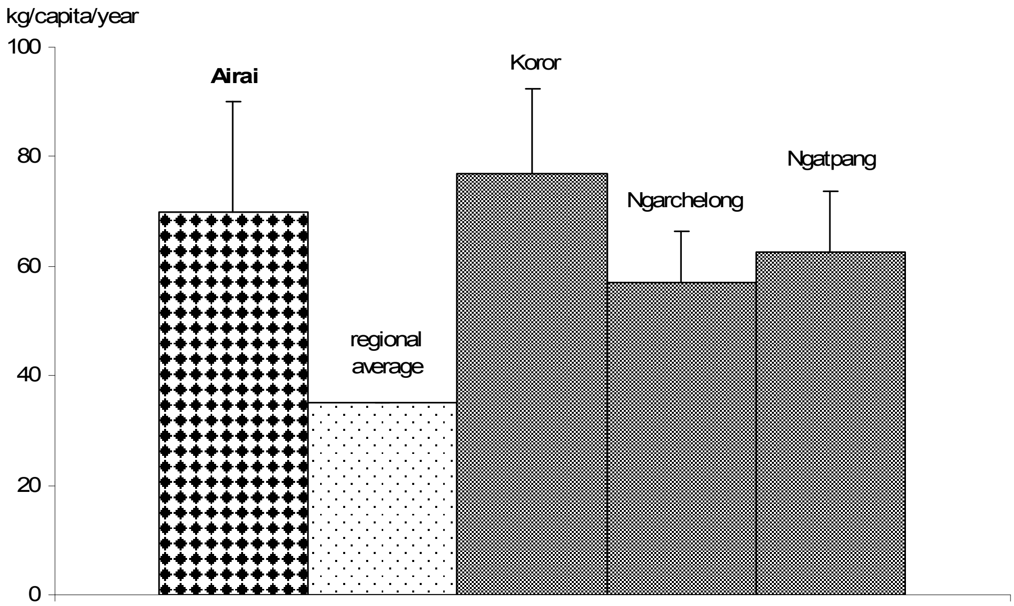

Figure 4.3: Per capita consumption (kg/year) of fresh fish in Airai (n = 27) compared to the regional average (FAO 2008) and the other three CoFish sites in Palau.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

The consumption of invertebrates (meat only) is ~5 kg/person/year (Figure 4.4) and significantly lower than finfish consumption and also slightly lower than the average invertebrate consumption found for all CoFish sites in Palau. Canned fish consumption is low (~6.6 kg/person/year) and almost the same as the average for all CoFish sites in Palau (~6 kg/person/year ±7.91) (Table 4.1).

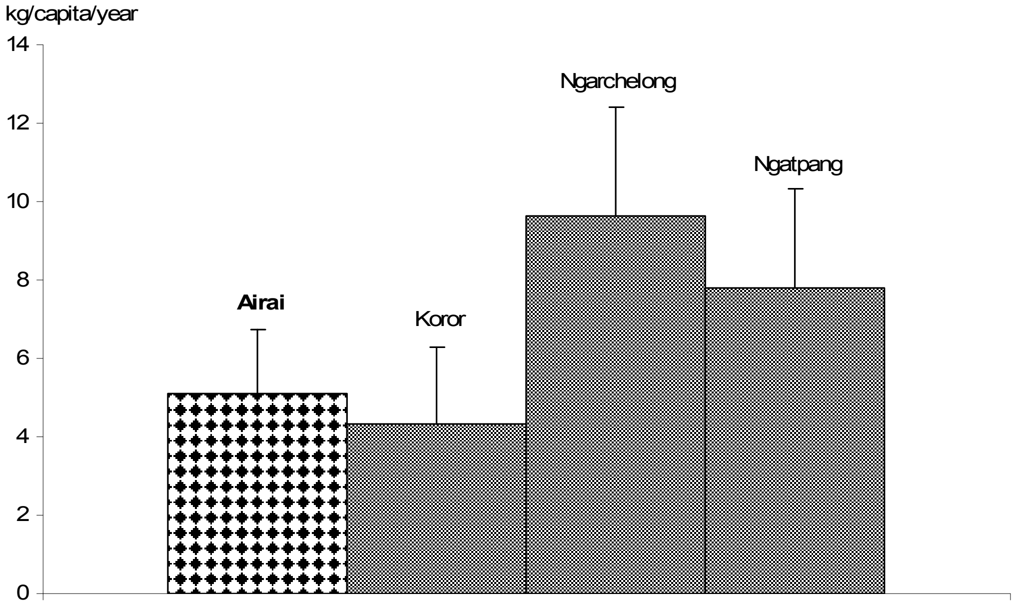

Figure 4.4: Per capita consumption (kg/year) of invertebrates (meat only) in Airai (n = 27) compared to the other three CoFish sites in Palau.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparing results among all sites investigated in Palau (Table 4.1), the households investigated in Airai depend slightly more on fisheries for income generation, and the people eat about as much fresh fish in a year as found on average across all sites. However, Airai people seem to eat slightly less invertebrates and about the average amount of canned fish. The household expenditure level is significantly higher than found on average and, as also found elsewhere, remittances are of no importance overall in Airai.

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

Survey coverage	Site (n = 27 HH)	Average across sites (n = 128 HH)
Demography		
HH involved in reef fisheries (%)	77.8	74.2
Number of fishers per HH	1.30 (±0.21)	1.12 (±0.08)
Male finfish fishers per HH (%)	45.7	53.8
Female finfish fishers per HH (%)	2.9	4.2
Male invertebrate fishers per HH (%)	0.0	0.7
Female invertebrate fishers per HH (%)	8.6	9.1
Male finfish and invertebrate fishers per HH (%)	20.0	16.1
Female finfish and invertebrate fishers per HH (%)	22.9	16.1
Income		
HH with fisheries as 1st income (%)	14.8	9.4
HH with fisheries as 2nd income (%)	14.8	13.3
HH with agriculture as 1st income (%)	7.4	3.9
HH with agriculture as 2nd income (%)	3.7	3.1
HH with salary as 1st income (%)	51.9	67.2
HH with salary as 2nd income (%)	11.1	4.7
HH with other sources as 1st income (%)	33.3	23.4
HH with other sources as 2nd income (%)	14.8	14.1
Expenditure (USD/year/HH)	8488.89 (±705.08)	6365.28 (±392.62)
Remittance (USD/year/HH) (1)	1200.00 (n/a)	1830.00 (±575.82)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	69.96 (±20.18)	68.79 (±7.91)
Frequency fresh fish consumed (times/week)	4.04 (±0.36)	4.25 (±0.17)
Quantity fresh invertebrate consumed (kg/capita/year)	5.10 (±1.64)	6.20 (±7.91)
Frequency fresh invertebrate consumed (times/week)	0.93 (±0.21)	0.80 (±0.09)
Quantity canned fish consumed (kg/capita/year)	6.64 (±1.87)	5.92 (±0.62)
Frequency canned fish consumed (times/week)	2.06 (±0.41)	1.94 (±0.15)
HH eat fresh fish (%)	100.0	99.2
HH eat invertebrates (%)	66.7	68.0
HH eat canned fish (%)	77.8	85.2
HH eat fresh fish they catch (%)	77.8	77.8
HH eat fresh fish they buy (%)	33.3	33.3
HH eat fresh fish they are given (%)	59.3	59.3
HH eat fresh invertebrates they catch (%)	40.7	40.7
HH eat fresh invertebrates they buy (%)	29.6	29.6
HH eat fresh invertebrates they are given (%)	14.8	14.8

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

4.2.2 Fishing strategies and gear: Airai

Degree of specialisation in fishing

Fishing in Airai is performed by both genders (Figure 4.5). However, ~49% of all fishers exclusively target finfish (46% males, 3% females). Not many females collect invertebrates either (~9%). No male fishers specialise only in invertebrates, but 20% of male fishers target invertebrates in combination with finfish, as do 23% of female fishers.

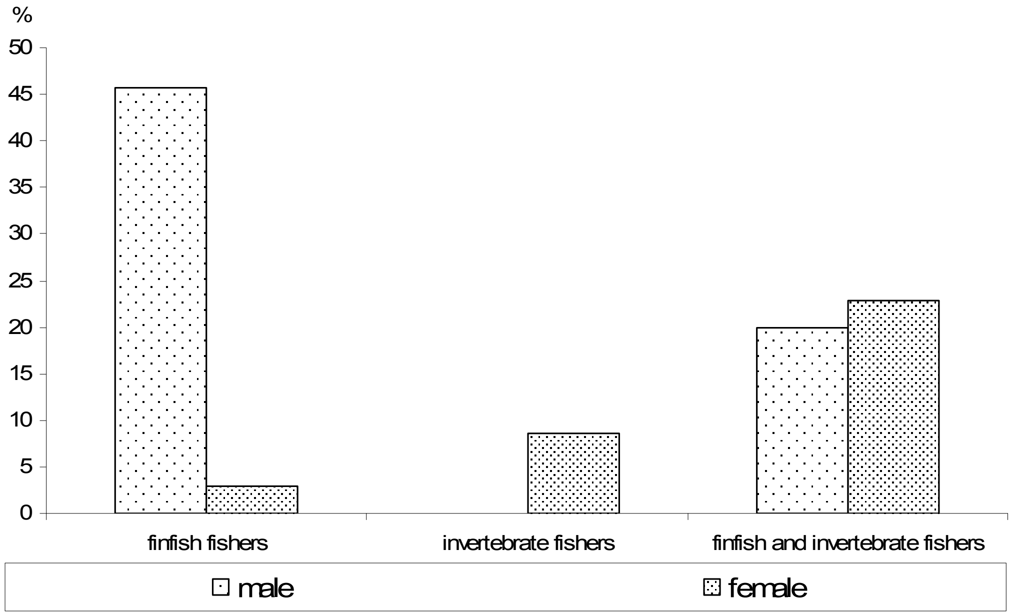

Figure 4.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Airai.
All fishers = 100%.

Targeted stocks/habitat

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

Resource	Fishery / Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	11.8	25.0
	Sheltered coastal reef & lagoon	5.9	0.0
	Lagoon	64.7	75.0
	Lagoon & outer reef	5.9	0.0
	Outer reef	23.5	25.0
Invertebrates	Reeftop	40.0	55.6
	Seagrass	80.0	77.8
	Mangrove	40.0	0.0

Finfish fisher interviews, males: n = 17; females: n = 8. Invertebrate fisher interviews, males: n = 5; females, n = 9.

Fishing patterns and strategies

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

Our survey sample suggests that fishers in Airai can choose among the sheltered coastal reef, lagoon and outer-reef habitats. Some fishers combine the sheltered coastal reef and lagoon, or the lagoon with the outer reef in one fishing trip, but not often (~12% of fishers). Most fishers, males and females, target the lagoon. About 37% of all fishers also target the sheltered coastal reef and another 49% the outer reef. Both habitats are also targeted by female fishers.

Invertebrate fisheries in Airai include reeftop, soft-benthos (seagrass) and mangrove gleaning. Most fishers (females and males) target the soft benthos (seagrass), and fewer the reeftops; only males fish the mangroves. If considering overall participation (Figure 4.6), soft-benthos collection represents 55%, reeftop gleaning another 35%, and mangrove gleaning only 10% of all fishing.

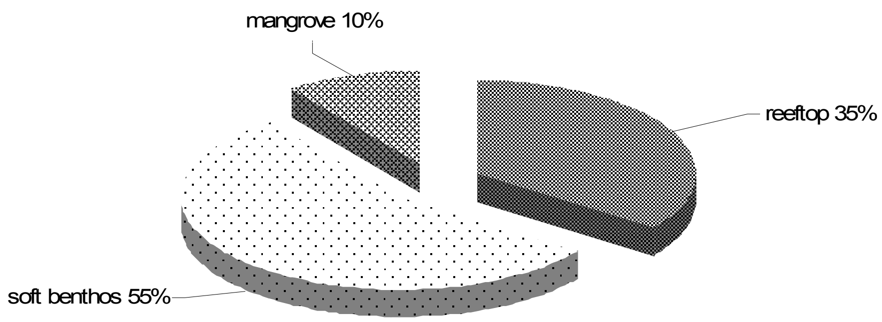

Figure 4.6: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Airai.
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

As shown in Figure 4.7, participation by males and females does not differ much in soft-benthos (seagrass) and reeftop fisheries. However, more females than males engage in reeftop gleaning.

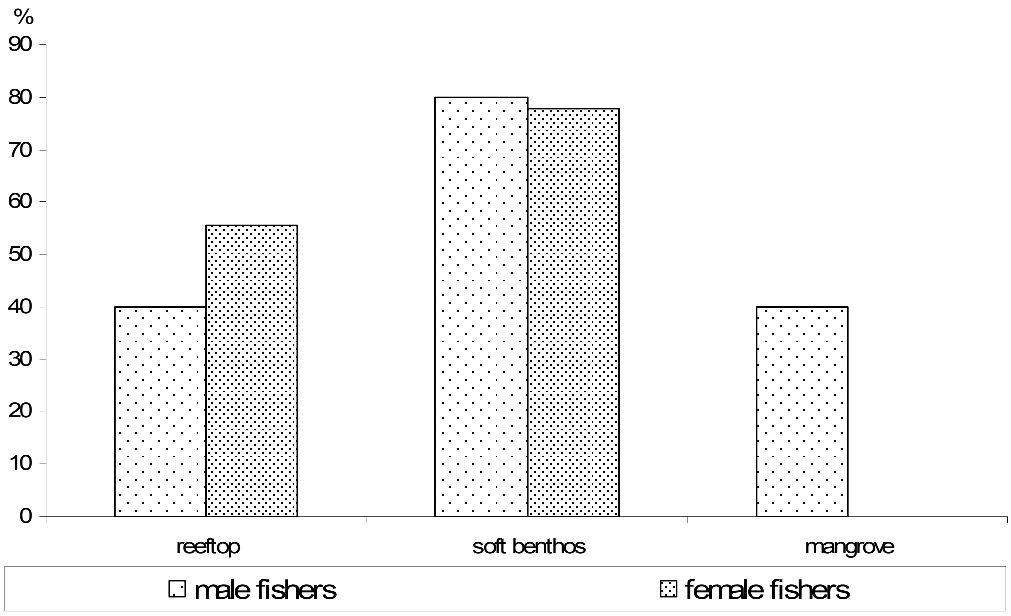

Figure 4.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Airai.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 5 for males, n = 9 for females.

Gear

Figure 4.8 shows that handlining is the main technique used in reef habitats, including the sheltered coastal reef, the sheltered coastal reef combined with the lagoon in the same trip, and the sheltered coastal reef combined with the outer reef. However, castnetting in combination with other techniques is the main method used in the lagoon and the lagoon and outer reef combined in one fishing trip. Various fishing gear is used in the lagoon: castnets, gillnets, handlines, spear diving, fishing rods, and any combination of these. The use of mostly motorised boat transport increases from the sheltered coastal reef and the lagoon to the outer reef.

Gleaning and free diving for invertebrates is done using very simple tools only. Reeftop, soft-benthos (seagrass) and mangrove gleaning are done by hand, mainly using plastic containers to collect molluscs, holothurians, sea urchins and clams. Half of all trips to the mangroves are made by walking, the other half by motorised boat transport. Most trips to the reeftop and to the soft-benthos (seagrass) fishing grounds use boats; half of all trips to the reef are made in paddle boats and the other half in motorised boats. Trips to the soft-benthos (seagrass) habitats mostly use motorised boats.

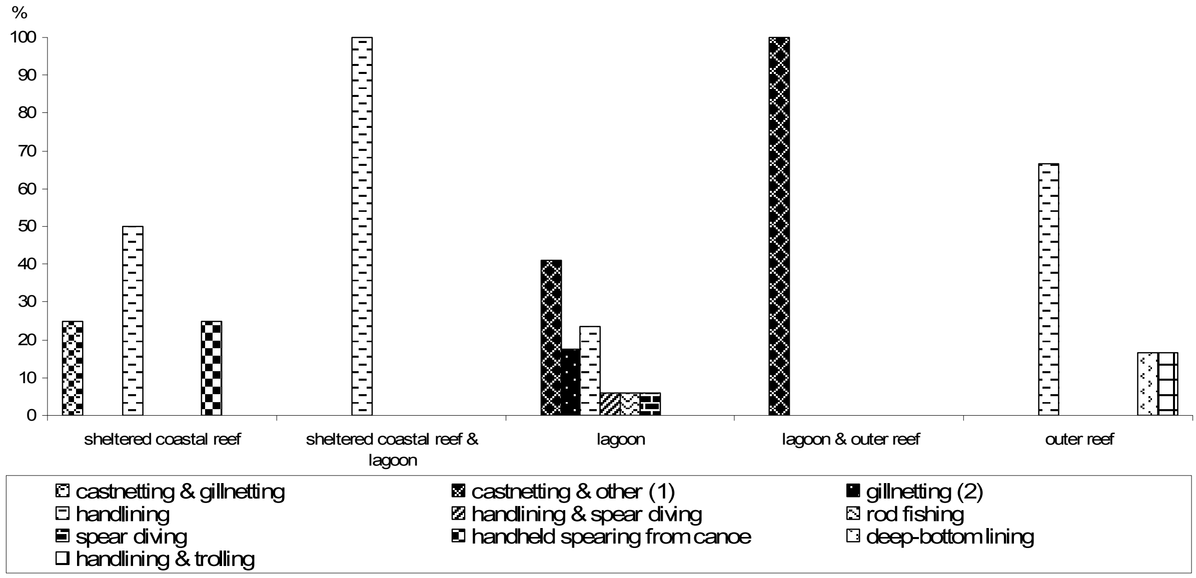

Figure 4.8: Fishing methods commonly used in different habitat types in Airai.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip. 'Other (1)' refers to spear diving, rod fishing, gillnetting, handheld spearing and handlining; (2) may include use of handheld spearing at times.

Frequency and duration of fishing trips

As shown in Table 4.3 the frequency of fishing trips does not differ much between lagoon and outer-reef fishers, who go out 1.6–2 times/week. Female fishers seem to go much less often to the outer reef (<1 time/week). In general, the sheltered coastal reef is the least often visited habitat (0.6–0.8 trips/week). However, the average trip duration increases from fishing at the sheltered coastal reef (~3 hours), to the lagoon (~4.5 hours) and the outer reef (6 hours). These times apply to both male and female fishers.

Concerning invertebrate collection, all habitats seem to be visited once a week on average by male fishers and slightly less often by females. Trip duration increases on average from 1 hour/trip targeting the reeftop to ~2 hours/trip if collecting on soft benthos (seagrass), and 4 hours/trip in the mangroves.

Finfish fishing is usually done during the day or depending on tides, i.e. either day or night. In some cases, particularly spear diving in the lagoon and at the outer reef, night diving becomes important too. Fishing continues throughout the year.

Invertebrate collection is exclusively performed during the day if reeftops and soft benthos (seagrass) are targeted. In the case of mangroves there is a strong preference for daytime fishing, perhaps due to the occurrence of crocodiles. Only a few fishers also venture out either at day or at night, depending on the tides. Invertebrate harvesting, like finfish fishing, is done throughout the year.

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

Resource	Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	0.85 (±0.15)	0.62 (±0.38)	3.25 (±0.75)	3.25 (±1.25)
	Sheltered coastal reef & lagoon	2.00 (n/a)	0	8.00 (n/a)	0
	Lagoon	2.22 (±0.40)	2.08 (±0.66)	4.32 (±0.51)	4.75 (±0.57)
	Lagoon & outer reef	2.00 (n/a)	0	5.50 (n/a)	0
	Outer reef	1.62 (±0.56)	0.73 (±0.27)	6.00 (±0.82)	6.00 (±0.00)
Invertebrates	Reeftop	1.08 (±0.08)	0.91 (±0.55)	1.00 (±0.00)	2.40 (±0.51)
	Soft benthos (seagrass)	1.17 (±0.29)	0.76 (±0.25)	2.13 (±1.30)	3.36 (±0.75)
	Mangrove	1.00 (±0.00)	0	4.00 (±2.00)	0

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 17; females: n = 8. Invertebrate fisher interviews, males: n = 5; females: n = 9.

4.2.3 Catch composition and volume – finfish: Airai

Catches from the lagoon, the main habitat targeted, include the greatest variety of fish species and species groups, with Lethrinidae (*Lethrinus* spp., *L. olivaceus*, *L. lentjan*, *L. xanthochilus*) determining >33%, and Siganidae (*Siganus lineatus*, *S. canaliculatus*, *S. fuscescens*,
S. punctatus) accounting for another 21%. In addition, major proportions of the reported catch are of Lutjanidae (*Lutjanus gibbus*) and Mugilidae (*Valamugil seheli*, *Liza vaigiensis*), each family contributing 10% of the total reported catch. Outer-reef catches are reported to mainly include Lutjanidae (30%), Lethrinidae (29%), Serranidae (19%) and Carangidae (10%). If the lagoon and the outer reef are jointly targeted in one fishing trip, species of the families of Siganidae (*Siganus canaliculatus*, *S. fuscescens*, *S. lineatus*) and Acanthuridae (*Acanthurus xanthopterus*) become more important, determining 32% and 20% respectively of the total reported catch, in addition to Lutjanidae (24%), Lethrinidae (16%) and Serranidae (8%). Reported catches from the sheltered coastal reef are less diverse and seem to include mostly Siganidae (38%) Scaridae (20%) and smaller Carangidae (*C. sexfasciatus*, *Selar crumenophthalmus*) (11%) rather than Mullidae, Lethrinidae, Serranidae and Lutjanidae, as reported for catches from the other habitats. (Detailed data are provided in Appendix 2.3.1.).

Our survey sample of finfish fishers interviewed represents <5% of the projected total number of finfish fishers in Airai. Due to the limited sample size and the selection criteria, representation of the entire community cannot be assumed. Hence we have not extrapolated our results but have used our recorded data to estimate the total annual fishing pressure imposed by the people of Airai on their fishing ground. The reliability of the extrapolated figures is discussed.

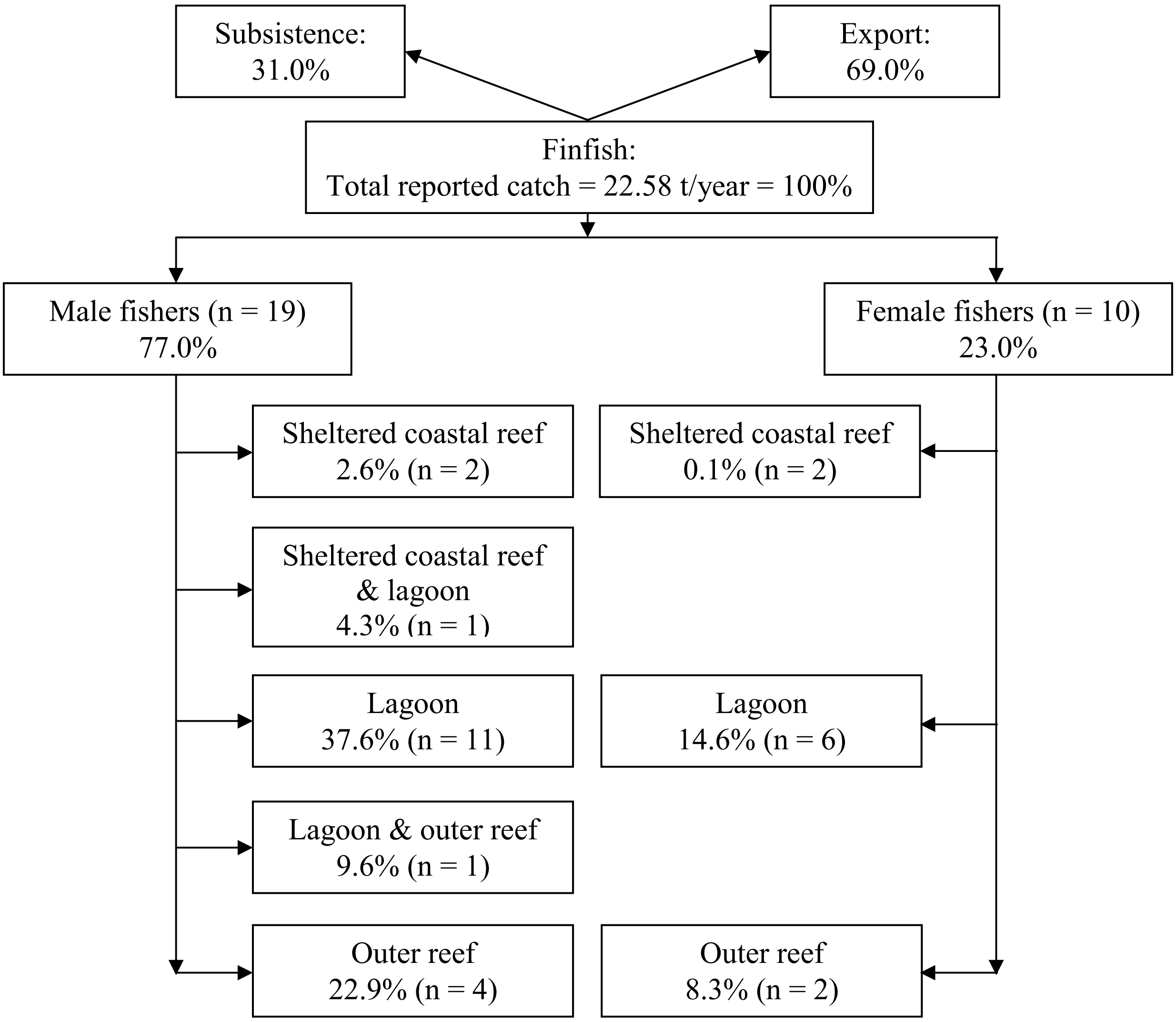

Figure 4.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Airai.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

If we extrapolate the data from respondents to the calculated total number of finfish fishers in Airai, the estimated total impact amounts to 447.8 t/year (Figure 4.9). The distribution of impact is comparable to the above figure, i.e. with highest pressure on the lagoon habitat, less on the outer reef, and least on the sheltered coastal reef. However, this figure is an overestimation of the total annual production, and presumably to a great extent. The fact that mainly households that are very active in small-scale commercial fisheries were selected, and those that were known to include very active fishers, both subsistence and commercial fishers, stipulates this higher fisheries production figure. It can be assumed that, although there may still be quite a high proportion of households in Airai that sometimes engage in mainly subsistence fishing, most families that are not represented here may derive their income from other activities, mainly salaries. These are the households that will depend on the active fishers to provide fish that they can buy on the local market.

Focusing on the relative impact only, Figure 4.9 shows that the major impact (69%) is due to commercial reef fishing, i.e. catches that are sold at any of the Airai or Koror markets.

Subsistence need only determines about 31% of all reported catches. Most of the catch is taken by male fishers; females play a much lesser role (~23%). Highest pressure is imposed on the lagoon area, with much less impact on the outer reef (~31%) and least impact on the sheltered coastal reef (2.7%).

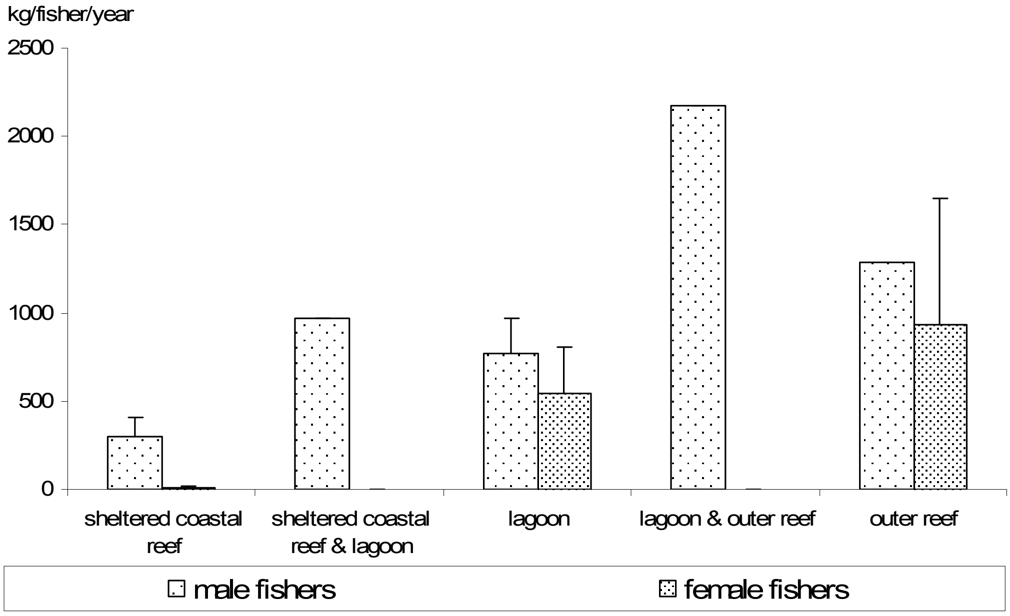

Figure 4.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Airai.
Bars represent standard error (+SE)

The high impact on lagoon resources is more a function of the high number of fishers targeting this area rather than an outstanding average annual catch rate. As shown in Figure 4.10, average annual catches of lagoon fishers are about 500 kg/female fisher/year and 750 kg/male fisher/year. However, fishers targeting the outer reef are much more productive with an average catch rate of 950 kg/female fisher/year and 1250 kg/male fisher/year. The lowest average annual catch is associated with fishing the sheltered coastal reef; male fishers may catch almost 300 kg/year while female fishers' catch is almost negligible. Based on these results it is concluded that sheltered coastal reef fishing mainly serves subsistence needs, while lagoon and outer-reef fishing is for both subsistence and sale.

The above trend is confirmed if comparing the CPUE calculated for the different habitats fished (Figure 4.11). The highest efficiency is achieved by both female and male finfish fishers at the outer reef, with 3.5–>4 kg/hour fished. CPUEs achieved by male fishers in the lagoon are similar to CPUEs at the sheltered coastal reef, i.e. ~ 2.5 kg/hour fished. Females are slightly less efficient with ~2 kg/hour fished in the lagoon and <0.5 kg/hour fished at the sheltered coastal reef.

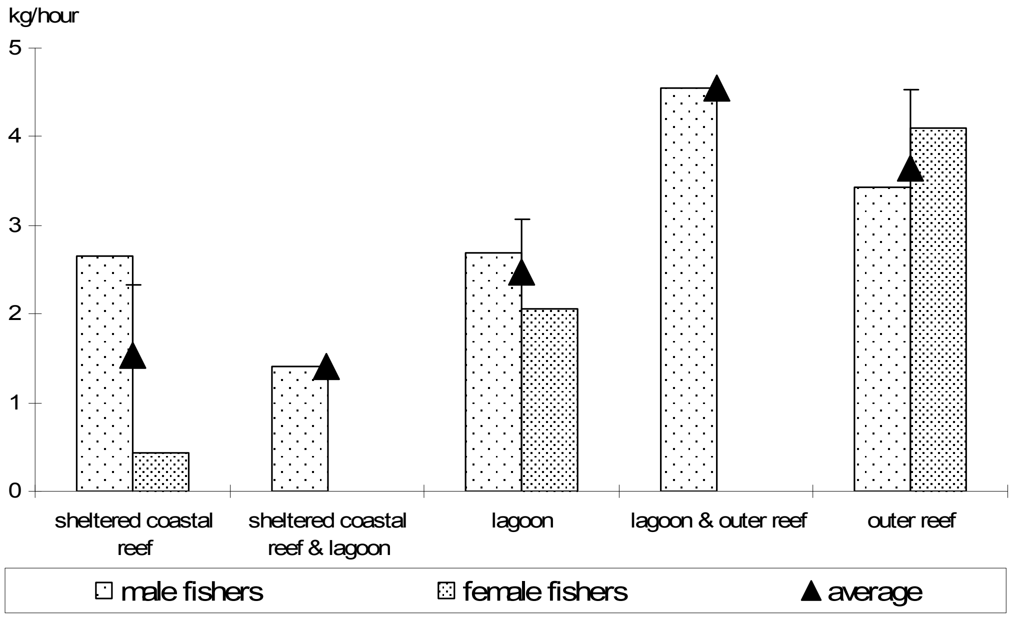

Figure 4.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Airai.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Figure 4.12 confirms the above interpretation that fishing at the sheltered coastal reef serves subsistence needs only. The share of catch intended for sale is substantial if fishers target the outer reef and the lagoon.

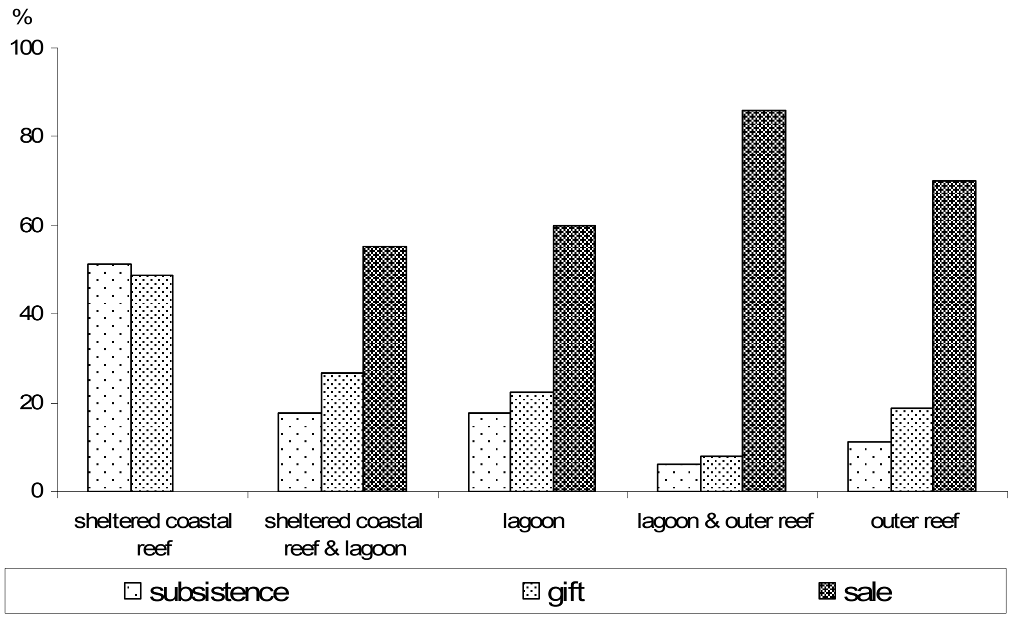

Figure 4.12: The use of finish catches for subsistence, gift and sale, by habitat in Airai.
Proportions are expressed in % of the total number of trips per habitat.

Data on the average reported finfish sizes by family and habitat (Figure 4.13) show great variation among families and habitats. Average fish sizes with no SE were not taken into account as they are represented by too small a sample size to be conclusive. Generally, the average fish sizes reported for catches from the outer reef are ~35 cm, Siganidae being an exception with ~25 cm of average length. Average fish sizes reported for the sheltered coastal reef are smaller (20–25 cm), except for Scaridae (30 cm). Average fish sizes in lagoon catches are mainly 20–25 cm, similar to fish size in the sheltered coastal reef. In general, average fish size increases from the sheltered coastal to the outer reef. Siganidae differ slightly from this pattern, showing a very uniform fish size across catches from all habitats. Similarly, Serranidae do not seem to differ much in average size between the sheltered coastal and the outer reef.

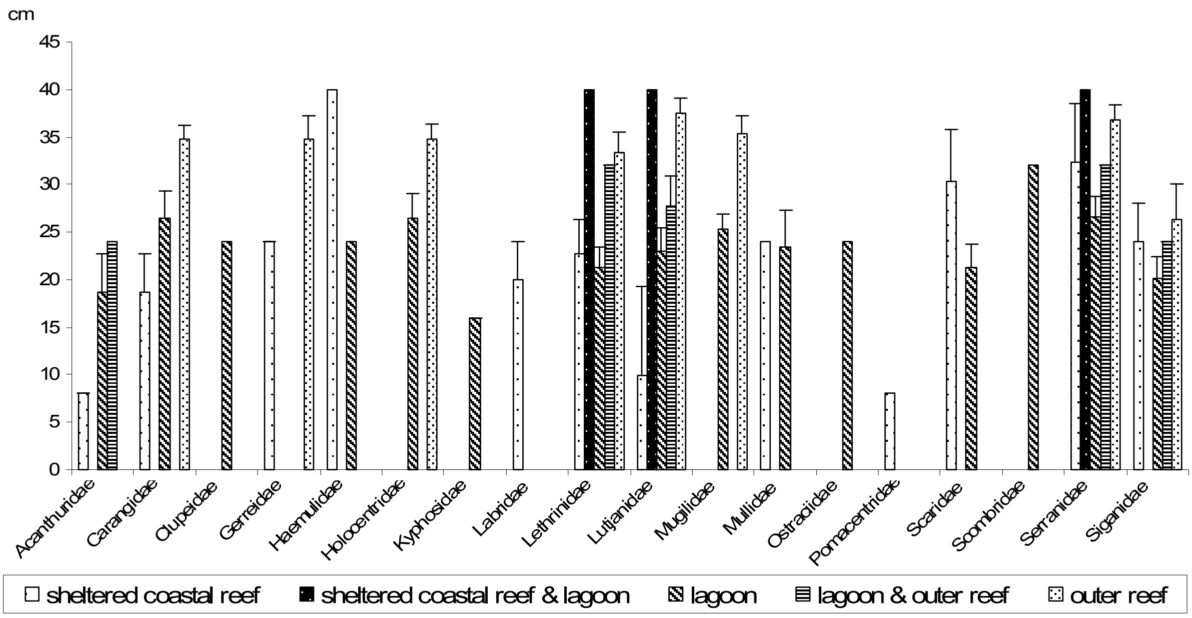

Figure 4.13: Average sizes (cm fork length) of fish caught by family and habitat in Airai.
Bars represent standard error (+SE).

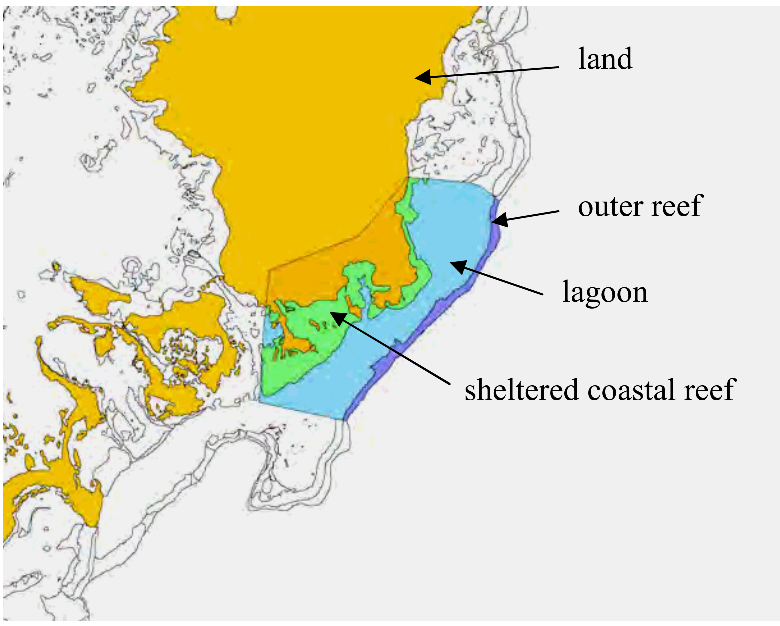

Figure 4.14: Fishing ground and habitat classification of Airai.

The parameters selected to assess the current fishing pressure on Airai's living reef resources are shown in Table 4.4. The comparison of habitat surfaces that are considered to represent the Airai fishing ground shows that the lagoon area is by far the largest, followed by the sheltered coastal reef; in comparison the available outer-reef surface is rather small. The two protected areas that fall within the Airai fishing ground are not considered here as they are open for subsistence fisheries. Comparison between the available surface area per habitat and the combination of average annual catch per fisher and fisher density reveals that the highest fisher pressure occurs at the outer reef where productivity is also highest. Lowest fisher density at the sheltered costal reef is associated with lowest annual catch rates and the moderate annual catch rates at the lagoon. The fact that the majority of all fishers target this habitat is balanced by the large surface area of the lagoon. As a result fisher density is rather low with 6 fishers/km². Taking into account that the outer reef is not the major target for Airai fishers, the figures presented in Table 4.4 are not alarming and do not raise concern about potential degradation of the resource. However, there are two factors that need to be considered and that are not included in the current analysis. Firstly, the local population reported a growing concern that sedimentation in their lagoon system is causing the mangrove areas to increase. This particularly affects the lagoon areas that receive estuarine sediment, which smothers corals and stimulates algae growth. Secondly, Airai is close to Koror and thus the Airai community's fishing grounds are subject to substantial impact by external fishers. The quantity and quality of this external fishing impact is difficult to assess, and there is no monitoring or reporting on the numbers of boats, fishers or catch.

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

Parameters	Habitat						
	Sheltered coastal reef	Sheltered coastal reef & lagoon	Lagoon	Lagoon & outer reef	Outer reef	Total reef area	Total fishing ground
Fishing ground area (km^2)	22.22	n/a	55.91	n/a	8.24	41.45	86.37
Total number of fishers	73	21	326	21	116	557	557
Density of fishers (number of fishers/km^2 fishing ground) (1)	3		6		14	13	7
Population density (people/km^2) (2)						56	27
Average annual finfish catch (kg/fisher/year) (3)	153.55 (±93.71)	972.80 (n/a)	693.20 (±152.52)	2171.43 (n/a)	1172.72 (±300.06)		
Total fishing pressure of subsistence catches (t/km^2)						3.02	1.45

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; (1) total number of fishers (= 557) is extrapolated from household surveys; (2) total population = 2333; total subsistence demand = 125.1 t/year; (3) catch figures are based on recorded data from survey respondents only.

4.2.4 Catch composition and volume – invertebrates: Airai

Calculations of the recorded annual catch rates per species groups are shown in Figure 4.15. The graph shows that the major impact by wet weight is mainly due to giant clams (*Tridacna* spp. and *Hippopus hippopus*) and to various bêche-de-mer species, including *Stichopus* spp., *Actinopyga* spp., *Holothuria scabra* and *H.* spp. Sea urchins (*Tripneustes gratilla*), which are also a preferred species, account for >1 t of respondents' total annual catches. The share of total annual catches reported for the other five species groups, including crabs (*Scylla serrata*), lobsters (*Panulirus* spp.), mangrove clams (*Anondonita edulenta*), and gastropods (*Cassis cornuta*) is small or insignificant (Detailed data are provided in Appendices 2.3.2 and 2.3.3.).

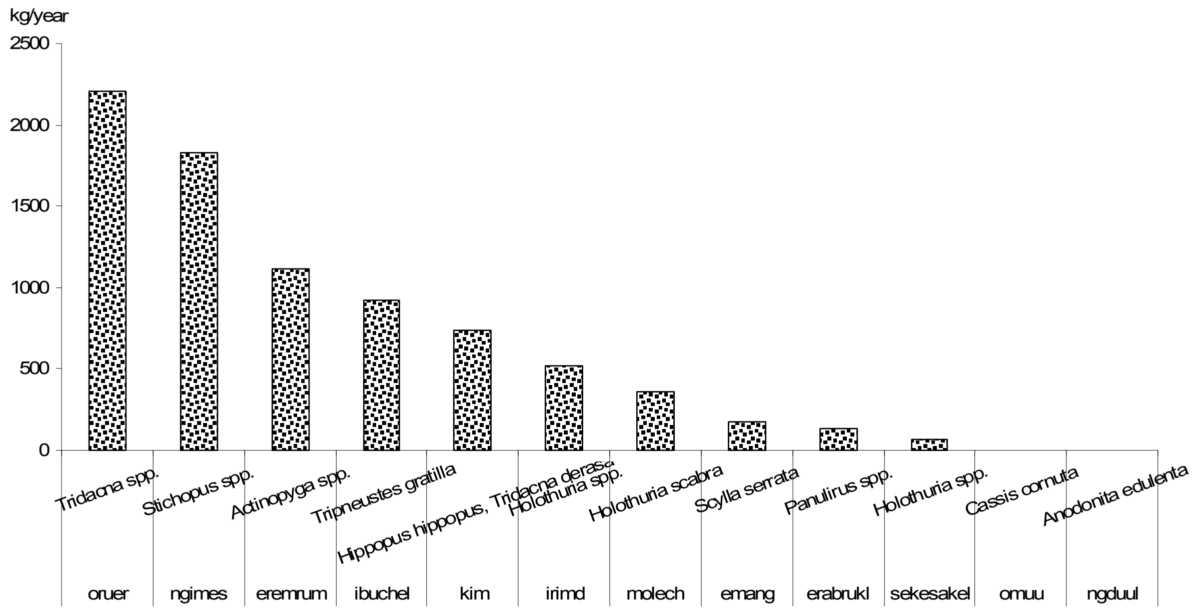

Figure 4.15: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Airai.

Overall, the diversity of vernacular names reported for any of the habitats targeted is low. Soft benthos (seagrass) is the main habitat where people from Airai collect bêche-de-mer and sea urchins that they eat or sell elsewhere. Thus, it is not surprising that the highest number of vernacular names occurs here. While there is a total of six vernacular names reported for reeftop gleaning, only one species (*ngduul*) was identified by vernacular name for mangrove catches (Figure 4.16).

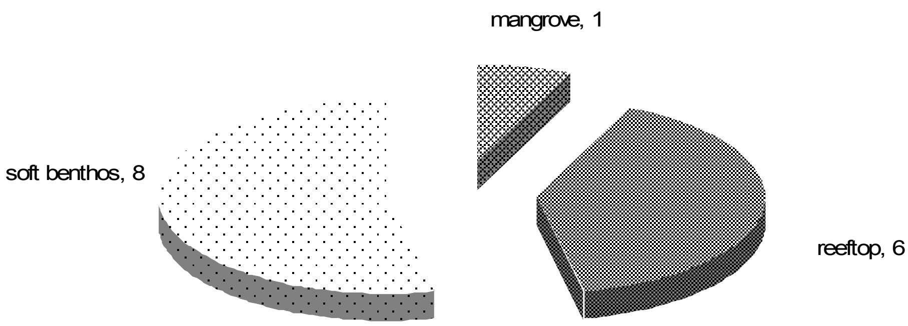

Figure 4.16: Number of vernacular names recorded for each invertebrate fishery in Airai.

Figure 4.17 shows again that the highest catch (~500 kg/fisher/year) by wet weight comes from soft benthos (seagrass), the main habitat for bêche-de-mer and sea urchins, which are the major target species for subsistence and local sale. The reeftop fishery yields 300–400 kg/fisher/year, while mangrove gleaning produces <50 kg/fisher/year. Catch rates from mangrove areas are insignificant. Figure 4.17 also shows that catch rates do not significantly differ between male and female invertebrate fishers, except that male fishers who glean the reeftop may be slightly more productive than females.

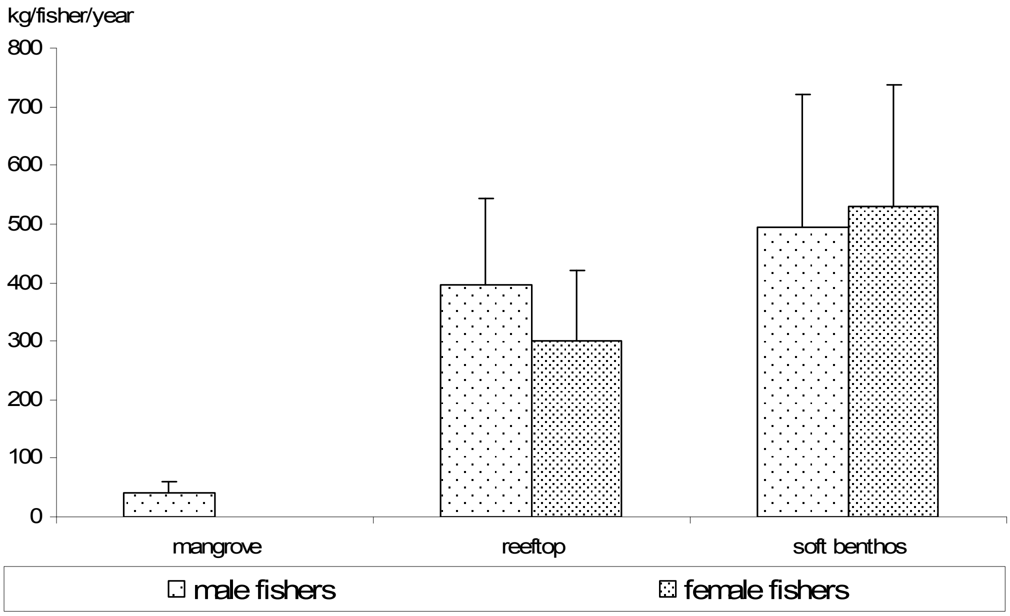

Figure 4.17: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Airai.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 5 for males, n = 9 for females). Bars represent standard error (+SE).

As demonstrated in Figure 4.18, most invertebrate fishing serves subsistence purposes. The share of the invertebrate catch sold is negligible, and may not exceed 13% of the total annual reported catch if we assume that exactly half of the 2041 kg/year in the category 'consumption & sale' is sold and half is eaten.

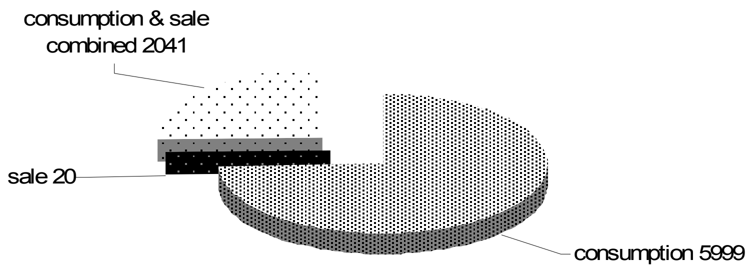

Figure 4.18: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Airai.

The total annual catch volume (expressed in wet weight based on recorded data from all respondents interviewed) amounts to 8.06 t/year (Figure 4.19). As reported earlier, the main catches are from the soft benthos (seagrass) and, to a lesser extent, reeftop, representing ~70% and ~28% of the total annual catch respectively. Catches from mangrove collection determine only 1%. Female fishers account for ~65% of the total annual reported catches: ~46% from soft benthos (seagrass), and ~19% from reeftops.

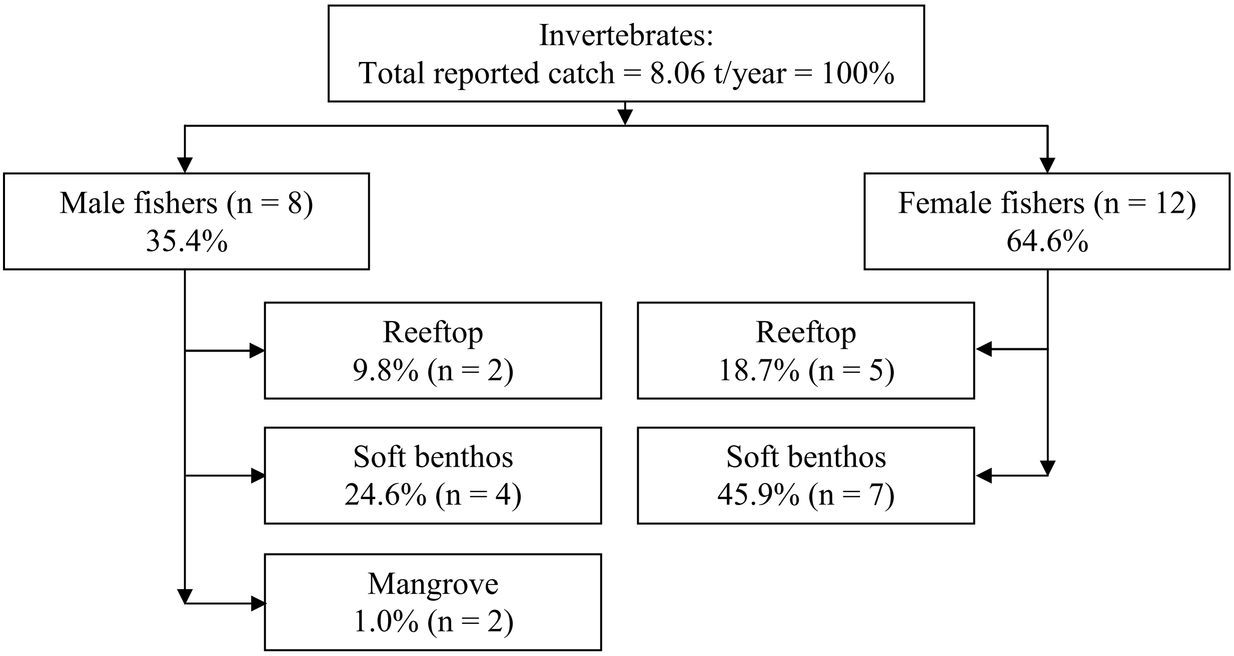

Figure 4.19: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Airai.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

Although only the reeftop area is known, none of the total numbers of fishers listed in Table 4.5 suggest a high current fishing pressure on any of the invertebrate fishery habitats in Airai. Reeftop fisher density is rather low with ~11 fishers/km^2 of reeftop area available. Comparison of average annual catches shows significant differences, with lowest catch rates for mangrove harvesting, and highest for soft-benthos gleaning. Overall, none of the figures suggest a currently detectable fishing pressure that may be detrimental to the resource.

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

Parameters	Fishery / Habitat		
	Mangrove	Reeftop	Soft benthos
Fishing ground area (km^2)	n/a	14.06	n/a
Number of fishers (per fishery) [(1)]	49	155	246
Density of fishers (number of fishers/km^2 fishing ground)		11	
Average annual invertebrate catch (kg/fisher/year) [(2)]	40.53 (±20.27)	328.61 (±89.13)	516.26 (±148.49)

Figures in brackets denote standard error; n/a = no information available; [(1)] number of fishers extrapolated from household surveys; [(2)] catch figures are based on recorded data from survey respondents only.

4.2.5 Discussion and conclusions: socioeconomics in Airai

- Fisheries are not an important sector for income generation in Airai. Only 30% of all households reported fisheries as an income source; half of these as their first, and the other half as their second income source. In contrast, salaries are of highest importance, complemented by other sources, such as retirement and social fees.

- All households consume fresh fish and more than half also consume invertebrates regularly. The per capita consumption of fresh fish is above the regional average and similar to the average consumption of all CoFish sites in Palau. The invertebrate per capita consumption is low and reaches about 5 kg/person/year only.

- The average household expenditure level is not of particular note other than to mention that people in Airai enjoy a more urbanised lifestyle than in most other sites in Palau. Accordingly, people in Airai spend more money than the average found across all sites investigated in Palau. Remittances do not play an important role.

- Most finfish fishing is performed by males, particularly if it is done exclusively. Females are more engaged in collecting invertebrates, and only females collect invertebrates exclusively. However, ~20% of all male and female fishers fish for both finfish and invertebrates. Finfish fishers mainly target the lagoon and much less the outer reef; only a few fish the sheltered coastal reef. Most of the catch from the lagoon and outer reef is sold, presumably mainly to Koror. Invertebrate fishers focus on collecting bêche-de-mer and sea urchins from soft benthos (seagrass), and giant clams, crabs and lobsters from the reeftop. Mangrove fishing targets one major clam species only. Most of the invertebrate fisheries in Airai serve subsistence purposes.

- Various techniques are used for fishing finfish: handlining is the main method used in the sheltered coastal reef and outer reef; castnetting combined with other techniques in the lagoon. Other techniques include gillnetting, spear diving and rod fishing. Most fishing is done with motorised boat transport, and more motorised boats are used in the outer reef than the sheltered coastal reef.

- Highest fishing pressure occurs on the outer reef. This is due to the high fisher density rather than the total number of fishers targeting this habitat. In general, the fishing pressure that results from the subsistence needs of the Airai community only is low, and ranges from 1.5 t/km^2/year of the total fishing ground to ~3 t/km^2/year of the reef surface only. CPUEs for sheltered coastal reef and lagoon fishing do not vary substantially but are much lower than those reported for outer-reef fishing. There is a general trend for the average reported fish size of almost all fish families to increase from landward habitats towards the outer reef. Siganidae may be the only family for which average fish size did not much differ among habitats. This observation suggests that the resource status is in no alarming condition, as fish size increases, following the expected trend. It also suggests that the fishing pressure at the outer reef has not reached any detrimental level despite the relatively high fisher density (14 fishers/km^2).

- Invertebrate fisheries mainly serve the subsistence needs of the Airai community. Highest fishing pressure is observed for the soft benthos (seagrass) and, to a lesser extent, for the reeftop fisheries. Bêche-de-mer species, giant clams and perhaps sea urchins, which are subject to seasonal harvesting, determine most of the total annual reported catch by wet weight.

The above observations lead to two major conclusions. Firstly, current pressure on finfish resources in Airai is moderate if fisher density and population density of the total fishing ground or the total reef area are taken into account. The subsistence catch (1.5 per total fishing ground or ~3 t/km^2/year per total reef area) also suggests fishing pressure is moderate. CPUEs and average finfish sizes for almost all families were reported to increase from the sheltered coastal reef to the outer reef as expected. Secondly, considering invertebrate fisheries, fisher densities seem to be moderate. However, if we consider that most of the annual catch is accounted for by very few species, mainly selected bêche-de-mer and giant clam species, present fishing pressure on these particular resources may be high and may need monitoring. The fact that neither finfish nor invertebrate fisheries represent the most important income source for the community could make it easier to implement fisheries management regulations that either temporarily or periodically limit locations, species and/or fishing techniques, in order to preserve reef and lagoon resources. Nevertheless, fishing still plays an integral component of the Airai people's life. Therefore, future fisheries management strategies must take into account the high interest in and the value of subsistence and leisure fisheries. Therefore, if restrictions are needed, measures must be identified in close cooperation with the community to ensure that these are acceptable and likely to be complied with. This process, however, may be more difficult in Airai than any of the other more rural villages visited, due to the size and the degree of urbanisation of the Airai community.

4.3 Finfish resource surveys: Airai

Finfish resources and associated habitats were assessed between 27 and 30 April 2007, from a total of 24 transects (5 coastal-reef, 7 intermediate-reef, 6 back-reef and 6 outer-reef transects; see Figure 4.20 for transect locations and Appendix 3.3.1 for coordinates).

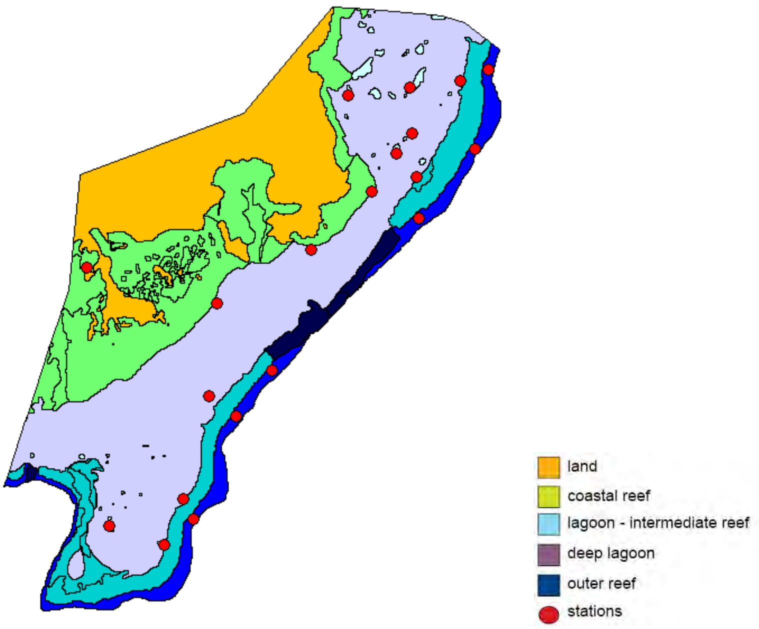

Figure 4.20: Habitat types and transect locations for finfish assessment in Airai.

4.3.1 Finfish assessment results: Airai

A total of 25 families, 69 genera, 219 species and 9730 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 52 genera, 187 species and 8063 individuals.

Finfish resources differed slightly among the four reef environments found in Airai (Table 4.6). The coastal reefs and back-reefs displayed the highest values of biomass but density was the lowest at back-reefs (0.3 fish/m²), while all other habitats shared the same value (0.4 fish/m²). Size ratio was highest at coastal reefs (62%), while average size was highest at back-reefs (19 cm FL). Biodiversity displayed the maximum value at outer reefs (60 species/transect), where the lowest absolute biomass was, however, recorded (47 g/m^2), smallest also among the outer reefs of all four sites.

Table 4.6: Primary finfish habitat and resource parameters recorded in Airai (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	7	6	6	24
Total habitat area (km^2)	22.2	0.8	11.0	6.2	40.2
Depth (m)	3 (1–10) (3)	7 (0–7) (3)	7 (1–14) (3)	10 (2–14) (3)	5 (0–17) (3)
Soft bottom (% cover)	1 ±1	28 ±6	27 ±12	7 ±3	10
Rubble & boulders (% cover)	19 ±13	41 ±8	27 ±8	13 ±4	21
Hard bottom (% cover)	50 ±15	17 ±7	25 ±10	33 ±6	40
Live coral (% cover)	24 ±5	10 ±2	16 ±3	40 ±4	24
Soft coral (% cover)	2 ±1	2 ±1	2 ±1	5 ±0	2
Biodiversity (species/transect)	30 ±4	43 ±2	48 ±9	60 ±3	51±2
Density (fish/m^2)	0.4 ±0.1	0.4 ±0.1	0.3 ±0.1	0.4 ±0.0	0.4
Biomass (g/m^2)	72.8 ±26.4	65.0 ±24.9	70.5 ±35.6	47.1 ±9.4	68.0
Size (cm FL) (4)	18 ±1	17 ±1	19 ±1	15 ±1	18
Size ratio (%)	62 ±3	57 ±3	55 ±3	56 ±2	59

(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.

Coastal-reef environment: Airai

The coastal-reef environment of Airai was strongly dominated by one herbivorous family: Acanthuridae (Figure 4.21). This family was represented by only seven species; particularly high biomass and abundance were recorded for *Acanthurus lineatus*, *Ctenochaetus striatus* and *A. nigricans* (Table 4.7). This reef environment presented a large surface covered by hard bottom (50%), relatively good cover of live coral (24%) and no soft bottom (Table 4.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus lineatus*	Lined surgeonfish	0.10 ±0.04	34.0 ±13.9
	Ctenochaetus striatus	Striated surgeonfish	0.14 ±0.06	23.5 ±10.5
	Acanthurus nigricans	Whitecheek surgeonfish	0.04 ±0.02	3.7 ±1.7

The density, size ratio and biomass of finfish in the coastal reefs of Airai were the highest among the four habitats. In contrast, biodiversity was the smallest (30 species/transect). When compared to the other two country sites with coastal reefs, Airai displayed the smallest values of all parameters except size ratio (60%), which was the largest among all the coastal reefs. Herbivores heavily dominated the trophic structure, due to the extremely high abundance of *A. lineatus* and *C. striatus*. Carnivores were present in small numbers and contributed little to the biomass composition of the fish community. Size ratio was particularly low for Lethrinidae (30%), Lutjanidae (47%), Siganidae (44%) and Kyphosidae (39%), suggesting an impact from fishing. In accordance with this observation, Siganidae was found to be the most frequently caught fish family. Substrate was dominated by hard bottom and live coral, with a large cover of rubble, while soft bottom was practically absent. Families usually associated with soft bottom (Mullidae and Lethrinidae) were therefore almost nonexistent, while surgeonfish, associated with hard bottom, were dominant.

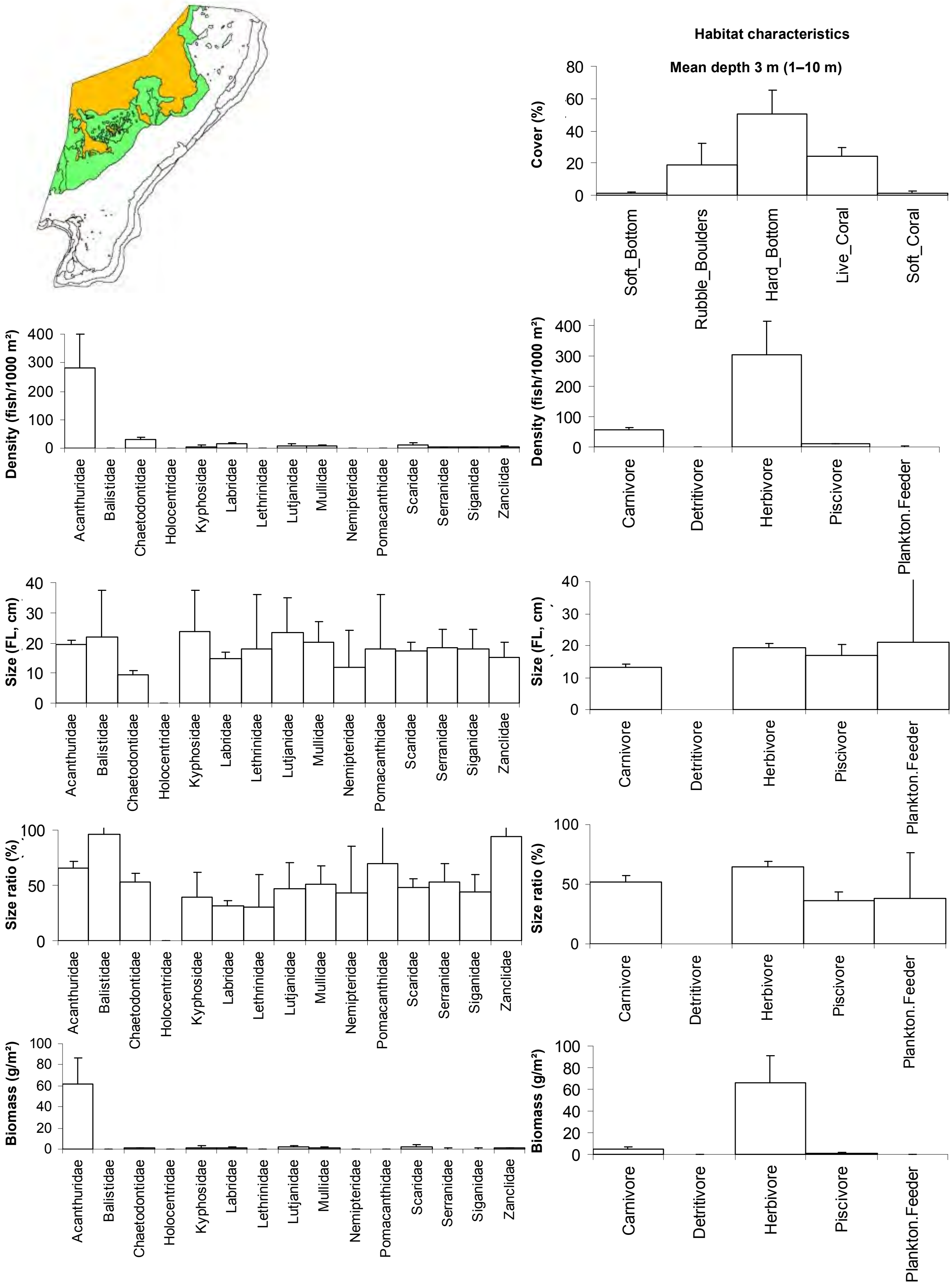

Figure 4.21: Profile of finfish resources in the coastal-reef environment of Airai.
Bars represent standard error (+SE); FL = fork length.

Intermediate-reef environment: Airai

The intermediate-reef environment of Airai was dominated in terms of density by two herbivorous families: Acanthuridae and Scaridae and, in terms of biomass only, by two carnivorous families: Lethrinidae and Lutjanidae (Figure 4.22). These four major families were represented by 36 species; particularly high biomass and/or abundance were recorded for *Ctenochaetus striatus*, *Monotaxis grandoculis*, *Macolor macularis*, *Acanthurus lineatus*, *Chlorurus sordidus*, *Naso brevirostris* and *Lutjanus bohar* (Table 4.8). This reef environment presented a substrate composition dominated by rubble (41%) and soft bottom (28%), with a low cover of live coral (10%) and hard bottom (17%) (Table 4.6 and Figure 4.22).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.130 ±0.062	18.0 ±9.7
	Acanthurus lineatus	Lined surgeonfish	0.008 ±0.008	2.9 ±2.9
	Naso brevirostris	Spotted unicornfish	0.003 ±0.003	2.7 ±2.7
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.034 ±0.016	2.9 ±1.1
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.008 ±0.008	10.3 ±10.2
Lutjanidae	*Macolor macularis*	Black snapper	0.004 ±0.003	4.4 ±4.3
	Lutjanus bohar	Twinspot snapper	0.002 ±0.002	2.4 ±2.4

The density of finfish in the intermediate reef of Airai was similar to densities in the coastal and outer reefs (0.4 fish/m^2). Size ratio (57%) was lower only than the high value recorded on the coastal reef, while size and biomass were higher only than the low outer-reef values, and biodiversity was intermediate between the back-reef value (43 species/transect) and the highest outer-reef value (60 species/transect). Density and biomass values were lower only than the ones recorded at Koror intermediate reefs, the richest site of the four. Only biodiversity was extremely low, higher only than the value at Ngatpang (41 species/transect). Trophic composition was dominated by herbivores, mostly Acanthuridae and Scaridae; carnivores were essentially represented by Lethrinidae and Lutjanidae. These appeared to be among the most-fished families, representing respectively 33% and 10% of total catches. Mullidae, Scaridae and Serranidae displayed low size ratios, indicating a possible impact from fishing. This habitat displayed the highest fishing pressure, being the most frequently visited by fishers, with the highest annual catches compared to the outer and coastal reefs. Substrate was mostly composed of mobile bottom (69% rubble and sand) with very little hard bottom or live coral. This is a type of environment preferred, for example, by Mullidae and Lethrinidae, which were found in good numbers.

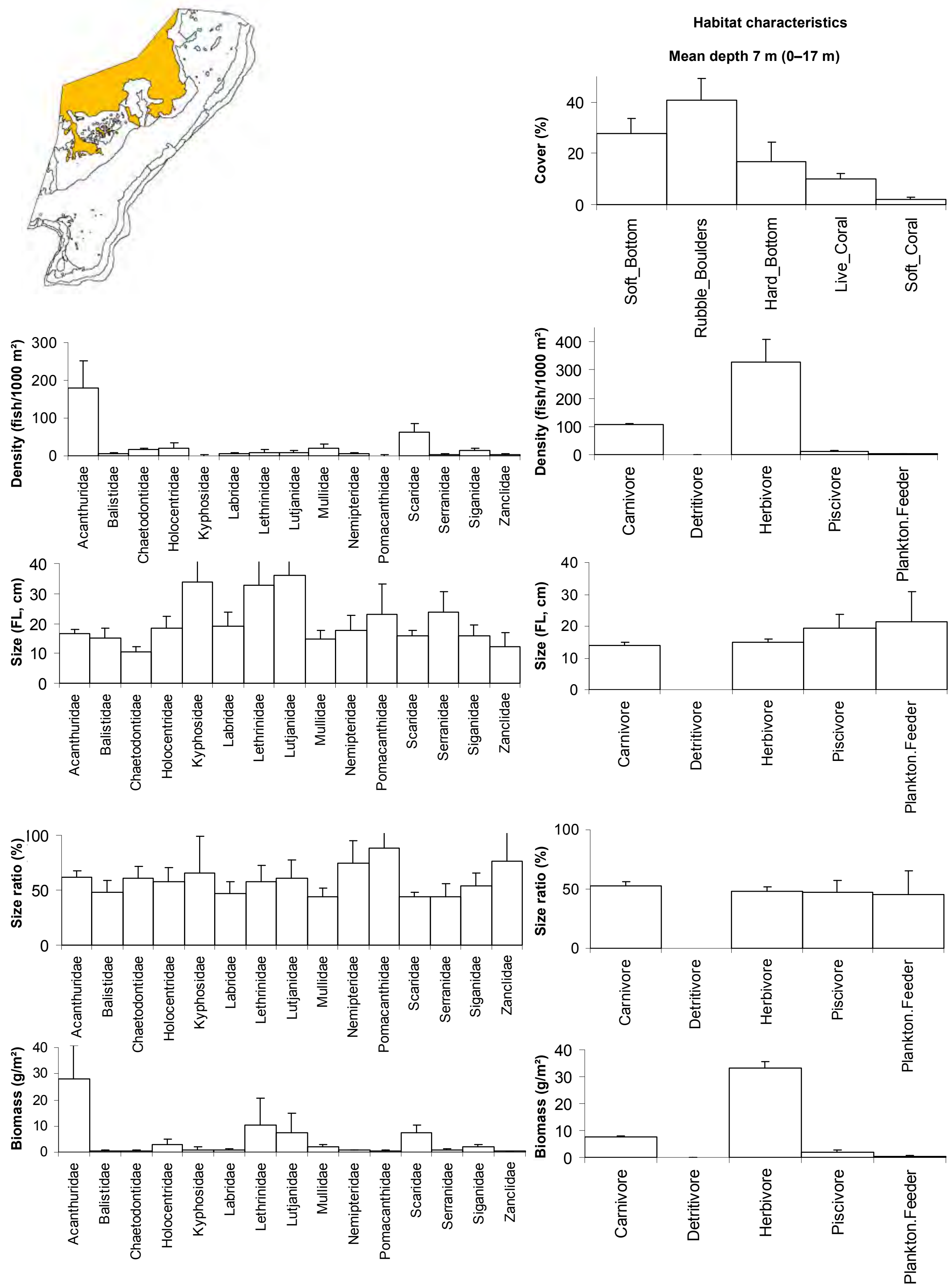

Figure 4.22: Profile of finfish resources in the intermediate-reef environment of Airai.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Airai

The back-reef environment of Airai was dominated by two herbivorous families: Acanthuridae and Scaridae and, to a lesser extent and only for biomass, by three carnivorous families: Lethrinidae, Lutjanidae and Mullidae (Figure 4.23). These five major families were represented by 56 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Naso unicornis*, *Monotaxis grandoculis*, *Parupeneus barberinus*, *Chlorurus sordidus*, *Acanthurus nigricauda*, *Lethrinus xanthochilus* and *Lutjanus gibbus* (Table 4.9). The substrate in this reef environment was composed of equal proportions of soft bottom (27%), rubble (27%) and hard bottom (25%), with little live-coral cover (16%) (Table 4.6 and Figure 4.23).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.071 ±0.026	8.6 ±3.7
	Naso unicornis	Bluespine unicornfish	0.009 ±0.008	7.0 ±6.4
	Acanthurus nigricauda	Epaulette surgeonfish	0.005 ±0.003	2.6 ±1.8
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.016 ±0.012	7.0 ±5.3
	Lethrinus xanthochilus	Yellowlip emperor	0.003 ±0.003	2.2 ±2.2
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.003 ±0.003	1.9 ±1.9
Mullidae	*Parupeneus barberinus*	Dash-and-dot goatfish	0.008 ±0.003	3.7 ±2.2

The density of finfish in the back-reef of Airai (0.3 fish/m^2) was the lowest at the site. Size was however the largest (19 cm FL) and therefore biomass was similar to the top value recorded at the coastal reefs (70 g/m^2). Biodiversity was lower only than in the outer reef. When comparing these results to parameters recorded on the other four back-reefs in the country, Airai back-reefs showed highest size and size ratio, second-highest biomass (surpassed only by the biomass in Koror) and biodiversity, and the lowest value only of density. Size ratio was slightly lower than 50% only for Lethrinidae, probably indicating a first impact from fishing. Trophic composition was dominated by herbivores, especially in terms of density, while the difference between the biomass of carnivores and that of herbivores was much smaller. Carnivores were essentially represented by Lethrinidae and Mullidae, with the large cover of soft bottom presenting the preferred habitat of these fish families. The abundance of certain species of Acanthuridae, such as *A. nigricauda*, was also related to the high coverage of soft-bottom.

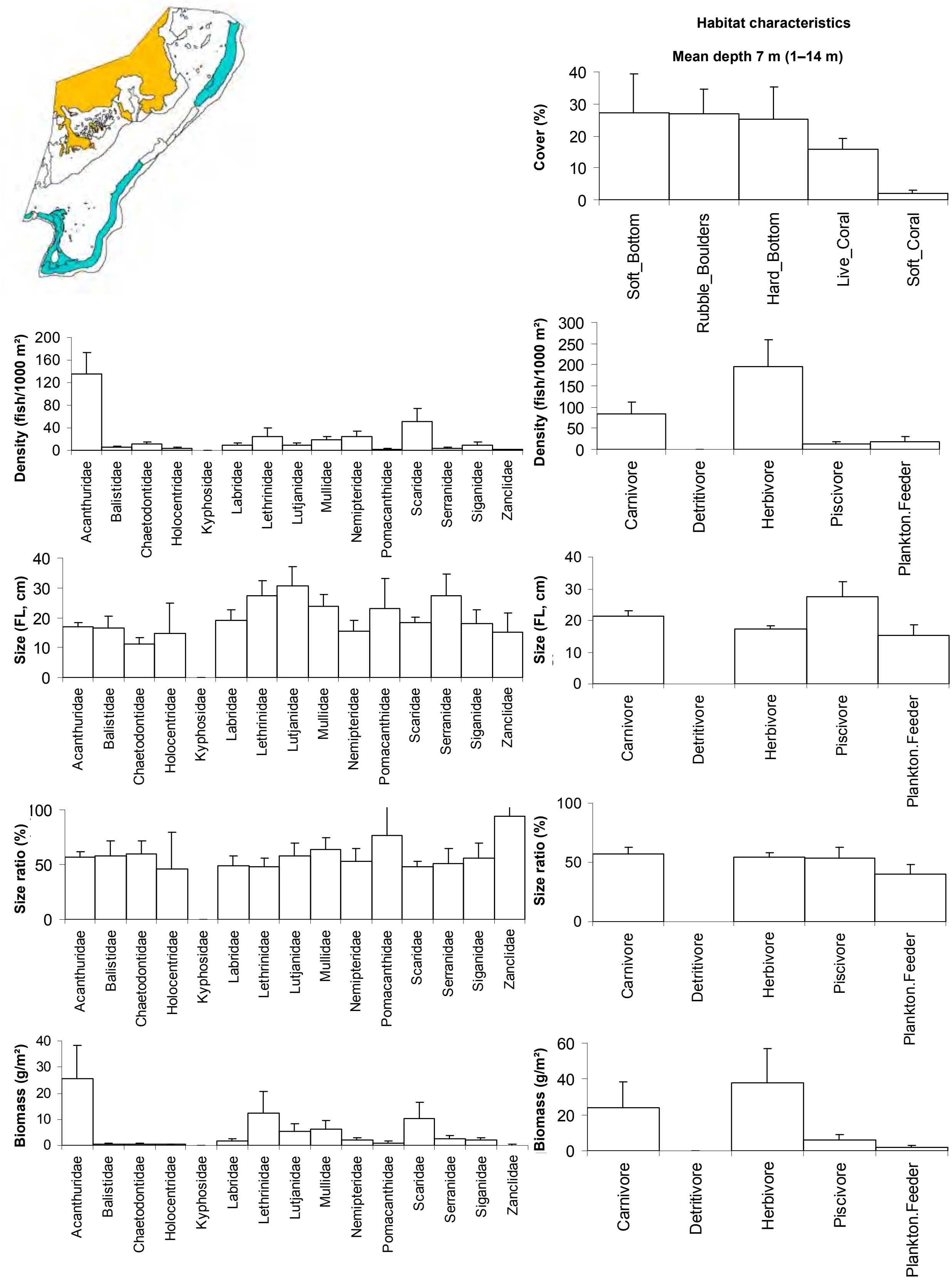

Figure 4.23: Profile of finfish resources in the back-reef environment of Airai.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Airai

The outer-reef environment of Airai was dominated by two herbivorous families: Acanthuridae and Scaridae (Figure 4.24). These two major families were represented by 29 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Acanthurus nigricans*, *Naso lituratus* and *N. unicornis* (Table 4.10). This reef environment presented a substrate composition dominated by live coral cover (40%), with also a high proportion of hard bottom (33%), but low cover of soft bottom (7%, Table 4.6 and Figure 4.24).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.180 ±0.024	23.0 ±5.2
	Acanthurus nigricans	Whitecheek surgeonfish	0.025 ±0.018	1.6 ±1.4
	Naso lituratus	Orangespine unicornfish	0.005 ±0.002	1.4 ±0.5
	Naso unicornis	Bluespine unicornfish	0.001 ±0.001	1.0 ±1.0
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.036 ±0.006	3.5 ±1.2

The density of finfish in the outer reef of Airai was similar to densities in the coastal and intermediate reefs. Size and biomass were the lowest, and size ratio the second-lowest at this site; however, biodiversity was the highest at the site (60 species/transect), as is often the case for outer reefs. When comparing these values to values recorded in the other three outer reefs in the country, Airai showed the smallest density, size and biomass, and only the third-ranked value of biodiversity, higher only than in Ngarchelong. Scaridae and Mullidae displayed very low size ratios, indicating a probable impact from fishing. This habitat did in fact show a high fishing pressure, with the second-highest yearly catches after lagoon fishing values. Trophic composition was dominated by herbivores. Carnivores were essentially represented by Lethrinidae and Mullidae, with the large percentage of soft bottom presenting their preferred habitat.

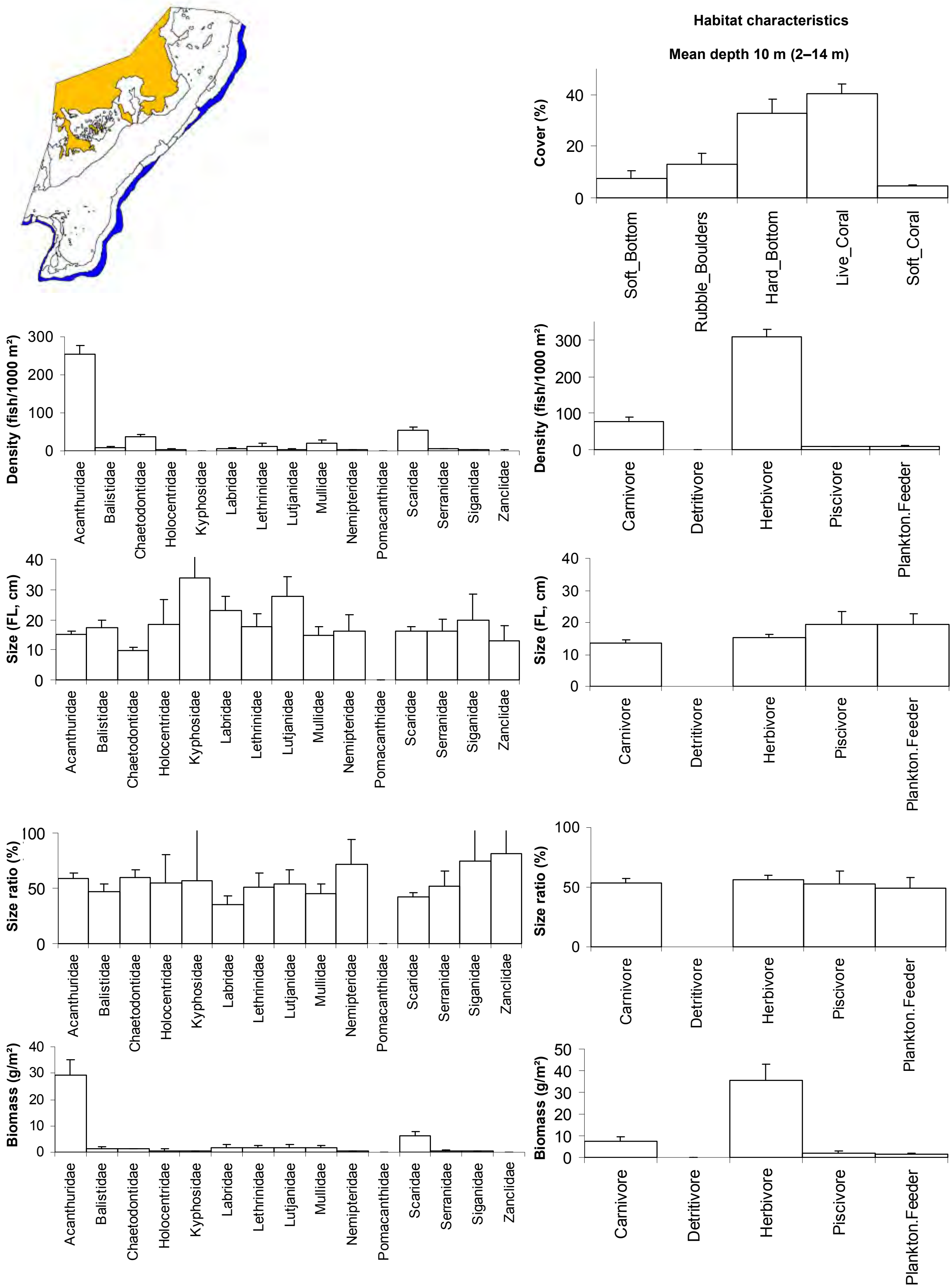

Figure 4.24: Profile of finfish resources in the outer-reef environment of Airai.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Airai

Overall, the fish assemblage of Airai was dominated by herbivorous Acanthuridae and Scaridae. Chaetodontidae, present with 19 species, displayed high abundance only (Figure 4.25). The three major families were represented by a total of 47 species; particularly high biomass and density were recorded for *Ctenochaetus striatus*, *Acanthurus lineatus*, *A. nigricans*, *Naso unicornis* and *Chlorurus sordidus* (Table 4.11). The average substrate was dominated by hard bottom (40%), and composed of a smaller amount of soft bottom and rubble (31%) and a relatively good cover of live coral (24%). The overall fish assemblage in Airai shared characteristics of primarily coastal reefs (55% of total habitat), then back-reefs (27%), outer reef (15%) and, only to a very small extent, intermediate reefs (2%) (Figure 4.25 and Table 4.6).

Table 4.11: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Airai (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	Lined surgeonfish	0.06	18.9
	Acanthurus nigricans	Whitecheek surgeonfish	0.02	2.3
	Naso unicornis	Bluespine unicornfish	0.00	2.1
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.02	1.5

Overall, Airai appeared to support an average to poor finfish resource with the lowest density and biodiversity of fish among the four country sites, second-poorest biomass, but highest average size and size ratios. A detailed assessment at the family level revealed a clear dominance of herbivores over carnivores. Carnivores were mainly represented by Lethrinidae, Lutjanidae and Mullidae. The relative lack of carnivores could be partially explained by the composition of the habitat, which was mainly coastal reef, characterised by a large cover of hard and a limited cover of soft substrate. Lethrinidae, Kyphosidae and, to a lesser extent, Scaridae displayed small size ratio (below 45% of their maximum sizes), probably suggesting an impact from fishing. High biodiversity but small density and biomass suggest that the site is naturally rich but already impacted.

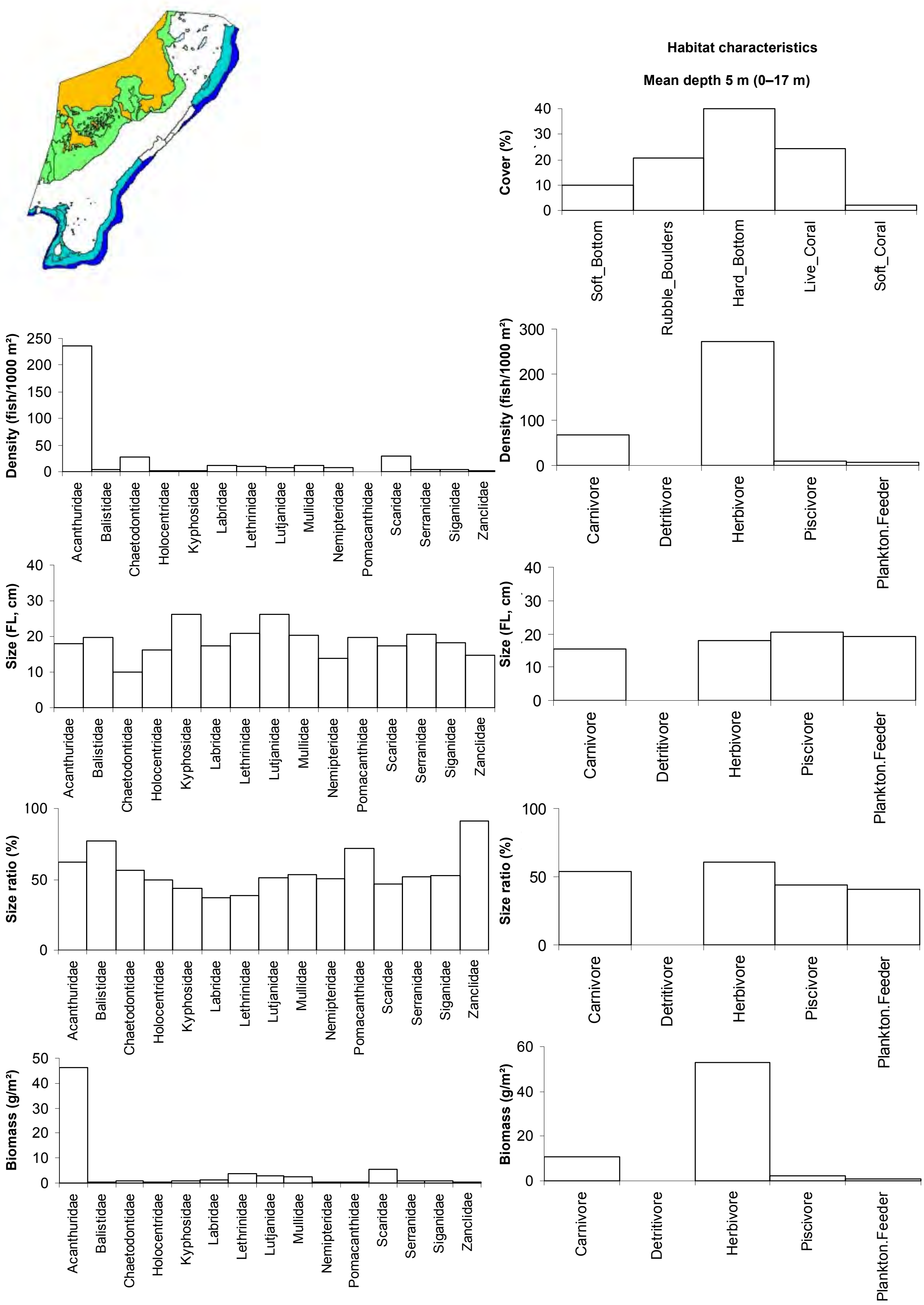

Figure 4.25: Profile of finfish resources in the combined reef habitats of Airai (weighted average).
FL = fork length.

4.3.2 Discussion and conclusions: finfish resources in Airai

The assessment indicated that the status of finfish resources in this site was rather meagre. The habitat was pretty poor and fish resources scarce, displaying parameters lower than at the other three country sites.

- Corals were rare and not healthy, especially the lagoon and back-reef, but were better on the outer reefs. Often the substrate, especially in the coastal habitat, was composed of coral slab covered in coralline algae and turf. At the intermediate habitats, the coral was rare and covered in macroalgae (*Sargassum*, *Padina*, *Halimeda*) and seagrasses.

- Fish biodiversity, abundance and biomass were lower than at the other sites, and sizes were generally small.

- The finfish community was everywhere dominated by herbivores, especially Acanthuridae and Scaridae, which could be partially explained by the type of environment, mainly composed by hard bottom. However, fishing might be a part of the cause of the poverty of the fish community. Carnivores (mainly Lethrinidae and Lutjanidae) were rare and apex predators even rarer.

- Average sizes were rather small and large-sized fish were almost absent. Larger Scaridae species were recorded only rarely; most Scaridae were small-sized species, such as *Chlorurus sordidus*. Similarly, Acanthuridae were mainly represented by the small-sized *Ctenochaetus striatus*. Size ratios of carnivores were low.

- Fish were rather wary and distant from divers, which suggests spear diving may be over-practised.

When analysed at the reef habitat level, resources displayed some disparities, although the habitat was less variable than at other sites.

- Coastal reefs were the healthiest of all the four habitats. However, when compared to other sites, fish density and biomass were intermediate-to-low. Herbivores heavily dominated the trophic structure; *Acanthurus lineatus* and *Ctenochaetus striatus* were especially abundant. This might be due to the particularly high cover of hard rock and live coral, which supports herbivores rather than most carnivore species. However, it might also be a response to fishing. Coastal reefs were the least fished of the habitats in Airai; however, some families displayed a very small size ratio: Lethrinidae (30%), Lutjanidae (47%), Siganidae (44%) and Kyphosidae (39%), suggesting an impact from fishing. The most frequently caught fish family was in fact Siganidae.

- Lagoon resources, highly exploited in terms of fisheries and mainly for sale, showed signs of impact as small size ratios, particularly for Mullidae, Scaridae and Serranidae. Biomass and density were of intermediate-to-low value.

- Back-reefs were in similar condition to coastal reefs, however, with higher biodiversity. Lethrinidae appeared to be impacted from fishing, since their sizes were lower than expected. Their presence in this environment is advantaged by the high percentage of soft bottom.

- Outer reefs appeared to be the poorest and the most impacted of the four habitats, with lowest biomass and sizes, both at the site and at the country level. Scaridae and Mullidae displayed very low size ratios, indicating a probable impact from fishing. This habitat had a high fishing pressure, with the second-highest annual catch after the lagoon.

- Fishing was mostly done by handlining, castnetting and gillnetting, but also spear diving, even in the lagoon, the most intensely fished habitat.

These observations, along with the overall analysis of the collected data, suggest that Airai is relatively impacted.

4.4 Invertebrate resource surveys: Airai

The diversity and abundance of invertebrate species at Airai were independently determined using a range of survey techniques (Table 4.12): broad-scale assessment (using the 'manta tow'; locations shown in Figure 4.26) and finer-scale assessment of specific reef and benthic habitats (Figures 4.27 and 4.28).

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

Table 4.12: Number of stations and replicates completed at Arai

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	19	114 transects
Soft-benthos transects (SBt)	14	84 transects
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	9	54 transects
Mother-of-pearl searches (MOPs)	1	6 search periods
Reef-front searches (RFs)	9	54 search periods
Reef-front search by walking (RFs_w)	0	0 search period
Sea cucumber day searches (Ds)	4	24 search periods
Sea cucumber night searches (Ns)	0	0 search period

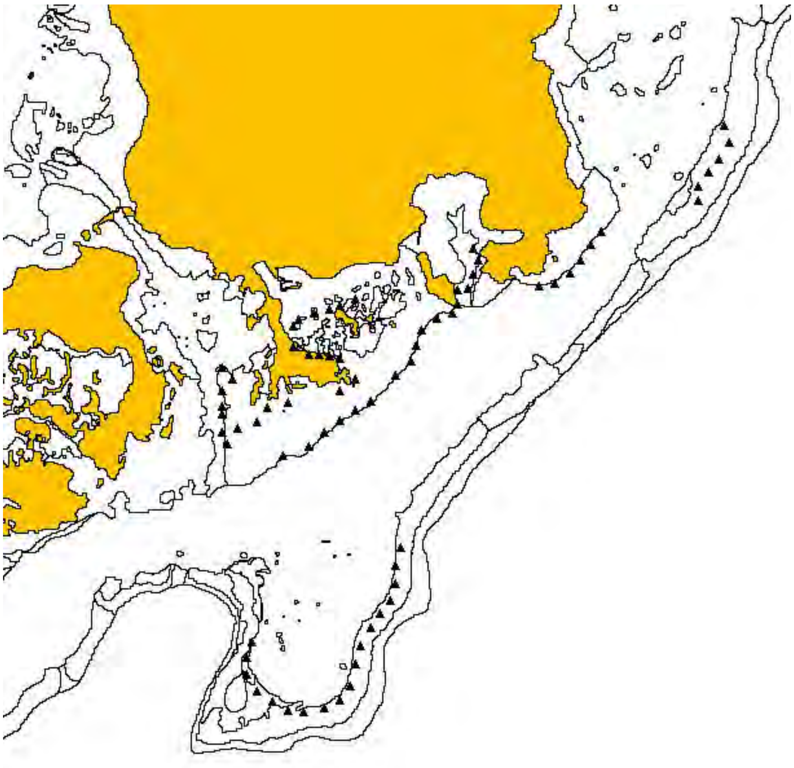

Figure 4.26: Broad-scale survey stations for invertebrates in Airai.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

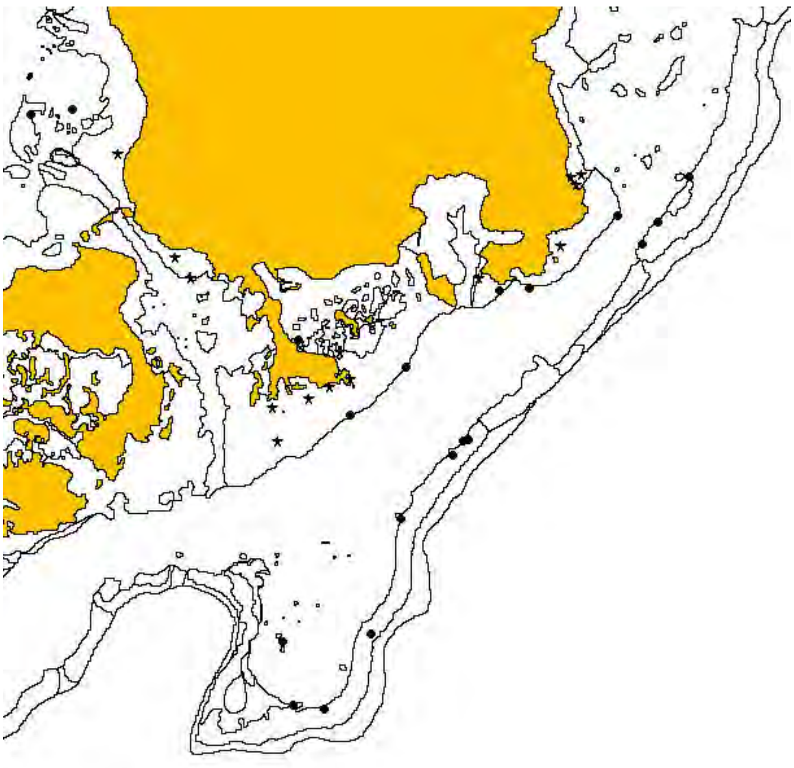

Figure 4.27: Fine-scale reef-benthos transect survey stations and soft-benthos transect survey stations in Airai.
Black circles: reef-benthos transect stations (RBt)
black stars: soft-benthos transect stations (SBt).

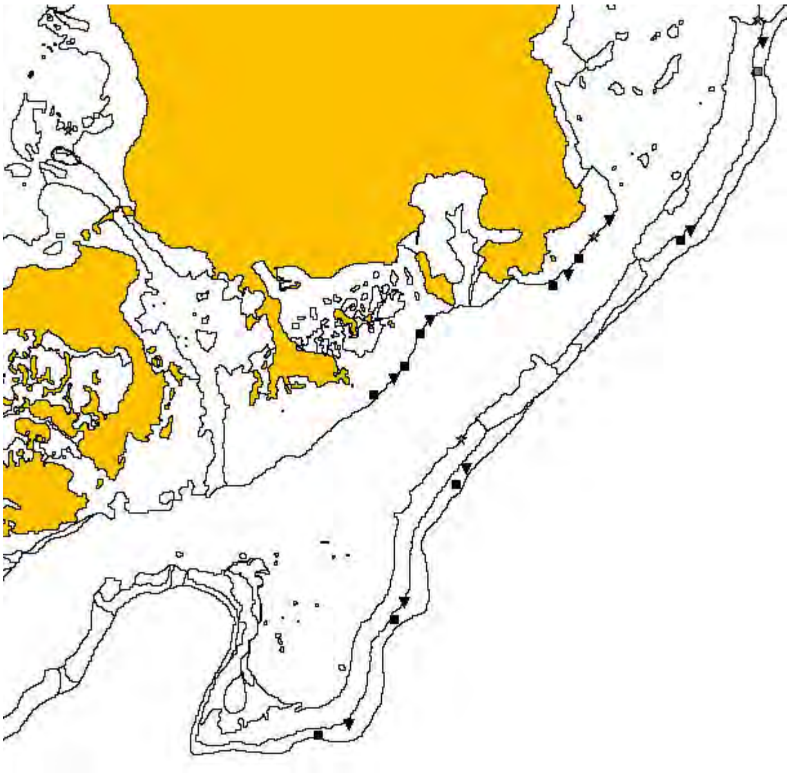

Figure 4.28: Fine-scale survey stations for invertebrates in Airai.
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey diamonds: sea cucumber day search stations (Ds).

Eighty-one species or species groupings (groups of species within a genus) were recorded in the Airai invertebrate surveys: 13 bivalves, 25 gastropods, 26 sea cucumbers, 6 urchins, 5 sea stars, 2 cnidarians and 3 lobsters (Appendix 4.3.1). Information on key families and species is detailed below.

4.4.1 Giant clams: Airai

Shallow-reef habitat that is suitable for giant clams was moderately extensive at Airai (23.3 km^2: approximately 14.1 km^2 within the lagoon and 9.2 km^2 on the reef front or slope of the barrier). The main lagoon area was extensive (in excess of 108.9 km^2), stretching east and west around the south of Babeldaob. Hard substrate was available at shoreline or coastal reef, within the lagoon and at the broad barrier reef. Although most of the lagoon was oceanic-influenced, there was a large, shallow-water embayment in front of Airai town, which was heavily depositional, affected by allochthonous (land) inputs from rivers, and generally too dirty to allow visual assessments to be completed near the coast.

Despite the high-island environment present, the land influence did not generally limit the distribution of clams, as water movement was generally very dynamic and especially strong where the easterly and westerly lagoon was linked by a passage to the south of Airai. In addition, numerous gaps in the barrier reef to the east of Airai allowed free mixing of lagoon and oceanic waters. Due to the reef structure and the full range of depths and exposure grades available, clams were not limited by habitat at this site.

Using all survey techniques, seven species of giant clam were noted. Broad-scale sampling provided a good overview of the distribution and density of these seven clam species recorded: the elongate clam *Tridacna maxima*, the boring clam *T. crocea*, the fluted clam *T. squamosa*, the smooth clam *T. derasa*, the true giant clam *T. gigas*, the horse-hoof or bear's paw clam *Hippopus hippopus*, and the china clam *H. porcellanus*. *H. porcellanus* has a limited distribution (Philippines to western Irian Jaya), and has not been recorded before in CoFish surveys of other Pacific Island countries.

Records from broad-scale sampling revealed that *T. crocea* had the widest occurrence (found in 12 stations and 56 transects), followed by *T. maxima* (10 stations and 40 transects), *T. squamosa* (6 stations and 7 transects), and *T. derasa* (2 stations and 2 transects). *H. hippopus,* which is well camouflaged and usually relatively sparsely distributed, was recorded in 8 stations (15 transects in total). This was the first time for our researchers to see *H. porcellanus* (2 stations and 2 transects), a less common species than *H. hippopus* (Figure 4.29).

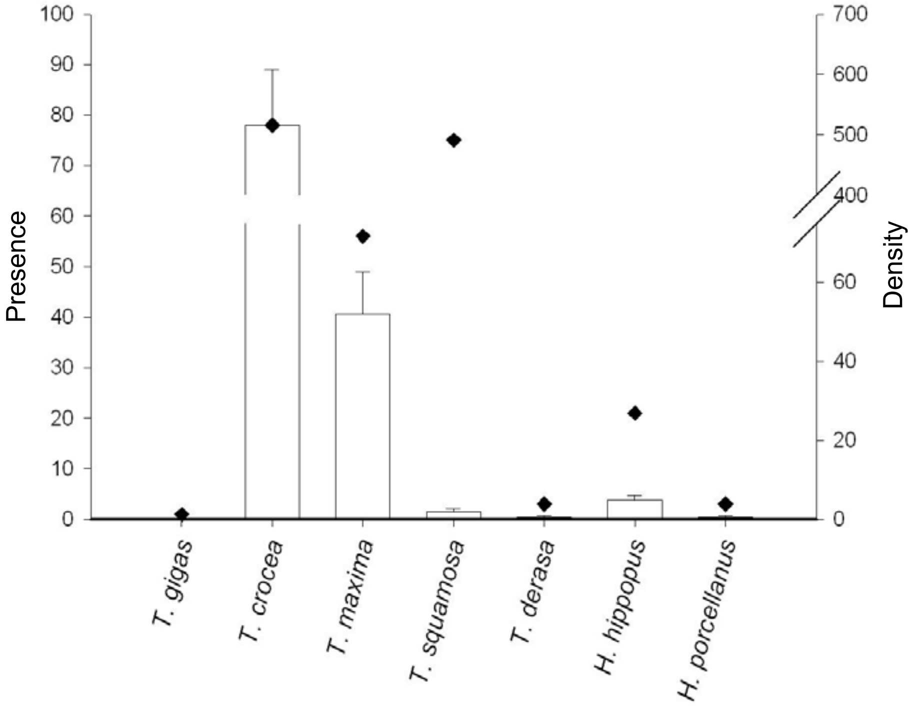

Figure 4.29: Presence and mean density of giant clam species at Airai based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 4.30). In these reef-benthos assessments (RBt) *T. crocea* was present in 89% of stations, the highest station density being 4583.3 /ha. ±1058.0. *T. maxima* was also relatively common (in 79% of stations), with moderate density. *T. squamosa* was less common than in neighbouring Koror, but still recorded in 32% of stations and at moderate density. No high-density patches of *T. squamosa* were located in survey, but densities for *H. hippopus* reached 291.7 /ha. in a station near the arm in the barrier reef southeast of Airai (Uchelbeluu). Although two *T. gigas* clams were recorded in RBt assessments, no *T. derasa* were noted (Figure 4.30).

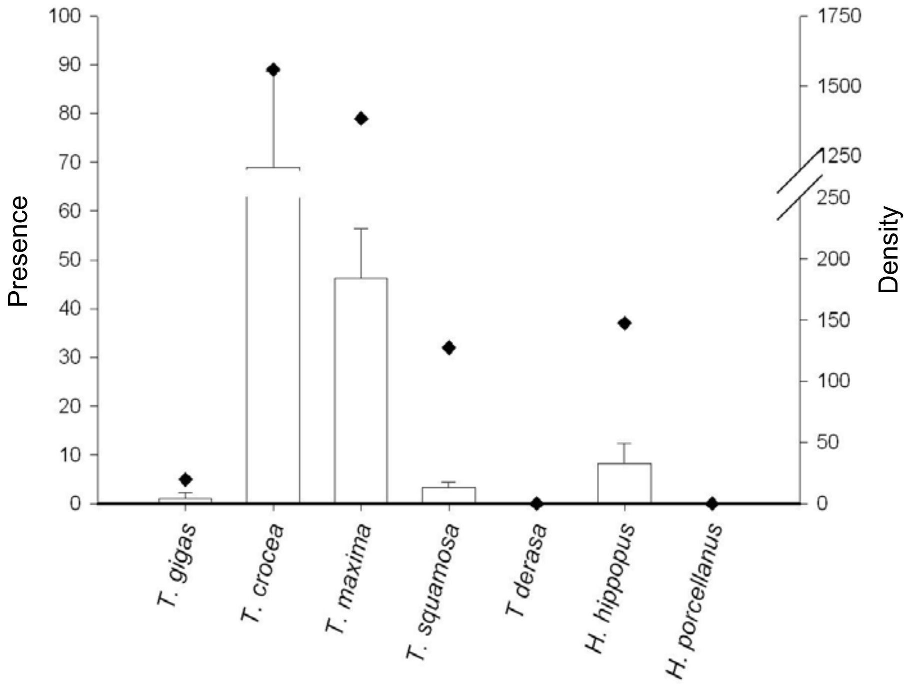

Figure 4.30: Presence and mean density of giant clam species at Arai based on all reef-benthos transect assessments.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

A full range of both small and large individuals of *T. crocea* (mean size 6.9 cm ±0.2) and *T. maxima* (mean size 15.5 cm ±0.5) was recorded in survey. *T. maxima* from reef-benthos transects alone (on shallow-water reefs) had a slightly smaller mean length (12.1 cm ±0.6, which represents a clam of ~5–6 years old).

A full range of sizes was recorded for the faster-growing *T. squamosa* (which grows to an asymptotic length L_∞ of 40 cm). This species averaged 23.8 cm shell length ±2.4 (which equates to a clam of ~5–6 years of age). *H. hippopus* (mean size 21.7 cm ±1.0) is generally well camouflaged on the benthos, but the length-frequency distribution indicates that recruitment is occurring. *H. porcellanus* (mean length 23.0 cm ±2.5), the less common *Hippopus* species, was not recorded in shallow reef-benthos transect surveys. The four *T. derasa* clams had a mean length of 44.5 cm ±7.5; the smallest clam was 29 cm (Figure 4.31). Seven *T. gigas* clams (which can reach adult lengths >1.3 m) were recorded in Airai (mean length 33.9 cm), the largest of which was >60 cm in length.

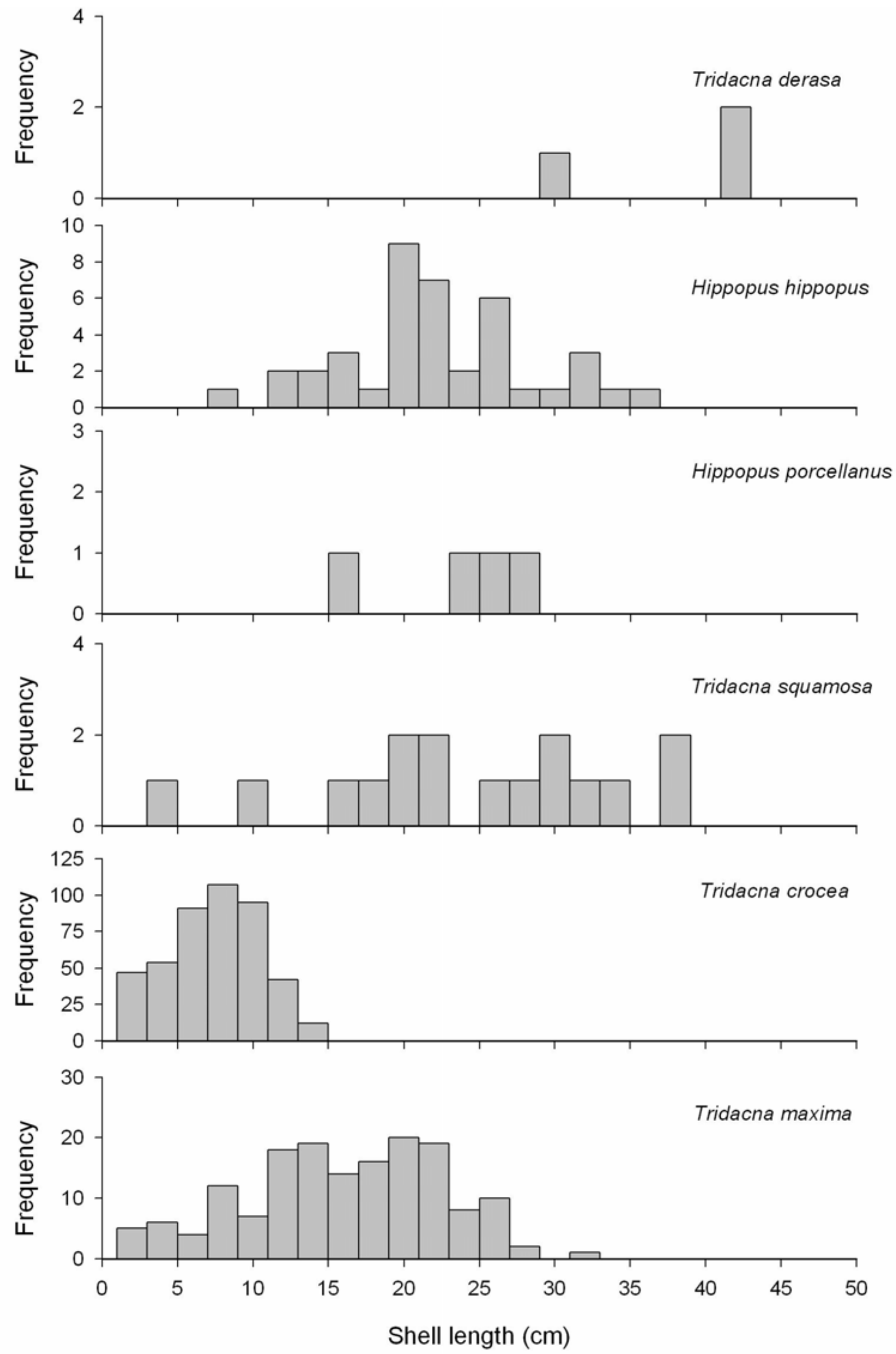

Figure 4.31: Size frequency histograms of giant clam shell length (cm) for Airai.
* One *T. derasa* clam of 65 cm shell length was also recorded.

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

Palau is within the natural distribution range of the commercial topshell *Trochus niloticus* in the Pacific. Due to the reef aspect and water-movement regime, a moderately extensive benthos for *T. niloticus* exists at Airai in the form of coastal reefs that face the swell (opposite gaps in the barrier reef) and the barrier reef (back-reef and front-reef slope). Survey work revealed (Table 4.13) that *T. niloticus* was present on reefs within the lagoon and coastal areas and on the barrier reef, which covered an area of ~18.8 km (lineal distance of exposed reef perimeter) The most significant trochus aggregations were very localised, and these important 'core' reefs held significant numbers of trochus, generally in more coastal areas. The management of the trochus fishery in Palau allows commercial fishing only once every 3–4 years, with subsequent rest periods for stock recovery.

Survey work revealed that significant areas for juvenile trochus were available at the front section of the inshore embayment, although few trochus were recorded from within the embayment itself. This coastal bank of reef in front of Airai 'feeds' the inshore reef slopes which receive influences (nutrients) from the shoreside embayment and from the ocean (from being opposite gaps in the barrier). In general, the barrier reef itself (back-reef and reef slopes at the exposed side), although suitable for trochus, was not heavily colonised; trochus on the barrier reefs and outer-reef slopes were generally only found at low density.

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

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
B-S	10.1	3.2	5/12 = 42	14/72 = 19
RBt	133.8	56.1	11/19 = 58	29/114 = 25
RFs	87.6	16.7	9/9 = 100	5/54 = 9
MOPt	608.8	160.9	9/9 =100	43/54 = 80
MOPs	2.3	n/a	1/1 = 100	4/6 = 67
Tectus pyramis				
B-S	3.5	1.1	6/12 = 25	11/72 = 6
RBt	133.8	32.7	16/19 = 84	38/114 = 33
RFs	12.2	5.1	6/9 = 67	9/54 = 17
MOPt	57.9	17.6	7/9 = 78	16/54 = 30
MOPs	22.7	n/a	1/1 = 100	2/6 = 33
Pinctada margaritifera				
B-S	1.6	0.7	4/12 = 33	6/72 = 8
RBt	6.6	3.6	3/19 = 16	3/114 = 3
RFs	0	0	0/9 = 0	0/54 = 0
MOPt	2.3	2.3	1/9 = 11	1/54 = 1
MOPs	0.0	0.0	0/1 = 0	0/6 = 0

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

A total of 578 trochus were recorded (n = 452 were measured) during the survey. This was 33% of the trochus noted in the four sites surveyed in Palau. The majority of the stock was on shallow reef (~1.5–2 m deep), which was easily accessible to fishers working with a mask and snorkel. More than half (58%) of the reef-benthos transect stations held trochus, at a density of 42–917 trochus/ha. In MOPt surveys, all stations held trochus, and the density was 187–1396 trochus/ha.

Highest-density aggregations were recorded in survey locations bordering the embayed lagoon, at the edge of the main lagoon directly in front of Airai. At these locations, 11% of reef-benthos stations and 33% of MOPt stations supported densities of trochus >500 /ha. A threshold of 500–600 trochus/ha. is suggested as the minimum density that main aggregations should reach before commercial fishing can be considered.

Shell size also gives important information on the status of stocks by highlighting new recruitment or lack of recruitment into the fishery, which could have implications for the numbers of trochus entering the capture size classes in the following two years.

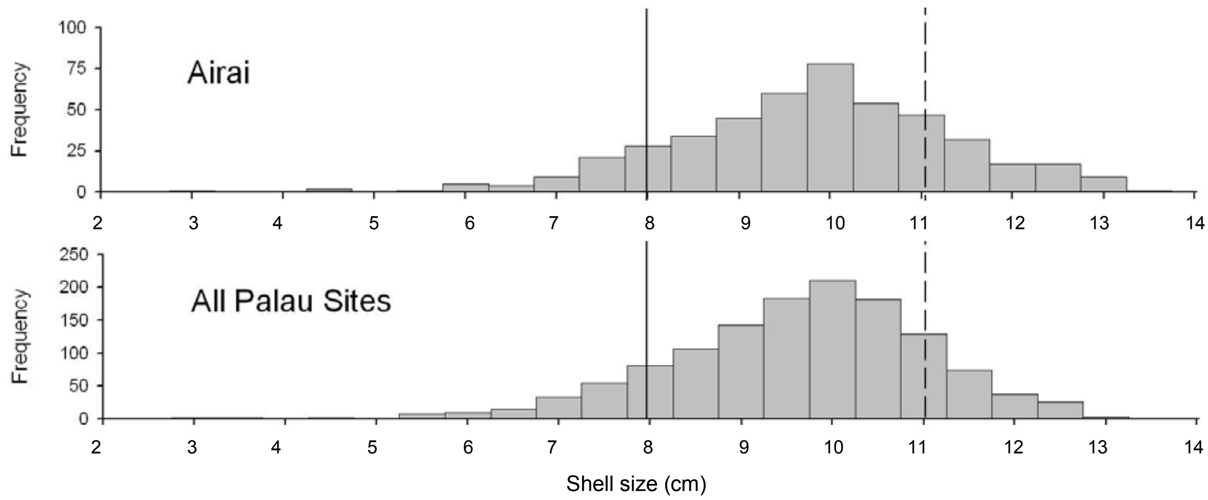

Figure 4.32: Size frequency histograms of *Trochus niloticus* shell base diameter (cm) for Airai and all Palau sites.

The mean basal width of trochus at Airai was 9.6 cm ±0.7 (Figure 4.32). A shell of 9.6 cm basal width weighs approximately 250 g. The length-frequency graph reveals that the bulk of stock at Airai is within the capture size classes (Trochus reach first maturity at 3 years of age, i.e. ~7–8 cm in shell size.). For this cryptic species, younger shells are normally only picked up in surveys from the size of ~5.5 cm, when small trochus are emerging from a cryptic style of life and joining the main stock. As can be seen from the length-frequency graph, no large recruitment pulse of young trochus was evident from records collected at Airai.

In addition, only 16% of the stock was from size classes >11 cm basal width, which is a relatively small proportion of mature shells for a population. In some other trochus fisheries, where stock has not been fished for an extended period or where there is a maximum basal width for commercial sale (shells >11 cm are protected from fishing), this portion of the stock makes up between 20–50% of the population. The result from Airai can be interpreted as an indication of the level of fishing in past harvests. Low numbers of large shells may indicate that trochus stocks were comprehensively targeted during the previous two fishing periods (in 2000 and 2005).

The level of suitability of reefs for grazing gastropods was also highlighted by results for the false trochus or green topshell (*Tectus pyramis*). This related, but less valuable species of topshell (an algal-grazing gastropod with a similar life history to trochus) was abundant at Airai (n = 529 recorded in survey). The mean size (basal width) of *T. pyramis* was 5.5 cm ±0.1 (Figure 4.33). Small *Tectus* (<5.5 cm) were recorded in survey, but again no large recruitment pulse was identified, which may suggest that conditions for recent spawning and/or settlement of these gastropods (including *T. niloticus*) may not have been especially favourable in recent years.

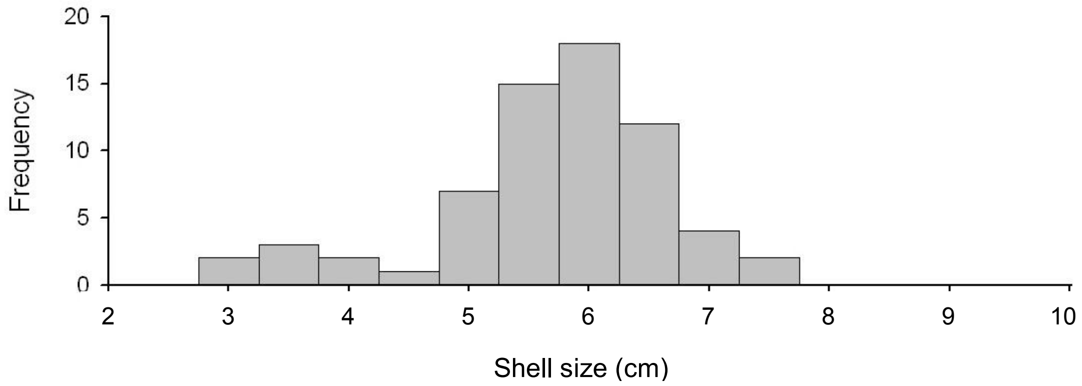

Figure 4.32: Size frequency histogram of the 'false' trochus *Tectus pyramis* shell base diameter (cm) for Airai.

Another mother-of-pearl species, the blacklip pearl oyster *Pinctada margaritifera*, is cryptic and normally sparsely distributed in open lagoon systems (such as those found at Airai). In survey, the number of blacklip seen during assessments was moderate (n = 12). The mean shell length (anterior–posterior measure) of these pearl oysters was 11.9 cm ±0.9.

4.4.3 Infaunal species and groups: Airai

Soft benthos at the coastal margins of Airai was generally suitable for seagrass, but access to these inshore areas was limited (better approached from land than by boat), and assessments concentrated on the important trochus fishery. As no concentrations of in-ground resources (shell 'beds') were noted, no infaunal 'digging' stations (quadrat surveys) were completed.

4.4.4 Other gastropods and bivalves: Airai

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was rare in survey (n = 1), and *Lambis lambis* was also moderately common (n = 5 in broad-scale survey; n = 27 in surveys of shallow-water reef and soft benthos). The average density found in reef-benthos and soft-benthos transect stations was 32.9 and 35.7 /ha, respectively. The only other *Lambis* species recorded was *Strombus lentiginosus* (n = 2). The strawberry or red-lipped conch *Strombus luhuanus* was also not common, with only one moderately dense patch recorded on back-reefs (Appendices 4.3.2 to 4.3.8).

Two species of turban shell, *Turbo agyrostomus* and *T. chrysostomus*, were recorded during surveys. The larger, silver-mouthed turban *T. agyrostomus* was common across the areas checked (recorded in 78% of reef-front search stations) and was found at a reasonable density in reef-benthos transect surveys (54.8 /ha ±19.7). Other resource species targeted by fishers (e.g. *Astralium*, *Cerithium*, *Charonia*, *Chicoreus*, *Conus*, *Cypraea*, *Latirolagena*, *Ovula*, *Pleuroploca*, *Tectus*, *Thais*, *Tutufa* and *Vasum*) were also recorded during independent surveys (Appendices 4.3.2 to 4.3.8).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Anadara*, *Atrina*, *Chama*, and *Spondylus*, are also in Appendices 4.3.2 to 4.3.8. No creel survey was conducted at Airai.

4.4.5 Lobsters: Airai

There was no dedicated night reef-front assessment of lobsters (See Methods.) and, due to the location of the site, with little access to inshore waters after dark, no night-time assessments (Ns) for nocturnal sea cucumber species (which would have offered a further opportunity to record lobster species) were made. Nevertheless, lobsters (*Panulirus versicolor* and *P.* spp.) were relatively common in survey (n = 14), in addition to prawn killers (*Lysiosquillina maculata*, n = 1) and mud lobsters, known as *cheramrou* in Palau (*Thalassina* sp., n = 54).

4.4.6 Sea cucumbers[9]: Airai

Around Airai there were extensive areas of shallow and deepwater lagoon bordering the elevated land mass of Babeldaob (108.9 km^2). Extensive reef margins and areas of shallow, mixed hard- and soft-benthos habitat were found, which are suitable for sea cucumbers, the inshore areas being especially rich. These inshore areas were very suitable for supporting a number of species that are valuable for subsistence and commercial markets (Sea cucumbers feed on detritus and other organic matter in the upper few mm of bottom substrates.). Dynamic water movement (flushing of oceanic water) was most notable in the deepwater lagoon, in the passages between Koror and Babeldaob, and around the main deep lagoon and barrier reefs.

The presence and density of sea cucumber species were determined through broad-scale, fine-scale and dedicated survey methods (Table 4.14, Appendices 4.3.2 to 4.3.8; see also Methods). Results from the full range of assessments yielded 25 commercial species of sea cucumber (plus one indicator species; see Table 4.14).

A sea cucumber species associated with shallow-reef areas, the medium-value leopardfish (*Bohadschia argus*), was common in distribution (42% of reef-benthos transects) and recorded at relatively high density (52.6 /ha ±25.5). High-value black teatfish (*Holothuria nobilis*) was also very common for a species easily targeted by industry (found in 35% of broad-scale transects and 50% of RBt stations), and was recorded at high density in shallow-reef transect stations (30.7 /ha ±9.5). The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was also common (in 21% of broad-scale transects and 47% of reef-benthos transects) and was at high density in reef-benthos transect stations (116.2 /ha, see Appendix 4.3.3).

Although not at high density, surf redfish (*Actinopyga mauritiana*) was recorded in a range of assessments. As this species is mostly found, where its name suggests, on reef fronts, reef-front searches provide a valuable signal on its status. In Airai, 89% of reef-front searches held *A. mauritiana*, but in most assessment techniques the density of this species was not found to be high (generally <50 /ha.). In other locations in the Pacific, this species is recorded in densities >400–500 /ha.

More protected areas of reef and soft benthos in the enclosed, relatively embayed areas of the lagoon also returned a good distribution and density 'signal' from sea cucumbers. Curryfish (*Stichopus hermanni*) was not very common or at high density but brown curryfish

[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.

(*Stichopus vastus*) was recorded in some very high-density patches on soft benthos (>6000 /ha. in some SBt stations). Blackfish (*Actinopyga miliaris*) and stonefish (*A. lecanora*) were also recorded. However, the species important to local interests is probably the currently unnamed *A.* sp. nov. (currently being described by Kris Netchy, University of Guam) and the *Holothuria pervicax/H. impatiens* group. In Palau, the three species of sea cucumbers exploited by the subsistence fishery and traditionally eaten are *Actinopyga* sp. nov., *Stichopus vastus*, and *H. pervicax* (*H. atra* is also sometimes used as a neurotoxin for catching octopus). *Actinopyga* sp. nov. has three colour morphs and is prepared by gutting and cleaning the animal before the body wall is finely chopped up and mixed with lime juice and sauce for use as a sashimi.

In Airai, the lower-value species of sea cucumbers, e.g. lollyfish (*H. atra*) and pinkfish (*H. edulis*), were also present at reasonable coverage and density. Few high-value sandfish, *H. scabra* were found in Airai, although mangrove and seagrass shoreline areas where this species is characteristically recorded were common (This species generally prefers 'richer' soft-benthos, depositional shorelines.). Local advice received while working at Airai was that harvesting had been a problem but that much of the inshore environment had suffered from recent sedimentation due to road-building materials washing down into inshore shallows during periods of heavy rain. It was interesting to note, however, that the lower-value false sandfish (*Bohadschia similis*), which uses the same habitat as sandfish, was present at high density in 36% of the soft-benthos transect stations.

Deep-water assessments (30 five-minute searches, average depth 23.3 m, maximum depth 31 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos with suitably dynamic water movement was present at moderate-to-large scale between Koror and Babeldaob and the mainland and barrier reef, but *H. fuscogilva* was only recorded in one of the four stations surveyed. At this station, the average station density for *H. fuscogilva* was low (2.4 /ha ±2.4). In general, the density of other deepwater species was not high.

4.4.7 Other echinoderms: Airai

At Airai, a few edible collector urchins *Tripneustes gratilla* (n = 4) and slate urchins *Heterocentrotus mammillatus* (n = 5) were recorded in survey. Urchins, such as *Diadema* spp. and *Echinothrix* spp., can be used within assessments as potential indicators of habitat condition. These species and *Echinometra mathaei* were recorded at relatively low levels in survey at Airai (Appendices 4.3.2 to 4.3.8).

Starfish (e.g. *Linckia laevigata* the blue starfish, and *L. guildingi*) were common (in 92% of broad-scale transects) and at moderate density. Corallivore (coral eating) starfish were common in the form of pincushion stars (*Culcita novaeguineae*) (n = 61), but crown of thorns starfish (*Acanthaster planci*) were rarely seen in surveys (n = 6).

The horned or chocolate chip star (*Protoreaster nodosus*) was recorded at low density, as was the doughboy sea star (*Choriaster granulatus*).

Table 4.14: Sea cucumber species records for Airai

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 19; SBt = 14			Other stations RFs = 9; MOPt = 9			Other stations Ds = 4		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinities	Deepwater redfish	M/H	0.2	16.7	1	53.6	250.0	21 SBt						
Actinopyga lecanora	Stonefish	M/H				3.0	41.7	7 SBt						
Actinopyga mauritiana	Surf redfish	M/H	5.0	59.5	8	19.7	125.0	16 RBt	20.9 55.6	23.5 71.4	89 RFs 78 MOPt			
Actinopyga miliaris	Blackfish	M/H	2.3	27.8	8	2.2 20.8	41.7 145.8	5 RBt 14 SBt						
Actinopyga sp. nov.	Undescribed species	M				4.4 113.1	83.3 791.7	5 RBt 14 SBt						
Bohadschia argus	Leopardfish	M	16.0	52.5	31	52.6	125.0	42 RBt	2.3	20.8	11 MOPt	2.4	4.8	55
Bohadschia graeffei	Flowerfish	L	11.6	76.0	15				4.6	41.7	11 MOPt			
Bohadschia similis	False sandfish	L				1381	3867	36 SBt						
Bohadschia vitiensis	Brown sandfish	L	14.0	169.4	8	943.5	1886.9	50 SBt				1.2	4.8	25
Holothuria atra	Lollyfish	L	384.9	554.2	69	440.8 3360	697.9 3360	63 RBt 100 SBt	13.9 9.3	62.7 41.7	22 RFs 22 MOPt	1.2	4.8	25
Holothuria coluber	Snakefish	L	2.8	25.0	11	37.3 50.6	708.3 141.7	5 RBt 36 SBt						
Holothuria edulis	Pinkfish	L	61.0	219.6	28	26.3 544.6	125.0 953.1	21 RBt 57 SBt	9.3	83.3	11 MOPt	3.0	11.9	25
Holothuria flavomaculata		L	18.8	192.9	10	4.4 1104	83.3 15458	5 RBt 7 SBt						
Holothuria fuscogilva [4]	White teatfish	H							0.9	7.8	11 RFs	2.4	9.5	25
Holothuria fuscopunctata	Elephant trunkfish	M	5.6	133.3	4				0.4	3.9	11 RFs	7.7	15.5	50
Holothuria nobilis [4]	Black teatfish	H	9.2	26.5	35	30.7	72.9	50 RBt	5.7 11.6	12.7 26.0	44 RFs 44 MOPt	1.2	4.8	25
Holothuria scabra	Sandfish	H	0.5	33.3	1	44.6	208.3	21 SBt						
Holothuria pervicax		L				3.0	41.7	7 SBt						
Stichopus chloronotus	Greenfish	H/M	13.9	66.7	21	116.2 3.0	245.4 41.7	47 RBt 7 SBt	8.3 113.4	18.6 340.3	44 RFs 33 MOPt			
Stichopus hermanni	Curryfish	H/M	6.3	75	8	4.4 14.9	41.7 104.2	11 RBt 14 SBt	0.4	3.9	11 RFs	1.2	4.8	25

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

Table 4.14: Sea cucumber species records for Airai (continued)

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 19; SBt = 14			Other stations RFs = 9; MOPt = 9			Other stations Ds = 4		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Stichopus horrens	Peanutfish	M/L				14.9	208.3	7 SBt						
Stichopus vastus	Brown curryfish	H/M	31.5	323.8	10	11.0 3164	104.2 6327	11 RBt 50 SBt						
Synapta spp.	-	-				8.9	62.5	14 SBt						
Thelenota ananas	Prickly redfish	H	3.5	31.3	11	3.0	41.7	11 RBt	1.3	5.9	22 RFs	1.2	2.4	50
Thelenota anax	Amberfish	M	0.5	33.3	1							9.5	12.7	75

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

4.4.8 Discussion and conclusions: invertebrate resources in Airai

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

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

- The wide range of shallow-water reef habitats and the dynamic water regime seen around Airai provide extensive suitable areas for giant clams.

- A complete range of giant clam species was present, some of which are becoming rare in other parts of the Pacific. There were few management issues to consider for the smaller species of clams (*Tridacna maxima* and *T. crocea*), but larger clam species need greater protection from fishing.

- The large true giant clam, *T. gigas*, and the smooth clam, *T.derasa*, were only recorded in small numbers here compared to similar sites in other parts of Palau. Stocks of the fluted clam, *T. squamosa*, although relatively well distributed around Airai, were also at lower density than expected. These species need the most support if further management measures, such as protected areas, or community education programmes are to be implemented.

- In general, the status of giant clams at Airai was reasonably healthy, especially for the most common species. Clam density and the 'full' range of clam size classes present support the assumption that, apart from some of the largest species, populations of giant clam are only partially impacted by fishing.

Data on distribution density and length recordings give a mixed picture of MOP stock health:

- The blacklip pearl oyster, *P. margaritifera* is not common at Airai.

- *Trochus niloticus*, the commercial topshell, are common at Airai, and local reef conditions constitute excellent habitat for juvenile and adult trochus. Commercial stocks are most common at easily accessible shallow-water reefs inside the lagoon; generally on reef fringing the mainland embayment but receiving influence of oceanic conditions (as these reefs face gaps in the barrier reef).

- The density of trochus noted in survey suggests that stocks are healthy, but 'core' aggregations (where trochus are typically in greatest abundance) still have significant potential (for growth in individual size and overall abundance), while 'non-core' areas (barrier reef) are presently only holding limited densities of stock.

- Size-class information reveals that previous harvests have comprehensively fished the trochus stock. There are only few aggregations dominated by old shell. Size-class information also reveals that shells of commercial trochus species are still relatively small (with a year or two to spend in the important commercial size ranges), and that no strong year-class is currently visible below the commercial size class range.

- On occasion, the resting period currently adopted in Palau may be too short for continued successful management of the fishery. Firstly, this approach relies on there being regular recruitment (no recruitment failures) which is uncommon with mollusc fisheries in general (Strong recruitment year classes only generally arrive every 3-5 years.). Secondly, most egg production originates from the largest individuals of the population, and trochus only reach these size classes at ≥6 years of age (from shells that would need to survive up to two harvest rotations under the current management scenario).

Results from the sea cucumber surveys indicated the following:

- Airai has a diverse range of environments and depths suitable for sea cucumbers, and a large embayment of protected shallow-water lagoon bordering Airai.

- The range of sea cucumber species recorded at Airai was large, partially reflecting the varied environment, but also the fact that the export fishery is highly controlled in Palau.

- Presence and density data suggest that sea cucumbers are not under significant fishing pressure and commercial export stocks are only lightly or moderately affected by previous fishing. The species fished by domestic fishers for subsistence are more impacted relative to other sites around Palau, and fishers were already travelling to more remote sites on Babeldaob to access stocks at higher density.

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

4.5 Overall recommendations for Airai

- Fisheries management regulations that either temporarily or periodically limit locations, species and/or fishing techniques be implemented, in order to preserve reef and lagoon resources. Future fisheries management strategies need to take into account the high interest of the community in subsistence and leisure fisheries. Therefore, if restrictions are needed, measures must be identified in close cooperation with the community to ensure that these are acceptable and likely to be complied with.

- Use of gillnets and spear diving be regulated and limited, particularly in the lagoon.

- Conservation areas be patrolled and regulations enforced.

- No development or increase of fish marketing be allowed.

- Groups of large, older clams be protected from fishing, to ensure there is sufficient breeding stock to create future generations.

- BMR attempt to increase most of the 'core' trochus fishery areas up to a threshold density of ~500–600 /ha before considering commercial fishing.

- BMR protect a proportion of trochus broodstock (sizes ≥11cm) by creating a 'gauntlet' fishery, with an upper as well as a lower size limit, creating small no-fish areas within core areas of the fishery, and by 'resting' areas within the main fishing locations from commercial fishing for longer periods.

- Careful management of sea cucumber fishing could allow commercial harvesting of a number of export species in Palau. Preferably, catches could be made using a pulse-harvest fishing strategy, similar to that currently employed for trochus, which allows a period of rest between fishing events and time to re-assess the stocks' response to fishing pressure.

5. PROFILE AND RESULTS FOR KOROR

5.1 Site characteristics

Koror, the fourth site assessed in Palau, is one of the four largest islands in the country, located south of Babeldaob and north of Peleliu, around 07°10'N, 134°20'E. Here is where the main town and economic hub are found and where most of the Republic's population lives. A highway connects Koror to the main harbour on Malakal Island. The outer reef is shared with the larger island of Badelbaob, and several hundred small islands are included inside the large lagoon. The study area did not meet the normal standard CoFish design due to specific local requests that allowed only areas principally exploited by fishers to be assessed. Moreover, the sampled zones only partially correspond to the general fishing area, which extends from Koror in the north to Peleliu Island in the south.

Due to the specific local request for assessments, the finfish team worked in specified sectors, often situated in habitat types not normally studied by CoFish: reef heads, channels, and passes. Moreover, priority had to be given to outer reefs compared to the other habitats. Even if the four typical habitats were present, only three could be sampled: outer, intermediate and back-reefs (Figure 5.1).

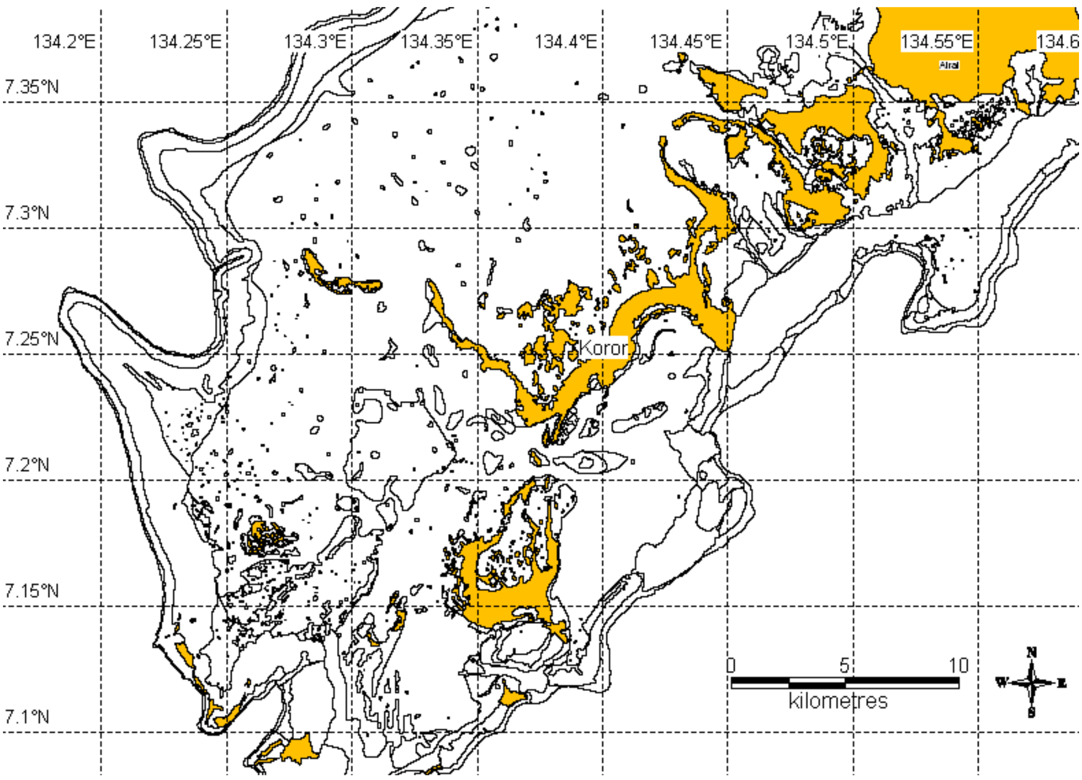

Figure 5.1: Map of Koror.

5.2 Socioeconomic surveys: Koror

Socioeconomic fieldwork was carried out in the greater urban area of Koror in May – June 2007. The survey covered two of the city's 12 hamlets, i.e. Meyuns and Ngermid. In Meyuns, a total of 25 households including 113 people, and in Ngermid, a total of 26 households including 131 people were surveyed. Thus, the survey represents about 14% and 15% of the hamlets' households respectively (a total of 164 households in each hamlet). If taking into account the total number of households of all the 12 hamlets (2019) and total population (8076) in Koror, the survey sample at Koror represents only 2.5–3% of the city's households and people. It should also be noted that, while the samples taken in each of the two hamlets are representative for the selected part of the community, both hamlets are rather peri-urban and likely to include households that still enjoy a rural rather than an urban lifestyle. If other hamlets were included, particularly those closer to Koror, there would probably be a higher percentage of households that are entirely dependent on salaries, less engaged in fishing, and hence more likely to purchase seafood for consumption. Thus, the results presented here represent the more peri-urban areas of Koror. Because both communities are very similar in their characteristics, size and location, results are jointly shown, and referred to as 'Koror' in the following.

Household interviews aimed at the collection of general demographic, socioeconomic and consumption parameters. A total of 30 individual interviews of finfish fishers (24 males, 6 females) and 15 invertebrate fishers (6 males, 9 females) were conducted. These fishers belonged to one of the 51 households surveyed. Sometimes, the same person was interviewed for both finfish and invertebrate fishing.

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

Our survey results (Table 5.1) suggest that a household in Koror has on average less than one fisher. If we extrapolate our survey results, we arrive at a total of 157 fishers in Koror. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 95 fishers who only fish for finfish (mostly males, very few females), a total of 10 fishers who only harvest invertebrates (all females) and 52 fishers who fish for both finfish and invertebrates (males and females).

More than half of all households surveyed in Koror are involved in fisheries (~63%). Less than half, i.e. ~37% of all households in Koror, own a boat. Most boats (~96%) are motorised, the remaining ~4% are non-motorised (canoes).

Ranked income sources (Figure 5.2) suggest that fisheries are not an important sector as compared to salaries. Only ~10% of the households reported fisheries as their first (~6%) or second (~4%) source of income. Salaries, on the other hand, provide ~73% of all households with first and an additional 2% with second income. Furthermore, other sources, including retirement payments, welfare and handicrafts, provide 24% of all households with first and 18% of all households with second income. Agriculture does not play any important role, providing only 2% of households with first income.

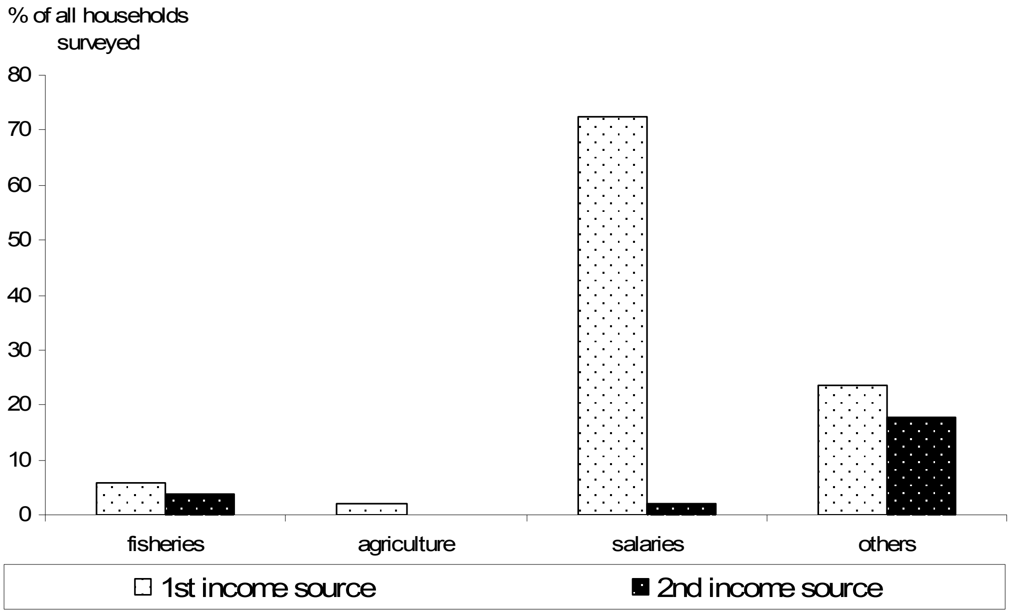

Figure 5.2: Ranked sources of income (%) in Koror.
Total number of households = 25 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly retirement payments, welfare and handicrafts.

The importance of fisheries, however, shows in the fact that almost all households (98%) eat fresh fish, and more than half (67%) also consume invertebrates. About half of the fish that is consumed is caught (~59%) by a member of the household or bought (~53%), and fish is often received as a gift (65%). The proportion of invertebrates caught by a member of the household where consumed is much lower (28%). Invertebrates are also bought frequently (38%) but not so often received as a gift (20%). These results suggest that finfish and invertebrates marketed do not only target the major shops in the centre of Koror but also the markets within individual hamlets.

Fresh fish consumption in Koror (~77 kg/person/year ±15.33) is above the regional average (FAO 2008) (Figure 5.3), and higher than the average across all CoFish sites investigated in Palau. The consumption of invertebrates is ~4 kg/person/year (Figure 5.4), significantly lower than that of finfish and also lower than the average found for all CoFish sites in Palau. Canned fish consumption is low (~5.5 kg/person/year) and about the same as the average consumption level found for all CoFish sites in Palau (~6 kg/person/year ±0.62) (Table 5.1).

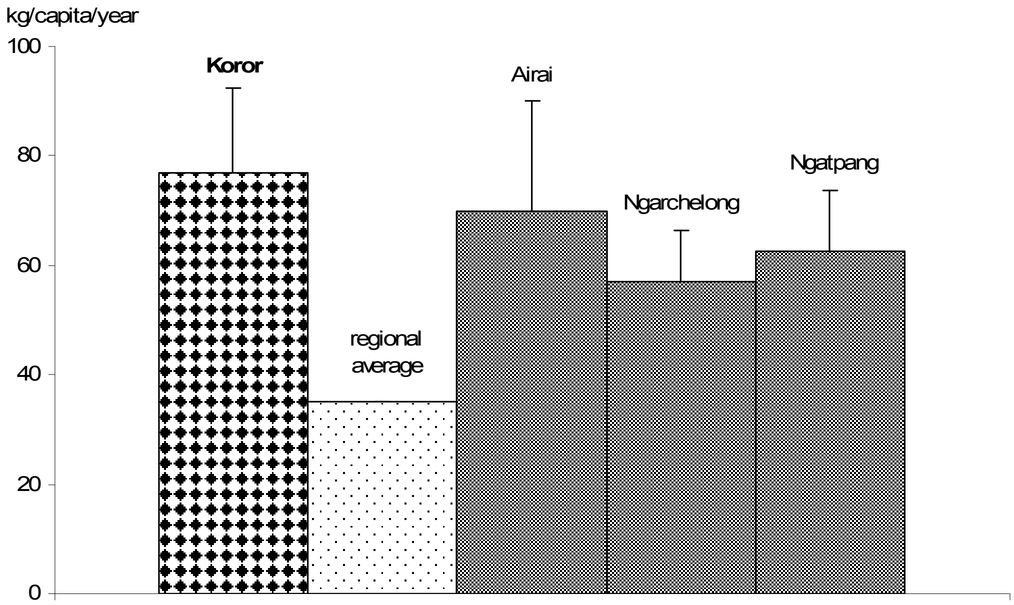

Figure 5.3: Per capita consumption (kg/year) of fresh fish in Koror (n = 25) compared to the regional average (FAO 2008) and the other three CoFish sites in Palau.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

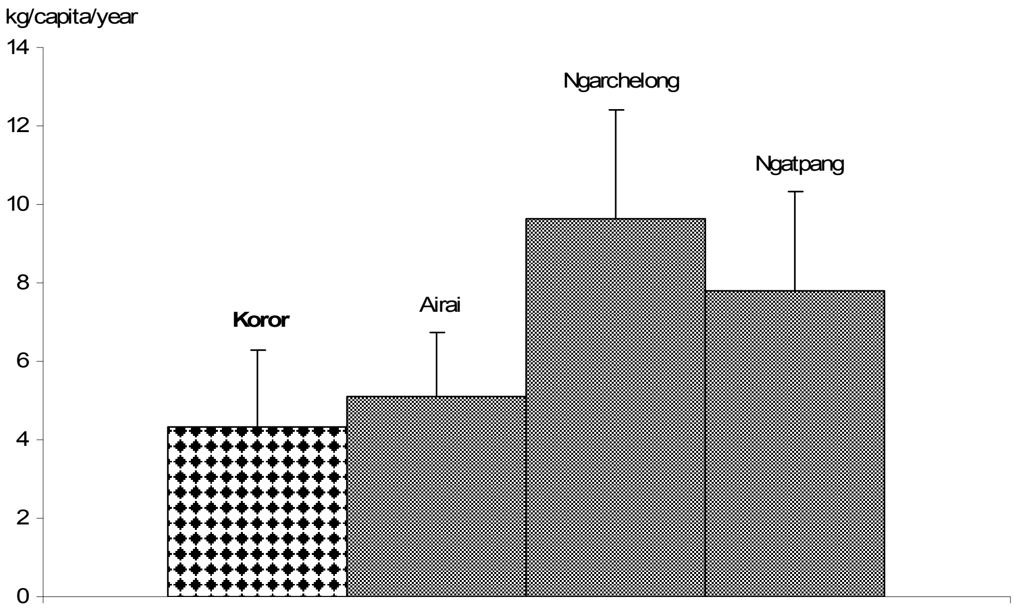

Figure 5.4: Per capita consumption (kg/year) of invertebrates (meat only) in Koror (n = 25) compared to the other three CoFish sites in Palau.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparison of results between all sites investigated in Palau (Table 5.1) reveals that the households surveyed in Koror are less dependent than average on fisheries for income generation. People eat more fresh fish than average but slightly less invertebrates and about the same amount of canned fish. Both the average household expenditure level and the importance of remittances seem to be slightly higher in Koror than found on average across all CoFish sites in Palau.

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

Survey coverage	Site (n = 51 HH)	Average across sites (n = 128 HH)
Demography		
HH involved in reef fisheries (%)	62.7	74.2
Number of fishers per HH	0.90 (±0.14)	1.12 (±0.08)
Male finfish fishers per HH (%)	58.7	53.8
Female finfish fishers per HH (%)	2.2	4.2
Male invertebrate fishers per HH (%)	0.0	0.7
Female invertebrate fishers per HH (%)	6.5	9.1
Male finfish and invertebrate fishers per HH (%)	19.6	16.1
Female finfish and invertebrate fishers per HH (%)	13.0	16.1
Income		
HH with fisheries as 1st income (%)	5.9	9.4
HH with fisheries as 2nd income (%)	3.9	13.3
HH with agriculture as 1st income (%)	2.0	3.9
HH with agriculture as 2nd income (%)	0.0	3.1
HH with salary as 1st income (%)	72.5	67.2
HH with salary as 2nd income (%)	2.0	4.7
HH with other sources as 1st income (%)	23.5	23.4
HH with other sources as 2nd income (%)	17.6	14.1
Expenditure (USD/year/HH)	6631.84 (±778.67)	6365.28 (±392.62)
Remittance (USD/year/HH) (1)	2650.00 (±1158.66)	1830.00 (±575.82)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	77.01 (±15.33)	68.79 (±7.91)
Frequency fresh fish consumed (times/week)	4.42 (±0.26)	4.25 (±0.17)
Quantity fresh invertebrate consumed (kg/capita/year)	4.32 (±1.96)	6.20 (±7.91)
Frequency fresh invertebrate consumed (times/week)	0.90 (±0.19)	0.80 (±0.09)
Quantity canned fish consumed (kg/capita/year)	5.46 (±0.84)	5.92 (±0.62)
Frequency canned fish consumed (times/week)	2.14 (±0.24)	1.94 (±0.15)
HH eat fresh fish (%)	98.0	99.2
HH eat invertebrates (%)	66.7	68.0
HH eat canned fish (%)	92.2	85.2
HH eat fresh fish they catch (%)	58.8	77.8
HH eat fresh fish they buy (%)	52.9	33.3
HH eat fresh fish they are given (%)	64.7	59.3
HH eat fresh invertebrates they catch (%)	27.5	40.7
HH eat fresh invertebrates they buy (%)	37.3	29.6
HH eat fresh invertebrates they are given (%)	19.6	14.8

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

5.2.2 Fishing strategies and gear: Koror

Degree of specialisation in fishing

Fishing in Koror is performed by both genders (Figure 5.5). However, ~60% of all fishers target exclusively finfish: ~59% males, and only ~1% females. Only a few females specialise in collecting only invertebrates (6.5% of all fishers), and the proportions of male and female fishers who fish for both finfish and invertebrates are small, i.e. ~20% and 13% of all fishers respectively.

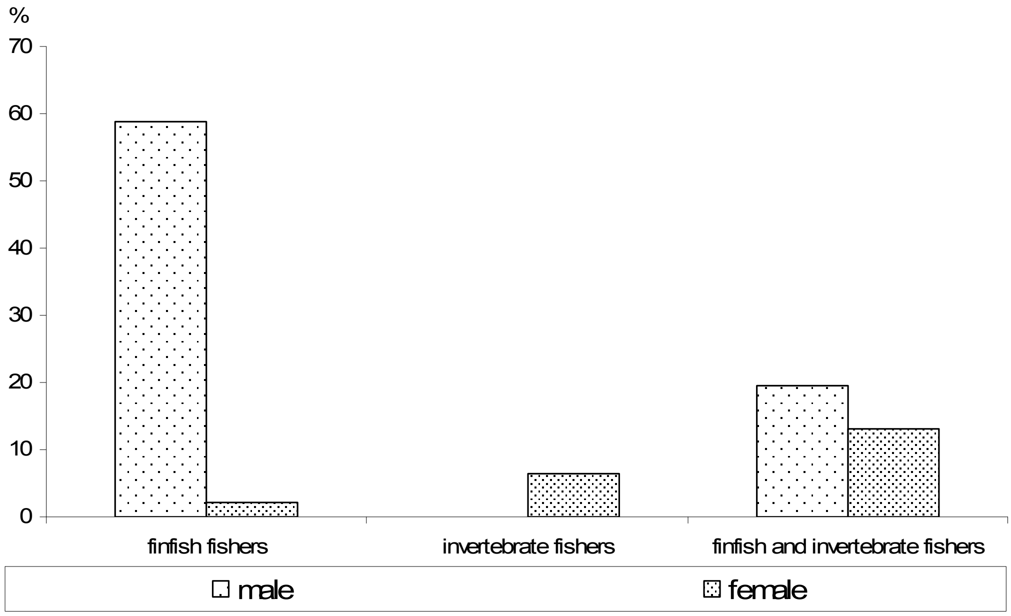

Figure 5.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Koror.
All fishers = 100%.

Targeted stocks/habitat

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef	12.5	0.0
	Lagoon	66.7	100.0
	Lagoon & outer reef	4.2	0.0
	Outer reef	37.5	0.0
Invertebrates	Mangrove	0.0	11.1
	Reeftop	66.7	55.6
	Soft benthos (seagrass)	66.7	77.8

Finfish fisher interviews, males: n = 24; females: n = 6. Invertebrate fisher interviews, males: n = 6; females, n = 9.

Fishing patterns and strategies

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

Our survey sample suggests that fishers in Koror can choose among the sheltered coastal reef, lagoon and outer-reef habitats. In very rare cases, the lagoon and the outer reef may be combined in one fishing trip. Most male and all female fishers, however, target the lagoon. A small proportion of male fishers (12.5%) also fish the sheltered coastal reef and about one-third the outer reef (37.5%).

Invertebrate fisheries in Koror include reeftop, soft-benthos (seagrass) and mangrove gleaning (Figure 5.6). Females and males mainly target soft benthos (seagrass) and reeftops, and only very few females reported also gleaning in the mangrove areas (Figure 5.7).

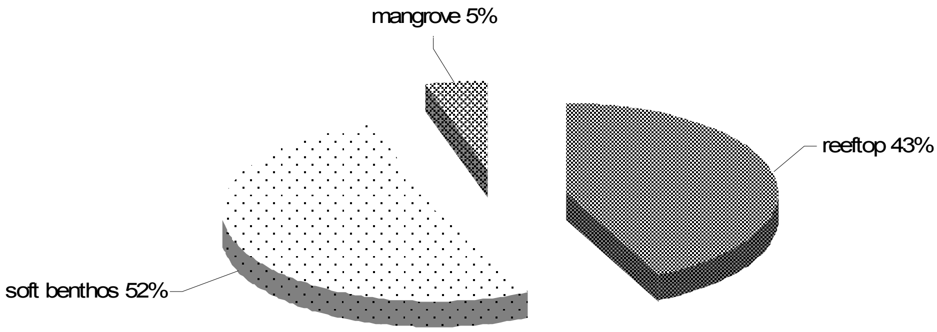

Figure 5.6: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Koror.
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

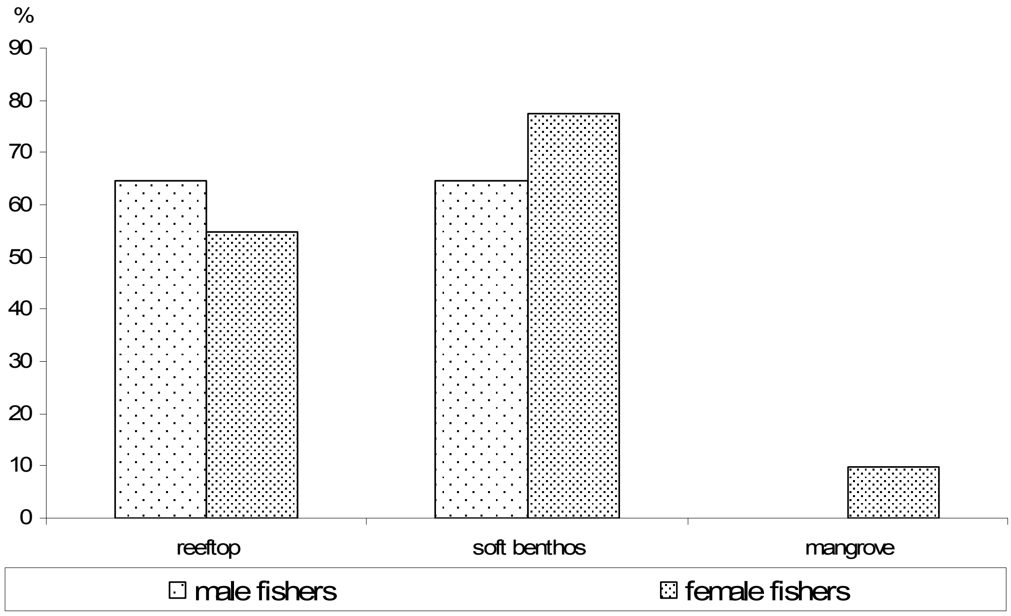

Figure 5.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Koror.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 6 for males, n = 9 for females.

Gear

Figure 5.8 shows that spear diving, in some cases in combination with trolling, is the dominant technique used in all habitats fished. However, handlining also plays a major role in the sheltered coastal reef. At the outer reef, spear diving is complemented by handlining and deep-bottom lining. The lagoon is the fishing zone where most techniques are used, including castnetting, handlining, and gillnetting. Most fishing trips are done using motorised boat transport except for fishing at the sheltered coastal reef, where fishers may sometimes walk or use non-motorised canoes.

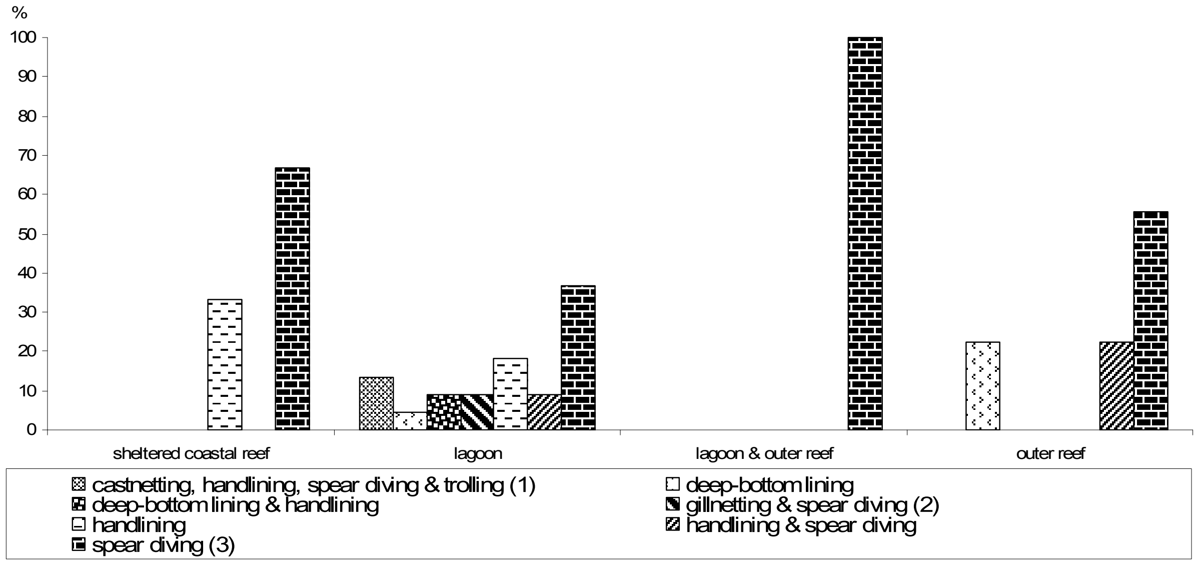

Figure 5.8: Fishing methods commonly used in different habitat types in Koror.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip. (1) could be any combination of only 2 techniques; (2) or exclusively gillnetting; (3) in rare cases with trolling.

Gleaning and free diving for invertebrates is done using very simple tools only. Reeftop, soft-benthos (seagrass) and mangrove gleaning are done by hand, mainly using plastic containers to collect molluscs, holothurians, sea urchins and clams. Most trips are done by walking. For example, respondents confirmed that they never use boat transport for collecting in mangroves, and only 22% and 27% of all respondents use motorised boat transport to reach reeftop and soft-benthos (seagrass) fishing grounds respectively.

Frequency and duration of fishing trips

As shown in Table 5.3 the frequency of fishing trips is 0.7–1.6 times/week. Fishers who target the sheltered coastal reef and the lagoon go out more frequently than those who fish at the outer reef. There is no difference between the frequencies of male and female fishers' trips to the lagoon. The average duration of fishing trips varies considerably among habitats. The shortest trips are those to the sheltered coastal reef (4 hours/trip), which may also be fished by walking. Fishing the lagoon and the outer reef seems to take 6–7 hours on average for male and female fishers.

Table 5.3 also shows that invertebrate collection is done much less often than finfish fishing. Fishers go out to mangroves, soft benthos (seagrass) and reeftop 1–2 times/month. Reeftop gleaning appears to be the most frequent activity performed by male and female invertebrate fishers. Invertebrate collection trips last on average 2.5–3.5 hours.

There is no pronounced preference for finfish fishing at a particular time of day or night. Data suggest a slight preference for night fishing at the sheltered coastal reef, while lagoon and outer-reef fishers may fish either during the day, or according to tidal conditions. Invertebrate collection is only performed during the day. All fishing, either for finfish or invertebrates, is continuous throughout the year.

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

Resource	Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.60 (±0.70)		4.00 (±1.15)	
	Lagoon	1.22 (±0.15)	1.22 (±0.27)	6.38 (±0.35)	6.50 (±0.50)
	Lagoon & outer reef	1.00 (n/a)	0	12.00 (n/a)	0
	Outer reef	0.65 (±0.20)	0	7.00 (±0.55)	0
Invertebrates	Reeftop	0.62 (±0.30)	0.78 (±0.33)	2.63 (±0.63)	2.80 (±0.86)
	Soft benthos (seagrass)	0.29 (±0.06)	0.52 (±0.14)	2.50 (±0.50)	3.43 (±0.72)
	Mangrove	0	0.23 (n/a)	0	2.00 (n/a)

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 24; females: n = 6. Invertebrate fisher interviews, males: n = 6; females: n = 9.

5.2.3 Catch composition and volume – finfish: Koror

The reported catch composition from lagoon catches, the main habitat for Koror fishers, includes the greatest variety of fish species and species groups. Scaridae determine the major proportion (~35%), complemented by Lethrinidae (~21%), Acanthuridae (~20%) and Lutjanidae (~13%). Catches from the sheltered coastal reef are dominated by three main families: Scaridae (36%), Serranidae (20%) and Acanthuridae (20%). The remaining catch includes species of Mullidae, Siganidae, Balistidae, Lutjanidae and others. At the outer reef, catches mainly consist of Scaridae (~27%), Acanthuridae (~21%), Lethrinidae (~16%) and Lutjanidae (~14%). The reported catch composition is a reflection of spear diving (complemented by handlining) being the main fishing technique used in all habitats (Detailed data are provided in Appendix 2.4.1.).

Our survey sample of finfish fishers interviewed represents ~20% of the projected total number of finfish fishers in the population of the two hamlets of Koror that were surveyed (Meyuns, Ngermid). This 20% representation is sufficient to allow the finfish fisher survey data to be extrapolated to assess the total fishing impact that may be imposed by the population of these two Koror hamlets (Figure 5.9). However, it should be noted that the two hamlets do not manage their own fishing grounds but that the assumed fishing grounds are shared by the entire population of Koror. Because our sample does not represent the greater Koror population, we have refrained from extrapolation to encompass the capital's total population, and hence its fishing pressure. The scale of possible impact of such a greater urban area as Koror, however, is addressed in the discussions below (Figure 5.14, Table 5.4).

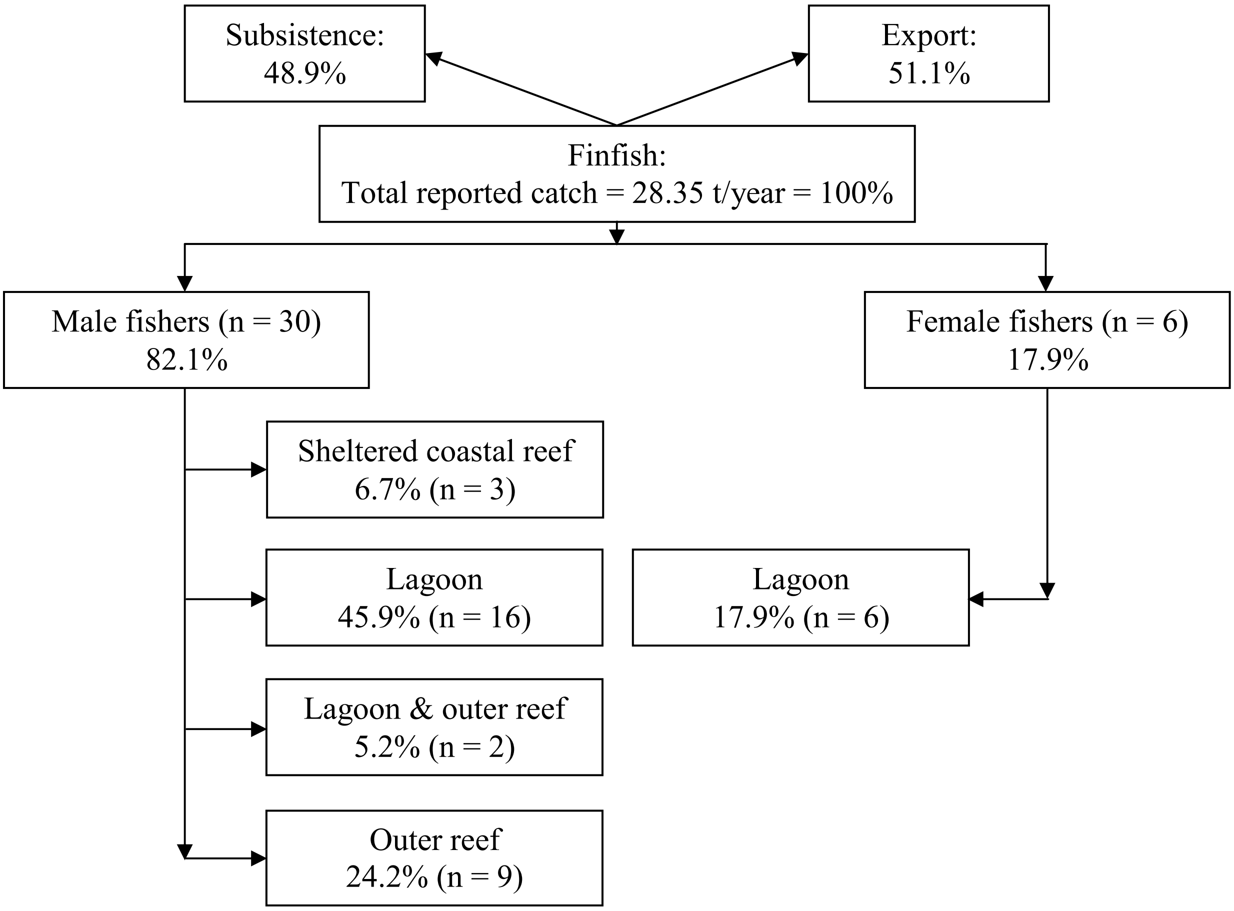

Figure 5.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Koror.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

If we extrapolate the data from respondents to the calculated total number of finfish fishers in Koror, the estimated total impact amounts to 118.78 t/year. The distribution of impact is comparable to the above figure, i.e. with highest pressure on the lagoon habitat, less on the outer reef, and least on the sheltered coastal reef. However, to what extent this figure is an overestimation or close to reality cannot be reliably answered. It should therefore only serve as a measure of possible scale.

Focusing on the relative impact only, Figure 5.9 shows that the impact is almost equally distributed between subsistence (48.9%) and commercial (51.1%) needs. This relationship underpins the high dependency of the community on finfish as a food source, and the distribution of the catch to other semi-urban and urban markets in greater Koror. Most of the catch is taken by male fishers; females contribute little (~18%). Highest pressure is imposed on the lagoon, with much less impact on the outer reef (~24%) and least impact on the sheltered coastal reef (~7%).

The high impact on lagoon resources is due more to the large number of fishers targeting these areas rather than an outstanding average catch rate. As shown in Figure 5.10, catches by lagoon fishers are about 800 kg/fisher/year for both male and female fishers, and almost the same for male fishers targeting the outer reef. Average catch by male fishers targeting the sheltered coastal reef drops to 600 kg/fisher/year. Based on these results, it is concluded that sheltered coastal reef fishing mainly serves subsistence needs, while the lagoon and outer-reef are fished for both subsistence and sale purposes.

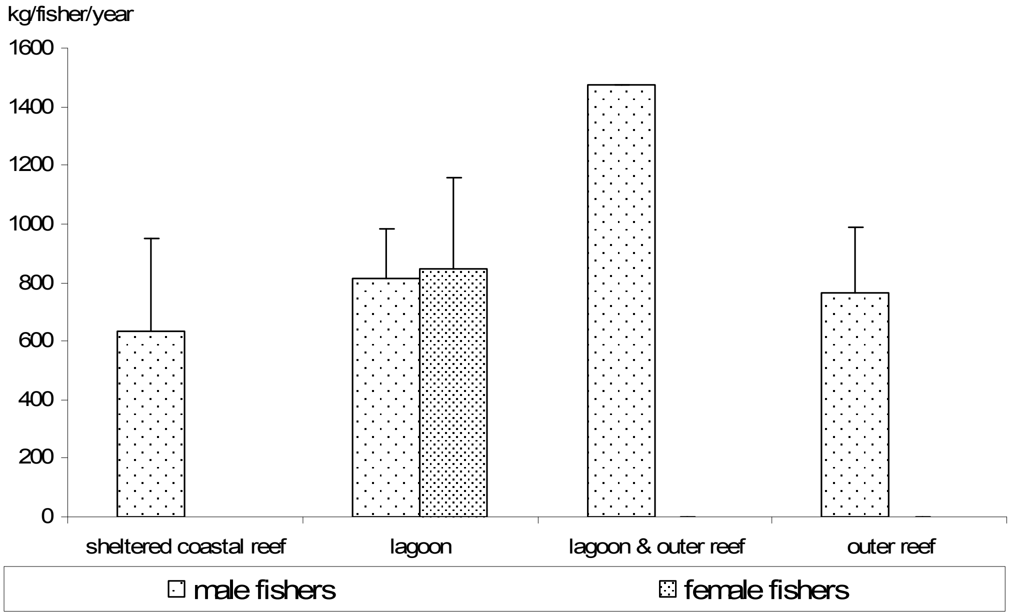

Figure 5.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Koror.
Bars represent standard error (+SE).

However, if comparing the CPUEs calculated for the different habitats fished, Figure 5.11 shows a significant increase in efficiency if the outer reef is fished. Here, fishers catch an average of 4 kg/hour fished. By comparison, CPUEs from lagoon and sheltered coastal reef fishing are both ~2.5 kg/hour. In the lagoon, there is no significant difference in CPUEs between male and female fishers.

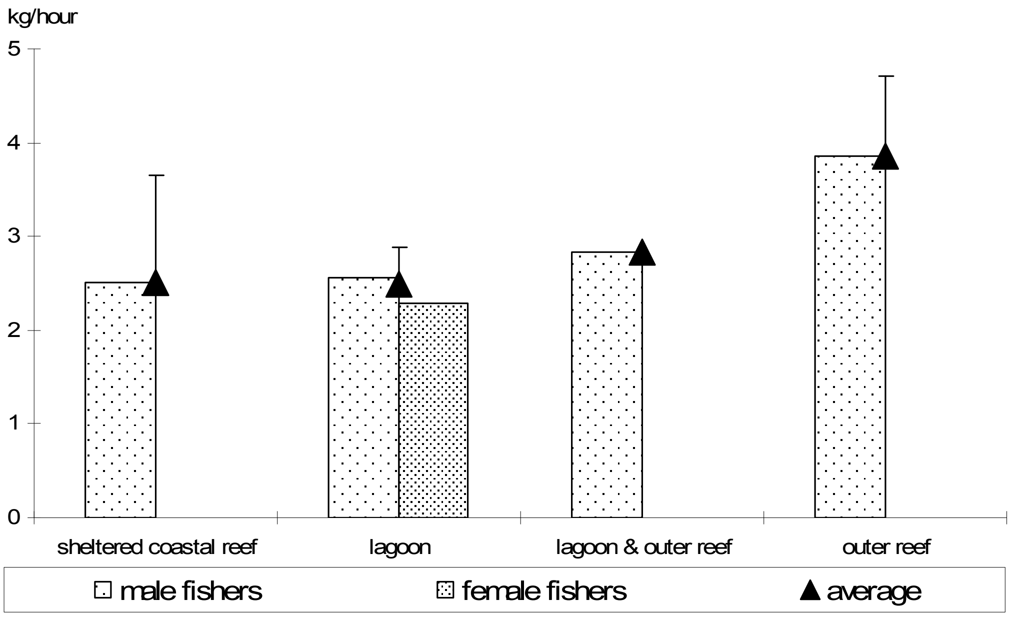

Figure 5.11: Catch per unit effort (kg/hour of total fishing trip) for male fishers by habitat in Koror.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Figure 5.12 confirms the earlier observation that fishing at the sheltered coastal reef serves subsistence needs only. The share of catch intended for sale is substantial if fishers target the outer reef, and is as equally important as subsistence purposes when fishing the lagoon habitat.

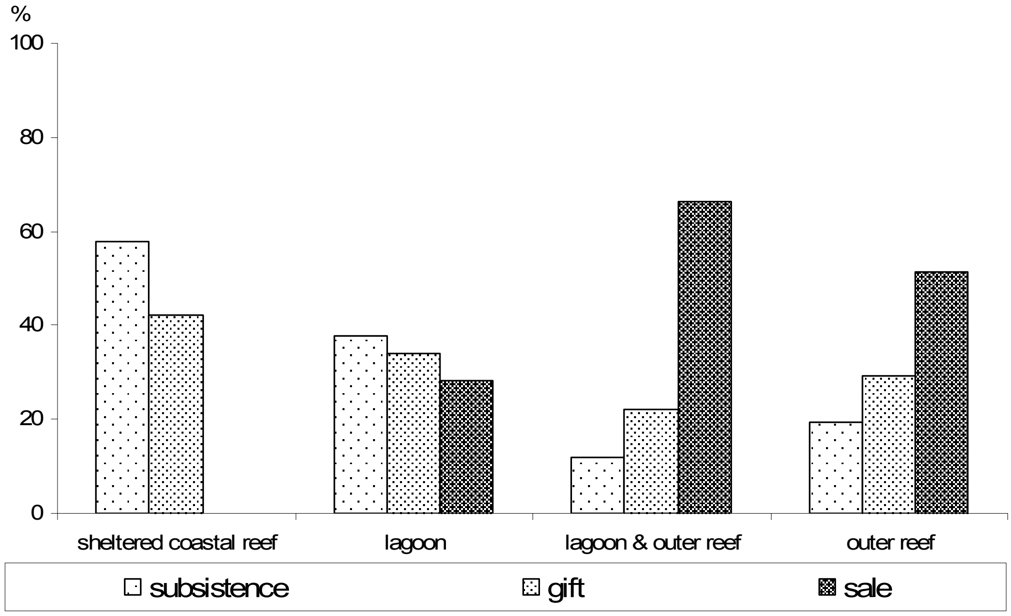

Figure 5.12: The use of finish catches for subsistence, gift and sale, by habitat in Koror.
Proportions are expressed in % of the total number of trips per habitat.

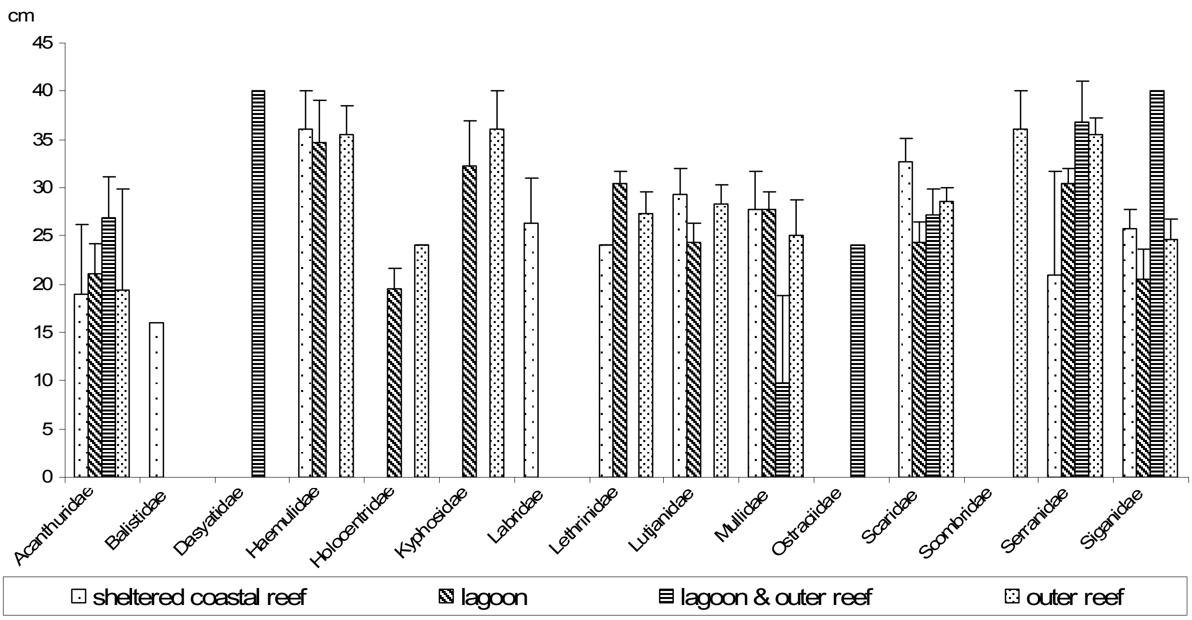

Figure 5.13: Average sizes (cm fork length) of fish caught by family and habitat in Koror.
Bars represent standard error (+SE).

Data on the average reported finfish sizes by family and habitat (Figure 5.13) do not show any conclusive trends and sizes vary considerably among habitats. Average fish sizes of the families Holocentridae, Siganidae and Acanthuridae are mostly 20–25 cm; others, including Haemulidae, Kyphosidea, and Serranidae, are ~35 cm. The major proportion, including

Lethrinidae, Lutjanidae, Mullidae and Scaridae, are 25–30 cm. Usually one would expect an increase in average fish size from the sheltered coastal reef to the outer reef. This seems to be the case for Serranidae and, to some extent, for Holocentridae and Kyphosidae. However, concerning most fish sizes reported for Koror, there is either small variability among habitats (Haemulidae, Siganidae), or an increase from sheltered coastal reef to lagoon followed again by a decrease from lagoon to the outer-reef catches (Acanthuridae, Lethrinidae) or a drop in fish size towards the outer reef (Mullidae, Scaridae). In the case of Scaridae, the drop in fish size for lagoon catches may be a response to the high fishing pressure imposed by the considerable use of spear diving.

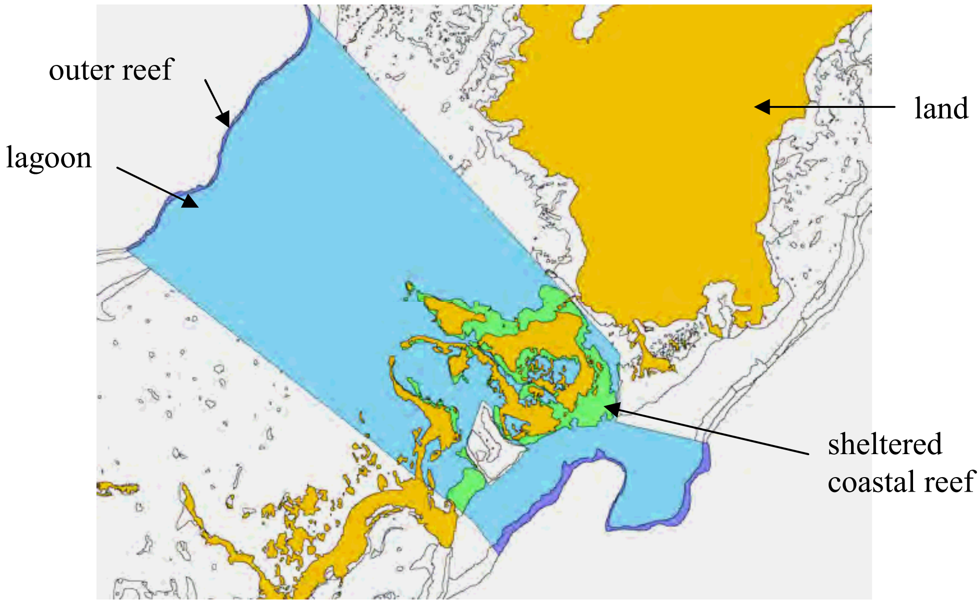

Figure 5.14: Fishing ground and habitat classification of Koror.

Parameters selected to assess the current fishing pressure on reef resources in Koror are shown in Table 5.4. Comparison of habitat surfaces that are considered to represent Koror's fishing ground shows that the lagoon is by far the largest area, while the sheltered coastal and outer reef are relatively small. The relationship among available surface area per habitat, average annual catch per fisher, and fisher density reveals that fisher pressure is always low. Population density is also low if calculated for the total reef area, and very low in relation to the total fishing ground. Also, if considering the annual subsistence need of the population, fishing pressure remains very low.

It has been explained earlier that the sample size is not necessarily representative of the greater Koror community. However, the total fishing ground area is considered here. In order to provide some scale of the possible fishing pressure imposed by Koror's total population, the sample size data is extrapolated. The resulting fisher and population density figures are, of course, higher but still yield only low values for fisher density and a moderate population density level. Also, the estimated subsistence need for the entire population of Koror is not alarming, in fact fishing pressure estimated for the total reef area and fishing ground remain low (0.83–3.81 t/km^2). Using the information obtained from the other three communities surveyed in Palau, it can be assumed that the fishing pressure imposed by the total population of Koror on its fishing ground is much less than at the other sites, as the other communities further north provide substantial amounts of reef fish to the Koror market.

Table 5.4: Parameters used in assessing fishing pressure on finfish resources in Koror
Parameters selected (±SE) to characterise current level of fishing pressure regarding the population of the two hamlets surveyed (Meyuns, Ngermid) and the total population (*figures in italic and in parenthesis*).

Parameters	Habitat					
	Sheltered coastal reef	**Lagoon**	**Lagoon & outer reef**	**Outer reef**	**Total reef area**	**Total fishing ground**
Fishing ground area (km^2)	28.81	752.19	n/a	33.03	193.35	814.03
Density of fishers (number of fishers/km^2 fishing ground) (1)	<1 *(5)*	<1 *(1)*	n/a *(n/a)*	1 *(13)*	<1 *(10)*	<1 *(2)*
Population density (people/km^2) (2)					4 *(46)*	1 *(10)*
Average annual finfish catch (kg/fisher/year) (3)	632.98 (±317.00)	823.08 (±146.74)	1476.57 (n/a)	763.06 (±226.96)		
Total fishing pressure of subsistence catches (t/km^2)					0.30 *(3.81)*	0.07 *(0.83)*
Total number of fishers	12 *(147)*	86 *(1063)*	4 *(49)*	36 *(442)*	138 *(1701)*	138 *(1701)*

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; (1) total number of fishers (= 138; *1701*) is extrapolated from household surveys; (2) total population = 833; *8076*; total subsistence demand = 518.59 t/year; *674.6 t/year*; (3) catch figures are based on recorded data from survey respondents only.

5.2.4 Catch composition and volume – invertebrates: Koror

Calculations of the recorded annual catch rates per species groups are shown in Figure 5.15. The graph shows that the major impact by wet weight is mainly due to the catch of giant clams (*Tridacna* spp. and *Hippopus hippopus*) and to various bêche-de-mer species, including *Actinopyga* spp., *Stichopus* spp., *Holothuria scabra* and *H.* spp., while *Tripneustes gratilla*, sea urchins, and the mangrove clam *Anodonita edentula* (*ngduul*) each account for a very small proportion of the reported annual catch only (Detailed data are provided in Appendices 2.4.2 and 2.4.3.).

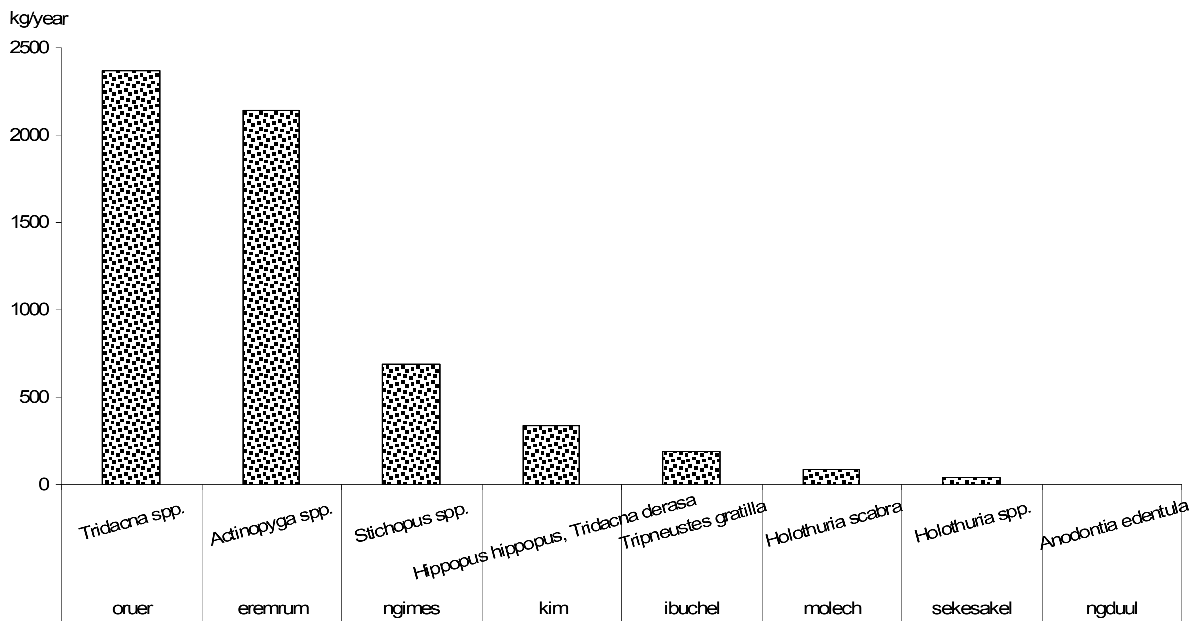

Figure 5.15: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Koror.

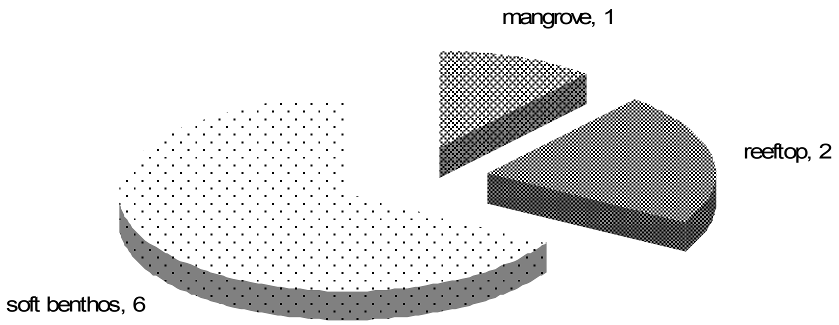

Figure 5.16: Number of vernacular names recorded for each invertebrate fishery in Koror.

Overall, the diversity of vernacular names reported is low for any of the habitats targeted. Soft benthos (seagrass) is the main habitat for collecting bêche-de-mer, some giant clams and sea urchins for food. Thus, it is not surprising that the highest number of vernacular names occurs here. While two vernacular names are reported for reeftop gleaning, only one species was identified by vernacular name (*ngduul*) for mangrove catches (Figure 5.16).

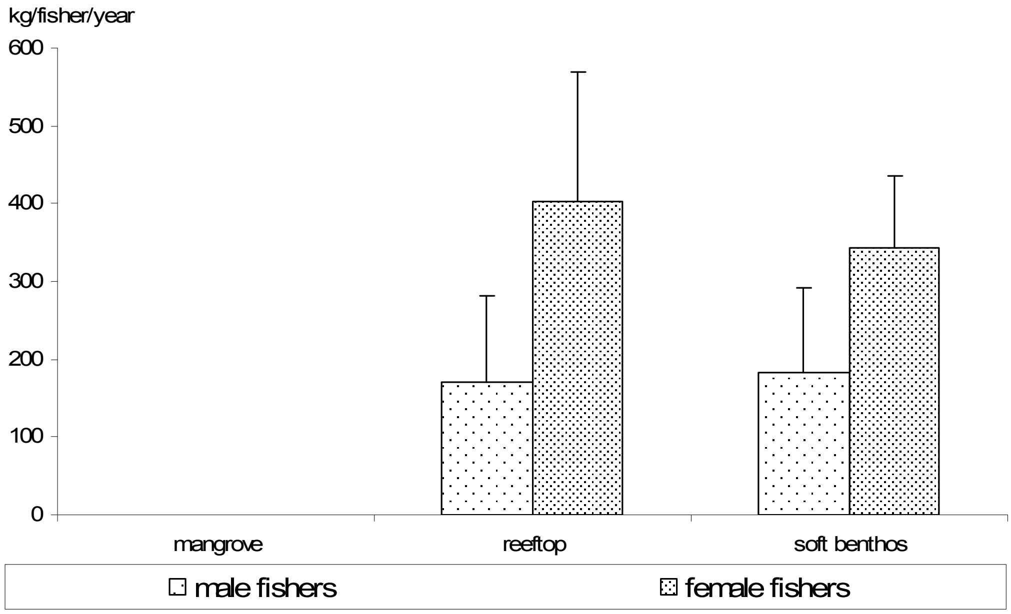

Figure 5.17: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Koror.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 6 for males, n = 9 for females). Bars represent standard error (+SE).

Figure 5.17 shows that the highest catches are achieved by female fishers, i.e. ~400 kg/fisher/year if harvesting reeftops, followed by soft-benthos (seagrass) catches with about 350 kg/fisher/year. The catch for mangrove clams is insignificant. Male fishers' catches are much lower and do not vary much between soft-benthos (seagrass) and reeftop collection with 150–180 kg/fishers/year (wet weight).

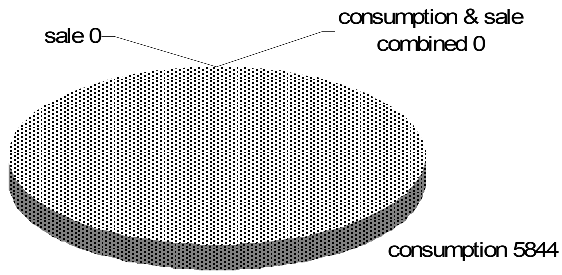

Figure 5.18: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Koror.

As demonstrated in Figure 5.18, all invertebrate fishing serves subsistence purposes, including the non-monetary exchange of catch among family or community members.

The total annual catch volume (expressed in wet weight based on recorded data from all respondents interviewed) amounts to 5.84 t/year (Figure 5.19). As reported earlier, catches from the two main habitats targeted, i.e. reeftop and soft benthos (seagrass), account for about half of the total annual catch each (46.2% and 53.8% respectively). Catches from mangrove collection are insignificant. Female fishers' collection accounts for 75% of the total annual reported catch.

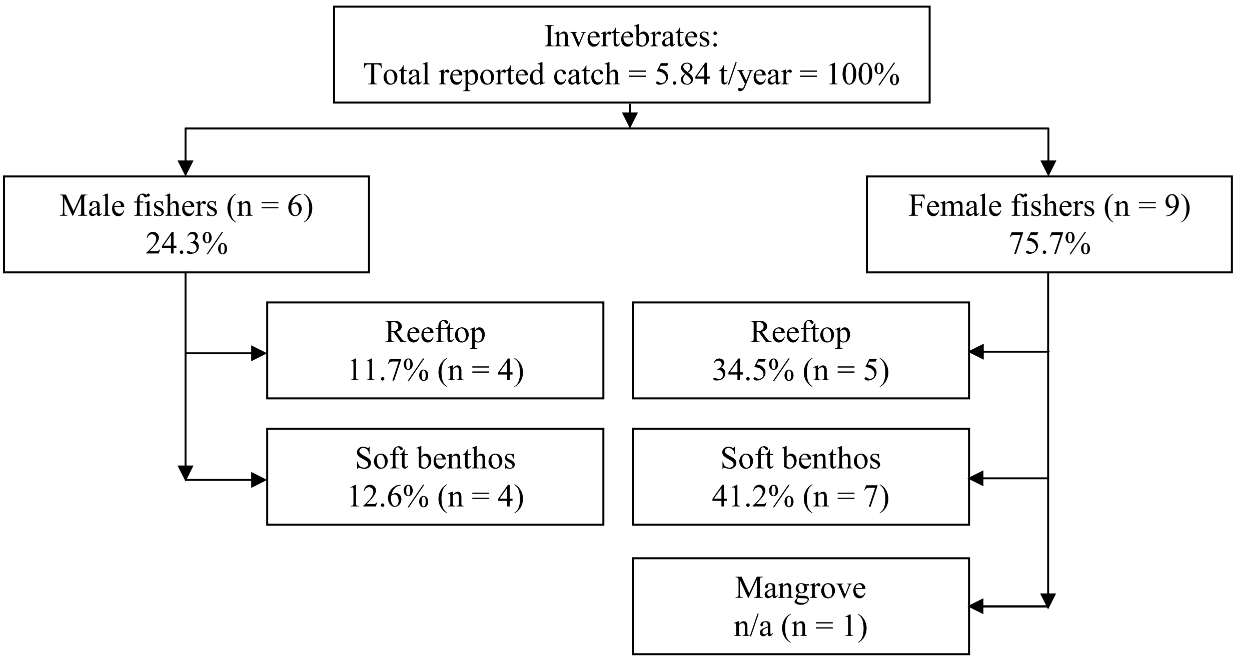

Figure 5.19: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Koror.
n is the total number of interviews conducted per each fishery; n/a = no information available; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

Table 5.5: Selected parameters (±SE) used to characterise the current level of fishing pressure of invertebrate fisheries in Koror

Parameters	Fishery / Habitat		
	Mangrove	Reeftop	Soft benthos
Fishing ground area (km^2)	n/a	59.31	n/a
Number of fishers (per fishery) [(1)]	3	38	44
Density of fishers (number of fishers/km^2 fishing ground)		<1	
Average annual invertebrate catch (kg/fisher/year) [(2)]		300.19 (±106.19)	285.62 (±71.05)

Figures in brackets denote standard error; n/a = no information available; [(1)] number of fishers extrapolated from household surveys; [(2)] catch figures are based on recorded data from survey respondents only.

Due to the large surface area of the reeftop and other invertebrate fishery areas in Koror, parameters used to assess the current fishing pressure are low. The total number of people targeting either reeftop or soft-benthos habitats to collect invertebrates in the two hamlets of Koror surveyed is rather low. Also, the average annual catch that these fishers collect from either of the two habitats is small, which suggests that catches are basically used for family consumption. While, locally, problems may exist, overall figures do not suggest that current fishing pressure has reached detrimental levels.

5.2.5 Discussion and conclusions: socioeconomics in Koror

- Fisheries are not important for income generation in Koror. Only 10% of all households reported obtaining some income from fisheries. In contrast, salaries are of highest importance, complemented by other sources, such as retirement and social fees.

- Almost all households consume fresh fish and more than half also consume invertebrates regularly. Fresh-fish consumption is above the regional average and also higher than the average consumption of all CoFish sites in Palau. Invertebrate consumption is low and reaches only ~4.5 kg meat/person/year.

- The average household expenditure level is slightly higher than found across all CoFish sites in Palau. This trend was to be expected considering that the two Koror communities surveyed (Meyuns, Ngermid) live a more urban lifestyle than the northern rural communities. Although remittances do not play an important role, they contribute more here than at other Palau CoFish sites.

- Most finfish fishing is performed by males, particularly if it is done exclusively. Very few females specialise in collecting invertebrates only; however, ~33% of male and female fishers fish for both finfish and invertebrates. Finfish fishers mainly target the lagoon and much less the outer reef; only a few fish the sheltered coastal reef. About half of the reported annual catch is consumed, the other half is sold. Invertebrate fishers focus on collecting giant clams, bêche-de-mer and sea urchins from the reeftop and soft benthos (seagrass). One species of mangrove clam is collected from mangroves, but its impact is insignificant. None of the invertebrate catch was reported for sale.

- Various techniques are used for fishing finfish: spear diving is the main method used in all habitats targeted. In most cases, spear diving is complemented by the use of handlines, and, in the lagoon, also castnets and gillnets; at the outer reef, deep-bottom lines are employed. With the exception of some sheltered coastal reef fishing, all finfish fishing uses motorised boat transport. Invertebrate collection, on the other hand, is almost exclusively done only by walking.

- Most fishers target the lagoon, which is by far the largest area. Fishing pressure expressed in fisher density, population density and subsistence catch per reef and fishing ground area are all low if considering only the two communities surveyed. However, even if survey results are extrapolated to the total population of Koror, fishing pressure remains low.

- While the average annual catch per fisher was not found to vary substantially between lagoon and outer reef, CPUEs were reported to be much higher at the outer reef than at any of the other two habitats. Data on average reported fish sizes per families and habitat was not conclusive. Also, the general variation in fish size is considerable, i.e. 20–40 cm.

- Invertebrate fisheries only serve the subsistence needs of the Koror community surveyed. Highest fishing pressure is observed for both main habitats targeted, the reeftop and soft benthos (seagrass), while impact on mangroves seems negligible. Collection is restricted to a few species, including giant clams, bêche-de-mer and sea urchins.

Given the limited sample size, it is difficult to draw major conclusions. However, the relationship among numbers of people and fishers, the large demand from local consumption, and the estimated total surface areas of reef and fishing ground available, suggests low density figures. Survey results from the other three CoFish sites in Palau suggest that there is also a significant amount of reef fish and the locally preferred invertebrates supplied to the greater Koror market from other areas. Hence, a substantial proportion of the Koror community's demand is presumably satisfied by catch taken outside its own fishing ground, thus decreasing pressure on the nearby reef areas. This observation is also supported by the fact that the two Koror hamlets surveyed are the most distant from the Koror centre and presumably more peri-urban than other communities. Again, it can be assumed that, since most Koror households depend on income from salaries or private business, fishing has become more a leisure rather than subsistence activity. The number of fish shops and supermarkets may support this argument.

Similarly, in the case of invertebrate fisheries, the impact from fishing is small, and invertebrates are only collected for home consumption. Again, it is argued that the more urban lifestyle of presumably most of the Koror population reduces the need to fish for invertebrates, and thus fishing pressure on the nearby soft-benthos (seagrass) and reeftop habitats is small.

It should also be noted that, although there is a considerable number of Philippine workers who may also prefer seafood, they are not active fishers but rather consumers of fisheries produce that is either bought or donated. Considering the relatively high price of local fresh seafood, Philippine workers do not represent a major demand, because they usually pursue a lifestyle of minimising local expenses in order to send money home to their families in the Philippines. In other words, they are likely to choose alternatives to the expensive local seafood.

5.3 Finfish resource surveys: Koror

Finfish resources and associated habitats were assessed in Koror between 2 and 7 April 2007, from a total of 24 transects (6 intermediate-, 7 back- and 11 outer-reef transects; see Figure 5.20 for transect locations and Appendix 3.4.1 for coordinates).

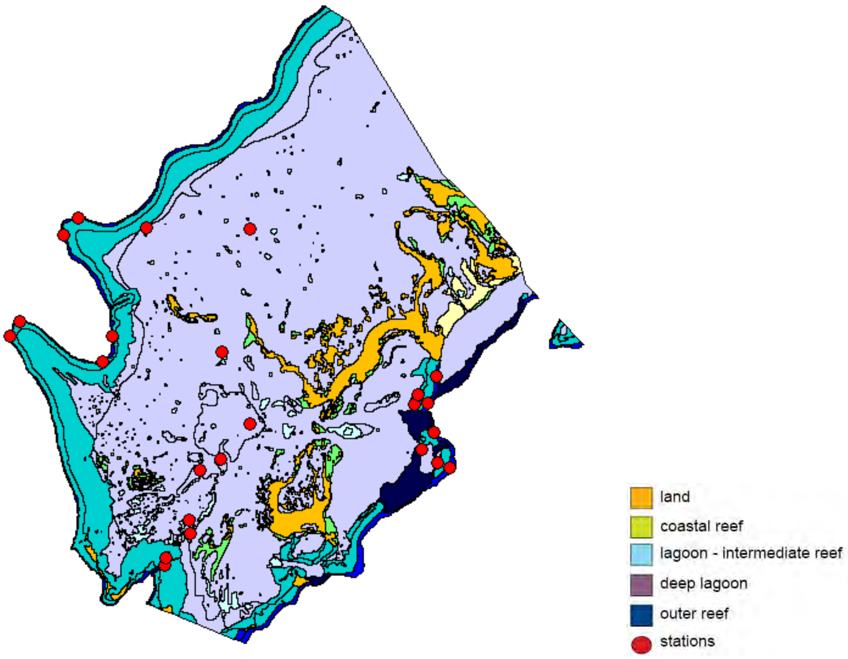

Figure 5.20: Habitat types and transect locations for finfish assessment in Koror.

5.3.1 Finfish assessment results: Koror

A total of 25 families, 70 genera, 240 species and 24,194 fish were recorded in the 24 transects (See Appendix 3.4.2 for list of species.). Only data on the 15 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 51 genera, 204 species and 18,170 individuals.

Finfish resources varied greatly among the four reef environments found in Koror (Table 5.6). The outer reef contained the far highest fish density, size and biomass of the Koro site and all the country sites (1.3 fish/m², 418 g/m²), as well as an exceptionally high biodiversity (the highest in the whole region, 70 species/transect). Intermediate reefs also displayed very high values of these parameters, again the highest of the four sites. The back-reef displayed the lowest values of all habitats at the site, but still the highest density, biomass and biodiversity among the back-reefs of the four sites.

Table 5.6: Primary finfish habitat and resource parameters recorded in Koror (average values ±SE)

Parameters	Habitat			
	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	7	11	24
Total habitat area (km^2)	16.7	131.5	16.6	164.8
Depth (m)	6 (2–12) (3)	6 (1–14) (3)	10 (6–14) (3)	6 (1–14) (3)
Soft bottom (% cover)	19 ±6	12 ±5	4 ±2	10
Rubble & boulders (% cover)	24 ±9	41 ±10	12 ±5	32
Hard bottom (% cover)	28 ± 4	12 ±3	30 ±6	14
Live coral (% cover)	24 ±7	27 ±4	47 ±6	26
Soft coral (% cover)	1 ±1	5 ±2	4 ±1	4
Biodiversity (species/transect)	52 ±3	52 ±4	70 ±5	60±23
Density (fish/m^2)	0.7 ±0.3	0.6 ±0.2	1.3 ±0.5	0.6
Biomass (g/m^2)	200.0 ±119.4	98.7 ±15.1	418.7 ±176.2	125.2
Size (cm FL) (4)	21 ±1	17 ±1	20 ±1	18
Size ratio (%)	60 ±2	54 ±2	56 ±2	55

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

Intermediate-reef environment: Koror

The intermediate-reef environment of Koror was dominated by two major families: herbivorous Acanthuridae, mainly in terms of density, and carnivorous Lutjanidae in terms of density and biomass. Other important families were Siganidae, Scaridae and Lethrinidae. In addition, Chaetodontidae were the fifth most important family in terms of density and were represented by 18 species (Figure 5.21). The five main families were represented by 57 species; particularly high biomass and abundance were recorded for *Lutjanus gibbus*, *Ctenochaetus striatus*, *Monotaxis grandoculis*, *Siganus fuscescens*, *Naso brevirostris*, *Chlorurus microrhinos* and *Cetoscarus bicolor* (Table 5.7). This reef environment presented a very diverse habitat with similar cover of hard bottom (28%), live coral (24%), rubble (24%) and soft bottom (19%, Table 5.6).

Table 5.7: Finfish species contributing most to main families in terms of densities and biomass in the intermediate-reef environment of Koror

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.158 ±0.148	88.3 ±85.6
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.194 ±0.086	32.2 ±12.5
	Naso brevirostris	Spotted unicornfish	0.007 ±0.007	3.5 ±3.5
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.022 ±0.012	9.6 ±7.5
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.003 ±0.002	3.5 ±3.0
	Cetoscarus bicolor	Bicolor parrotfish	0.003 ±0.002	2.6 ±1.3
Siganidae	*Siganus fuscescens*	Mottled spinefoot	0.043 ±0.043	4.6 ±4.6

The density, biomass and biodiversity of finfish in the intermediate reefs of Koror were the second-highest of the site, lower only than outer-reef values (0.7 versus 1.3 fish/m^2, 200 versus 418 g/m^2, and 52 versus 70 species/transect). Size and size ratio were, however, highest in Koror. When compared to the intermediate reefs of the other Palau sites, Koror displayed top values of all parameters, with a biomass that was three times higher than the second-highest value (Airai). Trophic composition was well balanced in terms of density of carnivores (45% of total density) and herbivores (48%), while carnivores dominated the biomass composition (61%), relative to herbivores (33%). The composition of the fish community was diverse and rich, with several families and many species contributing to the majority of the biomass. These are usually signs of a healthy ecosystem. Only Lethrinidae displayed an average size that was lower than the 50% of the average largest size for the family, probably indicating a fishing impact on this selected family. This family constituted 1/5 of the total annual catch from the lagoon. The lagoon also provided the highest total annual catches per fisher. The intermediate reefs of Koror displayed a very diverse composition of hard bottom, rubble, soft bottom and coral. Such complex habitat normally advantages a wide range of families: herbivorous Siganidae and Scaridae, and carnivorous Chaetodontidae, Lutjanidae, Labridae and Lethrinidae all displayed high values of biomass and were well represented.

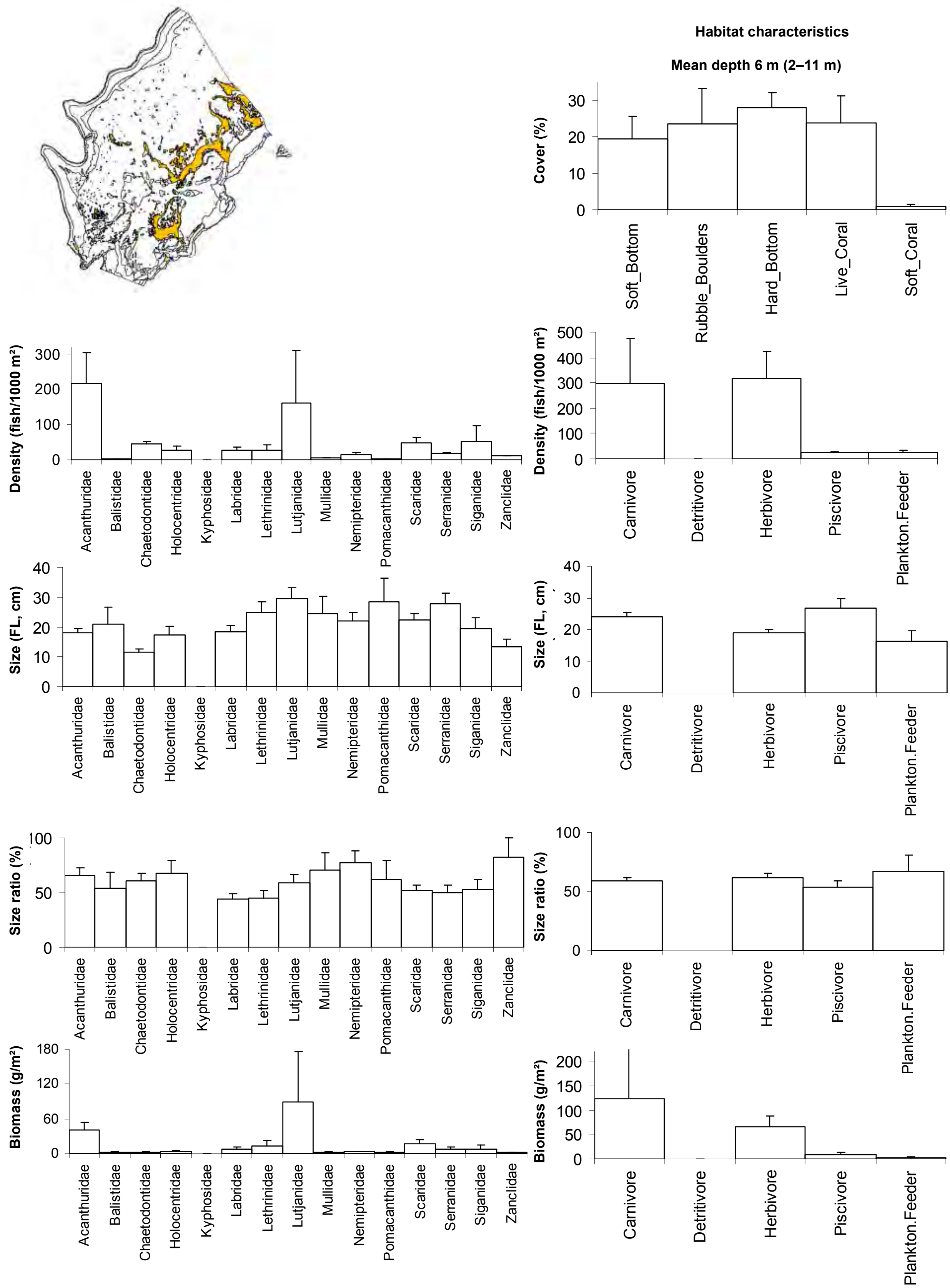

Figure 5.21: Profile of finfish resources in the intermediate-reef environment of Koror.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Koror

The back-reef environment of Koror was dominated by six families: mainly herbivorous Acanthuridae, Scaridae and Siganidae (for both density and biomass) but also carnivorous Lethrinidae, Lutjanidae and Mullidae, mainly in terms of biomass (Figure 5.22). These six families were represented by 62 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Naso brevirostris*, *Chlorurus sordidus*, *Monotaxis grandoculis*, *Parupeneus barberinus*, *Gnathodentex aureolineatus*, *Naso unicornis*, *Lutjanus gibbus* and *Siganus fuscescens* (Table 5.8). This reef environment presented a very diverse habitat with rubble dominating (41%), an equal cover of soft and hard bottom (12% each) and a good cover of live coral (27%) (Table 5.6 and Figure 5.23).

Table 5.8: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment of Koror

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.123 ±0.034	11.7 ±2.7
	Naso brevirostris	Spotted unicornfish	0.013 ±0.011	8.7 ±7.2
	Naso unicornis	Bluespine unicornfish	0.002 ±0.002	3.2 ±3.2
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.008 ±0.004	4.8 ±3.3
	Gnathodentex aureolineatus	Goldlined seabream	0.044 ±0.035	4.0 ±3.3
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.012 ±0.008	3.0 ±1.6
Mullidae	*Parupeneus barberinus*	Dash-and-dot goatfish	0.005 ±0.004	4.1 ±3.7
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.051 ±0.011	7.1 ±2.2
Siganidae	*Siganus fuscescens*	Mottled spinefoot	0.043 ±0.043	2.9 ±2.9

Density, size, size ratio and biomass of finfish in the back-reefs were the lowest of all habitats in Koror. Biodiversity was the same as in the intermediate reefs. However, when comparing Koror to the other three country sites, density, biomass and biodiversity of Koror back-reefs were the highest, while size and size ratio were second only to Airai values. The trophic structure was dominated by herbivores in terms of both density and biomass. Siganidae and, to a lesser extent, Scaridae showed size ratios below 50% of the maximum size for the relative species, suggesting a certain impact from fishing. The composition of the fish community was very complex and diverse, suggesting a healthy ecosystem. The substrate was dominated by rubble, but good cover of coral and similar amounts of hard and soft bottom cover ensured habitat choice for several species and families.

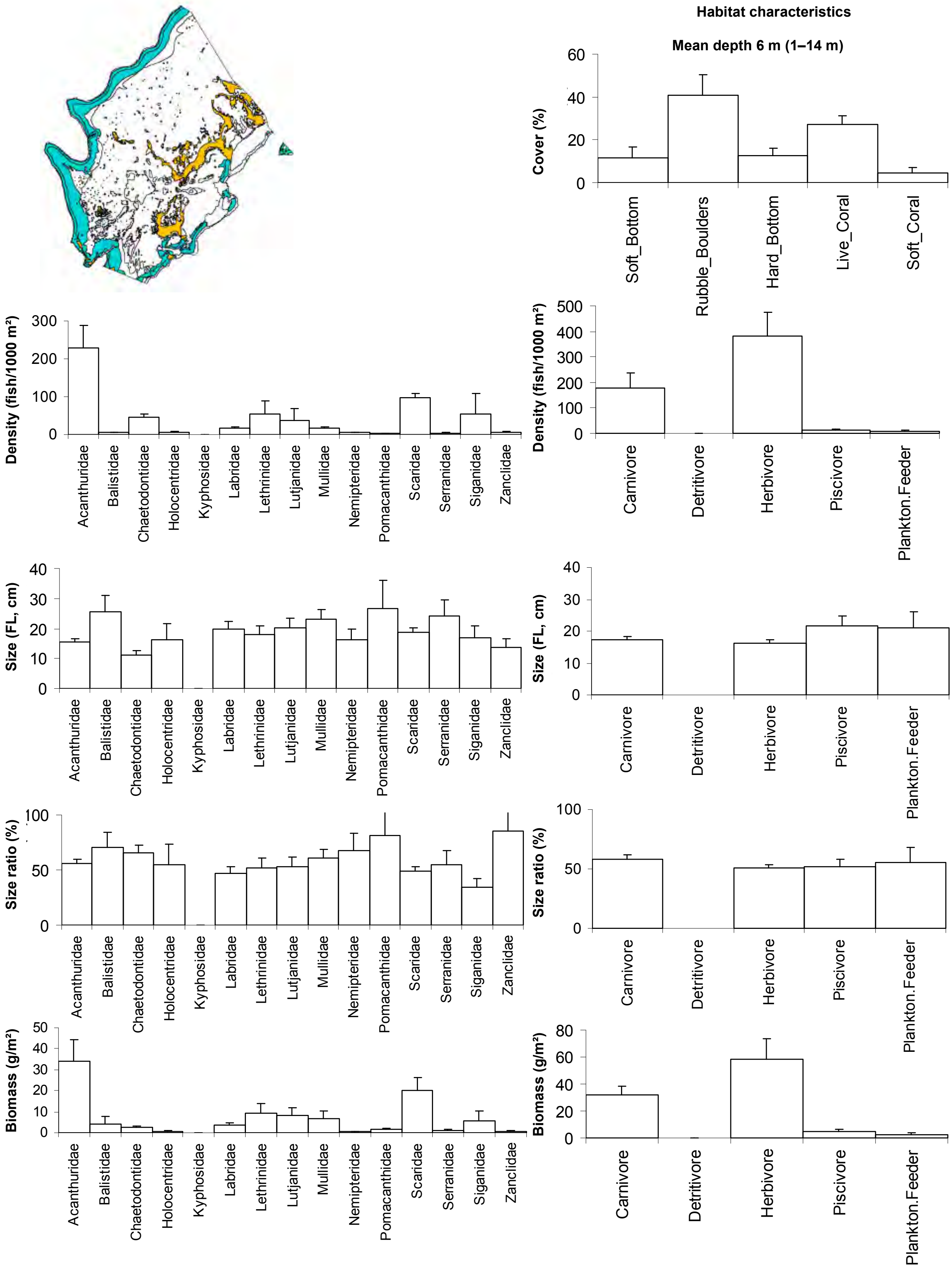

Figure 5.22: Profile of finfish resources in the back-reef environment of Koror.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Koror

The outer-reef environment of Koror was dominated by Lutjanidae in terms of numbers as well as biomass, followed by Scaridae (the second-most important family in terms of biomass), Acanthuridae, Holocentridae and Lethrinidae (Figure 5.23). A large component of the total biomass was represented by *Bolbometopon muricatum* and *Cheilinus undulatus*, of average to large size. The five main families were represented by 67 species; particularly high biomass and abundance were recorded for *Bolbometopon muricatum*, *Lutjanus gibbus*, *Myripristis adusta*, *Ctenochaetus striatus*, *Gnathodentex aureolineatus*, *M. kuntee*, *L. biguttatus*, *Hipposcarus longiceps*, *Monotaxis grandoculis*, *Naso vlamingii* and *L. bohar* (Table 5.9). This reef environment presented a very diverse habitat with very high cover of live coral (47%), high cover of hard rock (30%), little rubble (12%) and very little soft bottom (4%) (Table 5.6).

Table 5.9: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Koror

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.506 ±0.062	176.3 ±131.1
	Lutjanus biguttatus	Two-spot snapper	0.064 ±0.001	7.8 ±7.5
	Lutjanus bohar	Twinspot snapper	0.001 ±0.040	3.3 ±3.1
Scaridae	*Bolbometopon muricatum*	Bumphead parrotfish	0.009 ±0.009	110.6 ±108.1
	Hipposcarus longiceps	Pacific longnose parrotfish	0.041 ±0.002	3.9 ±3.5
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.139 ±0.002	14.4 ±2.0
	Naso vlamingii	Bignose unicornfish	0.003 ±0.044	3.3 ±1.9
Holocentridae	*Myripristis adusta*	Shadowfin soldierfish	0.065 ±0.051	20.0 ±13.0
	Myripristis kuntee	Shoulderbar soldierfish	0.059 ±0.035	7.8 ±6.5
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.064 ±0.005	8.6 ±4.7
	Monotaxis grandoculis	Bigeye bream	0.009 ±0.452	3.8 ±2.0

The density, biomass, and biodiversity of finfish were the highest recorded at the site and among the four country sites. Biomass was more than twice the value recorded on intermediate reefs and almost four times higher than the second-ranked value in the country for outer-reef biomass recorded at Ngatpang. Only size and size ratio were smaller than intermediate reef values. Size ratio was lower than recorded in Ngatpang and Ngarchelong outer reefs. Trophic composition was clearly dominated by carnivores in terms of both density and biomass, suggesting that resources are healthy and support a wide trophic web. Size ratio was low only for Scaridae (39% of maximum size for the corresponding species). Scaridae constitute the majority of catches from this habitat, where speardiving was the main fishing method used; therefore, the low size ratio is probably a first indication of impact. Acanthuridae dominated the herbivore density; Scaridae were more important in terms of biomass, the dominant species being parrotfish of large size (*Hipposcarus longiceps*, *Cetoscarus bicolor*, *Chlorurus microrhinos* and *B. muricatum*). Lutjanidae definitely dominated the carnivore community with abundant and large schools of *L. gibbus*. The outer reefs were dominated by live coral and hard bottom, with a smaller cover of rubble and soft bottom.

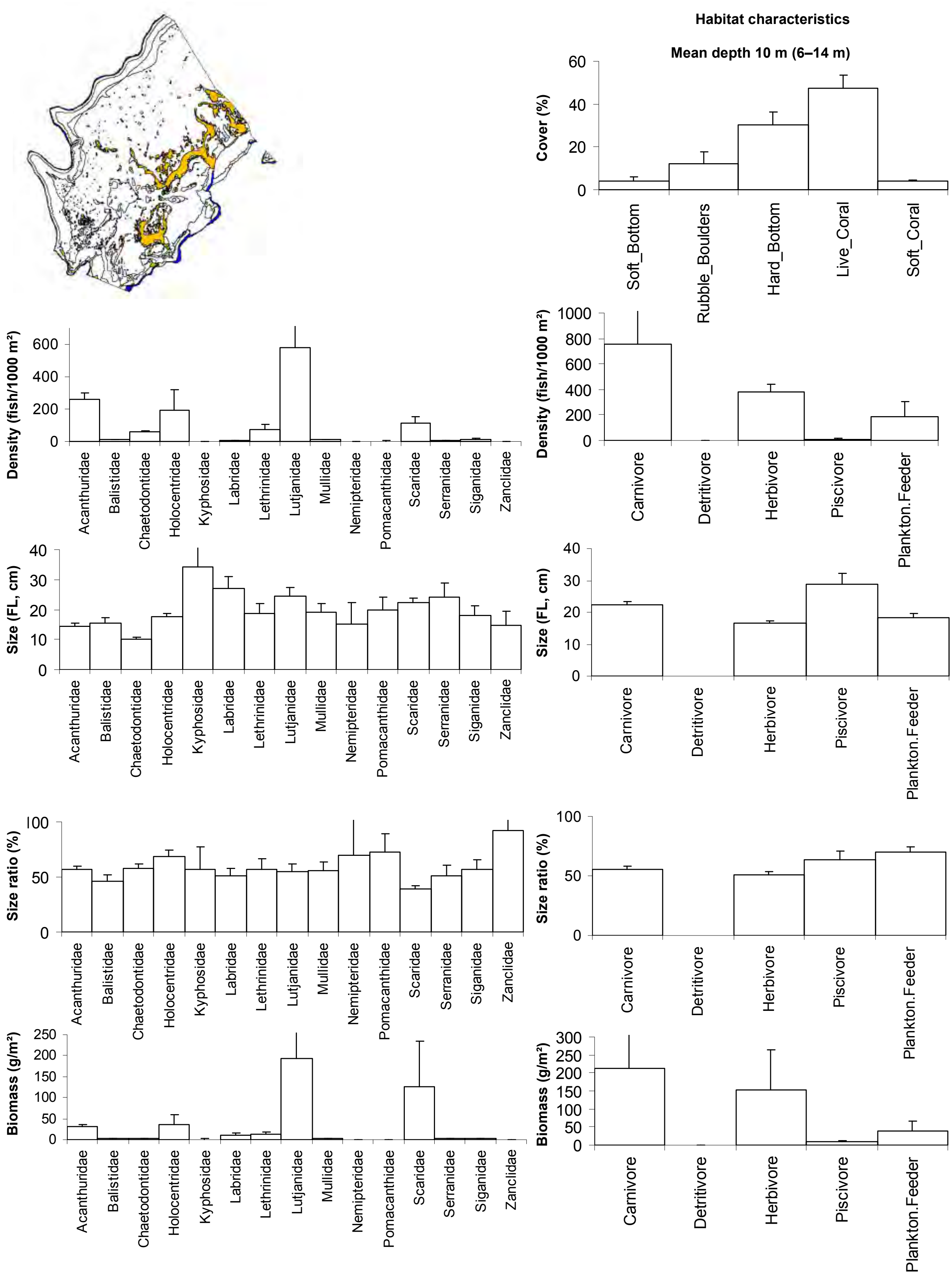

Figure 5.23: Profile of finfish resources in the outer-reef environment of Koror.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Koror

Overall, the fish assemblage of Koror comprised several families; the most important in terms of biomass as well as density were: herbivorous Acanthuridae, Scaridae and, to a lesser extent Siganidae, and carnivorous Lutjanidae and Lethrinidae, especially in terms of biomass (Figure 5.24). These five most important families were represented by a total of 80 species, dominated (in terms of biomass and density) by *Lutjanus gibbus*, *Ctenochaetus striatus*, *Bolbometopon muricatum*, *Naso brevirostris*, *Chlorurus sordidus*, *Monotaxis grandoculis*, *Gnathodentex aureolineatus* and *Siganus fuscescens* (Table 5.10). The average substrate at this site was dominated by rubble (32%) with a good cover of live coral (26%), and a smaller proportion of hard bottom (14%) and soft bottom (10%). The overall habitat and fish assemblage in Koror shared characteristics of mostly back-reefs (80% of total habitat surface), and outer and intermediate reefs in similar proportion(10% each).

Table 5.10: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Koror (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.117	12.5
	Naso brevirostris	Spotted unicornfish	0.010	6.6
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.068	25.8
Scaridae	*Bolbometopon muricatum*	Bumphead parrotfish	0.001	9.9
	Chlorurus sordidus	Daisy parrotfish	0.041	5.5
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.008	4.6
	Gnathodentex aureolineatus	Goldlined seabream	0.037	3.6
Siganidae	*Siganus fuscescens*	Mottled spinefoot	0.034	2.5

Overall, Koror appeared to support a very good finfish resource, with the highest density (0.6 fish/m²), biomass (125 g/m²), largest size (18 cm FL) and highest biodiversity (51 species/transect) among the analysed country sites. A detailed assessment at the family level revealed a high diversity of the fish community, composed by several families of high abundance and/or biomass. The trophic composition was quite complex and composed of similar proportions of carnivores and herbivores in terms of both density and biomass. These observations support the idea that Koror is a healthy site. Overall, size ratios were above the 50% threshold except for Scaridae and Siganidae. The reduced size of some families could be a first sign of impact of selective fishing. Habitat was composed of a good cover of coral (26%) and rubble (32%), with a smaller amount of hard bottom and soft bottom (24% combined) offering good habitats for many fish families with different requirements.

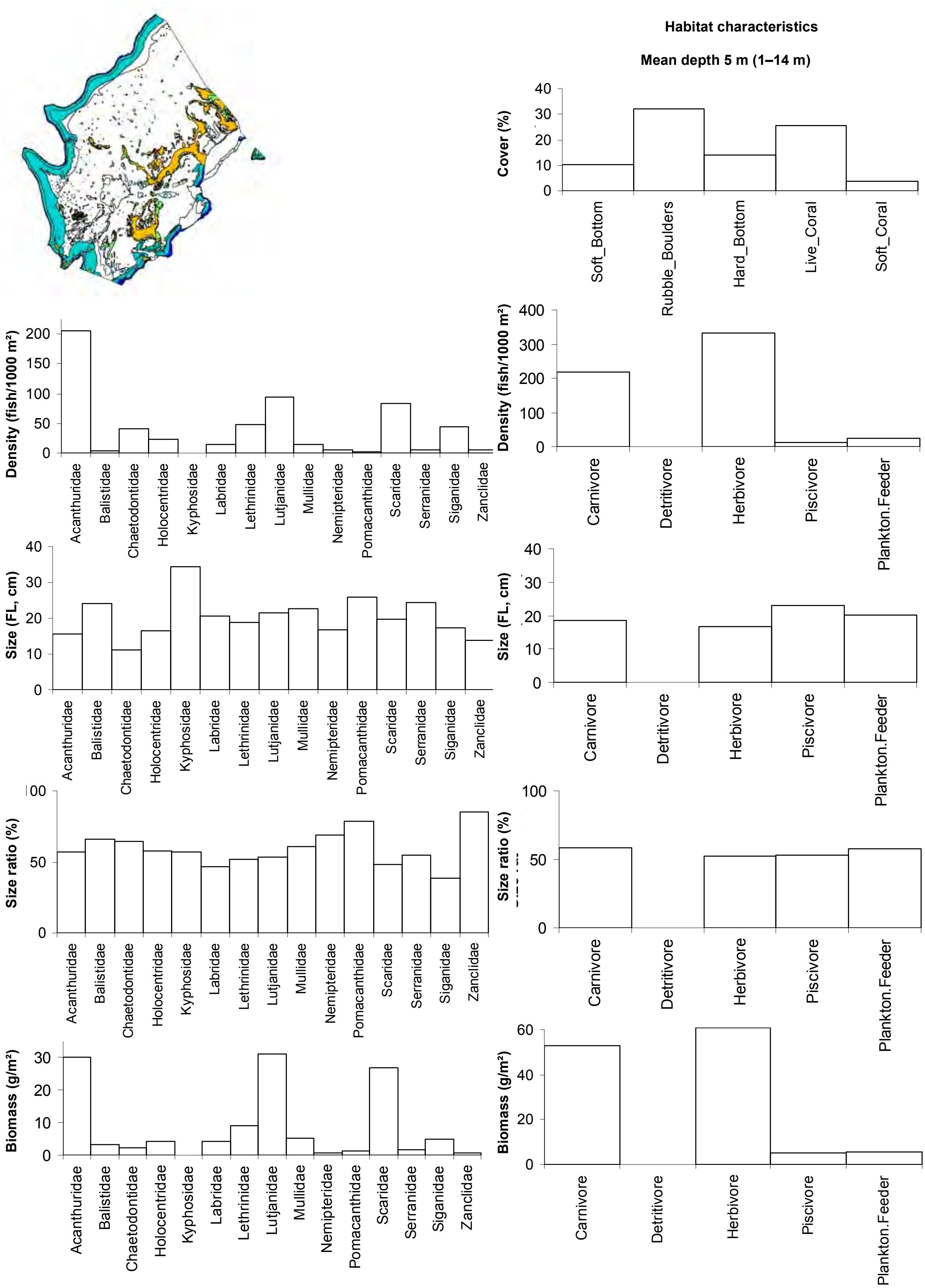

Figure 5.24: Profile of finfish resources in the combined reef habitats of Koror (weighted average).
FL = fork length.

5.3.2 Discussion and conclusions: finfish resources in Koror

Only back-, intermediate and outer reefs were surveyed, in accordance with specific local requests. The no-fishing areas were not accessible.

The assessment indicated that the status of finfish resources in this site was good at the time of surveys:

- The reefs appeared generally healthy and fairly rich in coral cover, more so than at the other country sites.

- Fish abundance and biomass were high, placing Koror among the twenty richest sites in the region. Biodiversity was particularly high and, as average value, the highest in the region. However, some signs of fishing impact were detectable as low average size ratios for certain families, especially Siganidae, Scaridae and Lethrinidae, which were recorded among the most targeted families by fishers.

However, at the reef habitat level and at more specific sites, resources were very variable among the three habitats and among the stations.

- Although intermediate and back-reefs displayed high coral cover, corals were often found in poor condition, either broken, diseased or attacked by crown-of-thorn starfish, still showing signs of the 2002 heavy bleaching events. Outer-reef corals were in a better state in terms of cover and health.

- Finfish resources were also very variable among the three habitats:

  1. The outer reefs of Koror were absolutely the richest habitat of all sites. Fish abundance, biomass and diversity in the outer reefs were the highest of the habitats at the site and among the highest in the region. Moreover, the trophic community was dominated by carnivores (especially Lutjanidae) in terms of density and biomass, further suggesting the ecosystem is functioning well. Plankton feeders were also well represented. The richest survey station, at an intermediate habitat between the channel and outer reef, was German Channel, a well-known site for tourist divers. Large parrotfish (e.g. *Hipposcarus longiceps*, *Bolbometopon muricatum*, *Chlorurus bleekeri*, *Cetoscarus bicolor*) and *Cheilinus undulatus* were recorded in this station. However, large carnivores as well as top predators were rather rare in the outer reefs, possibly indicating a first sign of fishing impact. Size ratios were small for Scaridae, which made up the majority of catches from this habitat, where spear diving was the main method used; thus the low size ratio of parrotfish is probably the first indication of impact.

  2. In comparison, intermediate reefs displayed less than half of the biomass of outer reefs. These reefs resulted to be the most fished of the three habitats (highest catches per year) and Lethrinidae, which constituted ~20% of the total biomass of catches, here displayed low size ratio, possibly as a consequence of frequent fishing.

  3. Back-reefs, with the lowest density, biomass (~25% of the biomass found on the outer reefs) and size among the three habitats, were the poorest habitat of the site. In contrast to the other two habitats, the trophic community was dominated by

herbivores, further suggesting an impoverishment of the ecosystem. Siganidae and Scaridae displayed low size ratios, indicating a possible impact from catches.

- Some reserves established for tourism reasons were quite respected and displayed the highest biodiversity and biomass.

- These results, however, do not represent the whole picture of the level of fishing impact and state of the resource, since the areas accessible to the survey team were limited.

5.4 Invertebrate resource surveys: Koror

The diversity and abundance of invertebrate species at Koror were independently determined using a range of survey techniques (Table 5.11): broad-scale assessment (using the 'manta tow'; locations shown in Figure 5.25) and finer-scale assessment of specific reef and benthic habitats (Figures 5.26 and 5.27).

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

Table 5.11: Number of stations and replicates completed at Koror

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	19	114 transects
Soft-benthos transects (SBt)	13	78 transects
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	9	54 transects
Mother-of-pearl searches (MOPs)	4	24 search periods
Reef-front searches (RFs)	15	90 search periods
Reef-front search by walking (RFs_w)	0	0 search period
Sea cucumber day searches (Ds)	5	30 search periods
Sea cucumber night searches (Ns)	2	12 search periods

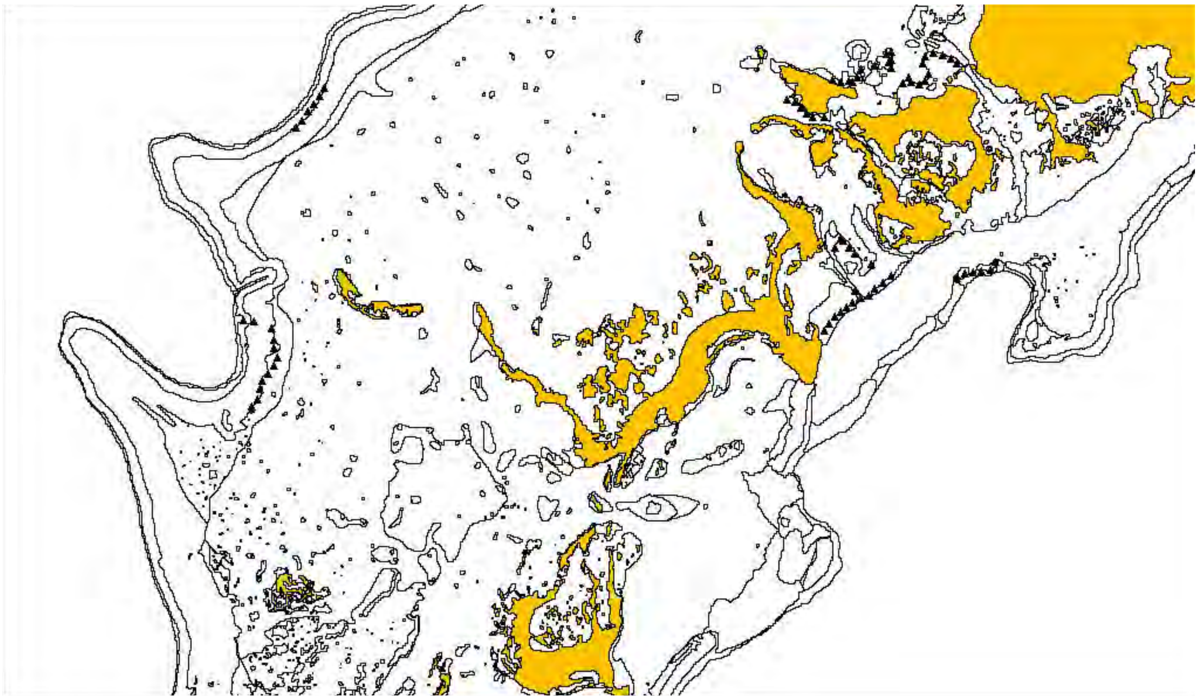

Figure 5.25: Broad-scale survey stations for invertebrates in Koror.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

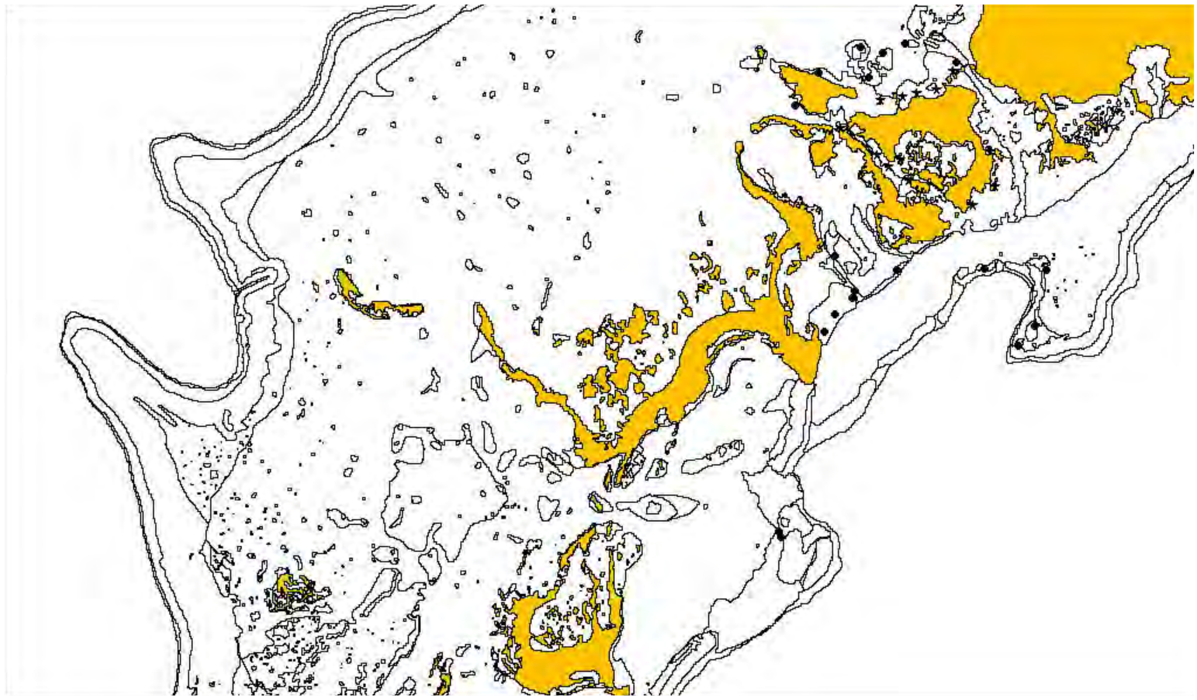

Figure 5.26: Fine-scale reef-benthos transect survey stations and soft-benthos transect survey stations in Koror.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

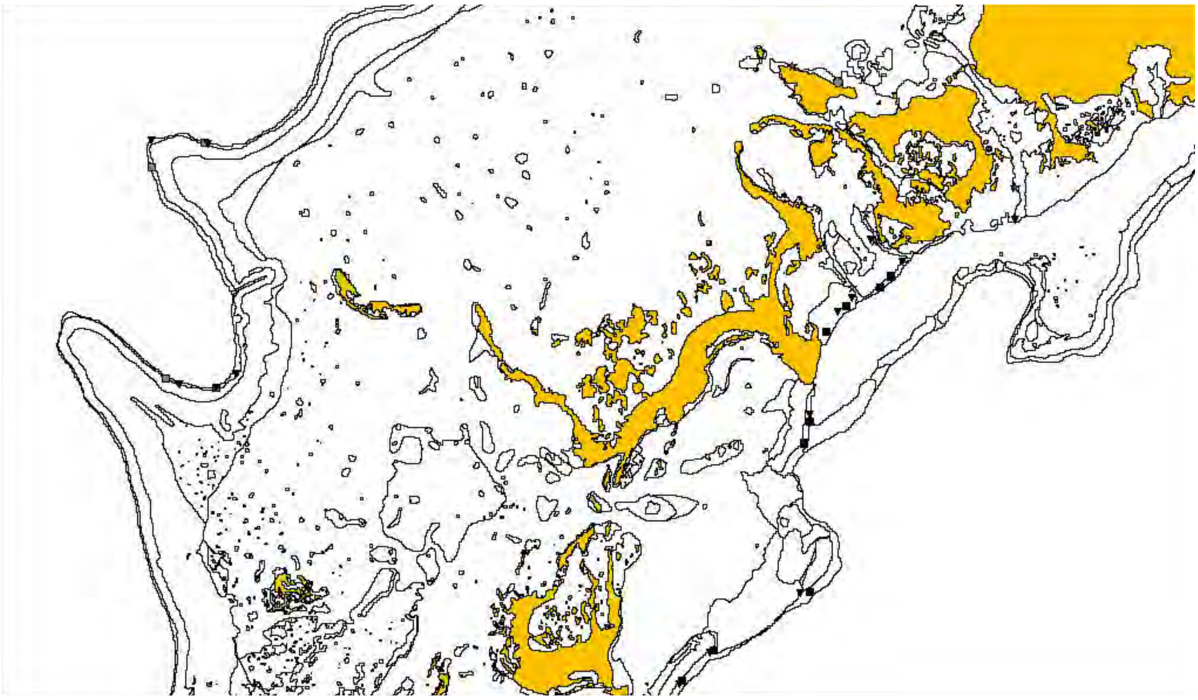

Figure 5.27: Fine-scale survey stations for invertebrates in Koror.
inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey diamonds: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Seventy-five species or species groupings (groups of species within a genus) were recorded in the Koror invertebrate surveys: 15 bivalves, 21 gastropods, 22 sea cucumbers, 4 urchins, 6 sea stars, 1 cnidarian and 3 lobsters (Appendix 4.4.1). Information on key families and species is detailed below.

5.4.1 Giant clams: Koror

Shallow-reef habitat that is suitable for giant clams was very extensive at Koror (81.4 km²: approximately 59.3 km² within the lagoon and 22.1 km² on the reef front or slope of the barrier reef). The lagoon area was very extensive (>666.4 km²) and hard substrate was available at the barrier reef, intermediate, and shoreline or coastal reef.

Despite the high-island environment present, the influence from the land (riverine inputs) did not generally limit the distribution of clams, as water movement was generally very dynamic throughout the system. Water movement through passages in the barrier reef was noted all the way into the small embayments near the town of Koror. In addition, the reefs traversed a variety of depths and exposure grades suitable for the broad range of clams found in Palau.

Using all survey techniques, seven species of giant clam were noted. Broad-scale sampling provided a good overview of giant clam distribution and density, and the six clam species recorded in broad-scale surveys were: the elongate clam *Tridacna maxima*, the boring clam *T. crocea*, the fluted clam *T. squamosa*, the smooth clam *T. derasa*, the horse-hoof or bear's paw clam *Hippopus hippopus*, and the china clam *H. porcellanus*. *H. porcellanus* has not been recorded before in CoFish surveys in the Pacific and has a limited distribution (Philippines to western Irian Jaya). The hatchery-reared true giant clam *T. gigas* was seen in large numbers near the fisheries harbour in Koror, but none were recorded during broad-scale surveys on reefs.

Records from broad-scale sampling revealed that *T. crocea* had the widest occurrence (found in 12 stations and 69 transects) followed by *T. maxima* (9 stations and 37 transects), *T. squamosa* (9 stations and 17 transects) and *T. derasa* (2 stations and 3 transects). *H. hippopus*, which is well camouflaged and usually relatively sparsely distributed, was recorded in 5 stations (7 transects in total). This was the first time for our researchers to see *H. porcellanus* (2 stations and 2 transects), a less common species than *H. hippopus* (Figure 5.28).

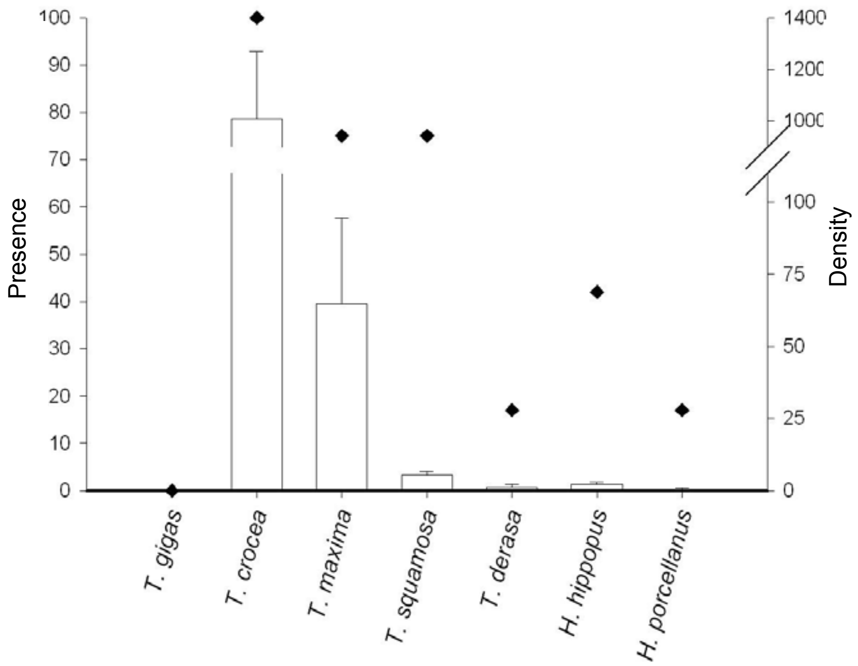

Figure 5.28: Presence and mean density of giant clam species at Koror based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 5.29). In these reef-benthos assessments (RBt), *T. crocea* was present in 100% of stations, the highest station density being 5666.7 clams/ha ±647.6. *T. maxima* was also relatively common (in 60% of stations), with moderate density. *T. squamosa* had a good coverage (in 68.4% of stations) and relatively high density in these shallow-water locations. Three stations contained average densities of 125 clams/ha for *T. squamosa*, and one station had a similar density for *H. hippopus*, both of which species are normally recorded at lower density around the Pacific. *T. derasa* were recorded only rarely (Figure 5.29) in both broad-scale and reef-benthos transects.

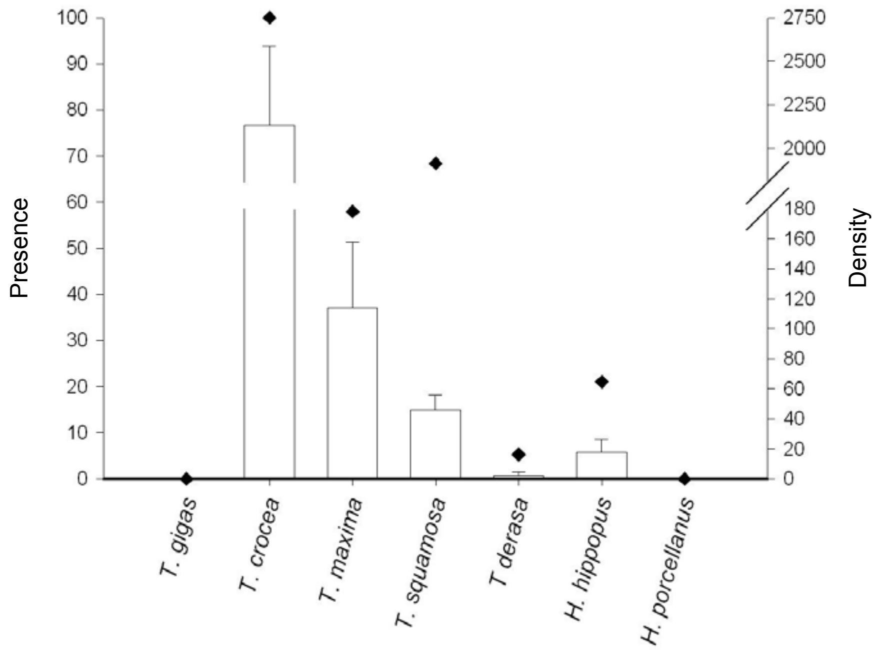

Figure 5.29: Presence and mean density of giant clam species at Koror based on reef-benthos transect survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

A full range of sizes was recorded for *T. crocea* (mean size 7.4 cm ±0.1) and *T maxima* (mean size 14.5 cm ±0.3) in survey. *T. maxima* from reef-benthos transects alone (shallow-water reefs) had a slightly smaller mean length (13.7 cm ±0.8), which represents a clam of about 6 years old.

A full range of sizes was recorded for the faster-growing *T. squamosa* (which grows to an asymptotic length L_∞ of 40 cm). This species averaged 20.6 cm shell length ±1.2, which equates to a clam of approximately 5–6 years of age. *H. hippopus* (mean size 22.8 cm ±1.0) is generally well camouflaged on the benthos, especially at smaller size classes, and therefore the lack of small size classes in the distribution does not necessarily indicate recruitment failure. *H. porcellanus* (mean length 28.5 cm ±3.5), the less common *Hippopus* species, was not recorded in shallow reef-benthos transect surveys. The seven *T. derasa* clams had a mean size of 28.7 cm ±3.5; the smallest of these clams was a juvenile at 7 cm (Figure 5.30). Only one individual *T. gigas* (which can reach adult lengths in excess of 1.3 m) was recorded in Koror. This clam was 60 cm in length.

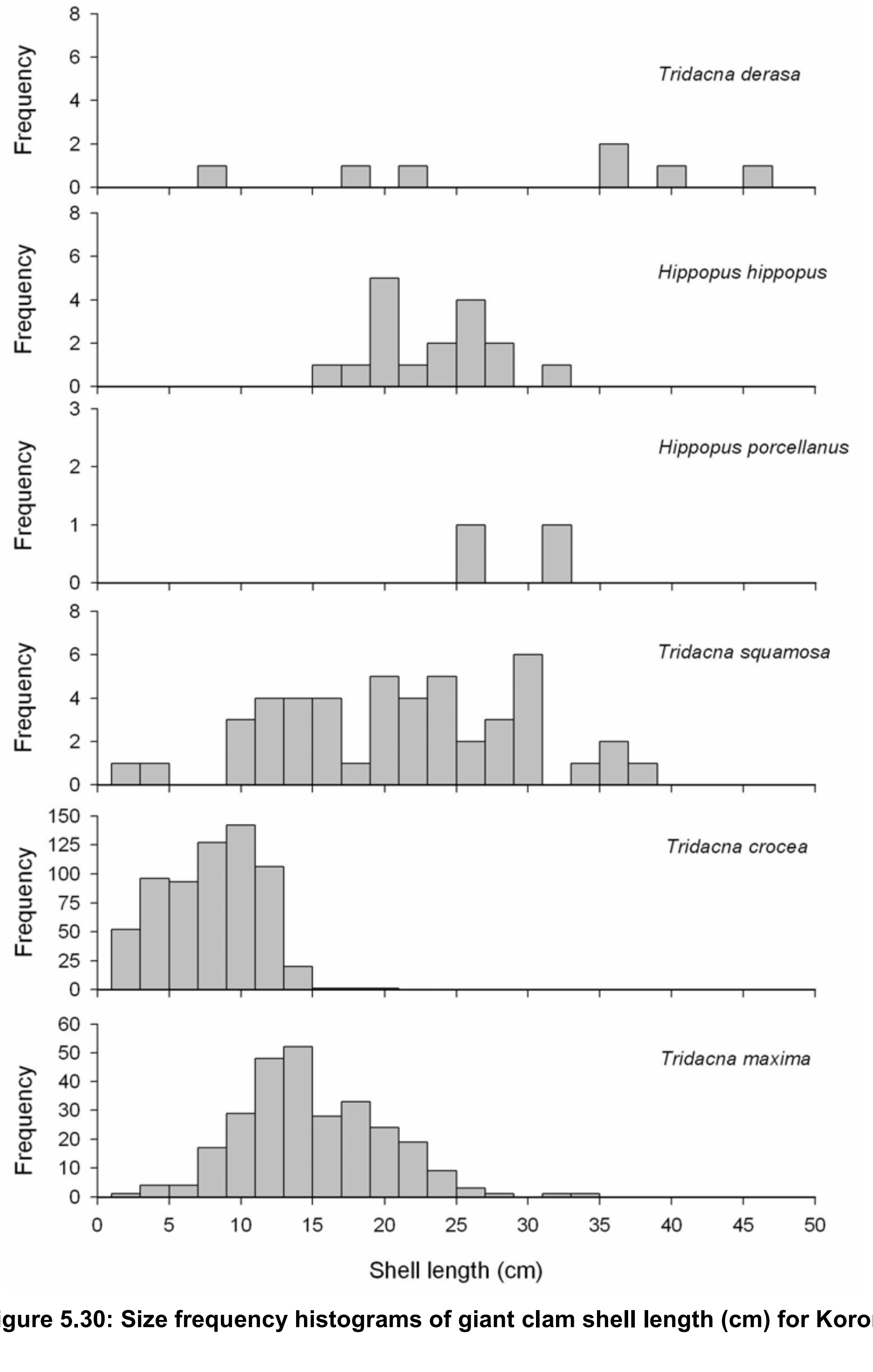

Figure 5.30: Size frequency histograms of giant clam shell length (cm) for Koror.

5.4.2 Mother-of-pearl species (MOP): trochus and pearl oysters – Koror

Palau is within the natural distribution range of the commercial topshell *Trochus niloticus* in the Pacific. Due to the reef aspect and water movement regime, the barrier reef (outer and back-reef) intermediate reef, and coastal reefs constitute an extensive benthos for *T. niloticus* at Koror. CoFish survey work revealed that *T. niloticus* was present across most reefs in the lagoon, but was at greatest density on inshore reefs and reefs associated with water flows in passages. This area (61.8 km lineal distance of exposed reef perimeter) supports significant numbers of trochus, which are concentrated in aggregations around specific reefs in the system. In general, reef slopes at the exposed side of the barrier reef had suitable, if not extensive, shoals before sloping into deeper water, and gaps in the barrier reef subjected more inshore reefs to conditions preferred by trochus. Trochus on barrier reefs and outer-reef slopes were generally only found at low density, with some exceptions in the southeast. The most significant trochus aggregations were very localised, and these important 'core' reefs held significant numbers of trochus. The management of the trochus fishery in Palau allows commercial fishing only once every 3–4 years, with subsequent rest periods for stock recovery.

CoFish survey work revealed that *T. niloticus* was present on both the barrier reef (outer-reef slope and back-reef) and on reefs within the lagoon and coastal areas (Table 5.12).

Table 5.12: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Koror.
Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
B-S	12.5	4.1	5/12 = 42	17/72 = 24
RBt	230.3	151.1	6/19 = 32	21/114 = 18
RFs	76.1	22.3	12/15 = 80	55/90 = 61
MOPt	613.4	97.4	9/9 = 100	51/54 = 94
MOPs	7.6	3.1	3/4 = 75	4/24 = 17
Tectus pyramis				
B-S	1.6	0.8	3/12 = 25	4/72 = 6
RBt	144.7	65.5	6/19 = 32	25/114 = 22
RFs	10.5	3.0	10/15 = 67	24/90 = 27
MOPt	99.5	24.5	9/9 = 100	24/54 = 44
MOPs	3.8	3.8	1/4 = 25	1/24 = 4
Pinctada margaritifera				
B-S	0.7	0.4	3/12 = 25	3/72 = 4
RBt	2.2	2.2	1/19 = 25	1/114 = 1
RFs	0.3	0.3	1/15 = 7	1/90 = 1
MOPt	0.0	0.0	0/9 = 0	0/54 = 0
MOPs	2.5	1.6	0/4 = 0	0/24 = 0

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

A total of 720 trochus were recorded during the survey (n = 553 were measured), which was 40% of the trochus noted in the four sites surveyed in Palau. The majority of the stock was on very shallow reef (~1.5 m deep), which is easily accessible to fishers working with a mask and snorkel.

Trochus density, as measured by average densities recorded through reef-benthos transect stations, was 42–2875 trochus/ha in the 32% of stations holding trochus. In MOPt surveys, all stations held trochus and the density was 229–917 trochus/ha.

Highest-density aggregations were recorded at southeasterly sites. At these sites, 5% of reef-benthos stations supported densities of trochus at >500 trochus/ha. In assessments of the main aggregations made on SCUBA (MOPt stations), 67% of stations in Koror had densities higher than the 500–600 /ha. threshold, which is the recommended minimum density that main aggregations should reach before commercial fishing can be considered.

Shell size also gives important information on the status of stocks by highlighting new recruitment, or the lack of recruitment into the fishery, which could have implications for the numbers of trochus entering the capture size classes in the following two years.

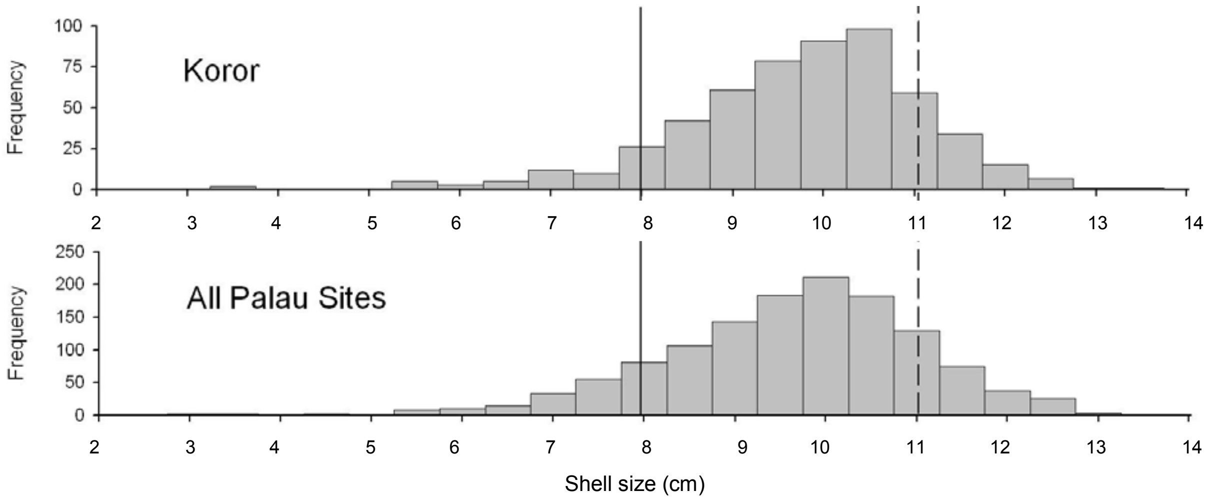

Figure 5.31: Size frequency histograms of *Trochus niloticus* shell base diameter (cm) for Koror and all Palau sites.

The mean basal width of trochus at Koror was 9.6 cm ±0.6 (Figure 5.31). A shell of 9.6 cm basal width weighs approximately 250 g. This indicates that the bulk of stock at Koror is within the capture-size classes, and there was no large recruitment pulse of young trochus evident (First maturity of trochus is at 7–8 cm or 3 years old.). For this cryptic species, younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic style of life and joining the main stock. This portion of the population was not strong in number from survey results taken from reefs in Koror.

In addition, only 8.9% of the stock was from size classes >11 cm basal width, which is a relatively small proportion of mature shells for a population. In some other trochus fisheries, where stock has not been fished for an extended period or where there is a maximum basal width for commercial sale (shells >11 cm are protected from fishing), this portion of the stock makes up 20–50% of the population. The result from Koror can be interpreted as an indication of the level of fishing in previous harvests. Low numbers of large shells may indicate that trochus stocks were comprehensively targeted during the previous two fishing periods (in 2000 and 2005).

The suitability of reefs for grazing gastropods was also highlighted by results collected for the false trochus or green topshell (*Tectus pyramis*). This related, but less valuable species of topshell (an algal-grazing gastropod with a similar life history to trochus) was abundant at Koror (n = 165 recorded in survey). The mean size (basal width) of *T. pyramis* was 5.4 cm ±0.1 (Figure 5.32). Small *Tectus* shells (<5.5 cm) were recorded in survey, but again no large recruitment pulses were identified, which may suggest that conditions for recent spawning and/or settlement of these gastropods may not have been especially favourable in recent years.

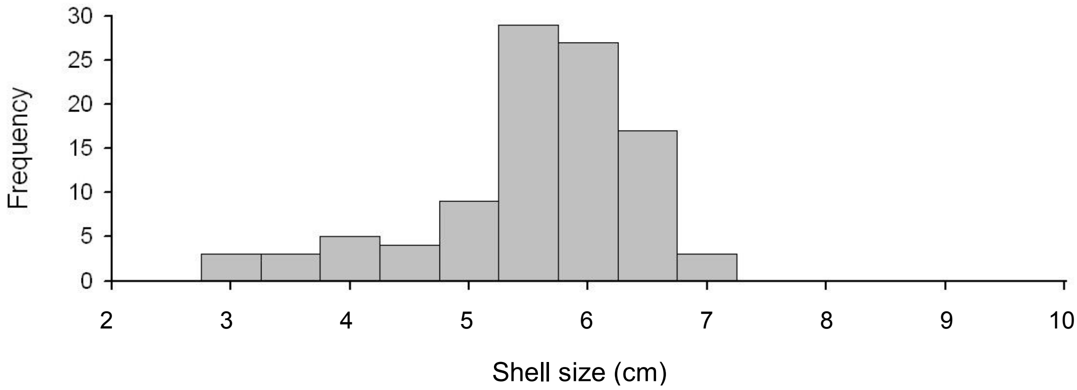

Figure 5.32: Size frequency histogram of the 'false' trochus *Tectus pyramis* shell base diameter (cm) for Koror.

Another mother-of-pearl species, the blacklip pearl oyster *Pinctada margaritifera*, is cryptic and normally sparsely distributed in open lagoon systems (such as found at Koror). In survey the number of blacklip seen was low (n = 5). The mean shell length (anterior–posterior measure) was 15.6 cm ±2.3.

5.4.3 Infaunal species and groups: Koror

Soft benthos at the coastal margins of Koror supports extensive areas of seagrass, but meadows were very sparsely populated by infaunal invertebrate resources and assessments concentrated on the important trochus fishery. As no concentrations of in-ground resources (shell 'beds') were noted, no infaunal 'digging' stations (quadrat surveys) were completed.

5.4.4 Other gastropods and bivalves: Koror

Seba's spider conch *Lambis truncata* (the larger of the two common spider conchs) was rare in survey (n = 1) and *Lambis lambis* was also moderately rare (n = 1 in broad-scale survey, and n = 16 in surveys of shallow-water reef and soft benthos, density 2.8–13.2 /ha). The only other *Lambis* species recorded was *L. chiragra*. The strawberry or red-lipped conch *Strombus luhuanus* was also rare, and was not noted in any formal assessments in Koror (Appendices 4.4.1 to 4.4.9).

Two species of turban shell: *Turbo agyrostomus* and *T. chrystostomus* were recorded during surveys. The larger silver-mouthed turban *T. agyrostomus* was not common (recorded in 33% of reef-front search stations) but was found at a reasonable density in reef-benthos transect surveys (19.7 /ha ±10.7). Other resource species targeted by fishers (e.g. *Astralium*, *Cassis*, *Cerithium*, *Charonia*, *Conus*, *Cypraea*, *Latirolagena*, *Pleuroploca*, *Tectus*, *Tutufa* and *Vasum*) were also recorded during independent surveys (Appendices 4.4.1 to 4.4.9).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Atrina*, *Chama*, *Hyotissa*, *Malleus*, and *Spondylus*, are also in Appendices 4.4.1 to 4.4.9. No creel survey was conducted at Koror.

5.4.5 Lobsters: Koror

There was no dedicated night reef-front assessment of lobsters (See Methods.). However, in addition to general day surveys, night-time assessments (Ns) for nocturnal sea cucumber species offered a further opportunity to record lobster species. Lobsters (*Panulirus versicolor* and *P.* spp.) were relatively common in survey (n = 24); about half of these were recorded using SCUBA. The prawn killer (*Lysiosquillina maculata*, n = 1) was also noted in broad-scale survey.

5.4.6 Sea cucumbers[10]: Koror

Around Koror there are extensive areas of shallow and deepwater lagoon (~666.4 km²) bordering the elevated land mass of Koror and the main island of Babeldaob. Reef margins, and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) were extensive throughout the lagoon (Sea cucumbers eat detritus and other organic matter in the upper few mm of bottom substrates.). Riverine inputs (and other inputs from land) were not very notable in most areas, apart from during periods of heavy rain, as water movement (flushing of oceanic water) was dynamic and the system was generally ocean-influenced. Despite the active water flow, there was a range of habitats suitable for sea cucumbers: from inshore seagrass areas close to Koror, to more exposed reef habits at the westerly and easterly barrier reefs. The presence and density of sea cucumber species were determined through broad-scale, fine-scale and dedicated survey methods (Table 5.13, Appendices 4.4.2 to 4.4.9; see also Methods). Results from the full range of assessments yielded 22 commercial species of sea cucumber (plus one indicator species; see Table 5.13).

A sea cucumber species associated with shallow-reef areas, the medium-value leopardfish (*Bohadschia argus*) was well distributed (found in 32% of reef-benthos transects) and recorded at reasonable but not high density (19.7 /ha ±7.4). The high-value black teatfish (*Holothuria nobilis*) was relatively common for a species easily targeted by industry (found in 26–28% of broad-scale transects and RBt stations) and was recorded at high density in shallow-reef transect stations (43.9 /ha ±23.9). The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was also common (in 33% of broad-scale transects and 47% of reef-benthos transects) at relatively high density (206.1 /ha ±94.4; see Appendix 4.4.3).

Although not overly common, the surf redfish (*Actinopyga mauritiana*) was recorded in a range of assessments. As this species is mostly found, where its name suggests, on reef fronts, reef-front searches provide a valuable signal on its status. In Koror, 47% of reef-front searches held *A. mauritiana*, but not at high densities (generally <20 /ha). In other locations in the Pacific, this species can be recorded at densities >400–500 /ha.

More protected areas of reef and soft benthos in the more enclosed areas of the lagoon also returned relatively good numbers of sea cucumbers. Curryfish (*Stichopus hermanni*) was not common or at high density but brown curryfish (*S. vastus*) was recorded in some very high-density patches. Blackfish (*Actinopyga miliaris*) and stonefish (*A. lecanora*) were recorded but the species of interest locally was a currently unnamed *Actinopyga* sp. nov. (This is currently being described.)

In Palau, the three species of sea cucumbers exploited by the subsistence fishery and traditionally eaten are *Actinopyga* sp. nov., *Stichopus vastus* and *Holothuria impatiens*

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

(*H. atra* is sometimes used as a neurotoxin for catching octopus.). *Actinopyga* sp. nov. has three colour morphs and is prepared by gutting and cleaning the animal before the body wall is finely chopped up and mixed with lime juice and sauce for use as a sashimi.

In Koror, the lower-value species of sea cucumbers, e.g. lollyfish (*H. atra*) and pinkfish (*H. edulis*) were also present at reasonable densities. No high-value sandfish (*H. scabra*) was found in Koror, but mangrove shorelines were less common in this state (This species generally prefers a 'richer' seagrass shoreline environment.). However, the low-value false sandfish (*Bohadschia similis*), which uses the same habitat as sandfish, was present in small numbers.

Deepwater assessments (30 five-minute searches, average depth 16 m, maximum depth 30 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos with suitably dynamic water movement was present at a large scale around Koror but *H. fuscogilva* was only recorded in two of the five stations surveyed. One station, which anecdotal reports revealed had supplied sea cucumbers to the fishery in previous years, yielded very high densities of white teatfish. At this passage station, the average station density for *H. fuscogilva* was 109.5 /ha. ±31.2, but in general the density of other deepwater species was not high.

5.4.7 Other echinoderms: Koror

At Koror, no edible collector urchin *Tripneustes gratilla* or slate urchin *Heterocentrotus mammillatus* were recorded in survey. Urchins, such as *Diadema* spp. and *Echinothrix* spp., can be used within assessments as potential indicators of habitat condition. These species and *Echinometra mathaei* were recorded at relatively low levels in survey at Koror (Appendices 4.4.2 to 4.4.9).

Starfish (e.g. *Linckia laevigata* the blue starfish, and *L. guildingi*) were relatively common (found in 56% of broad-scale transects) and were at moderate density. Corallivore (coral eating) starfish were quite common, with 47 recordings of the pincushion star (*Culcita novaeguineae*) and 40 crown-of-thorns starfish (*Acanthaster planci*) noted in survey.

The crown-of-thorns starfish 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/year. These starfish begin to eat coral at about six months of age (1 cm in size) and grow over two years to about 25 cm in diameter. During a severe outbreak, there can be several crown-of-thorns starfish/m^2 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. The most crown-of-thorns starfish recorded in surveys were noted along channel reefs, southeast of Koror. The density recorded was 7–11 /ha. in broad-scale and reef-benthos transect assessments. Although at relatively high density in some areas (compared to other reefs assessed in the Pacific), the numbers recorded are not indicative of a general active outbreak.

On the Great Barrier Reef of Australia, the following system is used for defining outbreaks of crown-of-thorns starfish (COTS):

- ***Incipient outbreak***: the density at which coral damage is likely. Occurs when there are 0.22 adults recorded per 2-minute manta tow; or >30 adults and subadults per ha. using

SCUBA diving counts. (Starfish may be mature at 2 years or at a size of 20 cm diameter but, for the definition of an outbreak, an indicator size of >26 cm is used.).

- ***Active outbreak***: COTS densities are >1.0 adults per 2-minute manta tow or, if SCUBA diving, at a density of >30 starfish (adults only) per ha.

The horned or chocolate chip star (*Protoreaster nodosus*) was sometimes recorded at high density and doughboy sea stars (*Choriaster granulatus*) were noted on occasion at an average depth of 15 m at low density.

Table 5.13: Sea cucumber species records for Koror

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 19; SBt = 13			Other stations RFs = 15; MOPt = 9; MOPs = 4			Other stations Ds = 5; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinities	Deepwater redfish	M/H												
Actinopyga lecanora	Stonefish	M/H	0.2	16.7	1				2.3	20.8	11 MOPt			
Actinopyga mauritiana	Surf redfish	M/H	1.1	27.1	4	11.0	69.4	16 RBt	6.8 16.2	14.6 48.6	47 RFs 33 MOPt			
Actinopyga miliaris	Blackfish	M/H	2.0	29.3	7				1.9	7.6	25 MOPs	1.4 4.4	7.1 8.9	20 Ds 50 Ns
Actinopyga sp. nov.	Undescribed species	M				12.8	83.3	15 SBt						
Bohadschia argus	Leopardfish	M	6.0	26.9	22	19.7	62.5	32 RBt	17.5 9.3	65.7 83.3	27 RFs 11 MOPt	4.3	7.1	60 Ds
Bohadschia graeffei	Flowerfish	L	3.7	33.3	11	4.4	41.7	11 RBt	1.0	7.8	13 RFs	1.9	4.8	40 Ds
Bohadschia similis	False sandfish	L				3.2	41.7	8 SBt						
Bohadschia vitiensis	Brown sandfish	L	0.5	16.7	3	125	541.7	23 SBt	0.8	11.8	7 RFs			
Holothuria atra	Lollyfish	L	36.3	58.0	62	94.3 7689	199.1 7689	47 RBt 100 SBt	22.7	42.6	53 RFs	3.3	16.7	20 Ds
Holothuria coluber	Snakefish	L	2.3	55.6	4	21.9	208.3	11 RBt				13.3	13.3	100 Ns
Holothuria edulis	Pinkfish	L	45.6	126.2	36	59.2	140.6	50 RBt	8.9	33.3	27 RFs	7.1	17.9	40 Ds
Holothuria flavomaculata		L	3.4	41.1	8	21.9	104.2	21 RBt	5.5	82.4	7 RFs	400	400	100 Ns
Holothuria fuscogilva [4]	White teatfish	H	0.7	16.7	4							23.8	59.5	40 Ds
Holothuria fuscopunctata	Elephant trunkfish	M	5.3	76.7	7	2.2	41.7	5 RBt	10.7	80.4	13 RFs	3.3	5.6	60 Ds
Holothuria nobilis [4]	Black teatfish	H	15.2	54.8	28	43.9	166.7	26 RBt	15.2 23.1	32.5 52.1	47 RFs 44 MOPt	1.0	2.4	40 Ds
Holothuria scabra	Sandfish	H												
Stichopus chloronotus	Greenfish	H/M	49.3	147.8	33	206.1	435.2	47 RBt	40.8 48.6	87.4 145.8	47 RFs 33 MOPt			
Stichopus hermanni	Curryfish	H/M	3.5	27.6	12.5	8.8	55.6	16 RBt	5.2	39.2	13 RFs	7.1	8.9	80 Ds

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

Table 5.13: Sea cucumber species records for Koror (continued)

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 19; SBt = 13			Other stations RFs = 15; MOPt = 9; MOPs = 4			Other stations Ds = 5; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Stichopus horrens	Peanutfish	M/L										17.8	17.8	100 Ns
Stichopus vastus	Brown curryfish	H/M	0.2	16.7	1	586.5	953.1	62 SBt				13.3	13.3	100 Ns
Synapta spp.	-	-				41.7	135.4	31 SBt						
Thelenota ananas	Prickly redfish	H	5.3	34.8	15	4.4	41.7	11 RBt	6.8 6.9	14.6 31.3	47 RFs 22 MOPt	4.8	7.9	60 Ds
Thelenota anax	Amberfish	M	1.4	33.3	4				8.1	121.6	7 RFs			

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

5.4.8 Discussion and conclusions: invertebrate resources – Koror

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

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

- The range of shallow-water reef habitats and dynamic water movement regime around Koror provides extensive areas suitable for giant clams. There was a complete range of giant clam species present, some of which are becoming rare in other parts of the Pacific. There were few management issues with the smaller species of clams (*Tridacna maxima* and *T. crocea*).

- The large true giant clam, *T. gigas*, was noticeably missing from many areas of Koror compared to similar sites in other parts of Palau. Stocks of *T. squamosa*, the fluted clam, were common in distribution around the lagoon but at lower density than expected. This species, together with *Tridacna derasa* and *T. gigas* need the most support if further management measures are to be implemented.

- In general, the status of giant clams at Koror was reasonably healthy, especially for the most common species. Clam density and the 'full' range of clam size classes present support the assumption that, apart from some of the largest species, populations of giant clam are only partially impacted by fishing.

Distribution, density and length recordings give a mixed picture of MOP stock health:

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

- *Trochus niloticus* is common, and local reef conditions constitute excellent habitat for adult and juvenile trochus. Commercial stocks are most common at easily accessible shallow-water reefs inside the lagoon; generally those fringing the mainland or influenced by passage water flows.

- The density of trochus noted in survey suggests that stocks are healthy, but 'core' aggregations (where trochus are typically in greatest abundance) still have significant potential for growth in individual size and overall abundance, while 'non-core' areas are currently holding only limited densities of stock.

- Trochus size-class information reveals that previous harvests have comprehensively fished the stock. There are few aggregations dominated by old shells. Size-class information also reveals that commercial-sized shells are still relatively small (with a year or two to spend in the important commercial size ranges), and that no strong year-class is currently visible below the commercial size class range.

Considerations for future management of trochus:

- On occasion, the three-year resting period currently adopted in Palau may be too short for continued successful management of the fishery. Firstly, this approach relies on there being regular recruitment (i.e. no recruitment failures) which is uncommon with mollusc fisheries in general (Strong recruitment year-classes only generally arrive every 3–5 years). Secondly, most egg production originates from the largest individuals of the population, and trochus only reach these size classes at ≥6 years of age (from shells that would need to survive two harvest rotations under the current management scenario).

Survey work for sea cucumbers suggested the following:

- Koror had a diverse range of environments and depths suitable for sea cucumbers, and had many embayments protected from exposure within the rock island system that is characteristic of Koror. Although the scale of the land masses was significant, the oceanic influence generally prevailed in the dynamic lagoon system.

- The range of sea cucumber species recorded at Koror was wide, partially reflecting the varied environment, but also the fact that the export fishery is highly controlled.

- The presence and density data collected in survey suggest that sea cucumbers are not under significant fishing pressure and commercial export stocks are only lightly or moderately affected by previous fishing. The species fished by domestic fishers for subsistence are more impacted relative to other sites around Palau, and fishers were already travelling to Babeldaob to access stocks at higher density.

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

5.5 Overall recommendations for Koror

- Implementation of regulations and patrolling of reserves not be limited to dive sites.

- Spearfishing be controlled and regulated.

- A monitoring system be planned with community input to strictly observe changes in resources since even the healthiest sites showed first signs of a decrease in finfish resources.

- BMR consider attempting to get most of the ‘core’ trochus fishery areas up to a threshold density of approximately 500–600 /ha before considering commercial fishing.

- BMR consider protecting a proportion of trochus broodstock (sizes ≥11 cm) by creating a ‘gauntlet’ fishery, with an upper as well as a lower size limit, creating small no-fish areas within core areas of the fishery, and by ‘resting’ areas from commercial fishing within the main fishing locations for longer periods.

- Careful management of sea cucumber fishing could allow commercial harvesting of a number of export species in Palau. Preferably, the allowance of such a harvest would adopt a pulse-harvest fishing strategy, currently employed for trochus, which allows a period of rest between fishing events and time to re-assess the stocks response to fishing pressure.

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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).

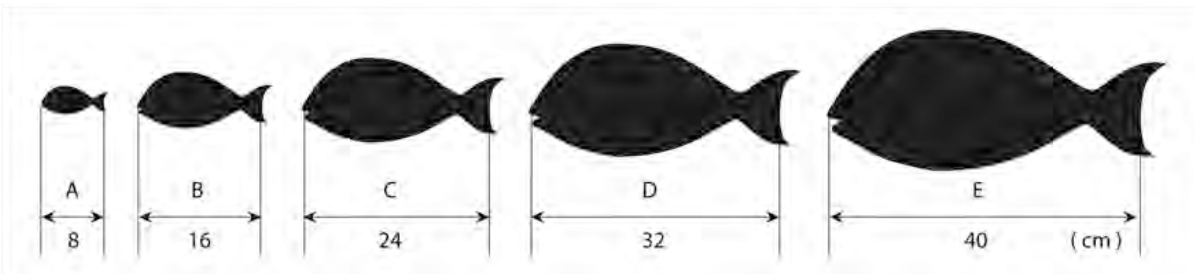

Figure A1.1.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).

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

[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.

0.83 = correction factor for consumption frequency

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

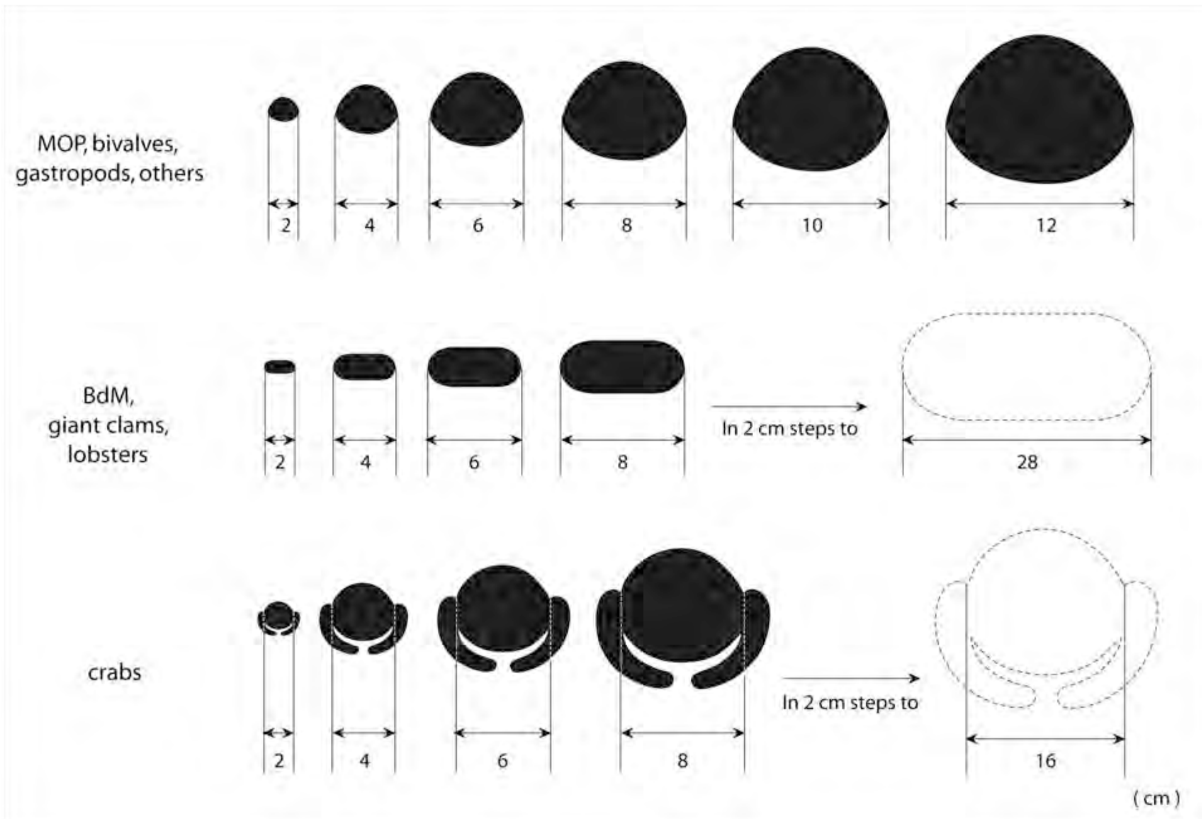

Figure A1.1.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).

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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).

Appendix 1: Survey methods
Socioeconomics

Data from the household survey regarding the number of fishers (by gender and type of fishery) in each household interviewed are extrapolated to determine the total number of men and women that target finfish, invertebrates, or both.

Data from the fisher survey are used to determine what proportion of men and women fishers target various habitats or combinations of habitats. These figures are assumed to be representative of the community as a whole, and hence are applied to the total number of fishers (as determined by the household survey). The total number of finfish fishers is the sum of all fishers who solely target finfish, and those who target both finfish and invertebrates; the same system is applied for invertebrate fishers (i.e. it includes those who collect only invertebrates and those who target both invertebrates and finfish. These numbers are also disaggregated by gender.

The total annual catch per fisher interviewed is calculated, and the average total annual catch reported for each type of fishing activity/fishery (including finfish and invertebrates) by gender is then multiplied by the total number of fishers (calculated as detailed above, for each type of fishing activity/fishery and both genders). More details on the calculation applied to invertebrate fisheries are provided below.

Total annual catch (t/year):

$$\text{TAC} = \sum_{h=1}^{N_h} \frac{Fif_h \bullet Acf_h + Fim_h \bullet Acm_h}{1000}$$

TAC = total annual catch t/year
Fif_h = total number of female fishers for habitat_h
Acf_h = average annual catch of female fishers (kg/year) for habitat_h
Fim_h = total number of male fishers for habitat_h
Acm_h = average annual catch of male fishers (kg/year) for habitat_h
N_h = number of habitats

Where:

$$\text{Acf}_\text{h} = \frac{\sum_{i=1}^{If_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12} \bullet Cfi}{If_h} \bullet \frac{\sum_{k=1}^{Rf_h} f_k \bullet 52 \bullet 0.83 \bullet \frac{Fm_k}{12}}{\sum_{i=1}^{If_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12}}$$

If_h = number of interviews of female fishers for habitat_h (total number of interviews where female fishers provided detailed information for habitat_h)
f_i = frequency of fishing trips (trips/week) as reported on interview_i
Fm_i = number of months fished (reported in interview_i)
Cf_i = average catch reported in interview_i (all species)
Rf_h = number of targeted habitats as reported by female fishers for habitat_h (total numbers of interviews where female fishers reported targeting habitat_h but did not necessarily provide detailed information)
f_k = frequency of fishing trips (trips/week) as reported for habitat_k
Fm_k = number of months fished for reported habitat_k (fishers = sum of finfish fishers and mixed fishers, i.e. people pursuing both finfish and invertebrate fishing)

Thus, we obtain the total annual catch by habitat and gender group. The sum of all catches from all habitats and both genders equals the total annual impact of the community on its fishing ground.

The accuracy of this calculation is determined by reliability of the data provided by interviewees, and the extrapolation procedure. The variability of the data obtained through fisher surveys is illuminated by providing standard errors for the calculated average total annual catches. The size of any error stemming from our extrapolation procedure will vary according to the total population at each site. As mentioned above, this approach is best suited to assess small and predominantly traditional coastal communities. Thus, the risk of over- or underestimating fishing impact increases in larger communities, and those with greater urban influences. We provide both the total annual catch by interviewees (as determined from fisher records) and the extrapolated total impact of the community, so as to allow comparison between recorded and extrapolated data.

The total annual finfish consumption of the surveyed community is used to determine the share of the total annual catch that is used for subsistence, with the remainder being the proportion of the catch that is exported (sold externally).

<u>Total annual finfish export:</u>

$$E = TAC - \left(\frac{F_{tot}}{1000} \bullet \frac{1}{0.8}\right)$$

Where:

E = total annual export (t)
TAC = total annual catch (t)
F_{tot} = total annual finfish consumption (net weight kg)
$\frac{1}{0.8}$ = to calculate total biomass/weight, i.e. compensate for the earlier deduction by 0.8 to determine edible weight parts only

In order to establish <u>fishing pressure</u>, we use the habitat areas as determined by satellite interpretation. However, as already mentioned, resource surveys and satellite interpretation do not include lagoon areas. Thus, we determine the missing areas by calculating the smallest possible polygon (Figure A1.1.3) that encompasses the total fishing ground determined with fishers and local people during the fieldwork. In cases where fishing grounds are gazetted, owned and managed by the community surveyed, the missing areas are determined using the community's fishing ground limits.

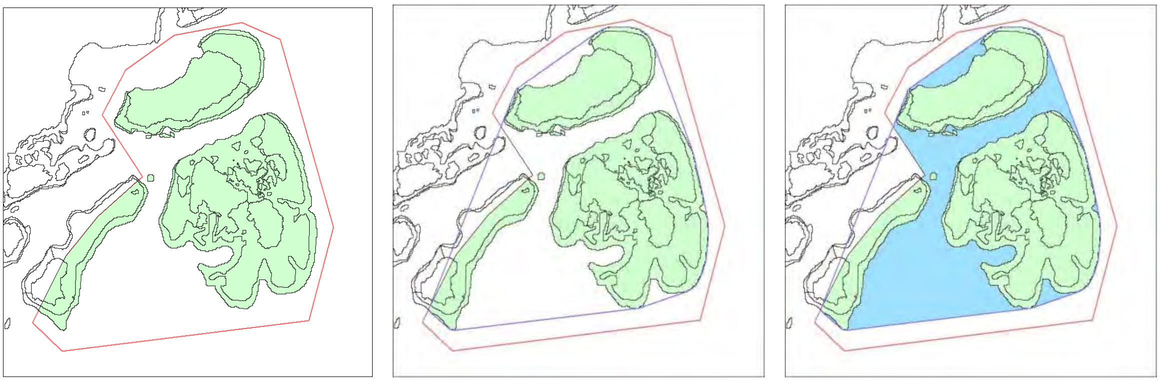

Figure A1.1.3: Determination of lagoon area.
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled as lagoon (in blue) (Developed using MapInfo).

We use the calculated total annual impact and fishing ground areas to determine relative fishing pressure. Fishing pressure indicators include the following:

- annual catch per habitat
- annual catch per total reef area
- annual catch per total fishing ground area.

Fisher density includes the total number of fishers per km^2 of reef and total fishing ground area, and productivity is the annual catch per fisher. Due to the lack of baseline data, we compare selected indicators, such as fisher density, productivity (catch per fisher and year) and total annual catch (per reef and total fishing ground area), across all sites for each country surveyed. This comparison may also be done at the regional level in the future.

The catch per unit effort (CPUE) is generally acknowledged as an indicator of the status of a resource. If an increasing amount of time is required to obtain a certain catch, degradation of the resource is assumed. However, taking into account that our project is based on a snapshot approach, CPUE is used on a comparative basis between sites within a country, and will be employed later on a regional scale. Its application and interpretation must also take into account the fact that fishing in the Pacific Islands does not necessarily follow efficiency or productivity maximisation strategies, but is often an integral component of people's lifestyles. As a result, CPUE has limited applicability.

In order to capture comparative data, in calculating CPUE we use the entire time spent on a fishing trip, including travel, fishing and landing. Thus, we divide the total average catch per fisher by the total average time spent per fishing trip. CPUE is determined as an overall average figure, by gender and habitat fished.

Invertebrate fisher survey

The objective, purpose and design of the invertebrate fisher survey largely follow those of the finfish fisher survey. Thus, the primary aim of the invertebrate fisher survey is to collect data needed to understand the strategies, patterns and dimensions of invertebrate fisheries, and hence the possible impacts on invertebrate resources. Invertebrate data collection faces several challenges, as retrieval of information from local people needs to match the resource survey parameters in order to enable joint data analysis. Some of the major issues are:

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(i) The invertebrate resource survey defines invertebrate fisheries using differing parameters (several are primarily determined by habitat, others by target species). However, these fisheries classifications do not necessarily coincide with the perceptions and fishing strategies of local people. In general, there are two major types of invertebrate fishers: those who walk and collect with simple tools, and those who free-dive using masks, fins, snorkel, hands, simple tools or spears. The latter group is often more commercially oriented, targeting species that are exploited for export (trochus, BdM, lobster, etc.). However, some of the divers may harvest invertebrates as a by-product of spearfishing for finfish. Fishers who primarily walk (some may or may not use non-motorised or even motorised transport to reach fishing grounds) are mainly gleaners targeting available habitats (or a combination of habitats, if convenient). While gleaning is often performed for subsistence needs, it may also be used as a source of income, albeit mostly serving national rather than export markets. While gleaning is an activity that may be performed by both genders, diving is usually men's domain.

We have addressed the problem of collecting information according to fisheries as defined by the resource survey by asking people to report according to the major habitats they target and/or species-specific dive fisheries they engage in. Very often this results in the grouping of various fisheries, as they are jointly targeted or performed on one fishing trip. Where possible, we have disaggregated data for these groups and allocated individuals to specific fisheries. Examples of such data disaggregation are the proportion of all fishers and fishers by gender targeting each of the possible fisheries at one site.

We have also disaggregated some of the catch data, because certain species are always or mostly associated with a particular fishery. However, the disagreement between people's perception and the resource classification becomes visible when comparing species composition per fishery (or combination of fisheries) as reported by interviewed fishers, and the species and total annual wet weight harvested allocated individually by fishery, as defined by the resource survey.

(ii) As is true for finfish, people usually provide information on invertebrate species by vernacular or common names, which are far less specific and thus not directly compatible with scientific nomenclature. Vernacular name systems are often very localised, changing with local languages, and thus may differ significantly between the sites surveyed in one country. Differing from finfish, vernacular names for invertebrates usually combine a group (often a family) of species, and are rarely species specific.

Similar to finfish, the issue of vernacular versus scientific names is addressed by trying to index as many scientific names as possible for any vernacular name recorded during the ongoing survey. Inconsistencies between informants are a limiting factor. The use of photographic indices is very useful, but may trigger misleading information; in addition, some reported species may not be depicted. Again, collaboration with local counterparts from fisheries departments is crucial.

The lack of specificity in the vernacular names used for invertebrates is an issue that cannot be resolved, and specific information regarding particular species that are included with others under one vernacular name cannot be accurately provided.

(iii) The assessment of possible fishing impacts is based on the collection of average data. This means that fishers are requested to provide information on a catch that is neither exceptionally good nor exceptionally bad. They are also requested to provide this information concerning the most commonly caught species. In the case of invertebrate fisheries this results in underestimation of the total number of species caught, and often greater attention is given to commercial species than to rare species that are used mainly for consumption. Seasonality of invertebrate species appears to be a less important issue than when compared to finfish.

We address these problems by encouraging people to also share with us the names of species they may only rarely catch.

(iv) Assessment of possible fishing impact requires knowledge of the size–weight relationship of (at least) the major species groups harvested. Unfortunately, a comparative tool (such as FishBase and others that are used for finfish) is not available for invertebrates. In addition, the proportion of edible and non-edible parts varies considerably among different groups of invertebrates. Further, non-edible parts may still be of value, as for instance in the case of trochus. However, these ratios are also not readily available and hence limit current data analysis.

We have dealt with this limitation by applying average weights (drawn from the literature or field measurements) for certain invertebrate groups. The applied wet weights are listed in Appendix 1.1.3. We used this approach to estimate total biomass (wet weight) removed; we have also listed approximations of the ratio between edible and non-edible biomass for each species.

Information on <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).

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The number of different vernacular names recorded for each fishery is useful to distinguish between opportunistic and specialised harvesting strategies. This distribution is particularly interesting when comparing gleaning fisheries, while commercial dive fisheries are species specific by definition.

The calculation of catch volumes is based on the determination of the total number of invertebrate fishers and fishers targeting both finfish and invertebrates, by gender group and by fishery, as described above.

The average invertebrate catch composition by number, size and species (with vernacular names transferred to scientific nomenclature), and by fishery and gender group, is extrapolated to include all fishers concerned. Conversion of numbers and species by average weight factors (Appendix 1.1.3) results in a determination of total biomass (wet weight) removed, by fishery and by gender. The sum of all weights determines the total annual impact, in terms of biomass removed.

To calculate total annual impact, we determine the total numbers of months fished by each interviewee. As mentioned above, seasonality of complementary activities, seasonal closing of fishing areas, etc. may result in distinct fishing patterns. Based on data provided by interviewees, we apply – as for finfish – a correction factor of 0.83 to take into account exceptional periods throughout the year when fishing is not possible or not pursued (this is determined on the basis that about two months (304/365 days) of each year are not used for fishing due to festivals, funerals and bad weather conditions).

Total annual catch:

$$\text{TACj} = \sum_{h=1}^{N_h} \frac{F_{inv}f_h \bullet Ac_{inv}f_{hj} + F_{inv}m_h \bullet Ac_{inv}m_{hj}}{1000}$$

TACj = total annual catch t/year for species$_j$
$F_{inv}f_h$ = total number of female invertebrate fishers for habitat$_h$
$Ac_{inv}f_{hj}$ = average annual catch by female invertebrate fishers (kg/year) for habitat$_h$ and species$_j$
$F_{inv}m_h$ = total number of male invertebrate fishers for habitat$_h$
$Ac_{inv}m_{hj}$ = average annual catch by male invertebrate fishers (kg/year) for habitat$_h$ and species$_j$
N_h = number of habitats

Where:

$$\text{Ac}_{\text{inv}}\text{f}_{\text{hj}} = \frac{\sum_{i=1}^{I_{inv}f_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12} \bullet Cf_{ij}}{I_{inv}f_h} \bullet \frac{\sum_{k=1}^{R_{inv}f_h} f_k \bullet 52 \bullet 0.83 \bullet \frac{Fm_k}{12}}{\sum_{i=1}^{I_{inv}f_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12}}$$

$I_{inv}f_h$ = number of interviews of female invertebrate fishers for habitat$_h$ (total numbers of interviews where female invertebrate fishers provided detailed information for habitat$_h$)
f_i = frequency of fishing trips (trips/week) as reported in interview$_i$

Fm_i = number of months fished as reported in interview$_i$
Cf_{ij} = average catch reported for species$_j$ as reported in interview$_i$
$R_{inv}f_h$ = number of targeted habitats reported by female invertebrate fishers for habitat$_h$ (total numbers of interviews where female invertebrate fishers reported targeting habitat$_h$ but did not necessarily provide detailed information)
f_k = frequency of fishing trips (trips/week) as reported for habitat$_k$
Fm_k = number of months fished for reported habitat$_k$

The total annual biomass (t/year) removed is also calculated and presented by species after transferring vernacular names to scientific nomenclature. Size frequency distributions are provided for the most important species, by total annual weight removed, expressed in percentage of each size group of the total annual weight harvested. The size frequency distribution may reveal the impact of fishing pressure for species that are represented by a wide size range (from juvenile to adult state). It may also be a useful parameter to compare the status of a particular species or species group across various sites at the national or even regional level.

To further determine fishing strategies, we also inquire about the purpose of harvesting each species (as recorded by vernacular name). Results are depicted as the proportion (in kg/year) of the total annual biomass (net weight) removed for each purpose: consumption, sale or both. We also provide an index of all species recorded through fisher interviews and their use (in percentage of total annual weight) for any of the three categories.

In order to gain an idea of the productivity of and differences between the fisheries practices used in each site we calculate the average annual catch per fisher, by gender and fishery. This calculation is based on the total biomass (net weight) removed from each fishery and the total number of fishers by gender group.

For invertebrate species that are marketed, detailed information is collected on total numbers (weight and/or combination of number and size), processing level, location of sale or client, frequency of sales and price received per unit sold. At this stage of our project we do not fully analyse this marketing information. However, prices received for major commercial species, as well as an approximation of sale volumes by fishery and fisher, help to assess what role invertebrate fisheries (or a particular fishery) play(s) in terms of income generation for the surveyed community, and in comparison to the possible earnings from finfish fisheries.

We use the calculated total annual impact in combination with the fishing ground area to determine relative fishing pressure. Fishing pressure indicators are calculated as the annual catch per km^2 for each area that is considered to support any of the fisheries present at each study site. In some instances (e.g. intertidal fisheries), areas are replaced by linear km; accordingly, fishing pressure is then related to the length (in km) of the supporting habitat. Due to the lack of baseline data, we compare selected indicators, such as the fisher density (number of fishers per km^2 – or linear km – of fishing ground, for each fishery), productivity (catch per fisher and year) and total annual catch per fishery, across all sites for each country surveyed. This comparison may also be done at the regional level in the future.

The differing nature of invertebrate species that may be caught during one fishing trip, and hence the great variability between edible and non-edible, useful and non-useful parts of species caught, make the determination of CPUE difficult. Substantial differences in the economic value of species add another challenge. We have therefore refrained from calculating CPUE values at this stage of the project.

Data entry and analysis

Data from all questionnaire forms are entered in the Reef Fisheries Integrated Database (RFID) system. All data entered are first verified and 'cleaned' prior to analysis. In the process of data entry, a comprehensive list of vernacular and corresponding scientific names for finfish and invertebrate species is developed.

Database queries have been defined and established that allow automatic retrieval of the descriptive statistics used when summarising results at the site and national levels.

1.1.2 Socioeconomic survey questionnaires

- Household census and consumption survey
- Finfish fishing and marketing survey (for fishers)
- Invertebrate fishing and marketing survey (for fishers)
- Fisheries (finfish and invertebrate and socioeconomics) general information survey

HOUSEHOLD CENSUS AND CONSUMPTION SURVEY

HH NO. ☐

Name of head of household: ________________ Village: _________________

Name of person asked: _____________________ Date: __________________

Surveyor's ID: __________________

1. Who is the head of your household? *(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:____

Appendix 1: Survey methods
Socioeconomics

INFORMATION BY FISHERY **Name of fisher: ______________** **HH NO.** ☐

coastal reef ☐ lagoon ☐ mangrove ☐ outer reef ☐

1. HOW OFTEN do you normally go out FISHING for this habitat? *(tick box)*

Every Day	5 days/ week	4 days/ week	3 days/ week	2 days/ week	1 day/ week	other, specify:
☐	☐	☐	☐	☐	☐	____________________

2. What time do you spend fishing this habitat per average trip? ____________________
(if the fisher can't specify, tick a box)

<2 hrs	2–6 hrs	6–12 hrs	>12 hrs
☐	☐	☐	☐

3. WHEN do you go fishing? *(tick box)* day ☐ night ☐ day & night ☐

4. Do you go all year?

Yes ☐ no ☐

5. If no, which months don't you fish?

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6. Which fishing techniques do you use (*in the habitat referred to here*)?

☐ handline

☐ castnet ☐ gillnet

☐ spear (dive) ☐ longline

☐ trolling ☐ spear (handheld) walking ☐ canoe ☐

☐ deep bottom line ☐ poison: which one? ______________

☐ other, specify: ____

7. Do you use more than one technique per trip for this habitat? If yes, which ones usually?

☐ one technique/trip ☐ more than one technique/trip:

____

8. Do you use ice on your fishing trips?

☐ always ☐ sometimes ☐ never

☐ is it homemade? ☐ or bought?

9. What is your average catch (kg) per trip? ☐ Kg <u>OR:</u>

size class:	A	B	C	D	E	>E (cm)
number:	☐	☐	☐	☐	☐	☐

10. Do you sell fish? yes ☐ no ☐

11. Do you give fish as a gift (for no money)? yes ☐ no ☐

12. Do you use your catch for family consumption? yes ☐ no ☐

13. How much of your usual catch do you keep for family consumption?

kg ☐ <u>OR:</u>

size class	A	B	C	D	E	>E (cm)
no	☐	☐	☐	☐	☐	☐

and the rest you gift? yes ☐

how much? kg ☐ <u>OR:</u>

size class	A	B	C	D	E	>E (cm)
no.	☐	☐	☐	☐	☐	☐

and/or sell? yes ☐

how much? kg ☐ <u>OR</u>:

size class	A	B	C	D	E	>E (cm)
no.	☐	☐	☐	☐	☐	☐

14. What sizes of fish do you use for your family consumption, what for sale and what do you give away without getting any money?

size classes:	all	A	B	C	D	E	and larger (no. and cm)
consumption	☐	☐	☐	☐	☐	☐	☐
sale	☐	☐	☐	☐	☐	☐	☐
give away	☐	☐	☐	☐	☐	☐	☐

15. You sell where?

☐ inside village ☐ outside village where? ___________________________

and to whom?

market ☐ agents/middlemen ☐ shop owners ☐ others ☐ ___________

16. In an average catch what fish do you catch, and how much of each species? *(write down the species in the table)*

technique usually used:____________________ boat type usually used:_______________
habitat usually fished: ____

Specify the number by size

Name of fish	kg	A	B	C	D	E	>E cm

20. Do you also fish invertebrates?

Yes ☐ no ☐ if yes for consumption? ☐ sale? ☐

–THANK YOU–

INVERTEBRATE FISHING AND MARKETING SURVEY
FISHERS

HH NO. ☐

Name: ____

Gender: ☐ female ☐ male Age: ☐

Village: ____

Date: ________________ Surveyor's name: ____________________

Invertebrates = everything that is not a fish with fins!

1. Which type of fisheries do you do?

☐ seagrass gleaning ☐ mangrove & mud gleaning

☐ sand & beach gleaning ☐ reeftop gleaning

☐ bêche-de mer diving ☐ mother-of-pearl diving trochus, pearl shell, etc.

☐ lobster diving ☐ other, such as clams, octopus

2. *(if more than one fishery in question 1):* Do you usually go fishing at only one of the fisheries or do you visit several during one fishing trip?

☐ one only ☐ several

If several fisheries at a time, which ones do you combine?

----

3. How often do you go gleaning/diving (*tick as from questions 1 and 2 above and watch for combinations*) and for how long, and do you also finfish at the same time?

(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				

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 **<u>INVERTEBRATE</u>** species that you do not catch during the total year? Can you specify the particular months that they are **<u>NOT</u>** fished?

Vernacular name	Scientific name(s)	Months NOT fished

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 spp.	21	35	65	7.35	Bivalves
Asaphis violascens	15	35	65	5.25	Bivalves
Astralium spp.	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 spp.	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 spp.	25	35	65	8.75	Bivalves
Codakia punctata	20	35	65	7	Bivalves
Coenobita spp.	50	35	65	17.5	Crustacean
Conus miles, *Strombus gibberulus gibbosus*	240	25	75	60	Gastropods
Conus spp.	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 spp.	95	25	75	23.75	Gastropods
Cypraea tigris	95	25	75	23.75	Gastropods
Dardanus spp.	10	35	65	3.5	Crustacean
Dendropoma maximum	15	25	75	3.75	Gastropods
Diadema spp.	50	48	52	24	Echinoderm
Dolabella auricularia	35	50	50	17.5	Others
Donax cuneatus	15	35	65	5.25	Bivalves
Drupa spp.	20	25	75	5	Gastropods
Echinometra mathaei	50	48	52	24	Echinoderm
Echinothrix spp.	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 spp.	2000	10	90	200	BdM (1)
Lambis lambis	25	25	75	6.25	Gastropods
Lambis spp.	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 spp.	550	90	10	495	Octopus
Panulirus ornatus	1000	35	65	350	Crustacean
Panulirus penicillatus	1000	35	65	350	Crustacean
Panulirus spp.	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 spp., *Periglypta* spp., *Spondylus* spp., *Spondylus* spp.,	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 spp.	35	35	65	12.25	Bivalves
Scylla serrata	700	35	65	245	Crustacean
Serpulorbis spp.	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 spp.	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

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
Tellina spp.	20	35	65	7	Bivalves
Terebra spp.	37.5	25	75	9.39	Gastropods
Thais armigera	20	25	75	5	Gastropods
Thais spp.	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 spp.	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 spp.	20	25	75	5	Gastropods

BdM = Bêche-de-mer; (1) edible part of dried Bêche-de-mer, i.e. drying process consumes about 90% of total wet weight; hence 10% are considered as the edible part only.

1.2 Methods used to assess the status of finfish resources

Fish counts

In order to count and size fish in selected sites, we use the **distance-sampling underwater visual census (D-UVC)** method (Kulbicki and Sarramegna 1999, Kulbicki *et al.* 2000), fully described in Labrosse *et al.* (2002). Briefly, the method consists of recording the species name, abundance, body length and the distance to the transect line for each fish or group of fish observed; the transect consists of a 50 m line, represented on the seafloor by an underwater tape (Figure A1.2.1). For security reasons, two divers are required to conduct a survey, each diver counting fish on a different side of the transect. Mathematical models are then used to estimate fish density (number of fish per unit area) and biomass (weight of fish per unit area) from the counts.

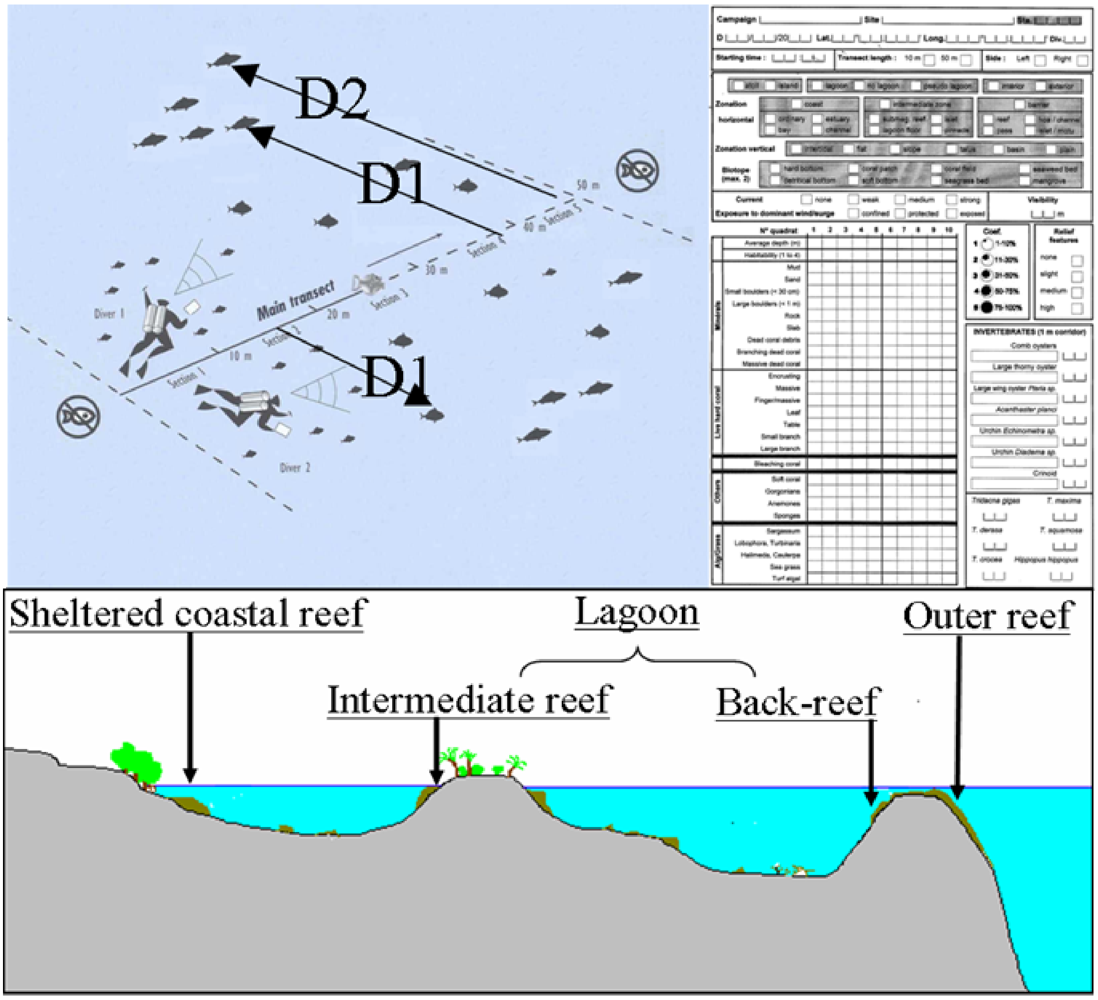


Figure A1.2.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys are conducted along 24 transects, with six transects in each of the four main geomorphologic coral reef structures: sheltered coastal reefs, intermediate reefs and back-reefs (lumped into the 'lagoon reef' category of socioeconomic assessment), and outer reefs. D1 is the distance of an observed fish from the transect line. If a school of fish is observed, D1 is the distance from the transect line to the closest fish; D2 the distance to the furthest fish.

Appendix 1: Survey methods
Finfish

Species selection

Only reef fish of interest for consumption or sale and species that could potentially serve as indicators of coral reef health are surveyed (see Table A1.2.1; Appendix 3.2 provides a full list of counted species and abundance for each site surveyed).

Table A1.2.1: List of finfish species surveyed by distance sampling underwater visual census (D-UVC)
Most frequently observed families on which reports are based are highlighted in yellow.

Family	Selected species
Acanthuridae	All species
Aulostomidae	*Aulostomus chinensis*
Balistidae	All species
Belonidae	All species
Caesionidae	All species
Carangidae	All species
Carcharhinidae	All species
Chaetodontidae	All species
Chanidae	All species
Dasyatidae	All species
Diodontidae	All species
Echeneidae	All species
Ephippidae	All species
Fistulariidae	All species
Gerreidae	*Gerres* spp.
Haemulidae	All species
Holocentridae	All species
Kyphosidae	All species
Labridae	*Bodianus axillaris, Bodianus loxozonus, Bodianus perditio, Bodianus* spp., *Cheilinus:* all species, *Choerodon:* all species, *Coris aygula, Coris gaimard, Epibulus insidiator, Hemigymnus:* all species, *Oxycheilinus diagrammus, Oxycheilinus* spp.
Lethrinidae	All species
Lutjanidae	All species
Monacanthidae	*Aluterus scriptus*
Mugilidae	All species
Mullidae	All species
Muraenidae	All species
Myliobatidae	All species
Nemipteridae	All species
Pomacanthidae	*Pomacanthus semicirculatus, Pygoplites diacanthus*
Priacanthidae	All species
Scaridae	All species
Scombridae	All species
Serranidae	Epinephelinae: all species
Siganidae	All species
Sphyraenidae	All species
Tetraodontidae	*Arothron*: all species
Zanclidae	All species

Appendix 1: Survey methods
Finfish

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.

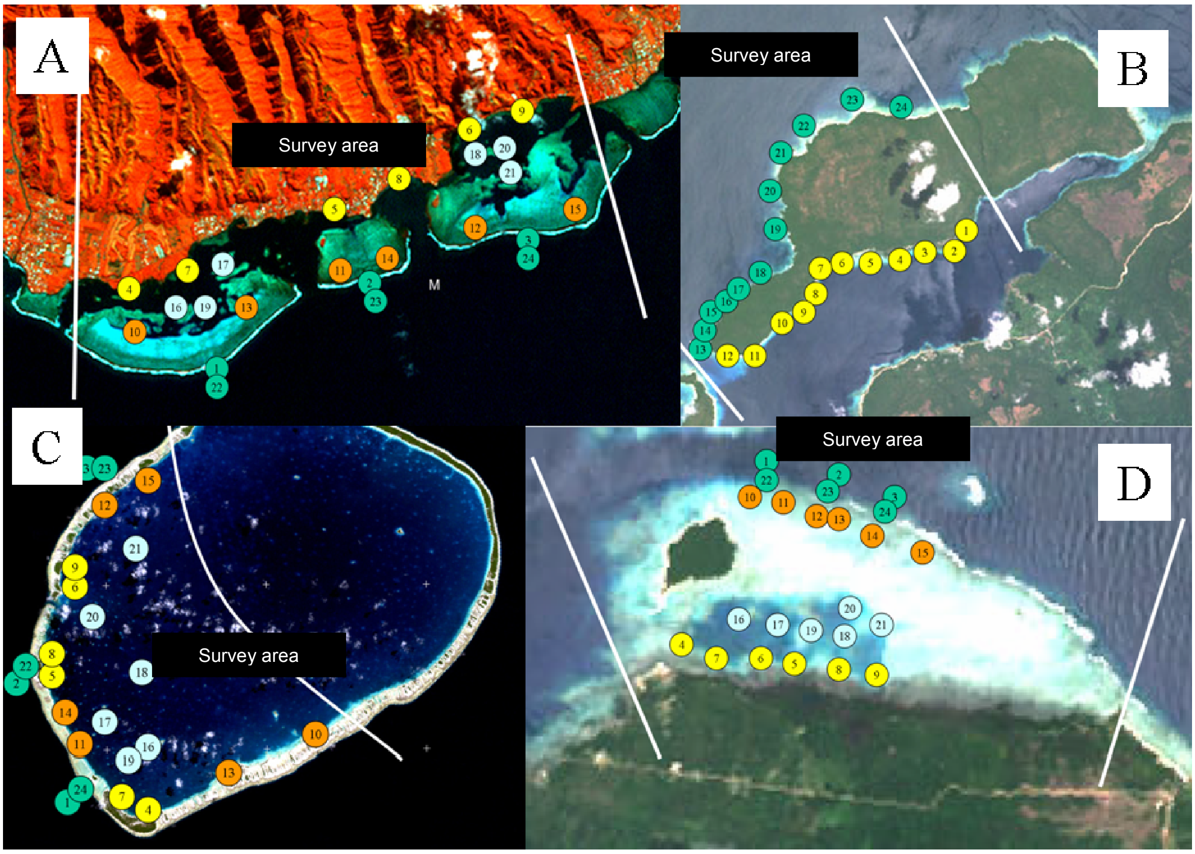


Figure A1.2.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, lagoon 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).

Scaling

Maps from the Millennium Project allow the calculation of reef areas in each studied site, and those areas can be used to scale (using weighted averages) the resource assessment at any spatial level. For example, the average biomass (or density) of finfish at site (i.e. village) level would be calculated by relating the biomass (or density) recorded in each of the habitats sampled at the site ('the data') to the proportion of surface of each type of reef over the total reef present in the site ('the weights'), by using a weighted average formula. The result is a village-level figure for finfish biomass that is representative of both the intrinsic characteristics of the resource and its spatial distribution. Technically, the weight given to the average biomass (or density) of each habitat corresponds to the ratio between the total area of that reef habitat (e.g. the area of sheltered coastal reef) and the total area of reef present (e.g. the area of sheltered coastal reef + the area of intermediate reef, etc.). Thus the calculated weighted biomass value for the site would be:

$$B_{Vk} = \sum j_l \, [B_{Hj} \bullet S_{Hj}] \, / \sum_j S_{Hj}$$

Where:

B_{Vk} = computed biomass or fish stock for village k
B_{Hj} = average biomass in habitat H_j
S_{Hj} = surface of that habitat H_j

A comparative approach only

Density and biomass estimated by D-UVC for each species recorded in the country are given in Appendix 3.2. However, it should be stressed that, since estimates of fish density and biomass (and other parameters) are largely dependent upon the assessment method used (this is true for any assessment), the resource assessment provided in this report can only be used for management in a comparative manner. Densities, biomass and other figures given in this report provide only estimates of the available resource; it would be a great mistake (possibly leading to mismanagement) to consider these as true indicators of the actual available resource.

Campaign |____________________| Site |__________________________________| Diver |__|__| Transect |__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|.|__|__|__|' Long.|__|__|__|°|__|__|.|__|__|__|' WT |__|__|__|

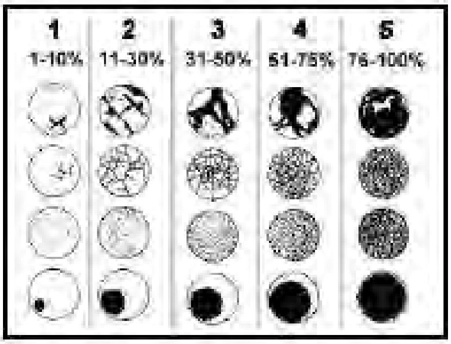
Starting time : |__|__| : |__|__| Visibility |__|__| m Side : Left ☐ Right ☐

☐ coast		☐ intermediate zone		☐ barrier	
☐ linear	☐ cape	☐ submerg. reef	☐ pinnacle	☐ outer slope	☐ pass
☐ bay mouth	☐ back of bay	☐ near surf. reef	☐ islet lagoon	☐ reef crest	☐ hoa/channel
☐ estuary	☐ channel	☐ lagoon floor	☐ islet fringing reef	☐ back reef	☐ motu

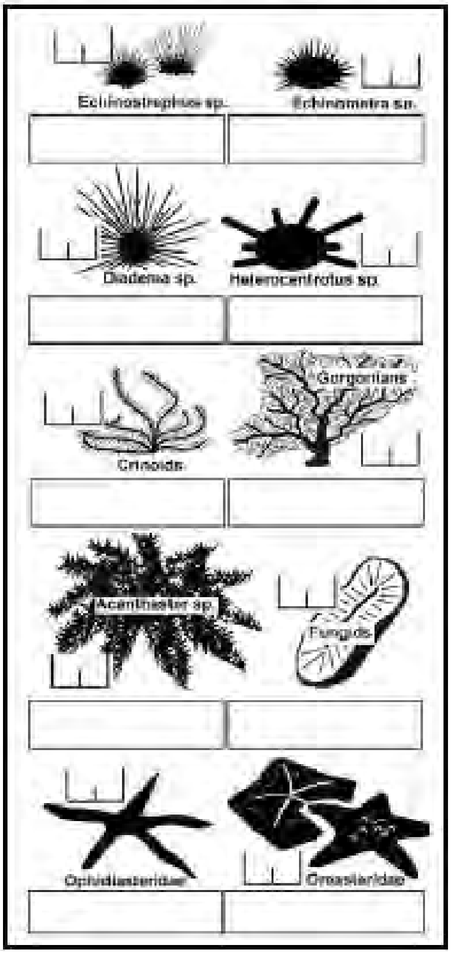
☐ intertidal ☐ flat ☐ gentle slope ☐ steep slope ☐ talus ☐ basin ☐ lagoon plain

☐ hard bottom ☐ large coral patches ☐ small coral patches ☐ coral field ☐ seaweed bed
☐ detritical bottom ☐ soft bottom ☐ seagrass bed ☐ mangrove

	current	relief features	exposure to dominant wind	oceanic influence	terrigenous influence
none	☐	☐	☐	☐	☐
medium	☐	☐	☐	☐	☐
strong	☐	☐	☐	☐	☐



Quadrat limits	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50
Average depth (m)										
Habitability (1 to 4)										
General coverage										
Mud										
Sand										
Dead coral debris										
Small boulders (< 30 cm)										
Large boulders (< 1 m)										
Eroded dead coral, rock										
Old dead coral in place										
Bleaching coral										
(1) Live corals										
(2) Soft invertebrates										
(1) Live corals										
Encrusting										
Massive										
Digitate										
Branch										
Foliose										
Tabulate										
Millepora sp.										
(2)										
Soft corals										
Sponges										
Grass/alg										
Cyanophyceae										
Sea grass										
Encrusting algae										
Small macro-algae										
Large macro-algae										
Drifting algae										
Micro-algae, Turf										
Others :										



Appendix 1: Survey methods
Finfish

Campaign |__________________| Site |____________________________| Diver |__|__| Transect |__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|’ Long.|__|__|__|°|__|__|,|__|__|__|’ Left ☐ Right ☐

ST	SCIENTIFIC NAME	NBER	LGT	D1	D2	COMMENTS

1.3 Invertebrate resource survey methods

1.3.1 Methods used to assess the status of invertebrate resources

Introduction

Coastal communities in the Pacific access a range of invertebrate resources. Within the PROCFish/C study, a range of survey methods were used to provide information on key invertebrate species commonly targeted. These provide information on the status of resources at scales relevant to species (or species groups) and the fishing grounds being studied that can be compared across sites, countries and the region, in order to assess relative status.

Species data resulting from the resource survey are combined with results from the socioeconomic survey of fishing activity to describe invertebrate fishing activity within specific 'fisheries'. Whereas descriptions of commercially orientated fisheries are generally recognisable in the literature (e.g. the sea cucumber fishery), results from non-commercial stocks and subsistence-orientated fishing activities (e.g. general reef gleaning) will also be presented as part of the results, so as to give managers a general picture of invertebrate fishery status at study sites.

Field methods

We examined invertebrate stocks (and fisheries) for approximately seven days at each site, with at least two research officers (SPC Invertebrate Biologist and Fisheries Officer) plus officers from the local fisheries department. The work completed at each site was determined by the availability of local habitats and access to fishing activity.

Two types of survey were conducted: fishery-dependent surveys and fishery independent surveys.

- Fishery-dependent surveys rely on information from those engaged in the fishery, e.g. catch data;
- Fishery-independent surveys are conducted by the researchers independently of the activity of the fisheries sector.

Fishery-dependent surveys were completed whenever the opportunity arose. This involved accompanying fishers to target areas for the collection of invertebrate resources (e.g. reef-benthos, soft-benthos, trochus habitat). The location of the fishing activity was marked (using a GPS) and the catch composition and catch per unit effort (CPUE) recorded (kg/hour).

This record was useful in helping to determine the species complement targeted by fishers, particularly in less well-defined 'gleaning' fisheries. A CPUE record, with related information on individual animal sizes and weights, provided an additional dataset to expand records from reported catches (as recorded by the socioeconomic survey). In addition, size and weight measures collected through fishery-dependent surveys were compared with records from fishery-independent surveys, in order to assess which sizes fishers were targeting.

For a number of reasons, not all fisheries lend themselves to independent snapshot assessments: density measures may be difficult to obtain (e.g. crab fisheries in mangrove systems) or searches may be greatly influenced by conditions (e.g. weather, tide and lunar conditions influence lobster fishing). In the case of crab or shoreline fisheries, searches are very subjective and weather and tidal conditions affect the outcome. In such cases, observed and reported catch records were used to determine the status of species and fisheries.

A further reason for accompanying groups of fishers was to gain a first-hand insight into local fishing activities and facilitate the informal exchange of ideas and information. By talking to fishers in the fishing grounds, information useful for guiding independent resource assessment was generally more forthcoming than when trying to gather information using maps and aerial photographs while in the village. Fishery-independent surveys were not conducted randomly over a defined site 'study' area. Therefore assistance from knowledgeable fishers in locating areas where fishing was common was helpful in selecting areas for fishery-independent surveys.

A series of fishery-independent surveys (direct, in-water resource assessments) were conducted to determine the status of targeted invertebrate stocks. These surveys needed to be wide ranging within sites to overcome the fact that distribution patterns of target invertebrate species can be strongly influenced by habitat, and well replicated as invertebrates are often highly aggregated (even within a single habitat type).

PROCFish/C assessments do not aim to determine the size of invertebrate populations at study sites. Instead, these assessments aim to determine the status of invertebrates within the main fishing grounds or areas of naturally higher abundance. The implications of this approach are important, as the haphazard measures taken in main fishing grounds are indicative of stock health in these locations only and should not be extrapolated across all habitats within a study site to gain population estimates.

This approach was adopted due to the limited time allocated for surveys and the study's goal of 'assessing the status of invertebrate resources' (as opposed to estimating the standing stock). Making judgements on the status of stocks from such data relies on the assumption that the state of these estimates of 'unit stock'[2] reflects the health of the fishery. For example, an overexploited trochus fishery would be unlikely to have high-density 'patches' of trochus, just as a depleted shallow-reef gleaning fishery would not hold high densities of large clams. Conversely, a fishery under no stress would be unlikely to be depleted or show skewed size ratios that reflected losses of the adult component of the stock.

In addition to examining the density of species, information on spatial distribution and size/weight was collected, to add confidence to the study's inferences.

The basic assumption that looking at a unit stock will give a reliable picture of the status of that stock is not without weaknesses. Resource stocks may appear healthy within a much-restricted range following stress from fishing or environmental disturbance (e.g. a cyclone), and historical information on stock status is not usually available for such remote locations. The lack of historical datasets also precludes speculation on 'missing' species, which may be 'fished-out' or still remain in remnant populations at isolated locations within study sites.

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[2] As used here, 'unit stock' refers to the biomass and cohorts of adults of a species in a given area that is subject to a well-defined fishery, and is believed to be distinct and have limited interchange of adults from biomasses or cohorts of the same species in adjacent areas (Gulland 1983).

As mentioned, specific independent assessments were not conducted for mud crab and shore crabs (mangrove fishery), lobster or shoreline stocks (e.g. nerites, surf clams and crabs), as limited access or the variability of snapshot assessments would have limited relevance for comparative assessments.

Generic terminology used for surveys: site, station and replicates

Various methods were used to conduct fishery-independent assessments. At each site, surveys were generally made within specific areas (termed 'stations'). At least six replicate measures were made at each station (termed 'transects', 'searches' or 'quadrats', depending on the resource and method) (Figure A1.3.1).

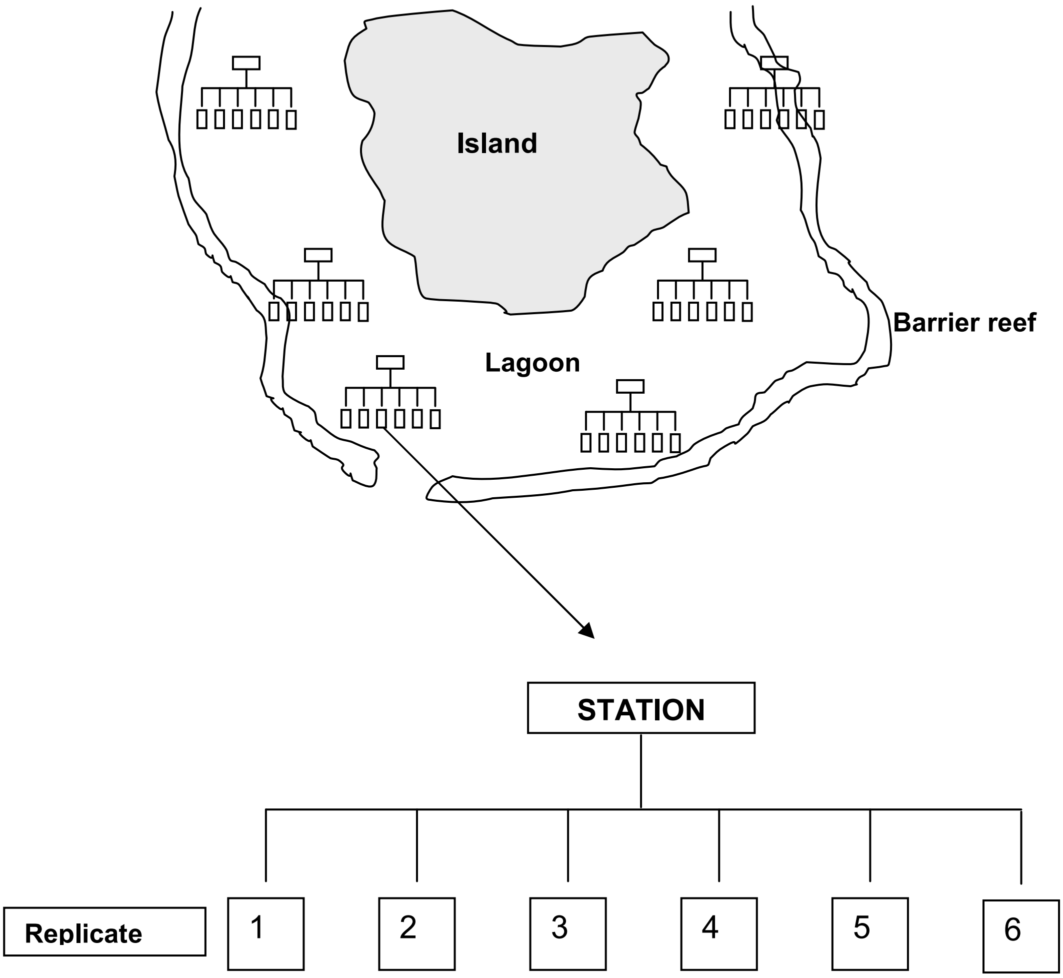


Figure A1.3.1: Stations and replicate measures at a given site.
Note: a replicate measure could be a transect, search period or quadrat group.

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).

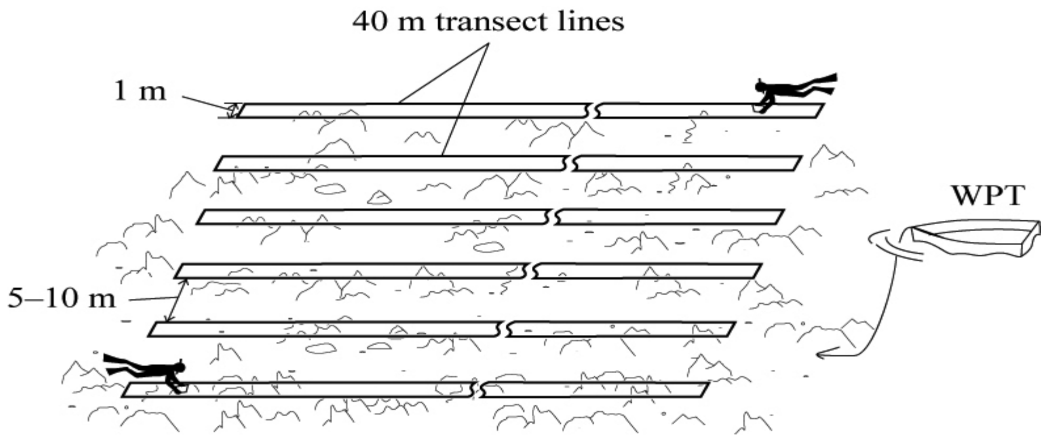


Figure A1.3.2: Example of a reef-benthos transect station (RBt).

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.

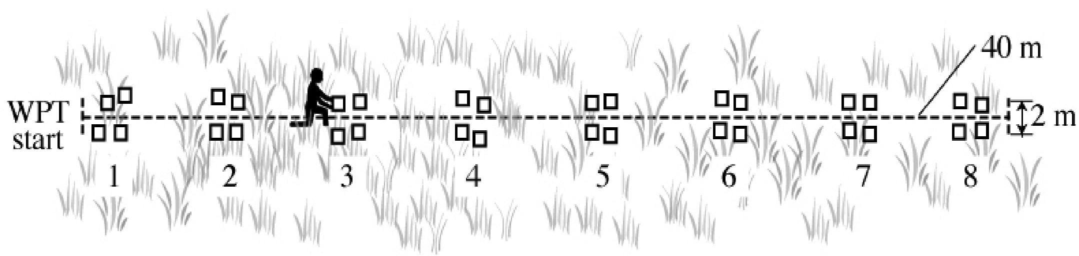


Figure A1.3.3: Soft-benthos (infaunal) quadrat station (SBq).
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

Mother-of-pearl (MOP) or sea cucumber (BdM) fisheries

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.

Reef-front searches (RFs and RFs_w)

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).

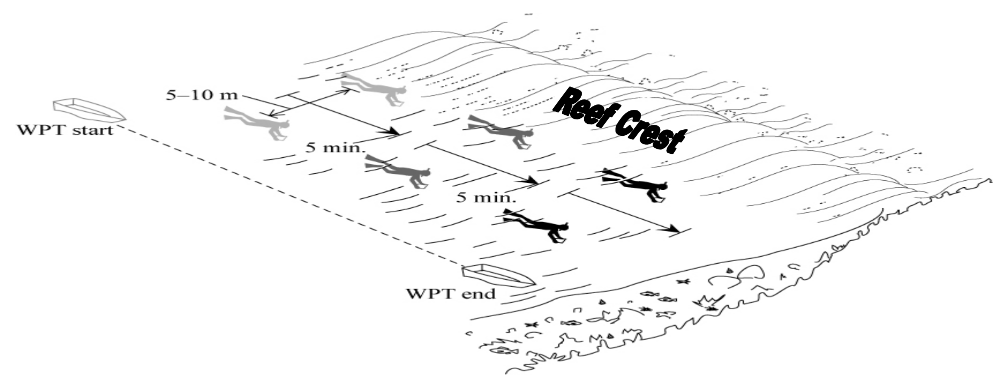


Figure A1.3.4: Reef-front search (RFs) station.

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.

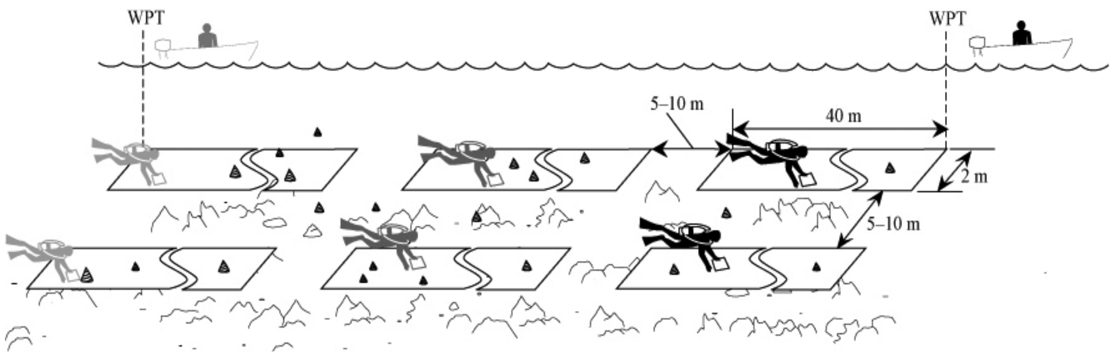


Figure A1.3.5: Mother-of-pearl transect station (MOPt).

Sea cucumber day search (Ds)

When possible, dives to 25–35 m were made to establish if white teatfish (*Holothuria (Microthele) fuscogilva*) populations were present and give an indication of abundance. In these searches two divers recorded the number and sizes of valuable deep-water sea cucumber species within three 5-min search periods (30 min total). This assessment from deep water does not yield sufficient presence/absence data for a very reliable inference on the status (i.e. 'health') of this and other deeper-water species.

Sea cucumber night search (Ns)

In the case of sea cucumber fisheries, dedicated night searches (Ns) for sea cucumbers and other echinoderms were conducted (using snorkel) for predominantly nocturnal species (blackfish *Actinopyga miliaris*, *A. lecanora*, and *Stichopus horrens*). Sea cucumbers were collected for three 5-min search periods by two snorkellers (30 min total), and if possible weighed (length and width measures for *A. miliaris* and *A. lecanora* are more dependent on the condition than the age of an individual).

Reporting style

For country site reports, results highlight the presence and distribution of species of interest, and their density at scales that yield a representative picture. Generally speaking, mean densities (average of all records) are presented, although on occasion mean densities for areas of aggregation ('patches') are also given. The later density figure is taken from records (stations or transects, as stated) where the species of interest is present (with an abundance >zero). Presentation of the relative occurrence and densities (without the inclusion of zero records) can be useful when assessing the status of aggregations within some invertebrate stocks.

An example and explanation of the reporting style adopted for invertebrate results follows.

1. The mean density range of *Tridacna* spp. on broad-scale stations (n = 8) was 10–120 per ha.

Density range includes results from all stations. In this case, replicates in each station are added and divided by the number of replicates for that station to give a mean. The lowest and highest station averages (here 10 and 120) are presented for the range. The number in brackets (n = 8) highlights the number of stations examined.

2. The mean density (per ha, ±SE) of all *Tridacna* clam species observed in broad-scale transects (n = 48) was 127.8 ±21.8 (occurrence in 29% of transects).

Mean density is the arithmetic mean, or average of measures across all replicates taken (in this case broad-scale transects). On occasion mean densities are reported for stations or transects where the species of interest is found at an abundance greater than zero. In this case the arithmetic mean would only include stations (or replicates) where the species of interest was found (excluding zero replicates). If this was presented for stations, even stations with a single clam from six transects would be included. (Note: a full breakdown of data is presented in the appendices.)

Written after the mean density figure is a descriptor that highlights variability in the figures used to calculate the mean. Standard error[3] (SE) is used in this example to highlight variability in the records that generated the mean density (SE = (standard deviation of records)/√n). This figure provides an indication of the dispersion of the data when trying to estimate a population mean (the larger the standard error, the greater variation of data points around the mean presented).

Following the variability descriptor is a presence/absence indicator for the total dataset of measures. The presence/absence figure describes the percentage of stations or replicates with a recording >0 in the total dataset; in this case 29% of all transects held *Tridacna* spp., which equated to 14 of a possible 48 transects (14/48*100 = 29%).

3. The mean length (cm, ±SE) of *T. maxima* was 12.4 ±1.1 (n = 114).

The number of units used in the calculation is indicated by *n*. In the last case, 114 clams were measured.

[3] In order to derive confidence limits around the mean, a transformation (usually y = log (x+1)) needs to be applied to data, as samples are generally non-normally distributed. Confidence limits of 95% can be generated through other methods (bootstrapping methods) and will be presented in the final report where appropriate.

1.3.2 General fauna invertebrate recording sheet with instructions to users

DATE		RECORDER		Pg No	

STATION NAME																		
WPT - WIDTH																		
RELIEF / COMPLEXITY **1–5**																		
OCEAN INFLUENCE **1–5**																		
DEPTH (M)																		
% SOFT SED (M – S – CS)																		
% RUBBLE / BOULDERS																		
% CONSOL RUBBLE / PAVE																		
% CORAL *LIVE*																		
% CORAL *DEAD*																		
SOFT / SPONGE / FUNGIDS																		
ALGAE *CCA*																		
CORALLINE																		
OTHER																		
GRASS																		
EPIPHYTES **1–5** / SILT **1–5**																		
bleaching: % of																		
entered /	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

Figure A1.3.6: Sample of the invertebrate fauna survey sheet.

The sheet above (Figure A1.3.6) has been modified to fit on this page (the original has more line space (rows) for entering species data). When recording abundance or length data against species names, columns are used for individual transects or 5-min search replicates. If more space is needed, more than a single column can be used for a single replicate.

A separate sheet is used by a recorder in the boat to note information from handheld GPS equipment. In addition to the positional information, this boat sheet has space for manta transect distance (from GPS odometer function) and for sketches and comments.

1.3.3 Habitat section of invertebrate recording sheet with instructions to users

Figure A1.3.7 depicts the habitat part of the form used during invertebrate surveys; it is split into seven broad categories.

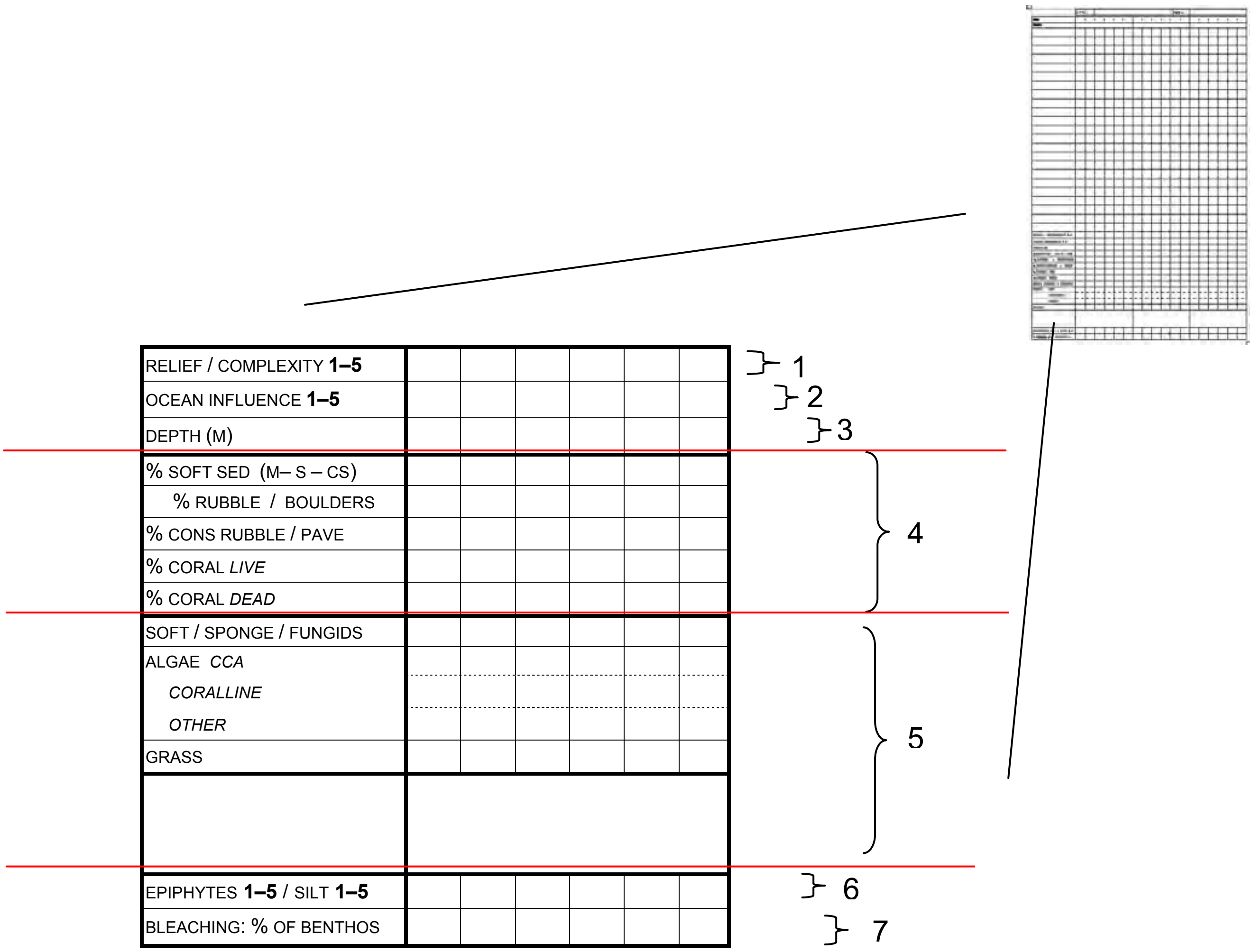


Figure A1.3.7: Sample of the invertebrate habitat part of survey form.

Relief and complexity (section 1 of form)

Each is on a scale of 1 to 5. If a record is written as 1/5, relief is 1 and complexity is 5, with the following explanation.

Relief describes average height variation for hard (and soft) benthos transects:
- 1 = flat (to ankle height)
- 2 = ankle up to knee height
- 3 = knee to hip height
- 4 = hip to shoulder/head height
- 5 = over head height

Complexity describes average surface variation for substrates (relative to places for animals to find shelter) for hard (and soft) benthos transects:
- 1 = smooth – no holes or irregularities in substrate
- 2 = some complexity to the surfaces but generally little

3 = generally complex surface structure
4 = strong complexity in surface structure, with cracks, spaces, holes, etc.
5 = very complex surfaces with lots of spaces, nooks, crannies, under-hangs and caves

Ocean influence (section 2 of form)

1 = riverine, or land-influenced seawater with lots of allochthonous input
2 = seawater with some land influence
3 = ocean and land-influenced seawater
4 = water mostly influenced by oceanic water
5 = oceanic water without land influence

Depth (section 3 of form)

Average depth in metres

Substrate – bird's-eye view of what's there (section 4 of form)

All of section 4 must make up 100%. Percentage substrate is estimated in units of 5% so, e.g. 5, 10, 15, 20 (%) etc. and not 2, 13, 17, 56.

Elements to consider:

Soft substrate	Soft sediment – mud
Soft substrate	Soft sediment – mud and sand
Soft substrate	Soft sediment – sand
Soft substrate	Soft sediment – coarse sand
Hard substrate	Rubble
Hard substrate	Boulders
Hard substrate	Consolidated rubble
Hard substrate	Pavement
Hard substrate	Coral live
Hard substrate	Coral dead

Mud, sand, coarse sand: The sand is not sieved – it is estimated visually and manually. Surveyors can use the 'drop test', where sand drops through the water column and mud stays in suspension. Patchy settled areas of silt/clay/mud in very thin layers on top of coral, pavement, etc. are not listed as soft substrate unless the layer is significant (>a couple of cm).

Rubble is small (<25–30 cm) fragments of coral (reef), pieces of coral stone and limestone debris. AIMS' definition is very similar to that for Reefcheck (found on the 'C-nav' interactive CD): 'pieces of coral (reef) between 0.5 and 15 cm. If smaller, it is sand; if larger, then rock or whatever organism is growing upon it'.

Boulders are detached, big pieces (>30 cm) of stone, coral stone and limestone debris.

Consolidated rubble is attached, cemented pieces of coral stone and limestone debris. We tend to use 'rubble' for pieces or piles loose in the sediment of seagrass, etc., and 'consolidated rubble' for areas that are not flat pavement but concreted rubble on reeftops and cemented talus slopes.

Appendix 1: Survey methods
Invertebrates

Pavement is solid, substantial, fixed, flat stone (generally limestone) benthos.

Coral live is any live hard coral.

Coral dead is coral that is recognisable as coral even if it is long dead. Note that long-dead and *eroded* coral that is found in flat pavements is called ‘pavement’ and when it is found in loose pieces or blocks it is termed ‘rubble’ or ‘boulders’ (depending on size).

Cover – what is on top of the substrate (section 5 of form)

This cannot exceed 100%, but can be anything from 0 to 100%. Surveyors give scores in blocks of 5%, so e.g. 5, 10, 15, 20 (%) etc. and not 2, 13, 17, 56.

Elements to consider:

Cover	Soft coral
Cover	Sponge
Cover	Fungids
Cover	Crustose-nongeniculate coralline algae
Cover	Coralline algae
Cover	Other (algae like sargassum, caulerpa and padina)
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 Ngarchelong socioeconomic survey data

2.1.1 Annual catch (kg) of fish groups per habitat – Ngarchelong
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon				
Melangmud	Lethrinidae	*Lethrinus* spp.	2557	13
Keremlal	Lutjanidae	*Lutjanus gibbus*	1909	10
Temekai	Serranidae	*Epinephelus* spp.	1280	6
Klsebuul	Siganidae	*Siganus lineatus*	1254	6
Ngyaoch	Scaridae	*Hipposcarus longiceps*	1093	6
Udech	Lethrinidae	*Lethrinus olivaceus*	843	4
Kotikou	Gerreidae	*Gerres macrosoma*	780	4
Esengel	Acanthuridae	*Acanthurus* spp.	773	4
Elebdechukel	Scaridae	*Scarus ghobban*	740	4
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	690	3
Rekruk	Lethrinidae	*Lethrinus rubrioperculatus*	679	3
Udel	Lutjanidae	*Aprion virescens*	651	3
Kedesau	Lutjanidae	*Lutjanus bohar*	651	3
Dukl	Scaridae	*Scarus ghobban*	591	3
Mesekuuk	Acanthuridae	*Acanthurus xanthopterus*	492	2
Otord	Lethrinidae	*Lethrinus* spp.	458	2
Bang	Mullidae	*Parupeneus barberinus*	438	2
Yaus	Haemulidae	*Plectorhinchus* spp.	418	2
Mechur	Lethrinidae	*Lethrinus xanthochilus*	412	2
Uluu	Mugilidae	*Liza vaigiensis*	400	2
Itotech	Lethrinidae	*Lethrinus harak*	362	2
Metengui	Lethrinidae	*Lethrinus* spp.	347	2
Um	Acanthuridae	*Naso unicornis*	250	1
Bebael	Siganidae	*Siganus punctatus*	179	1
Erangel	Acanthuridae	*Naso lituratus*	175	1
Baslokil	Serranidae	*Variola louti*	174	1
Maml	Labridae	*Cheilinus undulatus*	167	1
Bikl	Haemulidae	*Plectorhinchus albovittatus*	167	1
Budech	Labridae	*Choerodon anchorago*	140	1
Masch	Acanthuridae	*Ctenochaetus striatus*	130	1
Edui	Lutjanidae	*Symphorichthys spilurus*	120	1
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	90	0
Udondungelel	Scaridae	*Scarus* spp.	80	0
Desachel	Holocentridae	*Sargocentron* spp.	53	0
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	43	0
Drutm	Tetraodontidae	*Arothron stellatus*	43	0
Riamel	Ostraciidae	*Ostracion cubicus*	43	0
Komud	Kyphosidae	*Kyphosus* spp.	22	0
Mengardechelucheb	Serranidae	*Cephalopholis argus*	17	0
Eropk	Carangidae	*Caranx ignobilis*	13	0

2.1.1 Annual catch (kg) of fish groups per habitat – Ngarchelong (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon (continued)				
Orwidel	Carangidae	*Caranx melampygus*	12	0
Mokas	Serranidae	*Plectropomus leopardus*, *Plectropomus laevis*	4	0
Bsukel	Holocentridae	*Myripristis* spp.	4	0
Total:			**19,743**	**100**
Sheltered coastal reef				
Udech	Lethrinidae	*Lethrinus olivaceus*	5	63
Itotech	Lethrinidae	*Lethrinus harak*	3	38
Total:			**8**	**100**
Lagoon & outer reef				
Temekai	Serranidae	*Epinephelus* spp.	217	33
Keremlal	Lutjanidae	*Lutjanus gibbus*	174	27
Kedesau	Lutjanidae	*Lutjanus bohar*	87	13
Mechur	Lethrinidae	*Lethrinus xanthochilus*	87	13
Metengui	Lethrinidae	*Lethrinus* spp.	87	13
Total:			**651**	**100**
Outer reef				
Melangmud	Lethrinidae	*Lethrinus* spp.	589	18
Orwidel	Carangidae	*Caranx melampygus*	501	15
Eropk	Carangidae	*Caranx ignobilis*	478	14
Temekai	Serranidae	*Epinephelus* spp.	368	11
Keremlal	Lutjanidae	*Lutjanus gibbus*	325	10
Metengui	Lethrinidae	*Lethrinus* spp.	222	7
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	220	7
Mechur	Lethrinidae	*Lethrinus xanthochilus*	148	4
Udech	Lethrinidae	*Lethrinus olivaceus*	130	4
Kedesau	Lutjanidae	*Lutjanus bohar*	90	3
Rekruk	Lethrinidae	*Lethrinus rubrioperculatus*	87	3
Itotech	Lethrinidae	*Lethrinus harak*	87	3
Baslokil	Serranidae	*Variola louti*	87	3
Yaus	Haemulidae	*Plectorhinchus* spp.	23	1
Total:			**3355**	**100**

2.1.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Ngarchelong

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Lobster	Erabrukl	*Panulirus* spp.	100.0	159.9	159.9	203.4	203.4
Mangrove	Emang	*Scylla serrata*	100.0	43.4	30.4	55.2	38.7
	Ngduul			349.8		593.3	
Reeftop	Kim	*Hippopus hippopus*, *Tridacna derasa*	70.6	3145.9	1572.9	4414.7	2207.4
	Oruer	*Tridacna crocea*, *Tridacna gigas*, *Tridacna maxima*, *Tridacna squamosa*	26.9	1199.3	599.7	2034.1	1017.0
	Kmai	*Portunus pelagicus*	2.6	249.9	56.9	423.8	96.5
Soft benthos	Sekesakel	*Holothuria* spp.	38.3	15,673.5	3134.7	24,155.8	4831.2
	Ngimes	*Stichopus* spp.	20.4	8330.6	1666.1	12,747.6	2549.5
	Eremrum	*Actinopyga* spp.	19.1	5204.6	1561.4	8090.4	2427.1
	Irimd	*Holothuria* spp.	8.0	3257.1	651.4	5063.8	1012.8
	Molech	*Holothuria scabra*	7.9	3237.5	647.5	4938.3	987.7
	Ibuchel	*Tripneustes gratilla*	6.3	5184.7	518.5	8424.9	842.5

2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Ngarchelong

Vernacular name	Scientific name	Size class	% of total catch by species (number)
Emang	*Scylla serrata*	16 cm	100.0
Erabrukl	*Panulirus* spp.	24 cm	100.0
Eremrum	*Actinopyga* spp.	04 cm	8.3
		04–06 cm	16.7
		06–08 cm	33.4
		10 cm	33.2
		14 cm	8.3
Ibuchel	*Tripneustes gratilla*	06–08 cm	38.6
		08 cm	25.1
		10 cm	36.3
Irimd	*Holothuria* spp.	10 cm	33.3
		12 cm	66.7
Kim	*Hippopus hippopus*, *Tridacna derasa*	18–20 cm	4.8
		20–22 cm	4.0
		20–28 cm	19.1
		24 cm	27.6
		26–30 cm	3.2
		28 cm	41.4
Kmai	*Portunus pelagicus*	22 cm	100.0
Molech	*Holothuria scabra*	06–10 cm	40.2
		10–14 cm	18.5
		12 cm	26.8
		16 cm	13.4
		24–26 cm	1.0
Ngduul		04–06 cm	

2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Ngarchelong (continued)

Vernacular name	Scientific name	Size class	% of total catch by species (number)
Ngimes	*Stichopus* spp.	14 cm	45.3
		16 cm	39.1
		16–18 cm	15.6
Oruer	*Tridacna crocea*, *Tridacna gigas*, *Tridacna maxima*, *Tridacna squamosa*	12 cm	16.7
		12–16 cm	83.3
Sekesakel	*Holothuria* spp.	08 cm	24.9
		08–12 cm	45.2
		10 cm	8.3
		14–16 cm	7.7
		16 cm	13.9

2.2 Ngatpang socioeconomic survey data

2.2.1 Annual catch (kg) of fish groups per habitat – Ngatpang
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Mesekuuk	Acanthuridae	*Acanthurus xanthopterus*	364	15
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	261	11
Ngyaoch	Scaridae	*Hipposcarus longiceps*	261	11
Mokas	Serranidae	*Plectropomus leopardus*, *Plectropomus laevis*	261	11
Um	Acanthuridae	*Naso unicornis*	261	11
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	261	11
Klsebuul	Siganidae	*Siganus lineatus*	187	8
Meyas	Siganidae	*Siganus canaliculatus*, *Scarus fuscescens*	178	7
Temekai	Serranidae	*Epinephelus* spp.	130	5
Udech	Lethrinidae	*Lethrinus olivaceus*	112	5
Dech	Lethrinidae	*Lethrinus* spp.	103	4
Aol	Chanidae	*Chanos chanos*	40	2
Mechur	Lethrinidae	*Lethrinus xanthochilus*	9	0
Reall	Lutjanidae	*Lutjanus fulvus*	9	0
Total:			**2435**	**100**
Lagoon				
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	1080	9
Klsebuul	Siganidae	*Siganus lineatus*	1031	9
Udech	Lethrinidae	*Lethrinus olivaceus*	1002	8
Keremlal	Lutjanidae	*Lutjanus gibbus*	939	8
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	933	8
Mechur	Lethrinidae	*Lethrinus xanthochilus*	920	8
Temekai	Serranidae	*Epinephelus* spp.	776	6
Bang	Mullidae	*Parupeneus barberinus*	722	6
Melangmud	Lethrinidae	*Lethrinus* spp.	699	6
Metengui	Lethrinidae	*Lethrinus* spp.	631	5
Ngyaoch	Scaridae	*Hipposcarus longiceps*	566	5
Itotech	Lethrinidae	*Lethrinus harak*	420	4
Erangel	Acanthuridae	*Naso lituratus*	217	2
Mesekuuk	Acanthuridae	*Acanthurus xanthopterus*	204	2
Bikl	Haemulidae	*Plectorhinchus albovittatus*	200	2
Budech	Labridae	*Choerodon anchorago*	200	2
Mokas	Serranidae	*Plectropomus leopardus*, *Plectropomus laevis*	174	1
Um	Acanthuridae	*Naso unicornis*	174	1
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	174	1
Teriid			150	1
Esengel	Acanthuridae	*Acanthurus* spp.	130	1
Bebael	Siganidae	*Siganus punctatus*	130	1
Dech	Lethrinidae	*Lethrinus* spp.	100	1
Edui	Lutjanidae	*Symphorichthys spilurus*	100	1

2.2.1 Annual catch (kg) of fish groups per habitat – Ngatpang (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon (continued)				
Otord	Lethrinidae	*Lethrinus* spp.	76	1
Desachel	Holocentridae	*Sargocentron* spp.	70	1
Kedesau	Lutjanidae	*Lutjanus bohar*	65	1
Rekruk	Lethrinidae	*Lethrinus rubrioperculatus*	43	0.4
Dodes	Lutjanidae	*Lutjanus* spp.	43	0.4
Riamel	Ostraciidae	*Ostracion cubicus*	10	0.1
Yaus	Haemulidae	*Plectorhinchus* spp.	5	0.0
Total:			**11,986**	**100**
Lagoon & outer reef				
Melangmud	Lethrinidae	*Lethrinus* spp.	195	16
Keremlal	Lutjanidae	*Lutjanus gibbus*	152	12
Temekai	Serranidae	*Epinephelus* spp.	130	11
Ngyaoch	Scaridae	*Hipposcarus longiceps*	130	11
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	109	9
Metengui	Lethrinidae	*Lethrinus* spp.	109	9
Bebael	Siganidae	*Siganus punctatus*	87	7
Mechur	Lethrinidae	*Lethrinus xanthochilus*	65	5
Erangel	Acanthuridae	*Naso lituratus*	65	5
Um	Acanthuridae	*Naso unicornis*	43	4
Esengel	Acanthuridae	*Acanthurus* spp.	43	4
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	22	2
Bang	Mullidae	*Parupeneus barberinus*	22	2
Kedesau	Lutjanidae	*Lutjanus bohar*	22	2
Dukl	Scaridae	*Scarus ghobban*	22	2
Total:			**1216**	**100**
Outer reef				
Keremlal	Lutjanidae	*Lutjanus gibbus*	358	13
Mechur	Lethrinidae	*Lethrinus xanthochilus*	280	10
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	274	10
Temekai	Serranidae	*Epinephelus* spp.	229	9
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	153	6
Melangmud	Lethrinidae	*Lethrinus* spp.	137	5
Metengui	Lethrinidae	*Lethrinus* spp.	137	5
Udech	Lethrinidae	*Lethrinus olivaceus*	122	5
Rekruk	Lethrinidae	*Lethrinus rubrioperculatus*	119	4
Ngyaoch	Scaridae	*Hipposcarus longiceps*	117	4
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	87	3
Bang	Mullidae	*Parupeneus barberinus*	87	3
Erangel	Acanthuridae	*Naso lituratus*	83	3
Butiliang	Scaridae	*Scarus dimidiatus*	70	3
Bebael	Siganidae	*Siganus punctatus*	63	2
Baslokil	Serranidae	*Variola louti*	59	2
Um	Acanthuridae	*Naso unicornis*	55	2
Otord	Lethrinidae	*Lethrinus* spp.	50	2

2.2.1 Annual catch (kg) of fish groups per habitat – Ngatpang (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef (continued)				
Esengel	Acanthuridae	*Acanthurus* spp.	43	2
Masch	Acanthuridae	*Ctenochaetus striatus*	43	2
Kedesau	Lutjanidae	*Lutjanus bohar*	40	1
Mesekuuk	Acanthuridae	*Acanthurus xanthopterus*	30	1
Dodes	Lutjanidae	*Lutjanus* spp.	20	1
Desachel	Holocentridae	*Sargocentron* spp.	10	0.4
Orwidel	Carangidae	*Caranx melampygus*	10	0.4
Ngimer	Labridae	*Cheilinus undulatus*	5	0.2
Total:			**2681**	**100**

2.2.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Ngatpang

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Mangrove	Emang	*Scylla serrata*	77.31	482	337	607	425
	Kmai	*Portunus pelagicus*	22.69	434	99	382	87
	Ngduul			2861	0	6182	0
Reeftop	Kim	*Hippopus hippopus*, *Tridacna derasa*	96.23	3301	1650	3541	1771
	Erabrukl	*Panulirus* spp.	3.77	43	43	38	38
Soft benthos	Eremrum	*Actinopyga* spp.	72.20	16813	5044	29,900	8970
	Ngimes	*Stichopus* spp.	10.52	3674	735	3526	705
	Kim	*Hippopus hippopus*, *Tridacna derasa*	7.77	included in extrapolation "kim" reeftop			
	Molech	*Holothuria scabra*	4.54	1585	317	2128	426
	Irimd	*Holothuria* spp.	3.11	1086	217	955	191
	Ibuchel	*Tripneustes gratilla*	1.86	1303	130	1147	115

2.2.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Ngatpang

Vernacular name	Scientific name	Size class	% of total catch by species (number)
Emang	*Scylla serrata*	12 cm	4.2
		12–14 cm	25.9
		16 cm	69.9
Erabrukl	*Panulirus* spp.	27 cm	100.0
Eremrum	*Actinopyga* spp.	04–06 cm	15.5
		04–10 cm	17.8
		08 cm	37.7
		08–10 cm	15.5
		10 cm	7.7
		10–12 cm	5.2
		12 cm	0.5
Ibuchel	*Tripneustes gratilla*	10 cm	100.0
Irimd	*Holothuria* spp.	10–12 cm	100.0
Kim	*Hippopus hippopus*, *Tridacna derasa*	18–20 cm	26.3
		22 cm	13.2
		26 cm	32.9
		28 cm	27.6
Kmai	*Portunus pelagicus*	14 cm	100.0
Molech	*Holothuria scabra*	14–16 cm	68.5
		20 cm	31.5
Ngduul		04–06 cm	
		08–10 cm	
Ngimes	*Stichopus* spp.	06–08 cm	23.6
		12–14 cm	23.6
		16–18 cm	47.3
		24 cm	5.4

2.3 Airai socioeconomic survey data

2.3.1 Annual catch (kg) of fish groups per habitat – Airai

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Klsebuul	Siganidae	*Siganus lineatus*	164	28
Ngyaoch	Scaridae	*Hipposcarus longiceps*	117	20
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	60	10
Esuch	Carangidae	*Caranx sexfasciatus*	49	8
Bang	Mullidae	*Parupeneus barberinus*	35	6
Itotech	Lethrinidae	*Lethrinus harak*	28	5
Bikl	Haemulidae	*Plectorhinchus albovittatus*	25	4
Kotikou	Gerreidae	*Gerres macrosoma*	24	4
Edoched	Gerreidae	*Gerres filamentosus*	24	4
Terekrik	Carangidae	*Selar crumenophthalmus*	16	3
Temekai	Serranidae	*Epinephelus* spp.	12	2
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	12	2
Udech	Lethrinidae	*Lethrinus olivaceus*	4	1
Budech	Labridae	*Choerodon anchorago*	4	1
Keremlal	Lutjanidae	*Lutjanus gibbus*	3	1
Mirechorech	Serranidae	*Epinephelus merra*	3	1
Udel	Lutjanidae	*Aprion virescens*	1	0
Masch	Acanthuridae	*Ctenochaetus striatus*	1	0
Mud	Pomacentridae	*Pomacentrus reidi*	1	0
Belay	Acanthuridae	*Acanthurus lineatus*	1	0
Total:			**584**	**100**
Sheltered coastal reef & lagoon				
Keremlal	Lutjanidae	*Lutjanus gibbus*	174	18
Melangmud	Lethrinidae	*Lethrinus* spp.	174	18
Kedesau	Lutjanidae	*Lutjanus bohar*	174	18
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	174	18
Mechur	Lethrinidae	*Lethrinus xanthochilus*	174	18
Temekai	Serranidae	*Epinephelus* spp.	104	11
Total:			**973**	**100**
Lagoon				
Klsebuul	Siganidae	*Siganus lineatus*	1641	15
Udech	Lethrinidae	*Lethrinus olivaceus*	1454	13
Ngyaoch	Scaridae	*Hipposcarus longiceps*	1166	10
Keremlal	Lutjanidae	*Lutjanus gibbus*	1130	10
Itotech	Lethrinidae	*Lethrinus harak*	995	9
Kelat	Mugilidae	*Valamugil seheli*	751	7
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	641	6
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	467	4
Rekruk	Lethrinidae	*Lethrinus rubrioperculatus*	391	4
Uluu	Mugilidae	*Liza vaigiensis*	348	3
Metengui	Lethrinidae	*Lethrinus* spp.	247	2

2.3.1 Annual catch (kg) of fish groups per habitat – Airai (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon (continued)				
Metenguiremel	Lethrinidae	*Lethrinus lentjan*	186	2
Esuch	Carangidae	*Caranx sexfasciatus*	174	2
Bang	Mullidae	*Parupeneus barberinus*	167	1
Melangmud	Lethrinidae	*Lethrinus* spp.	160	1
Desachel	Holocentridae	*Sargocentron* spp.	150	1
Otord	Lethrinidae	*Lethrinus* spp.	136	1
Mekebud	Clupeidae	*Herklotsichthys quadrimaculatus*	120	1
Dech	Lethrinidae	*Lethrinus* spp.	120	1
Elas	Acanthuridae	*Acanthurus triostegus*	120	1
Bikl	Haemulidae	*Plectorhinchus albovittatus*	100	1
Temekai	Serranidae	*Epinephelus* spp.	97	1
Ngelngal	Scombridae	*Scomberomorus commerson*	65	1
Orwidel	Carangidae	*Caranx melampygus*	50	0
Mokas	Serranidae	*Plectropomus leopardus*, *Plectropomus laevis*	50	0
Bebael	Siganidae	*Siganus punctatus*	45	0
Cherangel	Acanthuridae	*Naso lituratus*	44	0
Mechur	Lethrinidae	*Lethrinus xanthochilus*	43	0
Mengardechelucheb	Serranidae	*Cephalopholis argus*	43	0
Dukl	Scaridae	*Scarus ghobban*	22	0
Riamel	Ostraciidae	*Ostracion cubicus*	22	0
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	4	0
Komud	Kyphosidae	*Kyphosus* spp.	4	0
Teboteb	Kyphosidae	*Kyphosus vaigiensis*	4	0
Masch	Acanthuridae	*Ctenochaetus striatus*	1	0
Total:			**11,157**	**100**
Lagoon & outer reef				
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	434	20
Mesekuuk	Acanthuridae	*Acanthurus xanthopterus*	434	20
Keremlal	Lutjanidae	*Lutjanus gibbus*	347	16
Klsebuul	Siganidae	*Siganus lineatus*	261	12
Melangmud	Lethrinidae	*Lethrinus* spp.	174	8
Kedesau	Lutjanidae	*Lutjanus bohar*	174	8
Mechur	Lethrinidae	*Lethrinus xanthochilus*	174	8
Temekai	Serranidae	*Epinephelus* spp.	87	4
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	87	4
Total:			**2171**	**100**
Outer reef				
Keremlal	Lutjanidae	*Lutjanus gibbus*	789	11
Melangmud	Lethrinidae	*Lethrinus* spp.	749	11
Temekai	Serranidae	*Epinephelus* spp.	676	10
Kedesau	Lutjanidae	*Lutjanus bohar*	608	9

2.3.1 Annual catch (kg) of fish groups per habitat – Airai (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef (continued)				
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	596	9
Mechur	Lethrinidae	*Lethrinus xanthochilus*	580	8
Udel	Lutjanidae	*Aprion virescens*	347	5
Sebus	Lutjanidae	*Lutjanus* spp.	347	5
Orwidel	Carangidae	*Caranx melampygus*	347	5
Omektutau	Carangidae	*Caranx lugubris*	261	4
Menges	Lethrinidae	*Lethrinus erythracanthus*	261	4
Kelat	Mugilidae	*Valamugil seheli*	254	4
Uluu	Mugilidae	*Liza vaigiensis*	228	3
Udech	Lethrinidae	*Lethrinus olivaceus*	174	3
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	174	3
Metengui	Lethrinidae	*Lethrinus* spp.	174	3
Klsebuul	Siganidae	*Siganus lineatus*	158	2
Esuch	Carangidae	*Caranx sexfasciatus*	80	1
Kotikou	Gerreidae	*Gerres macrosoma*	48	1
Desachel	Holocentridae	*Sargocentron* spp.	40	1
Bsukel	Holocentridae	*Myripristis* spp.	40	1
Total:			**6931**	**100**

2.3.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Airai

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Mangrove	Emang	*Scylla serrata*	100	246	172	5594	3916
Reeftop	Oruer	*Tridacna crocea*, *Tridacna gigas*, *Tridacna maxima*, *Tridacna squamosa*	58	4406	2203	99,114	49,557
	Kim	*Hippopus hippopus*, *Tridacna derasa*	32	1472	736	33,532	16,766
	Erabrukl	*Panulirus* spp.	6	130	130	2772	2772
	Emang	*Scylla serrata*	4	included in mangrove catch			
	Irimd	*Holothuria* spp.	1	included in soft benthos (seagrass) catch			
	Omuu	*Cassis cornuta*	0	included in soft benthos (seagrass) catch			
Soft benthos	Ngimes	*Stichopus* spp.	32	9160	1832	203,081	40,616
	Eremrum	*Actinopyga* spp.	20	3716	1115	82,551	24,765
	Ibuchel	*Tripneustes gratilla*	16	9265	927	213,090	21,309
	Oruer	*Tridacna crocea*, *Tridacna gigas*, *Tridacna maxima*, *Tridacna squamosa*	16	10	0	213	4
	Irimd	*Holothuria* spp.	9	2597	519	57,262	11,452
	Molech	*Holothuria scabra*	6	1787	357	38,022	7604
	Sekesakel	*Holothuria* spp.	1	343	69	7767	1553
	Ngduul			67	0	1418	0

2.3.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Airai

Vernacular name	Scientific name	Size class	% of total catch (weight)
Emang	*Scylla serrata*	14 cm	35.3
		16 cm	64.7
Erabrukl	*Panulirus* spp.	16 cm	100.0
Eremrum	*Actinopyga* spp.	02–04 cm	11.7
		04 cm	46.7
		04–08 cm	21.5
		16 cm	11.7
		18 cm	1.3
		27 cm	7.0
Ibuchel	*Tripneustes gratilla*	08 cm	93.3
		08–10 cm	4.7
		10 cm	1.6
		10–12 cm	0.4
Irimd	*Holothuria* spp.	04 cm	50.2
		12 cm	16.7
		16–18 cm	29.3
		20–24 cm	3.8
Kim	*Hippopus hippopus*, *Tridacna derasa*	12–14 cm	48.7
		18 cm	0.5
		18–28 cm	26.6
		20 cm	23.6
		20–24 cm	0.7
Molech	*Holothuria scabra*	12 cm	97.2
		16–18 cm	1.9
		18 cm	0.9
Ngduul		04–06 cm	
Ngimes	*Stichopus* spp.	02–04 cm	4.7
		06–12 cm	8.7
		08 cm	21.3
		10–12 cm	19.0
		14–16 cm	43.4
		27 cm	2.8
Omuu	*Cassis cornuta*	18 cm	100.0
Oruer	*Tridacna crocea*, *Tridacna gigas*, *Tridacna maxima*, *Tridacna squamosa*	04 cm	19.7
		06 cm	39.4
		08–10 cm	0.4
		10–12 cm	15.9
		12 cm	7.4
		12–14 cm	16.7
		12–16 cm	0.5
Sekesakel	*Holothuria* spp.	02–04 cm	12.7
		08–12 cm	87.3

2.4 Koror socioeconomic survey data

2.4.1 Annual catch (kg) of fish groups per habitat – Koror
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Ngyaoch	Scaridae	*Hipposcarus longiceps*	326	17.2
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	326	17.2
Mirechorech	Serranidae	*Epinephelus merra*	261	13.7
Elas	Acanthuridae	*Acanthurus triostegus*	261	13.7
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	98	5.2
Um	Acanthuridae	*Naso unicornis*	65	3.4
Bang	Mullidae	*Parupeneus barberinus*	65	3.4
Klsebuul	Siganidae	*Siganus lineatus*	65	3.4
Masch	Acanthuridae	*Ctenochaetus striatus*	65	3.4
Tungch	Balistidae	*Balistes* spp.	65	3.4
Keremlal	Lutjanidae	*Lutjanus gibbus*	53	2.8
Beadel	Scaridae	*Cetoscarus bicolor*	43	2.3
Budech	Labridae	*Choerodon anchorago*	43	2.3
Bikl	Haemulidae	*Plectorhinchus albovittatus*	43	2.3
Udech	Lethrinidae	*Lethrinus olivaceus*	31	1.6
Bebael	Siganidae	*Siganus punctatus*	22	1.1
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	22	1.1
Yaus	Haemulidae	*Plectorhinchus* spp.	22	1.1
Temekai	Serranidae	*Epinephelus* spp.	11	0.6
Mekngit dusel			9	0.5
Total:			**1897**	**100.0**
Lagoon				
Melangmud	Lethrinidae	*Lethrinus* spp.	1808	10.1
Ngyaoch	Scaridae	*Hipposcarus longiceps*	1661	9.2
Erangel	Acanthuridae	*Naso lituratus*	1612	9.0
Keremlal	Lutjanidae	*Lutjanus gibbus*	1427	7.9
Um	Acanthuridae	*Naso unicornis*	899	5.0
Mechur	Lethrinidae	*Lethrinus xanthochilus*	885	4.9
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	816	4.5
Ngesngis	Scaridae	*Cetoscarus bicolor*	805	4.5
Beadle	Scaridae	*Cetoscarus bicolor*	789	4.4
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	653	3.6
Mesekuuk	Acanthuridae	*Acanthurus xanthopterus*	648	3.6
Bebael	Siganidae	*Siganus punctatus*	618	3.4
Klsebuul	Siganidae	*Siganus lineatus*	509	2.8
Desachel	Holocentridae	*Sargocentron* spp.	482	2.7
Bang	Mullidae	*Parupeneus barberinus*	434	2.4
Udech	Lethrinidae	*Lethrinus olivaceus*	382	2.1
Temekai	Serranidae	*Epinephelus* spp.	379	2.1
Mertebetabek	Scaridae	*Scarus ghobban*	360	2.0
Metengui	Lethrinidae	*Lethrinus* spp.	300	1.7

2.4.1 Annual catch (kg) of fish groups per habitat – Koror (continued)

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon (continued)				
Dodes	Lutjanidae	*Lutjanus* spp.	294	1.6
Otord	Lethrinidae	*Lethrinus* spp.	266	1.5
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	263	1.5
Kedesau	Lutjanidae	*Lutjanus bohar*	217	1.2
Masch	Acanthuridae	*Ctenochaetus striatus*	176	1.0
Menges	Lethrinidae	*Lethrinus erythracanthus*	174	1.0
Komud	Kyphosidae	*Kyphosus* spp.	174	1.0
Sebus	Lutjanidae	*Lutjanus* spp.	130	0.7
Edui	Lutjanidae	*Symphorichthys spilurus*	120	0.7
Beduut	Siganidae	*Siganus argenteus*	120	0.7
Besechamel	Lethrinidae	*Monotaxis grandoculis*	120	0.7
Esengel	Acanthuridae	*Acanthurus* spp.	109	0.6
Udondungelel	Scaridae	*Scarus* spp.	105	0.6
Udel	Lutjanidae	*Aprion virescens*	87	0.5
Belay	Acanthuridae	*Acanthurus lineatus*	50	0.3
Itotech	Lethrinidae	*Lethrinus harak*	47	0.3
Butiliang	Scaridae	*Scarus dimidiatus*	35	0.2
Yaus	Haemulidae	*Plectorhinchus* spp.	6	0.0
Rekruk	Lethrinidae	*Lethrinus rubrioperculatus*	5	0.0
Total:			**17,966**	**100.0**
Lagoon & outer reef				
Bang	Mullidae	*Parupeneus barberinus*	586	39.7
Ngyaoch	Scaridae	*Hipposcarus longiceps*	174	11.8
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	174	11.8
Esengel	Acanthuridae	*Acanthurus* spp.	152	10.3
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	130	8.8
Ray	Dasyatidae	*Dasyatis* spp.	109	7.4
Klsebuul	Siganidae	*Siganus lineatus*	87	5.9
Riamel	Ostraciidae	*Ostracion cubicus*	43	2.9
Dukl	Scaridae	*Scarus ghobban*	22	1.5
Total:			**1477**	**100.0**
Outer reef				
Erangel	Acanthuridae	*Naso lituratus*	884	12.9
Keremlal	Lutjanidae	*Lutjanus gibbus*	510	7.4
Mellemau	Scaridae	*Scarus oviceps*, *Scarus rubroviolaceus*	500	7.3
Ngyaoch	Scaridae	*Hipposcarus longiceps*	453	6.6
Melangmud	Lethrinidae	*Lethrinus* spp.	404	5.9
Ngesngis	Scaridae	*Cetoscarus bicolor*	383	5.6
Tiau	Serranidae	*Plectropomus areolatus*, *Plectropomus leopardus*	358	5.2
Mechur	Lethrinidae	*Lethrinus xanthochilus*	304	4.4
Mesekuuk	Acanthuridae	*Acanthurus xanthopterus*	303	4.4
Um	Acanthuridae	*Naso unicornis*	283	4.1
Beadel	Scaridae	*Cetoscarus bicolor*	253	3.7

2.4.1 Annual catch (kg) of fish groups per habitat – Koror (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef (continued)				
Mertebetabek	Scaridae	*Scarus ghobban*	200	2.9
Metengui	Lethrinidae	*Lethrinus* spp.	189	2.8
Yaus	Haemulidae	*Plectorhinchus* spp.	178	2.6
Otord	Lethrinidae	*Lethrinus* spp.	148	2.2
Bang	Mullidae	*Parupeneus barberinus*	147	2.1
Kedesau	Lutjanidae	*Lutjanus bohar*	130	1.9
Ngelngal	Scombridae	*Scomberomorus commerson*	130	1.9
Sebus	Lutjanidae	*Lutjanus* spp.	130	1.9
Teboteb	Kyphosidae	*Kyphosus vaigiensis*	130	1.9
Temekai	Serranidae	*Epinephelus* spp.	101	1.5
Klsebuul	Siganidae	*Siganus lineatus*	89	1.3
Meyas	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	87	1.3
Butiliang	Scaridae	*Scarus dimidiatus*	87	1.3
Udel	Lutjanidae	*Aprion virescens*	87	1.3
Edui	Lutjanidae	*Symphorichthys spilurus*	80	1.2
Desachel	Holocentridae	*Sargocentron* spp.	80	1.2
Bebael	Siganidae	*Siganus punctatus*	60	0.9
Bikl	Haemulidae	*Plectorhinchus albovittatus*	43	0.6
Besechamel	Lethrinidae	*Monotaxis grandoculis*	40	0.6
Udech	Lethrinidae	*Lethrinus olivaceus*	27	0.4
Dodes	Lutjanidae	*Lutjanus* spp.	27	0.4
Beduut	Siganidae	*Siganus argenteus*	20	0.3
Masch	Acanthuridae	*Ctenochaetus striatus*	1	0.0
Total:			**6846**	**100.0**

2.4.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Koror

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Mangrove	Ngduul	*Anodonita edentula*	20.0				
Reeftop	Oruer	*Tridacna crocea*, *Tridacna gigas*, *Tridacna maxima*, *Tridacna squamosa*	87.5	4728	2364	17,647	8824
	Kim	*Hippopus hippopus*, *Tridacna derasa*	12.5	675	338	3126	1563
Soft benthos	Eremrum	*Actinopyga* spp.	68.2	7138	2141	27,080	8124
	Ngimes	*Stichopus* spp.	21.8	3419	684	13,839	2768
	Ibuchel	*Tripneustes gratilla*	6.0	1899	190	6479	648
	Molech	*Holothuria scabra*	2.8	434	87	1482	296
	Sekesakel	*Holothuria* spp.	1.3	200	40	682	136
	Ngduul	*Anodonita edentula*		87	0	7116	

2.4.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Koror

Vernacular name	Scientific name	Size class	% of total catch (weight)
Eremrum	*Actinopyga* spp.	06 cm	14.0
		06–08 cm	14.0
		06–10 cm	12.6
		08 cm	12.2
		08–10 cm	1.4
		08–14 cm	8.4
		10 cm	36.0
		10–12 cm	1.4
Ibuchel	*Tripneustes gratilla*	08 cm	100.0
Kim	*Hippopus hippopus*, *Tridacna derasa*	10 cm	25.7
		14–20 cm	5.9
		16 cm	16.1
		18 cm	46.4
		24 cm	5.9
Molech	*Holothuria scabra*	12 cm	100.0
Ngduul	*Anodonita edentula*	06 cm	
		10 cm	
Ngimes	*Stichopus* spp.	08–10 cm	29.2
		14 cm	44.5
		14–18 cm	1.5
		20 cm	17.5
		20–22 cm	7.3
Oruer	*Tridacna crocea*, *Tridacna gigas*, *Tridacna maxima*, *Tridacna squamosa*	08 cm	31.8
		08–10 cm	4.2
		08–14 cm	8.5
		10 cm	55.1
		16–20 cm	0.4
Sekesakel	*Holothuria* spp.	06 cm	100.0

APPENDIX 3: FINFISH SURVEY DATA

3.1 Ngarchelong finfish survey data

3.1.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Ngarchelong

Station name	Habitat	Latitude	Longitude
TRA03	Back-reef	7º43'02.1612" N	134º34'39.7812" E
TRA04	Back-reef	7º43'28.92" N	134º34'38.1" E
TRA06	Back-reef	7º49'14.0412" N	134º37'49.7388" E
TRA10	Back-reef	7º48'05.58" N	134º34'58.1412" E
TRA11	Back-reef	7º47'33.4212" N	134º35'30.7212" E
TRA12	Back-reef	7º45'38.7612" N	134º34'11.64" E
TRA14	Back-reef	7º45'27.72" N	134º35'05.8812" E
TRA15	Back-reef	7º45'34.6212" N	134º34'49.26" E
TRA22	Back-reef	7º48'14.76" N	134º32'44.16" E
TRA16	Coastal reef	7º40'45.4188" N	134º36'48.96" E
TRA17	Coastal reef	7º42'19.5012" N	134º36'19.26" E
TRA18	Coastal reef	7º44'33" N	134º36'50.8788" E
TRA19	Coastal reef	7º43'40.62" N	134º36'11.2212" E
TRA23	Coastal reef	7º45'05.1588" N	134º36'55.08" E
TRA24	Coastal reef	7º45'44.82" N	134º37'15.3588" E
TRA01	Lagoon	7º42'01.0188" N	134º36'00.0612" E
TRA02	Lagoon	7º41'13.4412" N	134º35'26.4588" E
TRA05	Lagoon	7º47'13.92" N	134º37'17.3388" E
TRA07	Lagoon	7º47'36.1788" N	134º38'00.8988" E
TRA08	Outer reef	7º42'21.7188" N	134º33'53.1612" E
TRA09	Outer reef	7º43'28.92" N	134º34'38.1" E
TRA13	Outer reef	7º46'44.8212" N	134º33'42.5988" E
TRA20	Outer reef	7º48'32.94" N	134º39'44.9388" E
TRA21	Outer reef	7º49'23.7" N	134º38'24.36" E

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Acanthurus blochii*	0.0013	0.120
Back-reef	Acanthuridae	*Acanthurus guttatus*	0.0002	0.010
Back-reef	Acanthuridae	*Acanthurus lineatus*	0.0033	0.266
Back-reef	Acanthuridae	*Acanthurus maculiceps*	0.0013	0.098
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0093	0.881
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0096	3.275
Back-reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0129	0.333
Back-reef	Acanthuridae	*Acanthurus olivaceus*	0.0018	0.149
Back-reef	Acanthuridae	*Acanthurus pyroferus*	0.0009	0.049
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.1356	18.392
Back-reef	Acanthuridae	*Ctenochaetus strigosus*	0.0073	0.161
Back-reef	Acanthuridae	*Naso lituratus*	0.0040	1.436
Back-reef	Acanthuridae	*Naso unicornis*	0.0002	0.022

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0249	1.163
Back-reef	Acanthuridae	*Zebrasoma veliferum*	0.0040	1.042
Back-reef	Balistidae	*Balistapus undulatus*	0.0020	0.218
Back-reef	Balistidae	*Melichthys vidua*	0.0009	0.104
Back-reef	Balistidae	*Rhinecanthus aculeatus*	0.0004	0.012
Back-reef	Balistidae	*Sufflamen bursa*	0.0004	0.045
Back-reef	Balistidae	*Sufflamen chrysopterum*	0.0016	0.140
Back-reef	Caesionidae	*Caesio teres*	0.0011	0.125
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0007	0.037
Back-reef	Chaetodontidae	*Chaetodon baronessa*	0.0004	0.041
Back-reef	Chaetodontidae	*Chaetodon bennetti*	0.0018	0.133
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0022	0.033
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0051	0.580
Back-reef	Chaetodontidae	*Chaetodon kleinii*	0.0071	0.220
Back-reef	Chaetodontidae	*Chaetodon lineolatus*	0.0004	0.057
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0056	0.184
Back-reef	Chaetodontidae	*Chaetodon oxycephalus*	0.0004	0.049
Back-reef	Chaetodontidae	*Chaetodon pelewensis*	0.0009	0.004
Back-reef	Chaetodontidae	*Chaetodon rafflesii*	0.0011	0.033
Back-reef	Chaetodontidae	*Chaetodon semeion*	0.0002	0.007
Back-reef	Chaetodontidae	*Chaetodon trifascialis*	0.0093	0.244
Back-reef	Chaetodontidae	*Chaetodon ulietensis*	0.0002	0.009
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0011	0.076
Back-reef	Chaetodontidae	*Heniochus acuminatus*	0.0002	0.016
Back-reef	Haemulidae	*Plectorhinchus chaetodonoides*	0.0002	0.097
Back-reef	Haemulidae	*Plectorhinchus lessonii*	0.0002	0.106
Back-reef	Holocentridae	*Myripristis adusta*	0.0024	0.680
Back-reef	Holocentridae	*Myripristis* spp.	0.0002	0.027
Back-reef	Holocentridae	*Myripristis violacea*	0.0018	0.182
Back-reef	Holocentridae	*Neoniphon sammara*	0.0031	0.247
Back-reef	Holocentridae	*Sargocentron caudimaculatum*	0.0007	0.045
Back-reef	Holocentridae	*Sargocentron spiniferum*	0.0002	0.060
Back-reef	Labridae	*Cheilinus chlorourus*	0.0002	0.046
Back-reef	Labridae	*Cheilinus fasciatus*	0.0018	0.378
Back-reef	Labridae	*Cheilinus undulatus*	0.0002	0.077
Back-reef	Labridae	*Choerodon anchorago*	0.0004	0.163
Back-reef	Labridae	*Epibulus insidiator*	0.0004	0.086
Back-reef	Labridae	*Hemigymnus melapterus*	0.0007	0.134
Back-reef	Lethrinidae	*Lethrinus atkinsoni*	0.0002	0.074
Back-reef	Lethrinidae	*Lethrinus erythropterus*	0.0002	0.093
Back-reef	Lethrinidae	*Lethrinus harak*	0.0029	0.488
Back-reef	Lethrinidae	*Lethrinus obsoletus*	0.0002	0.058
Back-reef	Lethrinidae	*Lethrinus* spp.	0.0002	0.068
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0027	0.558
Back-reef	Lutjanidae	*Aphareus furca*	0.0004	0.220
Back-reef	Lutjanidae	*Lutjanus bohar*	0.0002	0.093

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0027	1.559
Back-reef	Lutjanidae	*Lutjanus semicinctus*	0.0018	0.548
Back-reef	Lutjanidae	*Macolor macularis*	0.0002	0.070
Back-reef	Lutjanidae	*Macolor niger*	0.0007	0.187
Back-reef	Mullidae	*Mulloidichthys flavolineatus*	0.0009	0.047
Back-reef	Mullidae	*Parupeneus barberinus*	0.0018	1.086
Back-reef	Mullidae	*Parupeneus bifasciatus*	0.0009	0.171
Back-reef	Mullidae	*Parupeneus cyclostomus*	0.0004	0.117
Back-reef	Mullidae	*Parupeneus indicus*	0.0018	0.381
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0053	0.453
Back-reef	Nemipteridae	*Scolopsis bilineata*	0.0024	0.228
Back-reef	Nemipteridae	*Scolopsis margaritifera*	0.0009	0.099
Back-reef	Nemipteridae	*Scolopsis trilineata*	0.0004	0.024
Back-reef	Pomacanthidae	*Pomacanthus sexstriatus*	0.0002	0.171
Back-reef	Pomacanthidae	*Pygoplites diacanthus*	0.0004	0.049
Back-reef	Scaridae	*Cetoscarus bicolor*	0.0002	0.010
Back-reef	Scaridae	*Chlorurus bleekeri*	0.0013	0.506
Back-reef	Scaridae	*Chlorurus sordidus*	0.0328	2.211
Back-reef	Scaridae	*Hipposcarus longiceps*	0.0004	0.096
Back-reef	Scaridae	*Scarus dimidiatus*	0.0073	1.420
Back-reef	Scaridae	*Scarus flavipectoralis*	0.0027	0.226
Back-reef	Scaridae	*Scarus forsteni*	0.0009	0.203
Back-reef	Scaridae	*Scarus frenatus*	0.0007	0.109
Back-reef	Scaridae	*Scarus ghobban*	0.0007	0.198
Back-reef	Scaridae	*Scarus globiceps*	0.0012	0.235
Back-reef	Scaridae	*Scarus niger*	0.0007	0.267
Back-reef	Scaridae	*Scarus oviceps*	0.0033	1.014
Back-reef	Scaridae	*Scarus prasiognathos*	0.0002	0.207
Back-reef	Scaridae	*Scarus psittacus*	0.0051	0.583
Back-reef	Scaridae	*Scarus rubroviolaceus*	0.0007	1.518
Back-reef	Scaridae	*Scarus schlegeli*	0.0066	1.579
Back-reef	Scaridae	*Scarus* spp.	0.0013	0.376
Back-reef	Serranidae	*Cephalopholis argus*	0.0016	0.826
Back-reef	Serranidae	*Cephalopholis cyanostigma*	0.0002	0.033
Back-reef	Serranidae	*Cephalopholis urodeta*	0.0018	0.167
Back-reef	Serranidae	*Epinephelus hexagonatus*	0.0002	0.009
Back-reef	Serranidae	*Epinephelus merra*	0.0036	0.216
Back-reef	Serranidae	*Epinephelus ongus*	0.0002	0.046
Back-reef	Serranidae	*Plectropomus leopardus*	0.0002	0.070
Back-reef	Serranidae	*Variola louti*	0.0002	0.357
Back-reef	Siganidae	*Siganus argenteus*	0.0004	0.052
Back-reef	Siganidae	*Siganus corallinus*	0.0013	0.303
Back-reef	Siganidae	*Siganus doliatus*	0.0033	0.548
Back-reef	Siganidae	*Siganus puellus*	0.0031	0.572
Back-reef	Siganidae	*Siganus punctatissimus*	0.0004	0.053
Back-reef	Siganidae	*Siganus vermiculatus*	0.0007	0.080

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Siganidae	*Siganus vulpinus*	0.0007	0.196
Back-reef	Zanclidae	*Zanclus cornutus*	0.0024	0.269
Coastal reef	Acanthuridae	*Acanthurus blochii*	0.0073	4.582
Coastal reef	Acanthuridae	*Acanthurus guttatus*	0.0023	0.109
Coastal reef	Acanthuridae	*Acanthurus leucocheilus*	0.0003	0.122
Coastal reef	Acanthuridae	*Acanthurus lineatus*	0.0707	18.189
Coastal reef	Acanthuridae	*Acanthurus nigricans*	0.0077	0.785
Coastal reef	Acanthuridae	*Acanthurus nigricauda*	0.0157	7.841
Coastal reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0070	0.317
Coastal reef	Acanthuridae	*Acanthurus nigroris*	0.0003	0.071
Coastal reef	Acanthuridae	*Acanthurus* spp.	0.0010	0.246
Coastal reef	Acanthuridae	*Acanthurus triostegus*	0.0013	0.071
Coastal reef	Acanthuridae	*Ctenochaetus striatus*	0.2072	27.303
Coastal reef	Acanthuridae	*Ctenochaetus strigosus*	0.0027	0.302
Coastal reef	Acanthuridae	*Naso brevirostris*	0.0033	1.377
Coastal reef	Acanthuridae	*Naso lituratus*	0.0230	8.569
Coastal reef	Acanthuridae	*Naso* spp.	0.0010	0.648
Coastal reef	Acanthuridae	*Naso unicornis*	0.0027	0.586
Coastal reef	Acanthuridae	*Zebrasoma scopas*	0.0413	2.031
Coastal reef	Acanthuridae	*Zebrasoma veliferum*	0.0010	0.019
Coastal reef	Balistidae	*Balistapus undulatus*	0.0030	0.213
Coastal reef	Balistidae	*Sufflamen bursa*	0.0007	0.060
Coastal reef	Balistidae	*Sufflamen chrysopterum*	0.0003	0.036
Coastal reef	Caesionidae	*Caesio cuning*	0.0040	0.922
Coastal reef	Caesionidae	*Pterocaesio digramma*	0.0087	2.450
Coastal reef	Caesionidae	*Pterocaesio tile*	0.0080	0.839
Coastal reef	Carangidae	*Alectis ciliaris*	0.0003	0.751
Coastal reef	Carangidae	*Carangoides ferdau*	0.0003	1.811
Coastal reef	Carangidae	*Caranx melampygus*	0.0013	0.334
Coastal reef	Carangidae	*Scomberoides commersonnianus*	0.0003	2.610
Coastal reef	Chaetodontidae	*Chaetodon auriga*	0.0013	0.037
Coastal reef	Chaetodontidae	*Chaetodon baronessa*	0.0040	0.314
Coastal reef	Chaetodontidae	*Chaetodon bennetti*	0.0007	0.030
Coastal reef	Chaetodontidae	*Chaetodon citrinellus*	0.0013	0.014
Coastal reef	Chaetodontidae	*Chaetodon ephippium*	0.0020	0.244
Coastal reef	Chaetodontidae	*Chaetodon kleinii*	0.0083	0.242
Coastal reef	Chaetodontidae	*Chaetodon lineolatus*	0.0003	0.076
Coastal reef	Chaetodontidae	*Chaetodon lunula*	0.0017	0.094
Coastal reef	Chaetodontidae	*Chaetodon lunulatus*	0.0130	0.358
Coastal reef	Chaetodontidae	*Chaetodon plebeius*	0.0007	0.034
Coastal reef	Chaetodontidae	*Chaetodon rafflesii*	0.0007	0.020
Coastal reef	Chaetodontidae	*Chaetodon semeion*	0.0017	0.151
Coastal reef	Chaetodontidae	*Chaetodon trifascialis*	0.0093	0.404
Coastal reef	Chaetodontidae	*Chaetodon ulietensis*	0.0027	0.072
Coastal reef	Chaetodontidae	*Chaetodon vagabundus*	0.0047	0.162
Coastal reef	Chaetodontidae	*Heniochus acuminatus*	0.0003	0.011

Appendix 3: Finfish survey data
Ngarchelong

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Coastal reef	Chaetodontidae	*Heniochus chrysostomus*	0.0003	0.023
Coastal reef	Chaetodontidae	*Heniochus varius*	0.0010	0.053
Coastal reef	Haemulidae	*Plectorhinchus gibbosus*	0.0003	1.136
Coastal reef	Haemulidae	*Plectorhinchus lessonii*	0.0020	0.510
Coastal reef	Haemulidae	*Plectorhinchus orientalis*	0.0017	0.353
Coastal reef	Holocentridae	*Myripristis adusta*	0.0007	0.220
Coastal reef	Holocentridae	*Sargocentron caudimaculatum*	0.0007	0.106
Coastal reef	Holocentridae	*Sargocentron spiniferum*	0.0023	0.658
Coastal reef	Kyphosidae	*Kyphosus vaigiensis*	0.0063	4.420
Coastal reef	Labridae	*Cheilinus fasciatus*	0.0013	0.535
Coastal reef	Labridae	*Cheilinus undulatus*	0.0007	0.401
Coastal reef	Labridae	*Choerodon anchorago*	0.0030	1.103
Coastal reef	Labridae	*Choerodon jordani*	0.0007	0.070
Coastal reef	Labridae	*Epibulus insidiator*	0.0010	0.198
Coastal reef	Labridae	*Hemigymnus melapterus*	0.0083	1.590
Coastal reef	Labridae	*Oxycheilinus digramma*	0.0003	0.029
Coastal reef	Lethrinidae	*Lethrinus erythropterus*	0.0010	0.899
Coastal reef	Lethrinidae	*Lethrinus harak*	0.0043	1.470
Coastal reef	Lethrinidae	*Lethrinus obsoletus*	0.0007	0.257
Coastal reef	Lethrinidae	*Lethrinus olivaceus*	0.0003	0.415
Coastal reef	Lethrinidae	*Monotaxis grandoculis*	0.0157	7.998
Coastal reef	Lutjanidae	*Lutjanus bohar*	0.0003	0.087
Coastal reef	Lutjanidae	*Lutjanus fulvus*	0.0057	1.533
Coastal reef	Lutjanidae	*Lutjanus gibbus*	0.0249	7.975
Coastal reef	Lutjanidae	*Lutjanus monostigma*	0.0010	0.678
Coastal reef	Lutjanidae	*Lutjanus semicinctus*	0.0007	0.147
Coastal reef	Lutjanidae	*Lutjanus* spp.	0.0003	0.165
Coastal reef	Lutjanidae	*Macolor macularis*	0.0013	0.065
Coastal reef	Lutjanidae	*Macolor niger*	0.0023	0.612
Coastal reef	Mullidae	*Mulloidichthys flavolineatus*	0.0180	4.887
Coastal reef	Mullidae	*Mulloidichthys vanicolensis*	0.0200	2.610
Coastal reef	Mullidae	*Parupeneus barberinus*	0.0090	2.876
Coastal reef	Mullidae	*Parupeneus bifasciatus*	0.0033	0.730
Coastal reef	Mullidae	*Parupeneus cyclostomus*	0.0033	1.613
Coastal reef	Mullidae	*Parupeneus indicus*	0.0007	0.359
Coastal reef	Mullidae	*Parupeneus multifasciatus*	0.0073	1.209
Coastal reef	Nemipteridae	*Scolopsis margaritifera*	0.0197	4.039
Coastal reef	Nemipteridae	*Scolopsis temporalis*	0.0003	0.080
Coastal reef	Pomacanthidae	*Pomacanthus navarchus*	0.0003	0.128
Coastal reef	Pomacanthidae	*Pomacanthus sexstriatus*	0.0003	0.280
Coastal reef	Pomacanthidae	*Pomacanthus* spp.	0.0003	0.089
Coastal reef	Pomacanthidae	*Pygoplites diacanthus*	0.0007	0.117
Coastal reef	Scaridae	*Cetoscarus bicolor*	0.0017	0.768
Coastal reef	Scaridae	*Chlorurus bleekeri*	0.0040	1.344
Coastal reef	Scaridae	*Chlorurus sordidus*	0.0793	14.847
Coastal reef	Scaridae	*Hipposcarus longiceps*	0.0233	15.727

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Coastal reef	Scaridae	*Scarus dimidiatus*	0.0152	3.597
Coastal reef	Scaridae	*Scarus flavipectoralis*	0.0007	0.236
Coastal reef	Scaridae	*Scarus frenatus*	0.0003	0.063
Coastal reef	Scaridae	*Scarus ghobban*	0.0023	0.622
Coastal reef	Scaridae	*Scarus globiceps*	0.0023	0.556
Coastal reef	Scaridae	*Scarus oviceps*	0.0027	0.671
Coastal reef	Scaridae	*Scarus psittacus*	0.0177	2.411
Coastal reef	Scaridae	*Scarus quoyi*	0.0010	0.181
Coastal reef	Scaridae	*Scarus rivulatus*	0.0067	1.793
Coastal reef	Scaridae	*Scarus schlegeli*	0.0037	0.408
Coastal reef	Scombridae	*Rastrelliger kanagurta*	0.0020	0.318
Coastal reef	Serranidae	*Cephalopholis boenak*	0.0003	0.048
Coastal reef	Serranidae	*Cephalopholis urodeta*	0.0023	0.275
Coastal reef	Serranidae	*Epinephelus hexagonatus*	0.0003	0.019
Coastal reef	Serranidae	*Epinephelus merra*	0.0017	0.097
Coastal reef	Serranidae	*Epinephelus ongus*	0.0003	0.009
Coastal reef	Serranidae	*Plectropomus leopardus*	0.0003	0.226
Coastal reef	Siganidae	*Siganus corallinus*	0.0003	0.010
Coastal reef	Siganidae	*Siganus doliatus*	0.0043	1.152
Coastal reef	Siganidae	*Siganus lineatus*	0.0010	0.557
Coastal reef	Siganidae	*Siganus puellus*	0.0003	0.051
Coastal reef	Siganidae	*Siganus punctatissimus*	0.0003	0.098
Coastal reef	Siganidae	*Siganus punctatus*	0.0003	0.058
Coastal reef	Zanclidae	*Zanclus cornutus*	0.0073	0.825
Lagoon	Acanthuridae	*Acanthurus blochii*	0.0055	0.347
Lagoon	Acanthuridae	*Acanthurus fowleri*	0.0065	0.629
Lagoon	Acanthuridae	*Acanthurus guttatus*	0.0020	0.105
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.0125	1.110
Lagoon	Acanthuridae	*Acanthurus nigricans*	0.0140	0.961
Lagoon	Acanthuridae	*Acanthurus nigricauda*	0.0070	1.037
Lagoon	Acanthuridae	*Acanthurus nigrofuscus*	0.0095	0.358
Lagoon	Acanthuridae	*Ctenochaetus binotatus*	0.0065	0.117
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.1330	13.758
Lagoon	Acanthuridae	*Ctenochaetus strigosus*	0.0005	0.024
Lagoon	Acanthuridae	*Naso lituratus*	0.0040	0.544
Lagoon	Acanthuridae	*Naso unicornis*	0.0005	0.033
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.0030	0.073
Lagoon	Acanthuridae	*Zebrasoma veliferum*	0.0030	0.197
Lagoon	Balistidae	*Balistapus undulatus*	0.0035	0.418
Lagoon	Balistidae	*Sufflamen chrysopterum*	0.0025	0.294
Lagoon	Caesionidae	*Caesio teres*	0.0025	0.192
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.0030	0.105
Lagoon	Chaetodontidae	*Chaetodon baronessa*	0.0005	0.015
Lagoon	Chaetodontidae	*Chaetodon citrinellus*	0.0020	0.018
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.0035	0.292
Lagoon	Chaetodontidae	*Chaetodon kleinii*	0.0070	0.052

Appendix 3: Finfish survey data
Ngarchelong

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Chaetodontidae	*Chaetodon lunula*	0.0010	0.029
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0040	0.199
Lagoon	Chaetodontidae	*Chaetodon reticulatus*	0.0020	0.044
Lagoon	Chaetodontidae	*Chaetodon semeion*	0.0010	0.039
Lagoon	Chaetodontidae	*Chaetodon trifascialis*	0.0095	0.260
Lagoon	Chaetodontidae	*Chaetodon ulietensis*	0.0030	0.066
Lagoon	Chaetodontidae	*Chaetodon vagabundus*	0.0045	0.240
Lagoon	Chaetodontidae	*Forcipiger longirostris*	0.0020	0.086
Lagoon	Haemulidae	*Plectorhinchus lessonii*	0.0005	0.095
Lagoon	Haemulidae	*Plectorhinchus picus*	0.0005	0.016
Lagoon	Holocentridae	*Myripristis adusta*	0.0005	0.121
Lagoon	Holocentridae	*Sargocentron caudimaculatum*	0.0030	0.311
Lagoon	Holocentridae	*Sargocentron spiniferum*	0.0005	0.118
Lagoon	Labridae	*Cheilinus chlorourus*	0.0010	0.083
Lagoon	Labridae	*Cheilinus fasciatus*	0.0040	0.265
Lagoon	Labridae	*Choerodon anchorago*	0.0035	0.438
Lagoon	Labridae	*Epibulus insidiator*	0.0010	0.253
Lagoon	Labridae	*Hemigymnus melapterus*	0.0030	0.491
Lagoon	Lethrinidae	*Lethrinus harak*	0.0010	0.095
Lagoon	Lethrinidae	*Lethrinus obsoletus*	0.0005	0.025
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.0064	0.475
Lagoon	Lutjanidae	*Lutjanus semicinctus*	0.0005	0.057
Lagoon	Lutjanidae	*Macolor macularis*	0.0010	0.293
Lagoon	Lutjanidae	*Macolor niger*	0.0005	0.072
Lagoon	Mullidae	*Mulloidichthys flavolineatus*	0.0050	0.266
Lagoon	Mullidae	*Parupeneus barberinus*	0.0035	0.238
Lagoon	Mullidae	*Parupeneus bifasciatus*	0.0005	0.017
Lagoon	Mullidae	*Parupeneus cyclostomus*	0.0020	0.556
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0075	0.751
Lagoon	Nemipteridae	*Scolopsis bilineata*	0.0035	0.339
Lagoon	Nemipteridae	*Scolopsis margaritifera*	0.0075	0.837
Lagoon	Nemipteridae	*Scolopsis temporalis*	0.0035	0.318
Lagoon	Nemipteridae	*Scolopsis trilineata*	0.0010	0.053
Lagoon	Pomacanthidae	*Pygoplites diacanthus*	0.0015	0.267
Lagoon	Scaridae	*Cetoscarus bicolor*	0.0030	1.867
Lagoon	Scaridae	*Chlorurus bleekeri*	0.0010	0.353
Lagoon	Scaridae	*Chlorurus microrhinos*	0.0010	0.296
Lagoon	Scaridae	*Chlorurus sordidus*	0.0525	5.215
Lagoon	Scaridae	*Hipposcarus longiceps*	0.0035	0.375
Lagoon	Scaridae	*Scarus dimidiatus*	0.0135	1.612
Lagoon	Scaridae	*Scarus forsteni*	0.0020	0.471
Lagoon	Scaridae	*Scarus frenatus*	0.0020	0.481
Lagoon	Scaridae	*Scarus ghobban*	0.0015	0.262
Lagoon	Scaridae	*Scarus globiceps*	0.0025	0.134
Lagoon	Scaridae	*Scarus niger*	0.0015	0.151
Lagoon	Scaridae	*Scarus oviceps*	0.0055	0.392

Appendix 3: Finfish survey data
Ngarchelong

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Scaridae	*Scarus prasiognathos*	0.0005	0.124
Lagoon	Scaridae	*Scarus psittacus*	0.0200	1.249
Lagoon	Scaridae	*Scarus schlegeli*	0.0055	0.615
Lagoon	Scaridae	*Scarus* spp.	0.0035	0.123
Lagoon	Serranidae	*Aethaloperca rogaa*	0.0005	0.201
Lagoon	Serranidae	*Cephalopholis cyanostigma*	0.0005	0.074
Lagoon	Serranidae	*Cephalopholis urodeta*	0.0010	0.151
Lagoon	Serranidae	*Epinephelus merra*	0.0030	0.096
Lagoon	Serranidae	*Epinephelus ongus*	0.0005	0.032
Lagoon	Serranidae	*Plectropomus leopardus*	0.0020	0.317
Lagoon	Serranidae	*Variola louti*	0.0005	0.174
Lagoon	Siganidae	*Siganus corallinus*	0.0010	0.031
Lagoon	Siganidae	*Siganus doliatus*	0.0015	0.169
Lagoon	Siganidae	*Siganus puellus*	0.0005	0.039
Lagoon	Zanclidae	*Zanclus cornutus*	0.0010	0.168
Outer reef	Acanthuridae	*Acanthurus guttatus*	0.0008	0.059
Outer reef	Acanthuridae	*Acanthurus lineatus*	0.0139	2.005
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.0240	3.746
Outer reef	Acanthuridae	*Acanthurus nigricauda*	0.0108	3.442
Outer reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0368	0.620
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.2003	34.768
Outer reef	Acanthuridae	*Naso lituratus*	0.0056	2.303
Outer reef	Acanthuridae	*Naso unicornis*	0.0046	1.109
Outer reef	Acanthuridae	*Zebrasoma scopas*	0.0104	1.213
Outer reef	Acanthuridae	*Zebrasoma veliferum*	0.0028	0.865
Outer reef	Balistidae	*Balistapus undulatus*	0.0040	0.326
Outer reef	Balistidae	*Melichthys vidua*	0.0036	0.386
Outer reef	Balistidae	*Sufflamen bursa*	0.0028	0.277
Outer reef	Balistidae	*Sufflamen chrysopterum*	0.0020	0.267
Outer reef	Carangidae	*Carangoides ferdau*	0.0008	1.089
Outer reef	Carangidae	*Scomberoides commersonnianus*	0.0004	1.196
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0084	0.133
Outer reef	Chaetodontidae	*Chaetodon kleinii*	0.0116	0.345
Outer reef	Chaetodontidae	*Chaetodon lunula*	0.0016	0.140
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0032	0.093
Outer reef	Chaetodontidae	*Chaetodon melannotus*	0.0004	0.006
Outer reef	Chaetodontidae	*Chaetodon meyeri*	0.0004	0.015
Outer reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0012	0.026
Outer reef	Chaetodontidae	*Chaetodon rafflesii*	0.0016	0.109
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0032	0.170
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0016	0.051
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0060	0.365
Outer reef	Chaetodontidae	*Forcipiger flavissimus*	0.0016	0.066
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0016	0.069
Outer reef	Chaetodontidae	*Heniochus chrysostomus*	0.0008	0.043
Outer reef	Chaetodontidae	*Heniochus monoceros*	0.0004	0.033

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Chaetodontidae	*Heniochus varius*	0.0008	0.149
Outer reef	Holocentridae	*Myripristis adusta*	0.0008	0.265
Outer reef	Holocentridae	*Myripristis kuntee*	0.0004	0.108
Outer reef	Holocentridae	*Myripristis murdjan*	0.0048	0.507
Outer reef	Holocentridae	*Myripristis violacea*	0.0020	0.357
Outer reef	Holocentridae	*Sargocentron caudimaculatum*	0.0040	0.388
Outer reef	Labridae	*Cheilinus chlorourus*	0.0004	0.002
Outer reef	Labridae	*Cheilinus fasciatus*	0.0004	0.204
Outer reef	Labridae	*Coris gaimard*	0.0012	0.211
Outer reef	Labridae	*Epibulus insidiator*	0.0008	0.203
Outer reef	Labridae	*Hemigymnus melapterus*	0.0004	0.081
Outer reef	Labridae	*Oxycheilinus digramma*	0.0008	0.136
Outer reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0004	0.060
Outer reef	Lethrinidae	*Lethrinus erythropterus*	0.0004	0.105
Outer reef	Lethrinidae	*Lethrinus harak*	0.0004	0.122
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0008	0.658
Outer reef	Lutjanidae	*Aphareus furca*	0.0004	0.338
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0004	0.167
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0504	20.608
Outer reef	Lutjanidae	*Lutjanus monostigma*	0.0020	0.890
Outer reef	Lutjanidae	*Lutjanus semicinctus*	0.0004	0.064
Outer reef	Lutjanidae	*Macolor macularis*	0.0012	0.388
Outer reef	Lutjanidae	*Macolor niger*	0.0024	0.882
Outer reef	Mullidae	*Parupeneus barberinus*	0.0004	0.316
Outer reef	Mullidae	*Parupeneus bifasciatus*	0.0080	2.769
Outer reef	Mullidae	*Parupeneus cyclostomus*	0.0008	0.055
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0076	0.265
Outer reef	Nemipteridae	*Scolopsis bilineata*	0.0024	0.218
Outer reef	Pomacanthidae	*Pomacanthus imperator*	0.0004	0.093
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0008	0.129
Outer reef	Scaridae	*Cetoscarus bicolor*	0.0004	0.374
Outer reef	Scaridae	*Chlorurus japanensis*	0.0008	0.088
Outer reef	Scaridae	*Chlorurus sordidus*	0.0476	4.764
Outer reef	Scaridae	*Hipposcarus longiceps*	0.0028	1.620
Outer reef	Scaridae	*Scarus dimidiatus*	0.0056	2.169
Outer reef	Scaridae	*Scarus flavipectoralis*	0.0008	0.225
Outer reef	Scaridae	*Scarus forsteni*	0.0004	0.143
Outer reef	Scaridae	*Scarus frenatus*	0.0020	0.511
Outer reef	Scaridae	*Scarus ghobban*	0.0004	0.133
Outer reef	Scaridae	*Scarus globiceps*	0.0012	0.261
Outer reef	Scaridae	*Scarus niger*	0.0012	0.209
Outer reef	Scaridae	*Scarus oviceps*	0.0040	1.770
Outer reef	Scaridae	*Scarus prasiognathos*	0.0004	0.722
Outer reef	Scaridae	*Scarus psittacus*	0.0068	1.176
Outer reef	Scaridae	*Scarus rubroviolaceus*	0.0076	1.843
Outer reef	Scaridae	*Scarus schlegeli*	0.0020	1.215

3.1.2 Weighted average density and biomass of all finfish species recorded in Ngarchelong (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Scaridae	*Scarus* spp.	0.0008	0.141
Outer reef	Scaridae	*Scarus spinus*	0.0004	0.076
Outer reef	Serranidae	*Cephalopholis argus*	0.0012	0.650
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0100	0.593
Outer reef	Serranidae	*Variola louti*	0.0004	0.066
Outer reef	Siganidae	*Siganus argenteus*	0.0004	0.027
Outer reef	Siganidae	*Siganus puellus*	0.0008	0.089
Outer reef	Siganidae	*Siganus punctatissimus*	0.0004	0.134

3.2 Ngatpang finfish survey data

3.2.1 Coordinates (WGS84) of the 22 D-UVC transects used to assess finfish resource status in Ngatpang

Transect	Habitat	Latitude	Longitude
TRA12	Back-reef	7º31'28.8012" N	134º28'17.4612" E
TRA16	Back-reef	7º31'57.18" N	134º28'46.8588" E
TRA21	Back-reef	7º31'51.1788" N	134º28'43.0788" E
TRA22	Back-reef	7º31'04.9188" N	134º27'23.6988" E
TRA05	Coastal reef	7º30'02.6388" N	134º29'33" E
TRA02	Coastal reef	7º28'56.1" N	134º28'33.7188" E
TRA06	Coastal reef	7º30'02.9988" N	134º29'13.6788" E
TRA17	Coastal reef	7º27'35.46" N	134º27'57.8412" E
TRA18	Coastal reef	7º27'59.1588" N	134º28'13.6812" E
TRA19	Coastal reef	7º29'45.7188" N	134º28'47.7012" E
TRA01	Lagoon	7º28'20.64" N	134º28'23.2212" E
TRA03	Lagoon	7º28'04.9188" N	134º27'56.4588" E
TRA04	Lagoon	7º29'14.0388" N	134º27'05.6988" E
TRA07	Lagoon	7º30'24.9588" N	134º28'55.4412" E
TRA08	Lagoon	7º30'08.0388" N	134º28'18.2388" E
TRA20	Lagoon	7º29'23.46" N	134º26'26.2788" E
TRA09	Outer reef	7º32'07.1412" N	134º23'17.4012" E
TRA10	Outer reef	7º31'46.8588" N	134º24'11.9412" E
TRA11	Outer reef	7º31'18.3" N	134º25'23.52" E
TRA13	Outer reef	7º31'25.2588"N	134º22'45.9012" E
TRA14	Outer reef	7º31'15.96" N	134º24'52.6788" E
TRA15	Outer reef	7º31'47.1612" N	134º26'05.46" E

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Acanthurus lineatus*	0.0005	0.142
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0010	0.066
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0025	0.864
Back-reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0005	0.024
Back-reef	Acanthuridae	*Acanthurus pyroferus*	0.0005	0.023
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.1556	14.439
Back-reef	Acanthuridae	*Naso brevirostris*	0.0015	0.038
Back-reef	Acanthuridae	*Naso lituratus*	0.0005	0.051
Back-reef	Acanthuridae	*Naso* spp.	0.0005	0.035
Back-reef	Acanthuridae	*Naso unicornis*	0.0005	0.022
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0505	1.594
Back-reef	Balistidae	*Balistapus undulatus*	0.0045	0.141
Back-reef	Balistidae	*Rhinecanthus verrucosus*	0.0005	0.013
Back-reef	Caesionidae	*Caesio cuning*	0.0176	2.622
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0010	0.031
Back-reef	Chaetodontidae	*Chaetodon capistratus*	0.0010	0.004
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0025	0.039
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0100	0.781

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Chaetodontidae	*Chaetodon kleinii*	0.0050	0.203
Back-reef	Chaetodontidae	*Chaetodon lunula*	0.0040	0.357
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0130	0.291
Back-reef	Chaetodontidae	*Chaetodon melannotus*	0.0070	0.064
Back-reef	Chaetodontidae	*Chaetodon rafflesii*	0.0020	0.101
Back-reef	Chaetodontidae	*Chaetodon ulietensis*	0.0005	0.020
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0050	0.222
Back-reef	Chaetodontidae	*Forcipiger flavissimus*	0.0015	0.024
Back-reef	Chaetodontidae	*Forcipiger longirostris*	0.0010	0.030
Back-reef	Chaetodontidae	*Heniochus varius*	0.0015	0.229
Back-reef	Haemulidae	*Plectorhinchus lessonii*	0.0005	0.095
Back-reef	Haemulidae	*Plectorhinchus orientalis*	0.0010	0.280
Back-reef	Holocentridae	*Myripristis adusta*	0.0030	0.745
Back-reef	Holocentridae	*Myripristis kuntee*	0.0090	0.917
Back-reef	Holocentridae	*Myripristis murdjan*	0.0120	1.764
Back-reef	Holocentridae	*Myripristis violacea*	0.0015	0.189
Back-reef	Labridae	*Cheilinus chlorourus*	0.0010	0.080
Back-reef	Labridae	*Cheilinus fasciatus*	0.0010	0.101
Back-reef	Labridae	*Cheilinus undulatus*	0.0005	0.022
Back-reef	Labridae	*Choerodon anchorago*	0.0010	0.080
Back-reef	Labridae	*Hemigymnus melapterus*	0.0105	1.152
Back-reef	Labridae	*Oxycheilinus digramma*	0.0005	0.052
Back-reef	Lethrinidae	*Lethrinus erythropterus*	0.0005	0.187
Back-reef	Lethrinidae	*Lethrinus xanthochilus*	0.0005	0.696
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0005	0.050
Back-reef	Lutjanidae	*Lutjanus bohar*	0.0005	0.114
Back-reef	Lutjanidae	*Lutjanus decussatus*	0.0010	0.225
Back-reef	Lutjanidae	*Lutjanus fulviflamma*	0.0060	2.631
Back-reef	Lutjanidae	*Lutjanus fulvus*	0.0205	5.086
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0010	0.018
Back-reef	Lutjanidae	*Lutjanus semicinctus*	0.0010	0.165
Back-reef	Mullidae	*Parupeneus barberinus*	0.0005	0.020
Back-reef	Mullidae	*Parupeneus bifasciatus*	0.0015	0.256
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0045	0.378
Back-reef	Nemipteridae	*Scolopsis bilineata*	0.0040	0.195
Back-reef	Nemipteridae	*Scolopsis margaritifera*	0.0065	0.870
Back-reef	Pomacanthidae	*Pygoplites diacanthus*	0.0010	0.245
Back-reef	Scaridae	*Chlorurus sordidus*	0.0240	1.845
Back-reef	Scaridae	*Scarus dimidiatus*	0.0150	0.786
Back-reef	Scaridae	*Scarus flavipectoralis*	0.0005	0.035
Back-reef	Scaridae	*Scarus frenatus*	0.0005	0.199
Back-reef	Scaridae	*Scarus ghobban*	0.0005	0.016
Back-reef	Scaridae	*Scarus psittacus*	0.0150	0.270
Back-reef	Scaridae	*Scarus quoyi*	0.0005	0.095
Back-reef	Scaridae	*Scarus rivulatus*	0.0010	0.088
Back-reef	Scaridae	*Scarus schlegeli*	0.0005	0.205

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Scaridae	*Scarus* spp.	0.0005	0.018
Back-reef	Scombridae	*Sarda orientalis*	0.0090	2.069
Back-reef	Serranidae	*Anyperodon leucogrammicus*	0.0005	0.041
Back-reef	Serranidae	*Cephalopholis argus*	0.0005	0.087
Back-reef	Serranidae	*Cephalopholis urodeta*	0.0030	0.210
Back-reef	Serranidae	*Epinephelus merra*	0.0090	0.521
Back-reef	Serranidae	*Epinephelus spilotoceps*	0.0020	0.145
Back-reef	Siganidae	*Siganus corallinus*	0.0070	0.566
Back-reef	Siganidae	*Siganus doliatus*	0.0045	0.955
Back-reef	Siganidae	*Siganus guttatus*	0.0090	0.493
Back-reef	Siganidae	*Siganus lineatus*	0.0030	0.113
Back-reef	Zanclidae	*Zanclus cornutus*	0.0025	0.310
Coastal reef	Acanthuridae	*Acanthurus guttatus*	0.0010	0.061
Coastal reef	Acanthuridae	*Acanthurus lineatus*	0.0147	2.369
Coastal reef	Acanthuridae	*Acanthurus nigricans*	0.0023	0.129
Coastal reef	Acanthuridae	*Acanthurus nigricauda*	0.0017	0.386
Coastal reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0010	0.090
Coastal reef	Acanthuridae	*Acanthurus pyroferus*	0.0003	0.025
Coastal reef	Acanthuridae	*Acanthurus thompsoni*	0.0003	0.122
Coastal reef	Acanthuridae	*Acanthurus triostegus*	0.0137	0.846
Coastal reef	Acanthuridae	*Acanthurus xanthopterus*	0.0013	0.411
Coastal reef	Acanthuridae	*Ctenochaetus striatus*	0.0993	15.720
Coastal reef	Acanthuridae	*Naso unicornis*	0.0033	1.815
Coastal reef	Acanthuridae	*Zebrasoma scopas*	0.0353	2.530
Coastal reef	Acanthuridae	*Zebrasoma veliferum*	0.0010	0.209
Coastal reef	Balistidae	*Balistapus undulatus*	0.0017	0.107
Coastal reef	Balistidae	*Rhinecanthus aculeatus*	0.0003	0.023
Coastal reef	Balistidae	*Rhinecanthus rectangulus*	0.0003	0.028
Coastal reef	Balistidae	*Rhinecanthus verrucosus*	0.0010	0.044
Coastal reef	Caesionidae	*Caesio cuning*	0.0123	4.222
Coastal reef	Caesionidae	*Caesio teres*	0.3375	50.733
Coastal reef	Caesionidae	*Pterocaesio digramma*	0.0060	0.922
Coastal reef	Chaetodontidae	*Chaetodon auriga*	0.0017	0.108
Coastal reef	Chaetodontidae	*Chaetodon baronessa*	0.0007	0.050
Coastal reef	Chaetodontidae	*Chaetodon bennetti*	0.0013	0.066
Coastal reef	Chaetodontidae	*Chaetodon ephippium*	0.0040	0.400
Coastal reef	Chaetodontidae	*Chaetodon kleinii*	0.0007	0.015
Coastal reef	Chaetodontidae	*Chaetodon lineolatus*	0.0007	0.019
Coastal reef	Chaetodontidae	*Chaetodon lunula*	0.0027	0.140
Coastal reef	Chaetodontidae	*Chaetodon lunulatus*	0.0040	0.156
Coastal reef	Chaetodontidae	*Chaetodon plebeius*	0.0003	0.017
Coastal reef	Chaetodontidae	*Chaetodon rafflesii*	0.0013	0.034
Coastal reef	Chaetodontidae	*Chaetodon ulietensis*	0.0007	0.028
Coastal reef	Chaetodontidae	*Chaetodon vagabundus*	0.0030	0.159
Coastal reef	Chaetodontidae	*Forcipiger longirostris*	0.0003	0.017
Coastal reef	Haemulidae	*Plectorhinchus chaetodonoides*	0.0003	0.218

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Coastal reef	Haemulidae	*Plectorhinchus chrysotaenia*	0.0003	0.322
Coastal reef	Haemulidae	*Plectorhinchus lessonii*	0.0017	0.770
Coastal reef	Haemulidae	*Plectorhinchus lineatus*	0.0003	0.082
Coastal reef	Haemulidae	*Plectorhinchus orientalis*	0.0003	0.159
Coastal reef	Holocentridae	*Myripristis adusta*	0.0047	2.264
Coastal reef	Holocentridae	*Myripristis berndti*	0.0003	0.075
Coastal reef	Holocentridae	*Myripristis kuntee*	0.0007	0.149
Coastal reef	Holocentridae	*Neoniphon sammara*	0.0003	0.069
Coastal reef	Holocentridae	*Sargocentron caudimaculatum*	0.0003	0.078
Coastal reef	Holocentridae	*Sargocentron spiniferum*	0.0020	0.588
Coastal reef	Labridae	*Cheilinus chlorourus*	0.0017	0.149
Coastal reef	Labridae	*Cheilinus fasciatus*	0.0030	0.775
Coastal reef	Labridae	*Choerodon anchorago*	0.0080	0.935
Coastal reef	Labridae	*Coris gaimard*	0.0003	0.018
Coastal reef	Labridae	*Epibulus insidiator*	0.0003	0.028
Coastal reef	Labridae	*Hemigymnus melapterus*	0.0020	0.454
Coastal reef	Labridae	*Oxycheilinus digramma*	0.0020	0.255
Coastal reef	Lethrinidae	*Lethrinus harak*	0.0043	1.372
Coastal reef	Lethrinidae	*Lethrinus obsoletus*	0.0017	0.402
Coastal reef	Lethrinidae	*Monotaxis grandoculis*	0.0050	2.247
Coastal reef	Lutjanidae	*Lutjanus bohar*	0.0013	0.305
Coastal reef	Lutjanidae	*Lutjanus decussatus*	0.0037	1.024
Coastal reef	Lutjanidae	*Lutjanus ehrenbergii*	0.0003	0.182
Coastal reef	Lutjanidae	*Lutjanus fulviflamma*	0.1887	67.316
Coastal reef	Lutjanidae	*Lutjanus fulvus*	0.0107	4.467
Coastal reef	Lutjanidae	*Lutjanus gibbus*	0.0197	10.980
Coastal reef	Lutjanidae	*Lutjanus monostigma*	0.0003	0.252
Coastal reef	Lutjanidae	*Lutjanus semicinctus*	0.0020	0.532
Coastal reef	Lutjanidae	*Macolor macularis*	0.0017	0.161
Coastal reef	Lutjanidae	*Symphorichthys spilurus*	0.0003	0.132
Coastal reef	Mullidae	*Parupeneus barberinus*	0.0047	0.449
Coastal reef	Mullidae	*Parupeneus bifasciatus*	0.0013	0.215
Coastal reef	Mullidae	*Parupeneus cyclostomus*	0.0003	0.023
Coastal reef	Mullidae	*Parupeneus multifasciatus*	0.0083	0.826
Coastal reef	Nemipteridae	*Scolopsis bilineata*	0.0003	0.025
Coastal reef	Nemipteridae	*Scolopsis lineata*	0.0003	0.036
Coastal reef	Nemipteridae	*Scolopsis margaritifera*	0.0187	4.345
Coastal reef	Nemipteridae	*Scolopsis temporalis*	0.0017	0.322
Coastal reef	Pomacanthidae	*Centropyge bicolor*	0.0010	0.028
Coastal reef	Pomacanthidae	*Pomacanthus imperator*	0.0007	0.514
Coastal reef	Pomacanthidae	*Pomacanthus sexstriatus*	0.0030	3.041
Coastal reef	Pomacanthidae	*Pomacanthus* spp.	0.0010	0.704
Coastal reef	Pomacanthidae	*Pygoplites diacanthus*	0.0007	0.101
Coastal reef	Scaridae	*Cetoscarus bicolor*	0.0013	0.783
Coastal reef	Scaridae	*Chlorurus bleekeri*	0.0110	2.339
Coastal reef	Scaridae	*Chlorurus microrhinos*	0.0013	0.842

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Coastal reef	Scaridae	*Chlorurus sordidus*	0.0207	4.022
Coastal reef	Scaridae	*Hipposcarus longiceps*	0.0190	8.426
Coastal reef	Scaridae	*Scarus altipinnis*	0.0007	0.000
Coastal reef	Scaridae	*Scarus dimidiatus*	0.0137	5.154
Coastal reef	Scaridae	*Scarus flavipectoralis*	0.0053	1.042
Coastal reef	Scaridae	*Scarus ghobban*	0.0007	0.367
Coastal reef	Scaridae	*Scarus niger*	0.0003	0.166
Coastal reef	Scaridae	*Scarus oviceps*	0.0007	0.275
Coastal reef	Scaridae	*Scarus psittacus*	0.0233	2.843
Coastal reef	Scaridae	*Scarus quoyi*	0.0010	0.166
Coastal reef	Scaridae	*Scarus rivulatus*	0.0017	0.274
Coastal reef	Scaridae	*Scarus schlegeli*	0.0020	1.015
Coastal reef	Scaridae	*Scarus* spp.	0.0137	0.413
Coastal reef	Serranidae	*Cephalopholis argus*	0.0003	0.008
Coastal reef	Serranidae	*Cephalopholis boenak*	0.0003	0.009
Coastal reef	Serranidae	*Cephalopholis cyanostigma*	0.0003	0.075
Coastal reef	Serranidae	*Cephalopholis miniata*	0.0007	0.228
Coastal reef	Serranidae	*Cephalopholis* spp.	0.0003	0.312
Coastal reef	Serranidae	*Epinephelus merra*	0.0030	0.283
Coastal reef	Serranidae	*Epinephelus polyphekadion*	0.0007	0.656
Coastal reef	Serranidae	*Plectropomus leopardus*	0.0007	0.177
Coastal reef	Siganidae	*Siganus argenteus*	0.0897	18.051
Coastal reef	Siganidae	*Siganus canaliculatus*	0.0067	1.950
Coastal reef	Siganidae	*Siganus doliatus*	0.0040	0.784
Coastal reef	Siganidae	*Siganus fuscescens*	0.0932	8.168
Coastal reef	Siganidae	*Siganus randalli*	0.0002	0.009
Coastal reef	Siganidae	*Siganus spinus*	0.0003	0.093
Coastal reef	Zanclidae	*Zanclus cornutus*	0.0037	0.506
Lagoon	Acanthuridae	*Acanthurus guttatus*	0.0003	0.009
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.0013	0.377
Lagoon	Acanthuridae	*Acanthurus nigricauda*	0.0020	0.370
Lagoon	Acanthuridae	*Acanthurus nigrofuscus*	0.0003	0.089
Lagoon	Acanthuridae	*Acanthurus pyroferus*	0.0003	0.071
Lagoon	Acanthuridae	*Acanthurus triostegus*	0.0003	0.010
Lagoon	Acanthuridae	*Ctenochaetus binotatus*	0.0010	0.012
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.1055	13.027
Lagoon	Acanthuridae	*Naso lituratus*	0.0003	0.034
Lagoon	Acanthuridae	*Naso* spp.	0.0040	0.166
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.0033	0.140
Lagoon	Acanthuridae	*Zebrasoma veliferum*	0.0007	0.036
Lagoon	Balistidae	*Balistapus undulatus*	0.0063	0.416
Lagoon	Balistidae	*Balistoides viridescens*	0.0003	0.234
Lagoon	Balistidae	*Rhinecanthus verrucosus*	0.0013	0.063
Lagoon	Balistidae	*Sufflamen chrysopterum*	0.0013	0.087
Lagoon	Caesionidae	*Caesio teres*	0.0438	15.517
Lagoon	Caesionidae	*Pterocaesio tile*	0.0120	0.091

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Carangidae	*Carangoides plagiotaenia*	0.0013	1.020
Lagoon	Carangidae	*Caranx melampygus*	0.0003	0.591
Lagoon	Chaetodontidae	*Chaetodon aureofasciatus*	0.0007	0.029
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.0017	0.064
Lagoon	Chaetodontidae	*Chaetodon baronessa*	0.0017	0.126
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.0037	0.341
Lagoon	Chaetodontidae	*Chaetodon kleinii*	0.0073	0.038
Lagoon	Chaetodontidae	*Chaetodon lineolatus*	0.0007	0.031
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0217	0.311
Lagoon	Chaetodontidae	*Chaetodon melannotus*	0.0013	0.011
Lagoon	Chaetodontidae	*Chaetodon rafflesii*	0.0050	0.106
Lagoon	Chaetodontidae	*Chaetodon semeion*	0.0007	0.033
Lagoon	Chaetodontidae	*Chaetodon* spp.	0.0017	0.082
Lagoon	Chaetodontidae	*Chaetodon trifascialis*	0.0007	0.008
Lagoon	Chaetodontidae	*Chaetodon ulietensis*	0.0007	0.026
Lagoon	Chaetodontidae	*Chaetodon vagabundus*	0.0040	0.185
Lagoon	Ephippidae	*Platax teira*	0.0003	1.354
Lagoon	Holocentridae	*Sargocentron spiniferum*	0.0007	0.117
Lagoon	Labridae	*Cheilinus chlorourus*	0.0023	0.118
Lagoon	Labridae	*Cheilinus fasciatus*	0.0053	0.565
Lagoon	Labridae	*Cheilinus undulatus*	0.0013	2.281
Lagoon	Labridae	*Choerodon anchorago*	0.0027	0.479
Lagoon	Labridae	*Hemigymnus melapterus*	0.0057	0.763
Lagoon	Labridae	*Oxycheilinus digramma*	0.0047	0.433
Lagoon	Labridae	*Oxycheilinus unifasciatus*	0.0013	0.132
Lagoon	Lutjanidae	*Lutjanus biguttatus*	0.0003	0.048
Lagoon	Lutjanidae	*Lutjanus bohar*	0.0007	0.161
Lagoon	Lutjanidae	*Lutjanus decussatus*	0.0003	0.064
Lagoon	Lutjanidae	*Lutjanus gibbus*	0.0015	0.478
Lagoon	Lutjanidae	*Lutjanus semicinctus*	0.0007	0.263
Lagoon	Lutjanidae	*Macolor macularis*	0.0003	0.020
Lagoon	Lutjanidae	*Macolor niger*	0.0003	0.118
Lagoon	Mullidae	*Mulloidichthys vanicolensis*	0.0010	0.221
Lagoon	Mullidae	*Parupeneus barberinus*	0.0023	0.634
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0080	0.323
Lagoon	Nemipteridae	*Pentapodus* spp.	0.0020	0.088
Lagoon	Nemipteridae	*Scolopsis bilineata*	0.0007	0.037
Lagoon	Nemipteridae	*Scolopsis margaritifera*	0.0037	0.735
Lagoon	Nemipteridae	*Scolopsis* spp.	0.0003	0.086
Lagoon	Nemipteridae	*Scolopsis temporalis*	0.0003	0.062
Lagoon	Pomacanthidae	*Centropyge bicolor*	0.0020	0.045
Lagoon	Pomacanthidae	*Pomacanthus sexstriatus*	0.0003	0.448
Lagoon	Pomacanthidae	*Pygoplites diacanthus*	0.0003	0.087
Lagoon	Scaridae	*Cetoscarus bicolor*	0.0013	0.239
Lagoon	Scaridae	*Chlorurus bleekeri*	0.0019	0.312
Lagoon	Scaridae	*Chlorurus microrhinos*	0.0010	0.323

Appendix 3: Finfish survey data
Ngatpang

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Scaridae	*Chlorurus sordidus*	0.0297	2.316
Lagoon	Scaridae	*Hipposcarus longiceps*	0.0067	0.838
Lagoon	Scaridae	*Scarus dimidiatus*	0.0070	0.727
Lagoon	Scaridae	*Scarus flavipectoralis*	0.0017	0.200
Lagoon	Scaridae	*Scarus frenatus*	0.0003	0.055
Lagoon	Scaridae	*Scarus ghobban*	0.0003	0.076
Lagoon	Scaridae	*Scarus niger*	0.0007	0.179
Lagoon	Scaridae	*Scarus psittacus*	0.0047	0.104
Lagoon	Scaridae	*Scarus quoyi*	0.0013	0.253
Lagoon	Scaridae	*Scarus rivulatus*	0.0010	0.081
Lagoon	Scaridae	*Scarus schlegeli*	0.0110	2.586
Lagoon	Scaridae	*Scarus* spp.	0.0007	0.024
Lagoon	Scombridae	*Scomberomorus commerson*	0.0003	0.848
Lagoon	Serranidae	*Cephalopholis argus*	0.0003	0.017
Lagoon	Serranidae	*Epinephelus merra*	0.0030	0.230
Lagoon	Serranidae	*Plectropomus leopardus*	0.0010	0.311
Lagoon	Serranidae	*Variola louti*	0.0003	0.104
Lagoon	Siganidae	*Siganus corallinus*	0.0003	0.049
Lagoon	Siganidae	*Siganus doliatus*	0.0047	0.686
Lagoon	Siganidae	*Siganus puellus*	0.0027	0.453
Lagoon	Siganidae	*Siganus vulpinus*	0.0007	0.067
Lagoon	Zanclidae	*Zanclus cornutus*	0.0010	0.168
Outer reef	Acanthuridae	*Acanthurus leucocheilus*	0.0007	0.388
Outer reef	Acanthuridae	*Acanthurus lineatus*	0.0298	7.177
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.1032	9.171
Outer reef	Acanthuridae	*Acanthurus nigricauda*	0.0070	3.331
Outer reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0010	0.014
Outer reef	Acanthuridae	*Acanthurus nigroris*	0.0013	0.112
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.3222	41.747
Outer reef	Acanthuridae	*Naso brachycentron*	0.0003	0.268
Outer reef	Acanthuridae	*Naso lituratus*	0.0093	3.569
Outer reef	Acanthuridae	*Naso unicornis*	0.0003	0.081
Outer reef	Acanthuridae	*Zebrasoma scopas*	0.0407	1.747
Outer reef	Acanthuridae	*Zebrasoma veliferum*	0.0007	0.090
Outer reef	Balistidae	*Balistapus undulatus*	0.0073	0.752
Outer reef	Balistidae	*Melichthys niger*	0.0040	0.818
Outer reef	Balistidae	*Melichthys vidua*	0.0058	0.687
Outer reef	Balistidae	*Sufflamen bursa*	0.0007	0.040
Outer reef	Balistidae	*Sufflamen chrysopterum*	0.0003	0.036
Outer reef	Carangidae	*Carangoides ferdau*	0.0007	2.883
Outer reef	Carangidae	*Caranx melampygus*	0.0018	2.144
Outer reef	Carangidae	*Scomberoides* spp.	0.0003	0.997
Outer reef	Chaetodontidae	*Chaetodon auriga*	0.0007	0.030
Outer reef	Chaetodontidae	*Chaetodon baronessa*	0.0027	0.171
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0010	0.010
Outer reef	Chaetodontidae	*Chaetodon ephippium*	0.0013	0.087

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Chaetodontidae	*Chaetodon kleinii*	0.0097	0.364
Outer reef	Chaetodontidae	*Chaetodon lineolatus*	0.0017	0.115
Outer reef	Chaetodontidae	*Chaetodon lunula*	0.0013	0.074
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0077	0.209
Outer reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0013	0.065
Outer reef	Chaetodontidae	*Chaetodon pelewensis*	0.0007	0.004
Outer reef	Chaetodontidae	*Chaetodon punctatofasciatus*	0.0007	0.010
Outer reef	Chaetodontidae	*Chaetodon rafflesii*	0.0013	0.052
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0043	0.190
Outer reef	Chaetodontidae	*Chaetodon semeion*	0.0007	0.042
Outer reef	Chaetodontidae	*Chaetodon* spp.	0.0013	0.101
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0053	0.092
Outer reef	Chaetodontidae	*Chaetodon unimaculatus*	0.0007	0.032
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0013	0.060
Outer reef	Chaetodontidae	*Forcipiger flavissimus*	0.0007	0.015
Outer reef	Chaetodontidae	*Hemitaurichthys polylepis*	0.0042	0.138
Outer reef	Chaetodontidae	*Heniochus chrysostomus*	0.0010	0.030
Outer reef	Chaetodontidae	*Heniochus monoceros*	0.0003	0.085
Outer reef	Chaetodontidae	*Heniochus varius*	0.0020	0.150
Outer reef	Haemulidae	*Plectorhinchus gibbosus*	0.0003	1.393
Outer reef	Haemulidae	*Plectorhinchus lessonii*	0.0007	0.232
Outer reef	Holocentridae	*Myripristis adusta*	0.0156	4.182
Outer reef	Holocentridae	*Myripristis kuntee*	0.0017	0.388
Outer reef	Holocentridae	*Myripristis murdjan*	0.0127	1.841
Outer reef	Holocentridae	*Sargocentron caudimaculatum*	0.0053	0.485
Outer reef	Holocentridae	*Sargocentron spiniferum*	0.0003	0.091
Outer reef	Labridae	*Cheilinus fasciatus*	0.0003	0.049
Outer reef	Labridae	*Cheilinus undulatus*	0.0003	0.070
Outer reef	Labridae	*Epibulus insidiator*	0.0013	0.297
Outer reef	Labridae	*Hemigymnus fasciatus*	0.0003	0.182
Outer reef	Labridae	*Hemigymnus melapterus*	0.0010	0.233
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0127	3.992
Outer reef	Lutjanidae	*Aphareus furca*	0.0003	0.105
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0003	0.111
Outer reef	Lutjanidae	*Lutjanus fulvus*	0.0003	0.089
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0095	4.561
Outer reef	Lutjanidae	*Lutjanus semicinctus*	0.0003	0.137
Outer reef	Lutjanidae	*Macolor macularis*	0.0007	0.095
Outer reef	Lutjanidae	*Macolor niger*	0.0063	5.155
Outer reef	Mullidae	*Parupeneus barberinus*	0.0067	3.568
Outer reef	Mullidae	*Parupeneus bifasciatus*	0.0020	0.432
Outer reef	Mullidae	*Parupeneus cyclostomus*	0.0010	0.477
Outer reef	Mullidae	*Parupeneus indicus*	0.0010	0.911
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0040	0.670
Outer reef	Mullidae	*Parupeneus pleurostigma*	0.0153	4.627
Outer reef	Nemipteridae	*Scolopsis bilineata*	0.0007	0.082

3.2.2 Weighted average density and biomass of all finfish species recorded in Ngatpang (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0030	0.297
Outer reef	Scaridae	*Bolbometopon muricatum*	0.0003	0.928
Outer reef	Scaridae	*Cetoscarus bicolor*	0.0007	0.731
Outer reef	Scaridae	*Chlorurus microrhinos*	0.0003	0.231
Outer reef	Scaridae	*Chlorurus sordidus*	0.0127	2.573
Outer reef	Scaridae	*Hipposcarus longiceps*	0.0003	0.105
Outer reef	Scaridae	*Scarus dimidiatus*	0.0003	0.119
Outer reef	Scaridae	*Scarus flavipectoralis*	0.0007	0.236
Outer reef	Scaridae	*Scarus forsteni*	0.0003	0.094
Outer reef	Scaridae	*Scarus frenatus*	0.0003	0.055
Outer reef	Scaridae	*Scarus globiceps*	0.0003	0.040
Outer reef	Scaridae	*Scarus niger*	0.0010	0.222
Outer reef	Scaridae	*Scarus oviceps*	0.0013	0.258
Outer reef	Scaridae	*Scarus psittacus*	0.0012	0.169
Outer reef	Scaridae	*Scarus rivulatus*	0.0010	0.758
Outer reef	Scaridae	*Scarus schlegeli*	0.0010	0.342
Outer reef	Serranidae	*Cephalopholis argus*	0.0040	1.264
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0027	0.139
Outer reef	Serranidae	*Epinephelus macrospilos*	0.0003	0.107
Outer reef	Serranidae	*Plectropomus leopardus*	0.0003	0.065
Outer reef	Siganidae	*Siganus corallinus*	0.0010	0.508
Outer reef	Siganidae	*Siganus vulpinus*	0.0010	0.225
Outer reef	Tetraodontidae	*Arothron stellatus*	0.0003	1.058
Outer reef	Zanclidae	*Zanclus cornutus*	0.0043	0.393

3.3 Airai finfish survey data

3.3.1 Coordinates (WGS 84) of the 24 D-UVC transects used to assess finfish resource status in Airai

Transect	Habitat	Latitude	Longitude
TRA01	Back-reef	7º16'28.4988" N	134º32'59.2188" E
TRA02	Back-reef	7º16'28.56" N	134º32'59.2188" E
TRA03	Back-reef	7º17'09.06" N	134º33'16.3188" E
TRA04	Back-reef	7º17'09.1788"N	134º33'16.3188" E
TRA09	Back-reef	7º21'57.6612"N	134º36'45.72" E
TRA13	Back-reef	7º23'22.74" N	134º37'25.0788" E
TRA06	Coastal reef	7º20'04.56" N	134º33'46.44" E
TRA07	Coastal reef	7º20'36.24" N	134º31'49.5588" E
TRA08	Coastal reef	7º20'36.24" N	134º31'49.5588" E
TRA12	Coastal reef	7º21'44.5788" N	134º36'05.2812" E
TRA16	Coastal reef	7º20'52.6812" N	134º35'11.4612" E
TRA05	Lagoon	7º20'04.6788" N	134º33'46.3212" E
TRA10	Lagoon	7º22'18.0012" N	134º36'27.8388" E
TRA11	Lagoon	7º22'36.12" N	134º36'42.2388" E
TRA14	Lagoon	7º23'17.2788" N	134º36'39.8412" E
TRA15	Lagoon	7º23'09.8412" N	134º35'44.16" E
TRA20	Lagoon	7º18'41.04" N	134º33'39.4812" E
TRA24	Lagoon	7º16'45.66" N	134º32'09.6612" E
TRA17	Outer reef	7º18'23.1588" N	134º34'03.6588" E
TRA18	Outer reef	7º21'20.7" N	134º36'48.06" E
TRA19	Outer reef	7º19'04.62" N	134º34'35.4612" E
TRA21	Outer reef	7º23'32.9388"	134º37'49.9188" E
TRA22	Outer reef	7º22'21.9" N	134º37'38.7012" E
TRA23	Outer reef	7º16'51.78" N	134º33'24.9012" E

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Acanthurus blochii*	0.0020	1.722
Back-reef	Acanthuridae	*Acanthurus dussumieri*	0.0003	0.245
Back-reef	Acanthuridae	*Acanthurus guttatus*	0.0007	0.073
Back-reef	Acanthuridae	*Acanthurus lineatus*	0.0003	0.005
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0020	0.162
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0047	2.643
Back-reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0017	0.066
Back-reef	Acanthuridae	*Acanthurus nigroris*	0.0010	0.046
Back-reef	Acanthuridae	*Acanthurus olivaceus*	0.0027	0.891
Back-reef	Acanthuridae	*Acanthurus pyroferus*	0.0043	0.748
Back-reef	Acanthuridae	*Acanthurus triostegus*	0.0080	0.695
Back-reef	Acanthuridae	*Acanthurus xanthopterus*	0.0003	0.277
Back-reef	Acanthuridae	*Ctenochaetus binotatus*	0.0023	0.061
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.0707	8.570
Back-reef	Acanthuridae	*Naso brevirostris*	0.0007	0.487
Back-reef	Acanthuridae	*Naso lituratus*	0.0027	0.768

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Back-reef	Acanthuridae	*Naso* spp.	0.0010	0.444
Back-reef	Acanthuridae	*Naso unicornis*	0.0087	7.000
Back-reef	Acanthuridae	*Paracanthurus hepatus*	0.0003	0.248
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0200	0.600
Back-reef	Balistidae	*Balistapus undulatus*	0.0037	0.376
Back-reef	Balistidae	*Melichthys vidua*	0.0007	0.072
Back-reef	Balistidae	*Sufflamen bursa*	0.0003	0.036
Back-reef	Balistidae	*Sufflamen chrysopterum*	0.0010	0.081
Back-reef	Caesionidae	*Caesio teres*	0.0633	13.792
Back-reef	Caesionidae	*Pterocaesio tile*	0.0067	0.699
Back-reef	Caesionidae	*Pterocaesio trilineata*	0.0060	0.349
Back-reef	Carangidae	*Carangoides ferdau*	0.0007	1.480
Back-reef	Carangidae	*Carangoides plagiotaenia*	0.0013	0.287
Back-reef	Carangidae	*Caranx melampygus*	0.0003	0.628
Back-reef	Carangidae	*Elagatis bipinnulata*	0.0003	1.079
Back-reef	Carangidae	*Scomberoides commersonnianus*	0.0010	0.460
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0013	0.104
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0003	0.004
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0003	0.019
Back-reef	Chaetodontidae	*Chaetodon lunula*	0.0007	0.042
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0033	0.106
Back-reef	Chaetodontidae	*Chaetodon melannotus*	0.0007	0.010
Back-reef	Chaetodontidae	*Chaetodon rafflesii*	0.0003	0.013
Back-reef	Chaetodontidae	*Chaetodon reticulatus*	0.0003	0.004
Back-reef	Chaetodontidae	*Chaetodon semeion*	0.0007	0.033
Back-reef	Chaetodontidae	*Chaetodon trifascialis*	0.0003	0.004
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0023	0.099
Back-reef	Chaetodontidae	*Forcipiger flavissimus*	0.0007	0.105
Back-reef	Chaetodontidae	*Forcipiger longirostris*	0.0007	0.010
Back-reef	Haemulidae	*Plectorhinchus chaetodonoides*	0.0003	0.311
Back-reef	Haemulidae	*Plectorhinchus gibbosus*	0.0003	0.519
Back-reef	Holocentridae	*Myripristis adusta*	0.0027	0.219
Back-reef	Holocentridae	*Neoniphon sammara*	0.0003	0.053
Back-reef	Labridae	*Cheilinus fasciatus*	0.0036	0.550
Back-reef	Labridae	*Choerodon anchorago*	0.0007	0.135
Back-reef	Labridae	*Coris gaimard*	0.0003	0.018
Back-reef	Labridae	*Epibulus insidiator*	0.0010	0.062
Back-reef	Labridae	*Hemigymnus fasciatus*	0.0003	0.059
Back-reef	Labridae	*Hemigymnus melapterus*	0.0020	0.460
Back-reef	Labridae	*Oxycheilinus digramma*	0.0013	0.189
Back-reef	Lethrinidae	*Lethrinus erythropterus*	0.0013	0.838
Back-reef	Lethrinidae	*Lethrinus harak*	0.0025	0.539
Back-reef	Lethrinidae	*Lethrinus lentjan*	0.0013	0.983
Back-reef	Lethrinidae	*Lethrinus obsoletus*	0.0007	0.265
Back-reef	Lethrinidae	*Lethrinus olivaceus*	0.0007	0.600
Back-reef	Lethrinidae	*Lethrinus xanthochilus*	0.0027	2.194

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0157	6.952
Back-reef	Lutjanidae	*Aphareus furca*	0.0003	0.387
Back-reef	Lutjanidae	*Lutjanus bohar*	0.0003	0.172
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0033	1.881
Back-reef	Lutjanidae	*Lutjanus semicinctus*	0.0003	0.154
Back-reef	Lutjanidae	*Macolor macularis*	0.0007	0.051
Back-reef	Lutjanidae	*Macolor niger*	0.0013	0.917
Back-reef	Lutjanidae	*Symphorichthys spilurus*	0.0027	1.897
Back-reef	Mullidae	*Parupeneus barberinoides*	0.0040	1.372
Back-reef	Mullidae	*Parupeneus barberinus*	0.0083	3.707
Back-reef	Mullidae	*Parupeneus bifasciatus*	0.0027	0.669
Back-reef	Mullidae	*Parupeneus ciliatus*	0.0003	0.043
Back-reef	Mullidae	*Parupeneus cyclostomus*	0.0007	0.153
Back-reef	Mullidae	*Parupeneus indicus*	0.0010	0.241
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0017	0.090
Back-reef	Nemipteridae	*Pentapodus trivittatus*	0.0100	0.299
Back-reef	Nemipteridae	*Scolopsis affinis*	0.0073	0.604
Back-reef	Nemipteridae	*Scolopsis bilineata*	0.0007	0.025
Back-reef	Nemipteridae	*Scolopsis margaritifera*	0.0050	0.921
Back-reef	Nemipteridae	*Scolopsis temporalis*	0.0007	0.070
Back-reef	Nemipteridae	*Scolopsis trilineata*	0.0003	0.049
Back-reef	Pomacanthidae	*Pomacanthus navarchus*	0.0007	0.469
Back-reef	Pomacanthidae	*Pomacanthus xanthometopon*	0.0003	0.279
Back-reef	Pomacanthidae	*Pygoplites diacanthus*	0.0010	0.122
Back-reef	Scaridae	*Cetoscarus bicolor*	0.0003	0.148
Back-reef	Scaridae	*Chlorurus bleekeri*	0.0023	1.180
Back-reef	Scaridae	*Chlorurus japanensis*	0.0007	0.144
Back-reef	Scaridae	*Chlorurus microrhinos*	0.0017	1.033
Back-reef	Scaridae	*Chlorurus sordidus*	0.0283	3.451
Back-reef	Scaridae	*Hipposcarus longiceps*	0.0010	0.532
Back-reef	Scaridae	*Scarus dimidiatus*	0.0040	0.663
Back-reef	Scaridae	*Scarus flavipectoralis*	0.0007	0.329
Back-reef	Scaridae	*Scarus ghobban*	0.0010	0.158
Back-reef	Scaridae	*Scarus globiceps*	0.0003	0.034
Back-reef	Scaridae	*Scarus niger*	0.0057	0.463
Back-reef	Scaridae	*Scarus oviceps*	0.0010	0.511
Back-reef	Scaridae	*Scarus psittacus*	0.0010	0.217
Back-reef	Scaridae	*Scarus rivulatus*	0.0003	0.089
Back-reef	Scaridae	*Scarus schlegeli*	0.0027	1.452
Back-reef	Serranidae	*Aethaloperca rogaa*	0.0007	0.296
Back-reef	Serranidae	*Cephalopholis cyanostigma*	0.0003	0.150
Back-reef	Serranidae	*Cephalopholis urodeta*	0.0017	0.072
Back-reef	Serranidae	*Epinephelus fuscoguttatus*	0.0003	0.984
Back-reef	Serranidae	*Plectropomus laevis*	0.0003	0.179
Back-reef	Serranidae	*Plectropomus leopardus*	0.0007	0.520
Back-reef	Serranidae	*Variola louti*	0.0003	0.175

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Siganidae	*Siganus corallinus*	0.0003	0.073
Back-reef	Siganidae	*Siganus doliatus*	0.0020	0.712
Back-reef	Siganidae	*Siganus guttatus*	0.0003	0.056
Back-reef	Siganidae	*Siganus lineatus*	0.0050	0.160
Back-reef	Siganidae	*Siganus puellus*	0.0007	0.178
Back-reef	Siganidae	*Siganus punctatissimus*	0.0013	0.636
Back-reef	Siganidae	*Siganus vulpinus*	0.0007	0.172
Back-reef	Zanclidae	*Zanclus cornutus*	0.0013	0.183
Coastal reef	Acanthuridae	*Acanthurus lineatus*	0.1047	34.039
Coastal reef	Acanthuridae	*Acanthurus nigricans*	0.0352	3.667
Coastal reef	Acanthuridae	*Ctenochaetus striatus*	0.1380	23.485
Coastal reef	Acanthuridae	*Naso lituratus*	0.0004	0.067
Coastal reef	Acanthuridae	*Naso unicornis*	0.0004	0.085
Coastal reef	Acanthuridae	*Naso vlamingii*	0.0012	0.202
Coastal reef	Acanthuridae	*Zebrasoma veliferum*	0.0032	0.066
Coastal reef	Balistidae	*Rhinecanthus verrucosus*	0.0004	0.082
Coastal reef	Carangidae	*Decapterus* spp.	0.0004	0.312
Coastal reef	Chaetodontidae	*Chaetodon auriga*	0.0004	0.023
Coastal reef	Chaetodontidae	*Chaetodon baronessa*	0.0004	0.012
Coastal reef	Chaetodontidae	*Chaetodon bennetti*	0.0004	0.025
Coastal reef	Chaetodontidae	*Chaetodon citrinellus*	0.0016	0.015
Coastal reef	Chaetodontidae	*Chaetodon ephippium*	0.0004	0.001
Coastal reef	Chaetodontidae	*Chaetodon kleinii*	0.0004	0.003
Coastal reef	Chaetodontidae	*Chaetodon lineolatus*	0.0004	0.054
Coastal reef	Chaetodontidae	*Chaetodon lunula*	0.0020	0.245
Coastal reef	Chaetodontidae	*Chaetodon lunulatus*	0.0116	0.137
Coastal reef	Chaetodontidae	*Chaetodon melannotus*	0.0020	0.020
Coastal reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0016	0.091
Coastal reef	Chaetodontidae	*Chaetodon oxycephalus*	0.0016	0.078
Coastal reef	Chaetodontidae	*Chaetodon rafflesii*	0.0020	0.098
Coastal reef	Chaetodontidae	*Chaetodon reticulatus*	0.0008	0.039
Coastal reef	Chaetodontidae	*Chaetodon semeion*	0.0012	0.113
Coastal reef	Chaetodontidae	*Chaetodon ulietensis*	0.0040	0.111
Coastal reef	Chaetodontidae	*Forcipiger flavissimus*	0.0008	0.040
Coastal reef	Chaetodontidae	*Heniochus varius*	0.0004	0.034
Coastal reef	Kyphosidae	*Kyphosus vaigiensis*	0.0048	1.436
Coastal reef	Labridae	*Cheilinus chlorourus*	0.0020	0.171
Coastal reef	Labridae	*Cheilinus fasciatus*	0.0020	0.265
Coastal reef	Labridae	*Cheilinus trilobatus*	0.0004	0.108
Coastal reef	Labridae	*Choerodon anchorago*	0.0016	0.125
Coastal reef	Labridae	*Epibulus insidiator*	0.0012	0.218
Coastal reef	Labridae	*Hemigymnus fasciatus*	0.0012	0.147
Coastal reef	Labridae	*Hemigymnus melapterus*	0.0024	0.118
Coastal reef	Labridae	*Oxycheilinus celebicus*	0.0028	0.105
Coastal reef	Labridae	*Oxycheilinus digramma*	0.0008	0.023
Coastal reef	Lethrinidae	*Monotaxis grandoculis*	0.0004	0.057

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Coastal reef	Lutjanidae	*Lutjanus fulvus*	0.0004	0.072
Coastal reef	Lutjanidae	*Lutjanus gibbus*	0.0068	1.772
Coastal reef	Mullidae	*Parupeneus barberinus*	0.0020	0.225
Coastal reef	Mullidae	*Parupeneus bifasciatus*	0.0040	0.849
Coastal reef	Mullidae	*Parupeneus cyclostomus*	0.0008	0.241
Coastal reef	Nemipteridae	*Scolopsis margaritifera*	0.0004	0.012
Coastal reef	Pomacanthidae	*Pygoplites diacanthus*	0.0004	0.060
Coastal reef	Scaridae	*Cetoscarus bicolor*	0.0004	0.087
Coastal reef	Scaridae	*Chlorurus bleekeri*	0.0020	0.745
Coastal reef	Scaridae	*Chlorurus japanensis*	0.0012	0.411
Coastal reef	Scaridae	*Chlorurus sordidus*	0.0020	0.014
Coastal reef	Scaridae	*Scarus dimidiatus*	0.0040	0.116
Coastal reef	Scaridae	*Scarus flavipectoralis*	0.0008	0.435
Coastal reef	Scaridae	*Scarus oviceps*	0.0008	0.266
Coastal reef	Scaridae	*Scarus rivulatus*	0.0004	0.242
Coastal reef	Scaridae	*Scarus* spp.	0.0012	0.198
Coastal reef	Scombridae	*Rastrelliger kanagurta*	0.0028	0.325
Coastal reef	Serranidae	*Cephalopholis argus*	0.0024	0.409
Coastal reef	Serranidae	*Epinephelus merra*	0.0016	0.075
Coastal reef	Siganidae	*Siganus doliatus*	0.0008	0.047
Coastal reef	Siganidae	*Siganus puellus*	0.0008	0.127
Coastal reef	Siganidae	*Siganus* spp.	0.0004	0.237
Coastal reef	Siganidae	*Siganus vulpinus*	0.0004	0.017
Coastal reef	Zanclidae	*Zanclus cornutus*	0.0040	0.550
Lagoon	Acanthuridae	*Acanthurus blochii*	0.0003	0.063
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.0080	2.889
Lagoon	Acanthuridae	*Acanthurus nigricans*	0.0046	0.511
Lagoon	Acanthuridae	*Acanthurus nigricauda*	0.0011	0.296
Lagoon	Acanthuridae	*Acanthurus nigrofuscus*	0.0034	0.049
Lagoon	Acanthuridae	*Acanthurus olivaceus*	0.0003	0.070
Lagoon	Acanthuridae	*Acanthurus pyroferus*	0.0051	1.270
Lagoon	Acanthuridae	*Acanthurus thompsoni*	0.0063	0.978
Lagoon	Acanthuridae	*Ctenochaetus flavicauda*	0.0003	0.002
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.1300	18.049
Lagoon	Acanthuridae	*Naso brevirostris*	0.0026	2.725
Lagoon	Acanthuridae	*Naso lituratus*	0.0011	0.259
Lagoon	Acanthuridae	*Naso thynnoides*	0.0006	0.129
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.0160	0.408
Lagoon	Acanthuridae	*Zebrasoma veliferum*	0.0009	0.387
Lagoon	Balistidae	*Balistapus undulatus*	0.0046	0.373
Lagoon	Balistidae	*Sufflamen chrysopterum*	0.0006	0.062
Lagoon	Balistidae	*Sufflamen* spp.	0.0006	0.027
Lagoon	Caesionidae	*Caesio caerulaurea*	0.0186	2.109
Lagoon	Caesionidae	*Caesio teres*	0.0086	3.188
Lagoon	Caesionidae	*Pterocaesio digramma*	0.0343	1.600
Lagoon	Caesionidae	*Pterocaesio marri*	0.0221	1.299

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Caesionidae	*Pterocaesio tile*	0.0949	7.973
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.0006	0.026
Lagoon	Chaetodontidae	*Chaetodon baronessa*	0.0009	0.057
Lagoon	Chaetodontidae	*Chaetodon bennetti*	0.0006	0.009
Lagoon	Chaetodontidae	*Chaetodon citrinellus*	0.0020	0.034
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.0011	0.111
Lagoon	Chaetodontidae	*Chaetodon kleinii*	0.0034	0.054
Lagoon	Chaetodontidae	*Chaetodon lunula*	0.0017	0.130
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0023	0.053
Lagoon	Chaetodontidae	*Chaetodon rafflesii*	0.0006	0.009
Lagoon	Chaetodontidae	*Chaetodon trifascialis*	0.0003	0.007
Lagoon	Chaetodontidae	*Chaetodon vagabundus*	0.0026	0.112
Lagoon	Ephippidae	*Platax teira*	0.0003	0.897
Lagoon	Haemulidae	*Plectorhinchus obscurus*	0.0003	1.624
Lagoon	Holocentridae	*Myripristis adusta*	0.0003	0.050
Lagoon	Holocentridae	*Myripristis murdjan*	0.0029	0.421
Lagoon	Holocentridae	*Neoniphon argenteus*	0.0031	0.223
Lagoon	Holocentridae	*Neoniphon opercularis*	0.0080	1.277
Lagoon	Holocentridae	*Neoniphon sammara*	0.0014	0.204
Lagoon	Holocentridae	*Neoniphon* spp.	0.0011	0.144
Lagoon	Holocentridae	*Sargocentron caudimaculatum*	0.0014	0.146
Lagoon	Holocentridae	*Sargocentron spiniferum*	0.0011	0.248
Lagoon	Kyphosidae	*Kyphosus cinerascens*	0.0006	0.491
Lagoon	Kyphosidae	*Kyphosus vaigiensis*	0.0006	0.511
Lagoon	Labridae	*Cheilinus chlorourus*	0.0006	0.103
Lagoon	Labridae	*Cheilinus fasciatus*	0.0006	0.034
Lagoon	Labridae	*Cheilinus undulatus*	0.0003	0.291
Lagoon	Labridae	*Choerodon anchorago*	0.0003	0.067
Lagoon	Labridae	*Choerodon fasciatus*	0.0006	0.176
Lagoon	Labridae	*Epibulus insidiator*	0.0007	0.066
Lagoon	Labridae	*Hemigymnus fasciatus*	0.0009	0.063
Lagoon	Labridae	*Hemigymnus melapterus*	0.0005	0.080
Lagoon	Labridae	*Oxycheilinus digramma*	0.0006	0.055
Lagoon	Lethrinidae	*Gnathodentex aureolineatus*	0.0009	0.050
Lagoon	Lethrinidae	*Lethrinus erythropterus*	0.0006	0.102
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.0083	10.251
Lagoon	Lutjanidae	*Lutjanus bohar*	0.0023	2.447
Lagoon	Lutjanidae	*Lutjanus gibbus*	0.0011	0.580
Lagoon	Lutjanidae	*Macolor macularis*	0.0043	4.448
Lagoon	Mullidae	*Mulloidichthys vanicolensis*	0.0014	0.045
Lagoon	Mullidae	*Parupeneus barberinus*	0.0034	0.852
Lagoon	Mullidae	*Parupeneus bifasciatus*	0.0017	0.143
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0140	0.840
Lagoon	Nemipteridae	*Scolopsis bilineata*	0.0040	0.407
Lagoon	Nemipteridae	*Scolopsis ciliata*	0.0003	0.031
Lagoon	Nemipteridae	*Scolopsis margaritifera*	0.0011	0.266

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Pomacanthidae	*Pygoplites diacanthus*	0.0011	0.340
Lagoon	Scaridae	*Cetoscarus bicolor*	0.0003	0.155
Lagoon	Scaridae	*Chlorurus bleekeri*	0.0043	1.293
Lagoon	Scaridae	*Chlorurus bowersi*	0.0006	0.142
Lagoon	Scaridae	*Chlorurus sordidus*	0.0337	2.856
Lagoon	Scaridae	*Hipposcarus longiceps*	0.0006	0.141
Lagoon	Scaridae	*Scarus dimidiatus*	0.0094	1.149
Lagoon	Scaridae	*Scarus flavipectoralis*	0.0009	0.179
Lagoon	Scaridae	*Scarus frenatus*	0.0006	0.105
Lagoon	Scaridae	*Scarus ghobban*	0.0003	0.043
Lagoon	Scaridae	*Scarus niger*	0.0011	0.453
Lagoon	Scaridae	*Scarus oviceps*	0.0006	0.311
Lagoon	Scaridae	*Scarus psittacus*	0.0063	0.197
Lagoon	Scaridae	*Scarus schlegeli*	0.0026	0.343
Lagoon	Scaridae	*Scarus* spp.	0.0006	0.081
Lagoon	Scaridae	*Scarus spinus*	0.0003	0.024
Lagoon	Serranidae	*Cephalopholis urodeta*	0.0009	0.048
Lagoon	Serranidae	*Epinephelus merra*	0.0003	0.024
Lagoon	Serranidae	*Plectropomus areolatus*	0.0003	0.163
Lagoon	Serranidae	*Plectropomus leopardus*	0.0011	0.459
Lagoon	Serranidae	*Variola louti*	0.0006	0.109
Lagoon	Siganidae	*Siganus argenteus*	0.0009	0.020
Lagoon	Siganidae	*Siganus corallinus*	0.0006	0.024
Lagoon	Siganidae	*Siganus doliatus*	0.0017	0.625
Lagoon	Siganidae	*Siganus lineatus*	0.0006	0.336
Lagoon	Siganidae	*Siganus puellus*	0.0034	0.592
Lagoon	Siganidae	*Siganus* spp.	0.0003	0.010
Lagoon	Siganidae	*Siganus spinus*	0.0057	0.104
Lagoon	Siganidae	*Siganus vulpinus*	0.0009	0.163
Lagoon	Zanclidae	*Zanclus cornutus*	0.0034	0.231
Outer reef	Acanthuridae	*Acanthurus guttatus*	0.0003	0.009
Outer reef	Acanthuridae	*Acanthurus lineatus*	0.0007	0.160
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.0247	1.620
Outer reef	Acanthuridae	*Acanthurus nigricauda*	0.0030	0.465
Outer reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0140	0.507
Outer reef	Acanthuridae	*Acanthurus pyroferus*	0.0010	0.088
Outer reef	Acanthuridae	*Acanthurus thompsoni*	0.0007	0.039
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.1796	22.967
Outer reef	Acanthuridae	*Naso lituratus*	0.0048	1.366
Outer reef	Acanthuridae	*Naso unicornis*	0.0007	1.008
Outer reef	Acanthuridae	*Naso vlamingii*	0.0022	0.608
Outer reef	Acanthuridae	*Zebrasoma scopas*	0.0233	0.605
Outer reef	Acanthuridae	*Zebrasoma veliferum*	0.0007	0.036
Outer reef	Balistidae	*Balistapus* spp.	0.0007	0.725
Outer reef	Balistidae	*Balistapus undulatus*	0.0043	0.331
Outer reef	Balistidae	*Melichthys vidua*	0.0030	0.303

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Balistidae	*Sufflamen bursa*	0.0003	0.020
Outer reef	Balistidae	*Sufflamen chrysopterum*	0.0007	0.028
Outer reef	Caesionidae	*Caesio lunaris*	0.0107	2.663
Outer reef	Caesionidae	*Pterocaesio tile*	0.0833	4.845
Outer reef	Chaetodontidae	*Chaetodon baronessa*	0.0070	0.211
Outer reef	Chaetodontidae	*Chaetodon bennetti*	0.0003	0.017
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0030	0.046
Outer reef	Chaetodontidae	*Chaetodon ephippium*	0.0017	0.159
Outer reef	Chaetodontidae	*Chaetodon kleinii*	0.0067	0.127
Outer reef	Chaetodontidae	*Chaetodon lineolatus*	0.0023	0.109
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0040	0.122
Outer reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0010	0.016
Outer reef	Chaetodontidae	*Chaetodon rafflesii*	0.0013	0.045
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0047	0.123
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0010	0.015
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0007	0.030
Outer reef	Chaetodontidae	*Forcipiger flavissimus*	0.0027	0.057
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0003	0.017
Outer reef	Haemulidae	*Plectorhinchus lessonii*	0.0003	0.193
Outer reef	Holocentridae	*Myripristis adusta*	0.0027	0.451
Outer reef	Holocentridae	*Sargocentron spiniferum*	0.0003	0.104
Outer reef	Kyphosidae	*Kyphosus vaigiensis*	0.0003	0.298
Outer reef	Labridae	*Cheilinus fasciatus*	0.0003	0.025
Outer reef	Labridae	*Cheilinus undulatus*	0.0010	0.719
Outer reef	Labridae	*Coris aygula*	0.0003	0.158
Outer reef	Labridae	*Hemigymnus fasciatus*	0.0010	0.048
Outer reef	Labridae	*Hemigymnus melapterus*	0.0020	0.830
Outer reef	Labridae	*Novaculichthys taeniourus*	0.0007	0.173
Outer reef	Labridae	*Oxycheilinus digramma*	0.0010	0.047
Outer reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0093	0.820
Outer reef	Lethrinidae	*Lethrinus obsoletus*	0.0003	0.207
Outer reef	Lethrinidae	*Lethrinus xanthochilus*	0.0003	0.322
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0020	0.369
Outer reef	Lutjanidae	*Aphareus furca*	0.0017	0.954
Outer reef	Lutjanidae	*Aprion virescens*	0.0003	0.238
Outer reef	Lutjanidae	*Lutjanus decussatus*	0.0003	0.064
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0003	0.230
Outer reef	Lutjanidae	*Macolor macularis*	0.0003	0.083
Outer reef	Lutjanidae	*Macolor niger*	0.0003	0.048
Outer reef	Mullidae	*Parupeneus barberinoides*	0.0013	0.113
Outer reef	Mullidae	*Parupeneus barberinus*	0.0010	0.281
Outer reef	Mullidae	*Parupeneus bifasciatus*	0.0067	0.741
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0117	0.494
Outer reef	Nemipteridae	*Scolopsis bilineata*	0.0027	0.281
Outer reef	Scaridae	*Calotomus carolinus*	0.0003	0.072
Outer reef	Scaridae	*Cetoscarus bicolor*	0.0003	0.366

3.3.2 Weighted average density and biomass of all finfish species recorded in Airai (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Scaridae	*Chlorurus bleekeri*	0.0003	0.072
Outer reef	Scaridae	*Chlorurus sordidus*	0.0360	3.506
Outer reef	Scaridae	*Scarus chameleon*	0.0007	0.080
Outer reef	Scaridae	*Scarus dimidiatus*	0.0008	0.145
Outer reef	Scaridae	*Scarus frenatus*	0.0013	0.125
Outer reef	Scaridae	*Scarus ghobban*	0.0003	0.017
Outer reef	Scaridae	*Scarus globiceps*	0.0003	0.034
Outer reef	Scaridae	*Scarus niger*	0.0027	0.251
Outer reef	Scaridae	*Scarus oviceps*	0.0010	0.172
Outer reef	Scaridae	*Scarus psittacus*	0.0035	0.329
Outer reef	Scaridae	*Scarus rivulatus*	0.0010	0.214
Outer reef	Scaridae	*Scarus rubroviolaceus*	0.0007	0.109
Outer reef	Scaridae	*Scarus schlegeli*	0.0033	0.608
Outer reef	Scaridae	*Scarus spinus*	0.0007	0.062
Outer reef	Serranidae	*Anyperodon leucogrammicus*	0.0003	0.037
Outer reef	Serranidae	*Cephalopholis argus*	0.0007	0.159
Outer reef	Serranidae	*Cephalopholis cyanostigma*	0.0003	0.121
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0037	0.185
Outer reef	Siganidae	*Siganus corallinus*	0.0013	0.224
Outer reef	Siganidae	*Siganus vulpinus*	0.0007	0.172
Outer reef	Zanclidae	*Zanclus cornutus*	0.0013	0.114

3.4 Koror finfish survey data

3.4.1 Coordinates (WGS 84) of the 24 D-UVC transects used to assess finfish resource status in Koror

Transect	Habitat	Latitude	Longitude
TRA03	Back-reef	7º11'45.1788" N	134º26'21.66" E
TRA04	Back-reef	7º13'47.0388" N	134º26'12.2388" E
TRA07	Back-reef	7º11'15.2988" N	134º26'56.2812" E
TRA08	Back-reef	7º13'24.24" N	134º26'03.5988" E
TRA18	Back-reef	7º07'26.22" N	134º16'43.0788" E
TRA23	Back-reef	7º19'57.6588" N	134º16'02.82" E
TRA24	Back-reef	7º19'55.38" N	134º19'55.2612" E
TRA12	Lagoon	7º15'20.4012" N	134º18'51.7788" E
TRA16	Lagoon	7º12'41.8788" N	134º19'55.6788" E
TRA17	Lagoon	7º11'22.8012" N	134º18'49.86" E
TRA19	Lagoon	7º08'36.4812" N	134º17'42.4212" E
TRA20	Lagoon	7º10'57" N	134º18'03.1212" E
TRA22	Lagoon	7º09'06.3612"N	134º17'40.02" E
TRA01	Outer reef	7º14'27.42" N	134º26'53.9412" E
TRA02	Outer reef	7º12'22.5" N	134º26'47.5188" E
TRA05	Outer reef	7º13'27.0588" N	134º26'35.16" E
TRA06	Outer reef	7º11'02.8788" N	134º27'23.94" E
TRA09	Outer reef	7º19'40.3212" N	134º12'56.16" E
TRA10	Outer reef	7º16'29.1" N	134º11'18.4812" E
TRA11	Outer reef	7º15'56.9988" N	134º14'46.7412" E
TRA13	Outer reef	7º20'19.0212" N	134º13'28.56" E
TRA14	Outer reef	7º15'56.8188" N	134º10'57" E
TRA15	Outer reef	7º15'00.18" N	134º14'23.5212" E
TRA21	Outer reef	7º07'41.6388" N	134º16'47.64" E

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.1227	11.721
Back-reef	Acanthuridae	*Naso brevirostris*	0.0129	8.727
Back-reef	Acanthuridae	*Naso unicornis*	0.0017	3.230
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0683	2.787
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0051	2.342
Back-reef	Acanthuridae	*Naso lituratus*	0.0037	0.954
Back-reef	Acanthuridae	*Acanthurus blochii*	0.0009	0.786
Back-reef	Acanthuridae	*Naso vlamingii*	0.0023	0.768
Back-reef	Acanthuridae	*Acanthurus* spp.	0.0009	0.742
Back-reef	Acanthuridae	*Acanthurus pyroferus*	0.0029	0.649
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0017	0.360
Back-reef	Acanthuridae	*Acanthurus olivaceus*	0.0006	0.248
Back-reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0029	0.243
Back-reef	Acanthuridae	*Acanthurus guttatus*	0.0006	0.237
Back-reef	Acanthuridae	*Ctenochaetus binotatus*	0.0026	0.056
Back-reef	Acanthuridae	*Acanthurus thompsoni*	0.0003	0.026

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Balistidae	*Pseudobalistes flavimarginatus*	0.0009	3.391
Back-reef	Balistidae	*Balistapus undulatus*	0.0029	0.585
Back-reef	Balistidae	*Sufflamen chrysopterum*	0.0003	0.026
Back-reef	Balistidae	*Sufflamen bursa*	0.0003	0.013
Back-reef	Caesionidae	*Caesio teres*	0.0211	10.547
Back-reef	Caesionidae	*Caesio cuning*	0.0103	3.532
Back-reef	Caesionidae	*Pterocaesio tile*	0.0235	1.460
Back-reef	Caesionidae	*Pterocaesio marri*	0.0060	0.168
Back-reef	Carangidae	*Elagatis bipinnulata*	0.0074	14.692
Back-reef	Carangidae	*Caranx melampygus*	0.0100	10.323
Back-reef	Carangidae	*Carangoides ferdau*	0.0026	8.555
Back-reef	Carangidae	*Gnathanodon speciosus*	0.0003	0.010
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0043	0.973
Back-reef	Chaetodontidae	*Chaetodon baronessa*	0.0060	0.238
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0034	0.228
Back-reef	Chaetodontidae	*Chaetodon kleinii*	0.0094	0.179
Back-reef	Chaetodontidae	*Chaetodon lunula*	0.0023	0.153
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0046	0.132
Back-reef	Chaetodontidae	*Chaetodon lineolatus*	0.0029	0.130
Back-reef	Chaetodontidae	*Chaetodon trifascialis*	0.0031	0.072
Back-reef	Chaetodontidae	*Chaetodon rafflesii*	0.0011	0.071
Back-reef	Chaetodontidae	*Chaetodon octofasciatus*	0.0009	0.042
Back-reef	Chaetodontidae	*Heniochus chrysostomus*	0.0006	0.040
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0006	0.033
Back-reef	Chaetodontidae	*Heniochus varius*	0.0009	0.033
Back-reef	Chaetodontidae	*Chaetodon aureofasciatus*	0.0006	0.028
Back-reef	Chaetodontidae	*Chaetodon semeion*	0.0006	0.028
Back-reef	Chaetodontidae	*Chaetodon* spp.	0.0006	0.028
Back-reef	Chaetodontidae	*Chaetodon plebeius*	0.0006	0.024
Back-reef	Chaetodontidae	*Chaetodon reticulatus*	0.0006	0.022
Back-reef	Chaetodontidae	*Chaetodon bennetti*	0.0003	0.014
Back-reef	Chaetodontidae	*Chaetodon ulietensis*	0.0006	0.013
Back-reef	Chaetodontidae	*Chaetodon unimaculatus*	0.0003	0.010
Back-reef	Chaetodontidae	*Chaetodon speculum*	0.0006	0.010
Back-reef	Chaetodontidae	*Forcipiger longirostris*	0.0003	0.008
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0009	0.007
Back-reef	Holocentridae	*Myripristis adusta*	0.0023	0.403
Back-reef	Holocentridae	*Myripristis murdjan*	0.0020	0.202
Back-reef	Holocentridae	*Myripristis kuntee*	0.0006	0.063
Back-reef	Holocentridae	*Neoniphon sammara*	0.0003	0.033
Back-reef	Holocentridae	*Myripristis* spp.	0.0003	0.023
Back-reef	Labridae	*Hemigymnus melapterus*	0.0060	2.053
Back-reef	Labridae	*Cheilinus fasciatus*	0.0026	0.912
Back-reef	Labridae	*Oxycheilinus digramma*	0.0040	0.353
Back-reef	Labridae	*Epibulus insidiator*	0.0014	0.196
Back-reef	Labridae	*Cheilinus chlorourus*	0.0011	0.165

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Labridae	*Coris aygula*	0.0006	0.030
Back-reef	Labridae	*Oxycheilinus unifasciatus*	0.0006	0.016
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0076	4.823
Back-reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0440	4.044
Back-reef	Lethrinidae	*Lethrinus obsoletus*	0.0014	0.456
Back-reef	Lethrinidae	*Lethrinus erythropterus*	0.0006	0.093
Back-reef	Lethrinidae	*Lethrinus atkinsoni*	0.0003	0.084
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0116	2.968
Back-reef	Lutjanidae	*Lutjanus lutjanus*	0.0203	1.721
Back-reef	Lutjanidae	*Aprion virescens*	0.0006	1.647
Back-reef	Lutjanidae	*Aphareus furca*	0.0006	0.616
Back-reef	Lutjanidae	*Macolor macularis*	0.0009	0.599
Back-reef	Lutjanidae	*Macolor niger*	0.0006	0.394
Back-reef	Lutjanidae	*Lutjanus kasmira*	0.0031	0.315
Back-reef	Lutjanidae	*Lutjanus bohar*	0.0009	0.028
Back-reef	Mullidae	*Parupeneus barberinus*	0.0051	4.109
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0083	1.099
Back-reef	Mullidae	*Parupeneus cyclostomus*	0.0014	0.683
Back-reef	Mullidae	*Parupeneus bifasciatus*	0.0029	0.505
Back-reef	Mullidae	*Parupeneus indicus*	0.0003	0.260
Back-reef	Mullidae	*Parupeneus barberinoides*	0.0003	0.029
Back-reef	Nemipteridae	*Scolopsis bilineata*	0.0034	0.331
Back-reef	Nemipteridae	*Scolopsis margaritifera*	0.0009	0.141
Back-reef	Nemipteridae	*Scolopsis trilineata*	0.0006	0.043
Back-reef	Nemipteridae	*Scolopsis lineata*	0.0003	0.009
Back-reef	Pomacanthidae	*Pomacanthus sexstriatus*	0.0006	0.992
Back-reef	Pomacanthidae	*Pygoplites diacanthus*	0.0014	0.355
Back-reef	Pomacanthidae	*Pomacanthus xanthometopon*	0.0003	0.097
Back-reef	Scaridae	*Chlorurus sordidus*	0.0513	7.122
Back-reef	Scaridae	*Scarus schlegeli*	0.0083	2.567
Back-reef	Scaridae	*Chlorurus bleekeri*	0.0057	2.189
Back-reef	Scaridae	*Scarus dimidiatus*	0.0080	1.394
Back-reef	Scaridae	*Hipposcarus longiceps*	0.0020	1.127
Back-reef	Scaridae	*Chlorurus microrhinos*	0.0009	0.907
Back-reef	Scaridae	*Cetoscarus bicolor*	0.0017	0.846
Back-reef	Scaridae	*Scarus frenatus*	0.0011	0.754
Back-reef	Scaridae	*Scarus psittacus*	0.0049	0.637
Back-reef	Scaridae	*Scarus rivulatus*	0.0031	0.615
Back-reef	Scaridae	*Scarus niger*	0.0031	0.539
Back-reef	Scaridae	*Scarus forsteni*	0.0006	0.306
Back-reef	Scaridae	*Scarus oviceps*	0.0006	0.257
Back-reef	Scaridae	*Scarus quoyi*	0.0011	0.181
Back-reef	Scaridae	*Scarus hypselopterus*	0.0003	0.155
Back-reef	Scaridae	*Scarus flavipectoralis*	0.0003	0.155
Back-reef	Scaridae	*Scarus globiceps*	0.0009	0.155
Back-reef	Scaridae	*Scarus* spp.	0.0029	0.104

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Scaridae	*Scarus spinus*	0.0003	0.034
Back-reef	Serranidae	*Plectropomus leopardus*	0.0011	0.849
Back-reef	Serranidae	*Cephalopholis argus*	0.0006	0.156
Back-reef	Serranidae	*Anyperodon leucogrammicus*	0.0003	0.110
Back-reef	Serranidae	*Epinephelus merra*	0.0011	0.083
Back-reef	Serranidae	*Cephalopholis urodeta*	0.0006	0.037
Back-reef	Serranidae	*Epinephelus spilotoceps*	0.0003	0.007
Back-reef	Siganidae	*Siganus fuscescens*	0.0429	2.912
Back-reef	Siganidae	*Siganus canaliculatus*	0.0074	1.668
Back-reef	Siganidae	*Siganus puellus*	0.0009	0.350
Back-reef	Siganidae	*Siganus doliatus*	0.0009	0.319
Back-reef	Siganidae	*Siganus guttatus*	0.0023	0.125
Back-reef	Siganidae	*Siganus vulpinus*	0.0003	0.084
Back-reef	Siganidae	*Siganus corallinus*	0.0003	0.027
Back-reef	Siganidae	*Siganus lineatus*	0.0003	0.017
Back-reef	Tetraodontidae	*Arothron nigropunctatus*	0.0003	0.114
Back-reef	Zanclidae	*Zanclus cornutus*	0.0060	0.626
Lagoon	Acanthuridae	*Acanthurus guttatus*	0.0007	0.049
Lagoon	Acanthuridae	*Acanthurus nigricans*	0.0020	0.243
Lagoon	Acanthuridae	*Acanthurus nigricauda*	0.0040	2.022
Lagoon	Acanthuridae	*Acanthurus* spp.	0.0003	0.015
Lagoon	Acanthuridae	*Acanthurus thompsoni*	0.0013	0.146
Lagoon	Acanthuridae	*Ctenochaetus binotatus*	0.0003	0.010
Lagoon	Acanthuridae	*Ctenochaetus flavicauda*	0.0003	0.002
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.1943	32.217
Lagoon	Acanthuridae	*Naso brevirostris*	0.0067	3.502
Lagoon	Acanthuridae	*Naso lituratus*	0.0010	0.913
Lagoon	Acanthuridae	*Naso unicornis*	0.0010	0.574
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.0023	0.074
Lagoon	Acanthuridae	*Zebrasoma veliferum*	0.0017	0.214
Lagoon	Balistidae	*Balistapus undulatus*	0.0007	0.043
Lagoon	Balistidae	*Balistoides viridescens*	0.0010	1.602
Lagoon	Balistidae	*Rhinecanthus aculeatus*	0.0010	0.041
Lagoon	Balistidae	*Sufflamen chrysopterum*	0.0007	0.049
Lagoon	Caesionidae	*Caesio cuning*	0.0056	0.474
Lagoon	Caesionidae	*Caesio teres*	0.0957	31.539
Lagoon	Caesionidae	*Pterocaesio tessellata*	0.0087	1.496
Lagoon	Caesionidae	*Pterocaesio tile*	0.2128	31.134
Lagoon	Carangidae	*Caranx melampygus*	0.0007	2.058
Lagoon	Chaetodontidae	*Chaetodon aureofasciatus*	0.0010	0.033
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.0087	0.378
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.0070	1.002
Lagoon	Chaetodontidae	*Chaetodon kleinii*	0.0047	0.082
Lagoon	Chaetodontidae	*Chaetodon lineolatus*	0.0003	0.023
Lagoon	Chaetodontidae	*Chaetodon lunula*	0.0007	0.015
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0060	0.136

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Chaetodontidae	*Chaetodon octofasciatus*	0.0013	0.030
Lagoon	Chaetodontidae	*Chaetodon oxycephalus*	0.0013	0.078
Lagoon	Chaetodontidae	*Chaetodon rafflesii*	0.0003	0.010
Lagoon	Chaetodontidae	*Chaetodon semeion*	0.0027	0.184
Lagoon	Chaetodontidae	*Chaetodon speculum*	0.0003	0.018
Lagoon	Chaetodontidae	*Chaetodon ulietensis*	0.0040	0.150
Lagoon	Chaetodontidae	*Chaetodon vagabundus*	0.0030	0.102
Lagoon	Chaetodontidae	*Heniochus acuminatus*	0.0010	0.056
Lagoon	Chaetodontidae	*Heniochus chrysostomus*	0.0007	0.036
Lagoon	Chaetodontidae	*Heniochus monoceros*	0.0003	0.027
Lagoon	Chaetodontidae	*Heniochus varius*	0.0013	0.071
Lagoon	Haemulidae	*Plectorhinchus lineatus*	0.0003	0.464
Lagoon	Holocentridae	*Myripristis adusta*	0.0013	0.285
Lagoon	Holocentridae	*Myripristis berndti*	0.0007	0.109
Lagoon	Holocentridae	*Myripristis kuntee*	0.0123	1.444
Lagoon	Holocentridae	*Neoniphon opercularis*	0.0037	0.547
Lagoon	Holocentridae	*Neoniphon sammara*	0.0040	0.323
Lagoon	Holocentridae	*Neoniphon* spp.	0.0003	0.007
Lagoon	Holocentridae	*Sargocentron caudimaculatum*	0.0010	0.213
Lagoon	Holocentridae	*Sargocentron diadema*	0.0003	0.008
Lagoon	Holocentridae	*Sargocentron spiniferum*	0.0023	1.224
Lagoon	Labridae	*Cheilinus chlorourus*	0.0010	0.375
Lagoon	Labridae	*Cheilinus fasciatus*	0.0097	2.955
Lagoon	Labridae	*Cheilinus oxycephalus*	0.0013	0.302
Lagoon	Labridae	*Cheilinus trilobatus*	0.0003	0.052
Lagoon	Labridae	*Cheilinus undulatus*	0.0003	0.754
Lagoon	Labridae	*Choerodon anchorago*	0.0007	0.369
Lagoon	Labridae	*Coris aygula*	0.0073	0.000
Lagoon	Labridae	*Epibulus insidiator*	0.0023	0.651
Lagoon	Labridae	*Hemigymnus melapterus*	0.0050	2.414
Lagoon	Labridae	*Oxycheilinus digramma*	0.0010	0.114
Lagoon	Lethrinidae	*Gnathodentex aureolineatus*	0.0020	0.144
Lagoon	Lethrinidae	*Lethrinus erythracanthus*	0.0010	0.809
Lagoon	Lethrinidae	*Lethrinus harak*	0.0007	0.287
Lagoon	Lethrinidae	*Lethrinus obsoletus*	0.0017	1.390
Lagoon	Lethrinidae	*Lethrinus xanthochilus*	0.0003	0.567
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.0217	9.618
Lagoon	Lutjanidae	*Aphareus furca*	0.0003	0.282
Lagoon	Lutjanidae	*Lutjanus bohar*	0.0010	0.288
Lagoon	Lutjanidae	*Lutjanus gibbus*	0.1576	88.340
Lagoon	Lutjanidae	*Lutjanus lutjanus*	0.0007	0.193
Lagoon	Lutjanidae	*Lutjanus russellii*	0.0003	0.201
Lagoon	Lutjanidae	*Lutjanus semicinctus*	0.0013	0.491
Lagoon	Lutjanidae	*Macolor macularis*	0.0003	0.035
Lagoon	Mullidae	*Parupeneus barberinus*	0.0013	0.774
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0033	1.035

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Nemipteridae	*Scolopsis bilineata*	0.0003	0.009
Lagoon	Nemipteridae	*Scolopsis ciliata*	0.0007	0.084
Lagoon	Nemipteridae	*Scolopsis margaritifera*	0.0140	3.129
Lagoon	Nemipteridae	*Scolopsis* spp.	0.0007	0.072
Lagoon	Nemipteridae	*Scolopsis temporalis*	0.0003	0.080
Lagoon	Nemipteridae	*Scolopsis trilineata*	0.0003	0.098
Lagoon	Pomacanthidae	*Pomacanthus sexstriatus*	0.0030	2.194
Lagoon	Scaridae	*Cetoscarus bicolor*	0.0027	2.577
Lagoon	Scaridae	*Chlorurus bleekeri*	0.0003	0.181
Lagoon	Scaridae	*Chlorurus microrhinos*	0.0030	3.468
Lagoon	Scaridae	*Chlorurus sordidus*	0.0173	1.953
Lagoon	Scaridae	*Hipposcarus longiceps*	0.0080	1.960
Lagoon	Scaridae	*Scarus dimidiatus*	0.0043	1.558
Lagoon	Scaridae	*Scarus flavipectoralis*	0.0003	0.181
Lagoon	Scaridae	*Scarus forsteni*	0.0003	0.220
Lagoon	Scaridae	*Scarus frenatus*	0.0007	0.317
Lagoon	Scaridae	*Scarus ghobban*	0.0010	0.852
Lagoon	Scaridae	*Scarus niger*	0.0043	1.274
Lagoon	Scaridae	*Scarus prasiognathos*	0.0007	0.205
Lagoon	Scaridae	*Scarus psittacus*	0.0017	0.456
Lagoon	Scaridae	*Scarus quoyi*	0.0010	0.190
Lagoon	Scaridae	*Scarus rivulatus*	0.0003	0.246
Lagoon	Scaridae	*Scarus schlegeli*	0.0033	1.705
Lagoon	Serranidae	*Cephalopholis argus*	0.0007	0.044
Lagoon	Serranidae	*Cephalopholis boenak*	0.0010	0.092
Lagoon	Serranidae	*Cephalopholis urodeta*	0.0010	0.168
Lagoon	Serranidae	*Epinephelus areolatus*	0.0003	0.035
Lagoon	Serranidae	*Epinephelus merra*	0.0030	0.199
Lagoon	Serranidae	*Epinephelus polyphekadion*	0.0003	0.476
Lagoon	Serranidae	*Plectropomus leopardus*	0.0113	6.432
Lagoon	Siganidae	*Siganus doliatus*	0.0060	1.578
Lagoon	Siganidae	*Siganus fuscescens*	0.0430	4.564
Lagoon	Siganidae	*Siganus puellus*	0.0007	0.386
Lagoon	Siganidae	*Siganus punctatissimus*	0.0023	1.380
Lagoon	Siganidae	*Siganus stellatus*	0.0007	0.252
Lagoon	Zanclidae	*Zanclus cornutus*	0.0107	0.986
Outer reef	Acanthuridae	*Acanthurus maculiceps*	0.0002	0.059
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.0271	2.146
Outer reef	Acanthuridae	*Acanthurus nigricauda*	0.0027	1.629
Outer reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0029	0.093
Outer reef	Acanthuridae	*Acanthurus nigroris*	0.0007	0.020
Outer reef	Acanthuridae	*Acanthurus olivaceus*	0.0011	0.573
Outer reef	Acanthuridae	*Acanthurus pyroferus*	0.0031	0.283
Outer reef	Acanthuridae	*Acanthurus thompsoni*	0.0033	1.707
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.1394	14.388
Outer reef	Acanthuridae	*Ctenochaetus strigosus*	0.0058	0.145

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Acanthuridae	*Naso brevirostris*	0.0015	0.794
Outer reef	Acanthuridae	*Naso hexacanthus*	0.0004	0.565
Outer reef	Acanthuridae	*Naso lituratus*	0.0093	2.105
Outer reef	Acanthuridae	*Naso unicornis*	0.0004	0.550
Outer reef	Acanthuridae	*Naso vlamingii*	0.0031	3.253
Outer reef	Acanthuridae	*Zebrasoma scopas*	0.0605	2.070
Outer reef	Acanthuridae	*Zebrasoma veliferum*	0.0007	0.194
Outer reef	Balistidae	*Balistapus undulatus*	0.0051	0.541
Outer reef	Balistidae	*Balistoides conspicillum*	0.0004	0.191
Outer reef	Balistidae	*Balistoides viridescens*	0.0004	0.705
Outer reef	Balistidae	*Melichthys vidua*	0.0007	0.095
Outer reef	Balistidae	*Odonus niger*	0.0040	0.097
Outer reef	Balistidae	*Sufflamen bursa*	0.0007	0.044
Outer reef	Balistidae	*Sufflamen chrysopterum*	0.0005	0.043
Outer reef	Caesionidae	*Caesio caerulaurea*	0.0016	0.131
Outer reef	Caesionidae	*Caesio lunaris*	0.0171	3.486
Outer reef	Caesionidae	*Caesio teres*	0.0753	24.580
Outer reef	Caesionidae	*Pterocaesio marri*	0.0048	0.225
Outer reef	Caesionidae	*Pterocaesio tile*	0.1637	13.437
Outer reef	Carangidae	*Carangoides ferdau*	0.0007	2.029
Outer reef	Carangidae	*Carangoides orthogrammus*	0.0005	0.355
Outer reef	Carangidae	*Carangoides plagiotaenia*	0.0051	1.571
Outer reef	Carangidae	*Caranx lugubris*	0.0002	0.219
Outer reef	Carangidae	*Caranx melampygus*	0.0024	3.406
Outer reef	Carangidae	*Elagatis bipinnulata*	0.0002	1.095
Outer reef	Carangidae	*Scomberoides commersonnianus*	0.0002	0.544
Outer reef	Carcharhinidae	*Triaenodon obesus*	0.0002	3.830
Outer reef	Chaetodontidae	*Chaetodon aureofasciatus*	0.0004	0.018
Outer reef	Chaetodontidae	*Chaetodon auriga*	0.0007	0.033
Outer reef	Chaetodontidae	*Chaetodon baronessa*	0.0036	0.094
Outer reef	Chaetodontidae	*Chaetodon bennetti*	0.0004	0.018
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0016	0.010
Outer reef	Chaetodontidae	*Chaetodon ephippium*	0.0069	0.617
Outer reef	Chaetodontidae	*Chaetodon kleinii*	0.0133	0.220
Outer reef	Chaetodontidae	*Chaetodon lunula*	0.0009	0.035
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0065	0.159
Outer reef	Chaetodontidae	*Chaetodon melannotus*	0.0009	0.007
Outer reef	Chaetodontidae	*Chaetodon mertensii*	0.0004	0.004
Outer reef	Chaetodontidae	*Chaetodon meyeri*	0.0009	0.047
Outer reef	Chaetodontidae	*Chaetodon octofasciatus*	0.0002	0.009
Outer reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0009	0.062
Outer reef	Chaetodontidae	*Chaetodon oxycephalus*	0.0002	0.014
Outer reef	Chaetodontidae	*Chaetodon punctatofasciatus*	0.0031	0.032
Outer reef	Chaetodontidae	*Chaetodon rafflesii*	0.0018	0.087
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0035	0.179
Outer reef	Chaetodontidae	*Chaetodon semeion*	0.0015	0.110

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Chaetodontidae	*Chaetodon speculum*	0.0004	0.012
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0007	0.018
Outer reef	Chaetodontidae	*Chaetodon ulietensis*	0.0005	0.012
Outer reef	Chaetodontidae	*Chaetodon unimaculatus*	0.0004	0.022
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0005	0.018
Outer reef	Chaetodontidae	*Forcipiger flavissimus*	0.0035	0.058
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0020	0.094
Outer reef	Chaetodontidae	*Hemitaurichthys polylepis*	0.0013	0.017
Outer reef	Chaetodontidae	*Heniochus chrysostomus*	0.0011	0.089
Outer reef	Chaetodontidae	*Heniochus monoceros*	0.0002	0.046
Outer reef	Chaetodontidae	*Heniochus varius*	0.0004	0.047
Outer reef	Ephippidae	*Platax teira*	0.0007	1.661
Outer reef	Haemulidae	*Plectorhinchus chaetodonoides*	0.0073	11.860
Outer reef	Haemulidae	*Plectorhinchus lessonii*	0.0007	0.321
Outer reef	Haemulidae	*Plectorhinchus lineatus*	0.0005	0.852
Outer reef	Haemulidae	*Plectorhinchus orientalis*	0.0004	0.183
Outer reef	Haemulidae	*Plectorhinchus picus*	0.0013	1.283
Outer reef	Holocentridae	*Myripristis adusta*	0.0650	19.992
Outer reef	Holocentridae	*Myripristis berndti*	0.0025	0.409
Outer reef	Holocentridae	*Myripristis kuntee*	0.0585	7.793
Outer reef	Holocentridae	*Myripristis murdjan*	0.0111	1.413
Outer reef	Holocentridae	*Myripristis pralinia*	0.0074	0.596
Outer reef	Holocentridae	*Myripristis* spp.	0.0042	0.562
Outer reef	Holocentridae	*Myripristis violacea*	0.0015	0.220
Outer reef	Holocentridae	*Neoniphon argenteus*	0.0055	0.962
Outer reef	Holocentridae	*Neoniphon opercularis*	0.0005	0.045
Outer reef	Holocentridae	*Neoniphon sammara*	0.0153	1.357
Outer reef	Holocentridae	*Sargocentron caudimaculatum*	0.0211	1.891
Outer reef	Holocentridae	*Sargocentron spiniferum*	0.0011	0.904
Outer reef	Kyphosidae	*Kyphosus vaigiensis*	0.0009	0.864
Outer reef	Labridae	*Bodianus mesothorax*	0.0004	0.026
Outer reef	Labridae	*Cheilinus fasciatus*	0.0005	0.130
Outer reef	Labridae	*Cheilinus trilobatus*	0.0004	0.052
Outer reef	Labridae	*Cheilinus undulatus*	0.0004	6.890
Outer reef	Labridae	*Coris aygula*	0.0009	0.825
Outer reef	Labridae	*Epibulus insidiator*	0.0015	0.476
Outer reef	Labridae	*Hemigymnus fasciatus*	0.0013	0.296
Outer reef	Labridae	*Hemigymnus melapterus*	0.0011	0.350
Outer reef	Labridae	*Novaculichthys taeniourus*	0.0011	0.365
Outer reef	Labridae	*Oxycheilinus digramma*	0.0013	0.137
Outer reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0638	8.639
Outer reef	Lethrinidae	*Gymnocranius* spp.	0.0002	0.109
Outer reef	Lethrinidae	*Lethrinus erythropterus*	0.0002	0.068
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0087	3.811
Outer reef	Lutjanidae	*Aphareus furca*	0.0020	1.012
Outer reef	Lutjanidae	*Aprion virescens*	0.0004	1.767

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Lutjanidae	*Lutjanus biguttatus*	0.0640	7.788
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0007	3.268
Outer reef	Lutjanidae	*Lutjanus fulvus*	0.0009	0.266
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.5065	176.292
Outer reef	Lutjanidae	*Lutjanus monostigma*	0.0004	0.299
Outer reef	Lutjanidae	*Lutjanus russellii*	0.0009	0.650
Outer reef	Lutjanidae	*Lutjanus semicinctus*	0.0005	0.201
Outer reef	Lutjanidae	*Macolor macularis*	0.0022	1.227
Outer reef	Lutjanidae	*Macolor niger*	0.0002	0.013
Outer reef	Mullidae	*Parupeneus barberinoides*	0.0002	0.036
Outer reef	Mullidae	*Parupeneus barberinus*	0.0011	0.329
Outer reef	Mullidae	*Parupeneus bifasciatus*	0.0065	1.836
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0044	0.288
Outer reef	Nemipteridae	*Scolopsis bilineata*	0.0005	0.057
Outer reef	Nemipteridae	*Scolopsis ciliata*	0.0004	0.014
Outer reef	Pomacanthidae	*Pomacanthus xanthometopon*	0.0002	0.243
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0027	0.523
Outer reef	Scaridae	*Bolbometopon muricatum*	0.0089	110.583
Outer reef	Scaridae	*Cetoscarus bicolor*	0.0015	1.554
Outer reef	Scaridae	*Chlorurus bleekeri*	0.0005	0.296
Outer reef	Scaridae	*Chlorurus bowersi*	0.0002	0.022
Outer reef	Scaridae	*Chlorurus microrhinos*	0.0018	1.080
Outer reef	Scaridae	*Chlorurus sordidus*	0.0330	2.989
Outer reef	Scaridae	*Hipposcarus longiceps*	0.0411	3.907
Outer reef	Scaridae	*Scarus chameleon*	0.0011	0.236
Outer reef	Scaridae	*Scarus dimidiatus*	0.0002	0.034
Outer reef	Scaridae	*Scarus flavipectoralis*	0.0005	0.228
Outer reef	Scaridae	*Scarus forsteni*	0.0004	0.287
Outer reef	Scaridae	*Scarus frenatus*	0.0017	0.220
Outer reef	Scaridae	*Scarus ghobban*	0.0004	0.089
Outer reef	Scaridae	*Scarus globiceps*	0.0002	0.013
Outer reef	Scaridae	*Scarus hypselopterus*	0.0007	0.230
Outer reef	Scaridae	*Scarus niger*	0.0073	1.683
Outer reef	Scaridae	*Scarus oviceps*	0.0011	0.309
Outer reef	Scaridae	*Scarus psittacus*	0.0015	0.097
Outer reef	Scaridae	*Scarus quoyi*	0.0002	0.015
Outer reef	Scaridae	*Scarus rivulatus*	0.0009	0.604
Outer reef	Scaridae	*Scarus schlegeli*	0.0073	0.746
Outer reef	Scaridae	*Scarus* spp.	0.0025	0.176
Outer reef	Scaridae	*Scarus spinus*	0.0013	0.143
Outer reef	Scombridae	*Scomber* spp.	0.0005	0.807
Outer reef	Scombridae	*Scomberomorus commerson*	0.0002	0.593
Outer reef	Serranidae	*Anyperodon leucogrammicus*	0.0007	0.308
Outer reef	Serranidae	*Cephalopholis argus*	0.0011	0.359
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0015	0.060
Outer reef	Serranidae	*Epinephelus merra*	0.0002	0.007

3.4.2 Weighted average density and biomass of all finfish species recorded in Koror (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Serranidae	*Plectropomus areolatus*	0.0004	0.397
Outer reef	Serranidae	*Plectropomus laevis*	0.0004	0.083
Outer reef	Serranidae	*Plectropomus leopardus*	0.0004	0.321
Outer reef	Siganidae	*Siganus argenteus*	0.0058	0.261
Outer reef	Siganidae	*Siganus canaliculatus*	0.0002	0.108
Outer reef	Siganidae	*Siganus corallinus*	0.0015	0.355
Outer reef	Siganidae	*Siganus doliatus*	0.0004	0.124
Outer reef	Siganidae	*Siganus puellus*	0.0004	0.190
Outer reef	Siganidae	*Siganus punctatissimus*	0.0013	0.410
Outer reef	Siganidae	*Siganus vermiculatus*	0.0007	0.214
Outer reef	Siganidae	*Siganus vulpinus*	0.0020	0.308
Outer reef	Zanclidae	*Zanclus cornutus*	0.0020	0.265

APPENDIX 4: INVERTEBRATE SURVEY DATA

4.1 Ngarchelong invertebrate survey data

4.1.1 Invertebrate species recorded in different assessments in Ngarchelong

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga echinites*			+	
Bêche-de-mer	*Actinopyga lecanora*		+	+	
Bêche-de-mer	*Actinopyga mauritiana*		+		+
Bêche-de-mer	*Actinopyga miliaris*	+			+
Bêche-de-mer	*Actinopyga* spp.			+	+
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 hilla*		+	+	
Bêche-de-mer	*Holothuria nobilis*	+	+		+
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	*Stichopus vastus*			+	+
Bêche-de-mer	*Synapta* spp.			+	+
Bêche-de-mer	*Thelenota ananas*	+	+		+
Bêche-de-mer	*Thelenota anax*	+			+
Bivalve	*Anadara scapha*			+	
Bivalve	*Arca* spp.		+		
Bivalve	*Atrina* spp.	+			
Bivalve	*Beguina semiorbiculata*		+	+	
Bivalve	*Chama* spp.	+	+		+
Bivalve	*Hippopus hippopus*	+	+		+
Bivalve	*Hippopus porcellanus*	+	+		+
Bivalve	*Lopha cristagalli*	+			
Bivalve	*Pinctada margaritifera*	+	+		+
Bivalve	*Pinna* spp.			+	
Bivalve	*Pteria penguin*				+
Bivalve	*Spondylus* spp.		+	+	+
Bivalve	*Tridacna crocea*	+	+	+	+
Bivalve	*Tridacna derasa*	+	+		+
Bivalve	*Tridacna gigas*	+	+		+
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+	+	+	+
Cnidarian	*Cassiopea andromeda*			+	

+ = presence of the species.

Appendix 4: Invertebrate survey data
Ngarchelong

4.1.1 Invertebrate species recorded in different assessments in Ngarchelong (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Cnidarian	*Cassiopea* spp.			+	+
Cnidarian	*Stichodactyla* spp.	+		+	+
Crustacean	*Lysiosquillina maculata*		+	+	
Crustacean	*Panulirus* spp.	+	+		+
Crustacean	*Panulirus versicolor*		+		+
Crustacean	*Saron* spp.		+		
Crustacean	*Stenopus hispidus*		+		
Crustacean	*Thalassina* spp.		+	+	
Gastropod	*Astralium* spp.				+
Gastropod	*Bursa bufonia*				+
Gastropod	*Cerithium nodulosum*		+		+
Gastropod	*Chicoreus brunneus*		+		
Gastropod	*Conus distans*		+		+
Gastropod	*Conus eburneus*			+	
Gastropod	*Conus emaciatus*				+
Gastropod	*Conus flavidus*		+		
Gastropod	*Conus imperialis*				+
Gastropod	*Conus litteratus*			+	
Gastropod	*Conus lividus*		+		+
Gastropod	*Conus marmoreus*		+		
Gastropod	*Conus miles*		+		+
Gastropod	*Conus miliaris*		+		
Gastropod	*Conus rattus*		+		
Gastropod	*Conus sanguinolentus*				+
Gastropod	*Conus* spp.	+	+	+	+
Gastropod	*Conus vexillum*		+		
Gastropod	*Cypraea arabica*		+		
Gastropod	*Cypraea caputserpensis*		+		+
Gastropod	*Cypraea erosa*		+		
Gastropod	*Cypraea moneta*		+		
Gastropod	*Cypraea talpa*				+
Gastropod	*Cypraea tigris*	+	+	+	+
Gastropod	*Cypraea vitellus*		+		
Gastropod	*Dolabella auricularia*				+
Gastropod	*Drupa grossularia*		+		
Gastropod	*Haliotis asinina*		+		
Gastropod	*Lambis chiragra*	+	+		+
Gastropod	*Lambis lambis*	+	+	+	
Gastropod	*Latirolagena smaragdula*		+		+
Gastropod	*Ovula ovum*				+
Gastropod	*Pleuroploca filamentosa*		+		
Gastropod	*Strombus luhuanus*	+	+		+
Gastropod	*Tectus conus*		+		
Gastropod	*Tectus pyramis*	+	+	+	+
Gastropod	*Tectus* spp.				+
Gastropod	*Tectus triserialis*		+		
Gastropod	*Thais aculeata*				+

+ = presence of the species.

4.1.1 Invertebrate species recorded in different assessments in Ngarchelong (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Thais* spp.		+		+
Gastropod	*Trochus maculata*		+		+
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Trochus* spp.		+		+
Gastropod	*Turbo argyrostomus*	+	+		+
Gastropod	*Turbo chrysostomus*		+		+
Gastropod	*Turbo setosus*		+		+
Gastropod	*Vasum ceramicum*		+		+
Gastropod	*Vasum* spp.		+	+	+
Gastropod	*Vasum turbinellum*		+		
Octopus	*Octopus cyanea*				+
Star	*Acanthaster planci*	+	+		+
Star	*Choriaster granulatus*	+	+		+
Star	*Culcita novaeguineae*	+	+	+	+
Star	*Linckia guildingi*		+		
Star	*Linckia laevigata*	+	+	+	+
Star	*Protoreaster nodosus*		+	+	+
Urchin	*Echinometra mathaei*	+	+		+
Urchin	*Echinothrix calamaris*		+		
Urchin	*Echinothrix diadema*		+		+
Urchin	*Heterocentrotus mammillatus*		+		
Urchin	*Mespilia globulus*			+	
Urchin	*Tripneustes gratilla*			+	+

+ = presence of the species.

4.1.2 Ngarchelong 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	2.3	1.1	72	23.8	7.1	7	2.3	1.5	12	9.3	4.0	3
Actinopyga miliaris	0.4	0.3	72	15.7	1.0	2	0.5	0.3	12	2.7	0.1	2
Atrina spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Bohadschia argus	24.3	5.3	72	60.3	10.0	29	24.3	11.4	12	36.4	15.6	8
Bohadschia graeffei	3.9	1.1	72	21.8	2.2	13	3.9	1.6	12	5.9	2.1	8
Chama spp.	1.6	0.7	72	19.4	2.8	6	1.6	0.9	12	6.4	0.9	3
Choriaster granulatus	1.2	0.7	72	27.8	5.6	3	1.2	0.6	12	4.6	0.9	3
Conus spp.	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Culcita novaeguineae	3.5	0.9	72	19.2	1.7	13	3.5	1.1	12	5.9	1.1	7
Cypraea tigris	0.9	0.5	72	16.7	0.0	4	0.9	0.5	12	3.7	0.9	3
Echinometra mathaei	9.6	2.9	72	62.7	6.8	11	9.6	4.2	12	23.1	6.3	5
Hippopus hippopus	9.3	1.6	72	23.8	2.3	28	9.2	1.9	12	10.1	1.9	11
Hippopus porcellanus	1.4	0.5	72	16.3	0.3	6	1.4	0.5	12	3.3	0.6	5
Holothuria atra	24.1	4.5	72	49.5	7.2	35	24.1	6.6	12	28.9	6.9	10
Holothuria edulis	19.4	4.7	72	66.5	10.8	21	19.4	9.9	12	38.8	16.7	6
Holothuria fuscopunctata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.7		1
Holothuria nobilis	3.9	1.2	72	23.6	3.2	12	3.9	1.3	12	5.9	1.5	8
Lambis chiragra	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Lambis lambis	2.1	0.7	72	18.8	2.1	8	2.1	0.8	12	4.9	0.6	5
Linckia laevigata	183.8	35.0	72	249.6	44.3	53	183.8	79.9	12	200.5	85.6	11
Lopha cristagalli	0.7	0.4	72	16.7	0.0	3	0.7	0.5	12	4.2	1.4	2
Panulirus spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Pinctada margaritifera	4.6	1.2	72	20.8	2.4	16	4.6	1.2	12	6.2	1.3	9
Stichodactyla spp.	1.9	0.7	72	19.0	2.4	7	1.9	0.8	12	4.4	1.1	5
Stichopus chloronotus	23.6	6.4	72	70.8	15.4	24	23.6	9.2	12	31.5	11.1	9
Stichopus hermanni	7.2	2.2	72	32.3	6.7	16	7.2	3.7	12	17.2	6.7	5
Strombus luhuanus	1.1	0.8	72	39.9	10.1	2	1.1	0.8	12	6.9	1.4	2
Tectus pyramis	8.0	1.5	72	23.1	1.9	25	8.0	1.8	12	10.7	1.5	9

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.2 Ngarchelong 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
Thelenota ananas	5.6	2.1	72	30.8	9.0	13	5.5	2.0	12	8.3	2.5	8
Thelenota anax	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Tridacna crocea	3340.8	661.3	72	3537.3	693.1	68	3340.7	1386.4	12	3340.7	1386.4	12
Tridacna derasa	4.4	1.5	72	31.7	5.8	10	4.4	2.9	12	8.8	5.5	6
Tridacna gigas	3.0	1.0	72	21.7	2.5	10	3.0	0.9	12	5.2	0.7	7
Tridacna maxima	109.5	21.6	72	138.3	26.0	57	109.2	48.5	12	109.2	48.5	12
Tridacna squamosa	2.8	0.9	72	20.0	2.2	10	2.8	0.9	12	4.2	1.0	8
Trochus niloticus	10.8	3.1	72	37.0	8.1	21	10.9	3.4	12	13.0	3.7	10
Turbo argyrostomus	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.3 Ngarchelong reef-benthos transect (RBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Actinopyga lecanora	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Actinopyga mauritiana	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Arca spp.	54.9	32.1	132	1812.5	648.5	4	54.9	53.0	22	604.2	562.5	2
Beguina semiorbiculata	58.7	39.1	132	1291.7	751.2	6	58.7	54.9	22	645.8	562.5	2
Bohadschia argus	41.7	11.1	132	343.8	44.9	16	41.7	23.9	22	183.3	81.9	5
Cerithium nodulosum	9.5	4.2	132	250.0	0.0	5	9.5	5.4	22	69.4	13.9	3
Chama spp.	13.3	6.8	132	437.5	62.5	4	13.3	6.4	22	72.9	10.4	4
Chicoreus brunneus	7.6	3.7	132	250.0	0.0	4	7.6	3.5	22	41.7	0.0	4
Choriaster granulatus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Conus distans	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Conus flavidus	3.8	2.7	132	250.0	0.0	2	3.8	3.8	22	83.3		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.3 Ngarchelong reef-benthos transect (RBt) assessment data review (continued)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Conus lividus	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Conus marmoreus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Conus miles	7.6	3.7	132	250.0	0.0	4	7.6	3.5	22	41.7	0.0	4
Conus miliaris	37.9	14.8	132	555.6	130.3	9	37.9	25.3	22	166.7	96.8	5
Conus rattus	5.7	3.3	132	250.0	0.0	3	5.7	5.7	22	125.0		1
Conus spp.	18.9	7.9	132	357.1	74.3	7	18.9	9.4	22	83.3	26.4	5
Conus vexillum	5.7	3.3	132	250.0	0.0	3	5.7	3.1	22	41.7	0.0	3
Culcita novaeguineae	20.8	6.6	132	275.0	25.0	10	20.8	9.8	22	91.7	24.3	5
Cypraea arabica	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Cypraea caputserpensis	5.7	3.3	132	250.0	0.0	3	5.7	3.1	22	41.7	0.0	3
Cypraea erosa	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Cypraea moneta	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Cypraea tigris	20.8	7.1	132	305.6	36.7	9	20.8	9.0	22	91.7	15.6	5
Cypraea vitellus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Drupa grossularia	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Echinometra mathaei	339.0	58.0	132	972.8	119.9	46	339.0	107.6	22	532.7	146.4	14
Echinothrix calamaris	3.8	2.7	132	250.0	0.0	2	3.8	3.8	22	83.3		1
Echinothrix diadema	28.4	17.8	132	625.0	327.6	6	28.4	22.8	22	208.3	146.3	3
Haliotis asinina	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Heterocentrotus mammillatus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Hippopus hippopus	17.0	6.1	132	281.3	31.3	8	17.0	5.9	22	53.6	7.7	7
Hippopus porcellanus	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Holothuria atra	125.0	19.3	132	392.9	34.2	42	125.0	31.5	22	171.9	37.0	16
Holothuria coluber	5.7	3.3	132	250.0	0.0	3	5.7	4.2	22	62.5	20.8	2
Holothuria edulis	30.3	8.5	132	307.7	30.4	13	30.3	12.9	22	133.3	20.4	5
Holothuria hilla	9.5	5.0	132	312.5	62.5	4	9.5	6.7	22	104.2	20.8	2
Holothuria nobilis	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.3 Ngarchelong reef-benthos transect (RBt) assessment data review (continued)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Lambis chiragra	9.5	4.2	132	250.0	0.0	5	9.5	3.8	22	41.7	0.0	5
Lambis lambis	20.8	8.9	132	458.3	76.8	6	20.8	9.8	22	91.7	24.3	5
Latirolagena smaragdula	28.4	10.6	132	416.7	83.3	9	28.4	9.6	22	78.1	14.6	8
Linckia guildingi	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Linckia laevigata	401.5	56.4	132	726.0	84.8	73	401.5	116.0	22	464.9	128.6	19
Lysiosquillina maculata	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Panulirus spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Panulirus versicolor	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Pinctada margaritifera	15.2	5.2	132	250.0	0.0	8	15.2	5.2	22	47.6	6.0	7
Pleuroploca filamentosa	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Protoreaster nodosus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Saron spp.	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Spondylus spp.	5.7	3.3	132	250.0	0.0	3	5.7	3.1	22	41.7	0.0	3
Stenopus hispidus	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Stichopus chloronotus	109.8	22.0	132	500.0	58.2	29	109.8	40.7	22	302.1	73.3	8
Stichopus horrens	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Strombus luhuanus	7.6	6.0	132	500.0	250.0	2	7.6	5.9	22	83.3	41.7	2
Tectus conus	11.4	7.0	132	500.0	144.3	3	11.4	7.8	22	125.0	0.0	2
Tectus pyramis	204.5	39.2	132	509.4	81.6	53	204.5	66.7	22	250.0	77.8	18
Tectus triserialis	13.3	6.8	132	350.0	100.0	5	13.3	6.4	22	58.3	16.7	5
Thais spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Thalassina spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Thelenota ananas	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Tridacna crocea	2526.5	289.9	132	3059.6	329.2	109	2526.5	619.4	22	2526.5	619.4	22
Tridacna derasa	7.6	3.7	132	250.0	0.0	4	7.6	3.5	22	41.7	0.0	4
Tridacna gigas	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Tridacna maxima	378.8	46.8	132	724.6	66.1	69	378.8	91.9	22	463.0	102.3	18

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.3 Ngarchelong reef-benthos transect (RBt) assessment data review (continued)
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Tridacna squamosa	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Trochus maculata	37.9	11.9	132	384.6	67.1	13	37.9	14.0	22	92.6	24.8	9
Trochus niloticus	458.3	103.2	132	1 287.2	248.8	47	458.3	215.8	22	672.2	303.6	15
Trochus spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Turbo argyrostomus	47.3	14.5	132	480.8	77.3	13	47.3	29.6	22	208.3	108.7	5
Turbo chrysostomus	7.6	3.7	132	250.0	0.0	4	7.6	3.5	22	41.7	0.0	4
Turbo setosus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Vasum ceramicum	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Vasum spp.	30.3	8.5	132	307.7	30.4	13	30.3	11.0	22	74.1	19.4	9
Vasum turbinellum	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.4 Ngarchelong 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	16.0	7.0	78	250.0	0.0	5	16.0	7.5	13	52.1	10.4	4
Actinopyga lecanora	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Actinopyga spp.	3682.7	957.7	78	8 207.1	1 880.6	35	3 682.7	2 267.3	13	6 839.3	3 936.4	7
Anadara scapha	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Beguina semiorbiculata	6.4	6.4	78	500.0		1	6.4	6.4	13	83.3		1
Bohadschia argus	12.8	10.1	78	500.0	250.0	2	12.8	12.8	13	166.7		1
Bohadschia similis	496.8	170.7	78	2 039.5	580.6	19	496.8	384.9	13	1 291.7	948.0	5
Bohadschia vitiensis	439.1	113.2	78	1 317.3	268.7	26	439.1	254.3	13	815.5	434.8	7
Cassiopea spp.	12.8	6.3	78	250.0	0.0	4	12.8	5.6	13	41.7	0.0	4
Cassiopea andromeda	6.4	6.4	78	500.0		1	6.4	6.4	13	83.3		1
Conus eburneus	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.4 Ngarchelong 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
Conus litteratus	6.4	4.5	78	250.0	0.0	2	6.4	6.4	13	83.3		1
Conus spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Culcita novaeguineae	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Cypraea tigris	9.6	5.5	78	250.0	0.0	3	9.6	5.1	13	41.7	0.0	3
Holothuria atra	897.4	111.7	78	1093.8	123.2	64	897.4	229.6	13	897.4	229.6	13
Holothuria coluber	67.3	19.2	78	403.8	53.2	13	67.3	34.2	13	175.0	66.4	5
Holothuria edulis	105.8	42.2	78	825.0	229.9	10	105.8	88.8	13	343.8	274.5	4
Holothuria hilla	28.8	12.9	78	375.0	85.4	6	28.8	15.9	13	125.0	24.1	3
Holothuria scabra	455.1	94.5	78	1479.2	176.7	24	455.1	207.7	13	1 479.2	236.6	4
Lambis lambis	16.0	7.0	78	250.0	0.0	5	16.0	8.9	13	69.4	13.9	3
Linckia laevigata	32.1	11.5	78	312.5	40.9	8	32.1	15.8	13	104.2	26.9	4
Lysiosquillina maculata	12.8	6.3	78	250.0	0.0	4	12.8	7.3	13	55.6	13.9	3
Mespilia globulus	6.4	4.5	78	250.0	0.0	2	6.4	6.4	13	83.3		1
Pinna spp.	12.8	7.8	78	333.3	83.3	3	12.8	7.3	13	55.6	13.9	3
Protoreaster nodosus	57.7	19.8	78	500.0	72.2	9	57.7	44.9	13	250.0	168.4	3
Spondylus spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Stichodactyla spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Stichopus chloronotus	25.6	8.6	78	250.0	0.0	8	25.6	13.8	13	111.1	13.9	3
Stichopus horrens	19.2	8.9	78	300.0	50.0	5	19.2	11.2	13	83.3	24.1	3
Stichopus vastus	17,445.5	2474.9	78	22,307.4	2871.1	61	17,445.5	6071.2	13	20,617.4	6762.6	11
Synapta spp.	22.4	8.1	78	250.0	0.0	7	22.4	10.1	13	58.3	16.7	5
Tectus pyramis	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Thalassina spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Tridacna crocea	6.4	4.5	78	250.0	0.0	2	6.4	4.3	13	41.7	0.0	2
Tridacna squamosa	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Tripneustes gratilla	6.4	4.5	78	250.0	0.0	2	6.4	4.3	13	41.7	0.0	2
Vasum spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.5 Ngarchelong 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	5.2	2.4	54	35.3	11.8	8	5.2	3.1	9	11.8	5.5	4
Actinopyga miliaris	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Bohadschia argus	0.9	0.6	54	23.5	0.0	2	0.9	0.6	9	3.9	0.0	2
Bohadschia graeffei	2.2	1.4	54	39.2	15.7	3	2.2	1.7	9	9.8	5.9	2
Bursa bufonia	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Cerithium nodulosum	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Chama spp.	0.9	0.6	54	23.5	0.0	2	0.9	0.6	9	3.9	0.0	2
Conus distans	2.2	1.8	54	58.8	35.3	2	2.2	2.2	9	19.6		1
Conus emaciatus	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Conus lividus	1.3	1.0	54	35.3	11.8	2	1.3	1.3	9	11.8		1
Conus miles	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Conus sanguinolentus	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Conus spp.	2.2	1.1	54	29.4	5.9	4	2.2	0.9	9	4.9	1.0	4
Culcita novaeguineae	0.9	0.6	54	23.5	0.0	2	0.9	0.6	9	3.9	0.0	2
Cypraea caputserpensis	0.9	0.6	54	23.5	0.0	2	0.9	0.6	9	3.9	0.0	2
Cypraea tigris	2.2	1.1	54	29.4	5.9	4	2.2	1.3	9	6.5	2.6	3
Echinometra mathaei	123.3	30.2	54	277.5	53.7	24	123.3	54.2	9	222.0	71.5	5
Echinothrix diadema	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Hippopus hippopus	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Hippopus porcellanus	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Holothuria atra	3.9	1.5	54	30.3	4.3	7	3.9	2.0	9	8.8	2.9	4
Holothuria fuscopunctata	1.7	1.4	54	47.1	23.5	2	1.7	1.7	9	15.7		1
Holothuria nobilis	1.3	1.0	54	35.3	11.8	2	1.3	0.9	9	5.9	2.0	2
Lambis chiragra	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Latirolagena smaragdula	0.9	0.6	54	23.5	0.0	2	0.9	0.6	9	3.9	0.0	2
Linckia laevigata	8.7	6.6	54	117.6	79.2	4	8.7	7.8	9	26.1	22.2	3
Octopus cyanea	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Ovula ovum	0.9	0.9	54	47.1		1	0.9	0.9	9	7.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.5 Ngarchelong reef-front search (RFs) assessment data review (continued)
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
Panulirus spp.	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Panulirus versicolor	0.9	0.9	54	47.1		1	0.9	0.9	9	7.8		1
Pinctada margaritifera	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Stichopus chloronotus	2.2	0.9	54	23.5	0.0	5	2.2	1.2	9	6.5	1.3	3
Strombus luhuanus	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Tectus pyramis	14.4	3.5	54	40.9	6.4	19	14.4	3.5	9	16.2	3.4	8
Tectus spp.	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Thais aculeata	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Thelenota ananas	3.5	1.7	54	37.6	9.4	5	3.5	2.0	9	10.5	3.5	3
Tridacna crocea	63.2	15.3	54	113.7	23.9	30	63.2	32.7	9	63.2	32.7	9
Tridacna gigas	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Tridacna maxima	108.5	16.8	54	122.1	18.0	48	108.5	26.1	9	108.5	26.1	9
Trochus maculata	0.9	0.6	54	23.5	0.0	2	0.9	0.9	9	7.8		1
Trochus niloticus	22.2	8.1	54	70.6	21.8	17	22.2	10.6	9	28.6	12.7	7
Trochus spp.	1.3	0.7	54	23.5	0.0	3	1.3	0.7	9	3.9	0.0	3
Turbo argyrostomus	4.4	1.7	54	33.6	4.8	7	4.4	2.7	9	13.1	5.7	3
Turbo setosus	0.9	0.6	54	23.5	0.0	2	0.9	0.6	9	3.9	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.6 Ngarchelong 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	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Astralium spp.	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Bohadschia argus	60.6	15.2	3	60.6	15.2	3	5.1	5.1	6	30.3		1
Bohadschia graeffei	90.9		1	90.9		1	2.5	2.5	6	15.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.6 Ngarchelong mother-of-pearl search (MOPs) assessment data review (continued)

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Chama spp.	68.2	22.7	2	68.2	22.7	2	3.8	2.6	6	11.4	3.8	2
Conus imperialis	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Conus lividus	90.9		1	90.9		1	2.5	2.5	6	15.2		1
Conus miles	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Conus spp.	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Cypraea talpa	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Echinometra mathaei	1053.0	296.5	6	1053.0	296.5	6	175.5	171.0	6	526.5	503.8	2
Hippopus hippopus	54.5	9.1	5	54.5	9.1	5	7.6	5.2	6	22.7	7.6	2
Holothuria atra	58.4	8.4	7	58.4	8.4	7	11.4	3.8	6	13.6	3.7	5
Holothuria nobilis	68.2	22.7	4	68.2	22.7	4	7.6	6.2	6	22.7	15.2	2
Latirolagena smaragdula	113.6	22.7	2	113.6	22.7	2	6.3	6.3	6	37.9		1
Linckia laevigata	113.6	22.7	2	113.6	22.7	2	6.3	6.3	6	37.9		1
Pinctada margaritifera	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Spondylus spp.	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Stichodactyla spp.	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Stichopus hermanni	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Tectus pyramis	81.8	11.0	15	81.8	11.0	15	34.1	13.7	6	40.9	14.5	5
Thais spp.	102.3	43.0	4	102.3	43.0	4	11.4	9.9	6	34.1	26.5	2
Thelenota ananas	45.5	0.0	3	45.5	0.0	3	3.8	1.7	6	7.6	0.0	3
Tridacna crocea	280.3	69.7	18	280.3	69.7	18	140.2	87.9	6	168.2	102.1	5
Tridacna derasa	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Tridacna maxima	153.2	18.8	27	153.2	18.8	27	114.9	31.6	6	114.9	31.6	6
Tridacna squamosa	68.2	22.7	2	68.2	22.7	2	3.8	3.8	6	22.7		1
Trochus maculata	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Trochus niloticus	107.4	24.0	11	107.4	24.0	11	32.8	13.4	6	39.4	14.3	5
Trochus spp.	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Turbo argyrostomus	68.2	22.7	6	68.2	22.7	6	11.4	6.1	6	22.7	7.6	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.

4.1.6 Ngarchelong mother-of-pearl search (MOPs) assessment data review (continued)
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
Turbo chrysostomus	68.2	22.7	2	68.2	22.7	2	3.8	2.6	6	11.4	3.8	2
Vasum ceramicum	45.5		1	45.5		1	1.3	1.3	6	7.6		1
Vasum spp.	45.5		1	45.5		1	1.3	1.3	6	7.6		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.7 Ngarchelong mother-of-pearl transect (MOPt) assessment data review
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Astralium spp.	20.8	20.8	6	125.0		1	20.8		1	20.8		1
Bohadschia graeffei	104.2	81.8	6	312.5	187.5	2	104.2		1	104.2		1
Conus spp.	20.8	20.8	6	125.0		1	20.8		1	20.8		1
Cypraea tigris	41.7	26.4	6	125.0	0.0	2	41.7		1	41.7		1
Tectus pyramis	20.8	20.8	6	125.0		1	20.8		1	20.8		1
Tridacna crocea	83.3	52.7	6	250.0	0.0	2	83.3		1	83.3		1
Tridacna maxima	104.2	50.2	6	208.3	41.7	3	104.2		1	104.2		1
Trochus niloticus	979.2	217.5	6	979.2	217.5	6	979.2		1	979.2		1
Trochus spp.	20.8	20.8	6	125.0		1	20.8		1	20.8		1
Turbo argyrostomus	20.8	20.8	6	125.0		1	20.8		1	20.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.8 Ngarchelong 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 spp.	1204.4	537.6	12	2890.7	830.1	5	1204.4	1204.4	2	2408.9		1
Bohadschia argus	13.3	7.0	12	53.3	0.0	3	13.3	13.3	2	26.7		1
Bohadschia similis	75.6	54.3	12	302.2	175.1	3	75.6	75.6	2	151.1		1
Bohadschia vitiensis	1528.9	484.8	12	1528.9	484.8	12	1528.9	373.3	2	1528.9	373.3	2
Dolabella auricularia	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Holothuria atra	44.4	30.7	12	266.7	53.3	2	44.4	8.9	2	44.4	8.9	2
Holothuria coluber	13.3	13.3	12	160.0		1	13.3	13.3	2	26.7		1
Linckia laevigata	13.3	9.6	12	80.0	26.7	2	13.3	13.3	2	26.7		1
Pinctada margaritifera	8.9	6.0	12	53.3	0.0	2	8.9	8.9	2	17.8		1
Protoreaster nodosus	17.8	13.7	12	106.7	53.3	2	17.8	8.9	2	17.8	8.9	2
Stichopus vastus	1471.1	1112.3	12	5884.4	3772.5	3	1471.1	1471.1	2	2942.2		1
Synapta spp.	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Tripneustes gratilla	8.9	6.0	12	53.3	0.0	2	8.9	0.0	2	8.9	0.0	2
Trochus niloticus	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.9 Ngarchelong 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
Actinopyga miliaris	0.4	0.4	36	14.3		1	0.4	0.4	6	2.4		1
Bohadschia argus	0.8	0.8	36	28.6		1	0.8	0.8	6	4.8		1
Cassiopea spp.	1.6	0.9	36	19.0	4.8	3	1.6	1.6	6	9.5		1
Chama spp.	0.4	0.4	36	14.3		1	0.4	0.4	6	2.4		1
Choriaster granulatus	1.6	1.1	36	28.6	0.0	2	1.6	1.0	6	4.8	0.0	2
Culcita novaeguineae	1.2	0.9	36	21.4	7.1	2	1.2	0.8	6	3.6	1.2	2
Holothuria fuscogilva	5.2	2.1	36	23.2	6.0	8	5.2	3.3	6	7.7	4.6	4
Holothuria fuscopunctata	3.6	2.2	36	32.1	13.5	4	3.6	3.6	6	21.4		1
Holothuria nobilis	1.6	0.9	36	19.0	4.8	3	1.6	1.0	6	4.8	0.0	2
Lambis chiragra	0.4	0.4	36	14.3		1	0.4	0.4	6	2.4		1
Panulirus versicolor	0.4	0.4	36	14.3		1	0.4	0.4	6	2.4		1
Pteria penguin	0.8	0.6	36	14.3	0.0	2	0.8	0.5	6	2.4	0.0	2
Spondylus spp.	1.6	0.8	36	14.3	0.0	4	1.6	0.5	6	2.4	0.0	4
Stichopus hermanni	0.4	0.4	36	14.3		1	0.4	0.4	6	2.4		1
Thelenota ananas	4.8	1.8	36	24.5	4.1	7	4.8	3.1	6	9.5	5.0	3
Thelenota anax	3.2	1.2	36	16.3	2.0	7	3.2	1.9	6	6.3	2.9	3
Tridacna crocea	0.4	0.4	36	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.

4.1.10 Ngarchelong species size review – all survey methods

Species	Mean length (cm)	SE	n
Tridacna crocea	7.0	0.1	16,049
Stichopus vastus	12.8	0.3	5443
Actinopyga spp.	13.8	0.4	1149
Tridacna maxima	12.9	0.3	1019
Holothuria atra	18.5	0.7	472
Trochus niloticus	9.0	0.1	414
Bohadschia vitiensis	17.0	0.3	267
Tectus pyramis	5.8	0.1	205
Stichopus chloronotus	19.1	0.6	173
Bohadschia similis	17.8	0.4	155
Bohadschia argus	27.9	1.2	142
Holothuria scabra	16.5	0.3	142
Holothuria edulis	16.9	0.7	133
Hippopus hippopus	25.9	0.7	56
Thelenota ananas	46.7	1.4	48
Turbo argyrostomus	6.9	0.1	46
Stichopus hermanni	38.0	1.0	33
Holothuria nobilis	29.0	0.9	32
Pinctada margaritifera	13.3	0.7	32
Holothuria coluber	37.4	3.1	27
Lambis lambis	12.2	0.6	25
Cypraea tigris	7.2	0.2	25
Tridacna derasa	34.7	1.8	24
Trochus maculata	3.6	0.3	23
Latirolagena smaragdula	4.3	0.3	22
Conus spp.	5.6	0.7	20
Conus miliaris	3.0	0.0	20
Chama spp.	8.0	0.0	20
Tridacna squamosa	24.2	1.7	18
Vasum spp.	4.3	0.1	18
Tridacna gigas	65.5	6.1	15
Holothuria fuscopunctata	40.2	1.5	14
Actinopyga mauritiana	22.3	0.7	14
Holothuria fuscogilva	35.0	1.0	13
Strombus luhuanus	5.4	0.2	10
Thais spp.	4.1	0.0	10
Thelenota anax	46.6	3.0	9
Hippopus porcellanus	25.7	1.3	9
Spondylus spp.	6.0	0.0	9
Lambis chiragra	15.6	1.1	8
Turbo chrysostomus	4.3	0.7	7
Stichopus horrens	8.7	0.5	7
Conus lividus	4.9	0.5	7
Tectus triserialis	4.6	0.4	7
Conus distans	7.1	0.7	6
Cerithium nodulosum	7.2	0.4	6
Trochus spp.	3.8	0.4	6
Conus miles	3.8	0.1	6

SE = Standard error; n = number.

4.1.10 Ngarchelong species size review – all survey methods (continued)

Species	Mean length (cm)	SE	n
Tectus conus	4.1	0.1	6
Actinopyga echinites	14.7	0.8	5
Actinopyga miliaris	28.7	1.3	4
Chicoreus brunneus	5.2	0.0	4
Tripneustes gratilla	9.3	0.7	3
Conus vexillum	7.7	0.3	3
Turbo setosus	6.3	0.2	3
Conus rattus	3.5	0.0	3
Actinopyga lecanora	18.5	3.5	2
Vasum ceramicum	10.9	1.9	2
Mespilia globulus	7.8	1.3	2
Conus flavidus	4.2	0.3	2
Conus litteratus	9.3	0.3	2
Astralium spp.	3.5		2
Cypraea erosa	3.5		2
Anadara scapha	8.0		1
Conus eburneus	5.6		1
Conus emaciatus	3.8		1
Conus marmoreus	7.5		1
Conus sanguinolentus	4.0		1
Cypraea arabica	6.0		1
Cypraea vitellus	4.9		1
Haliotis asinina	6.0		1
Pleuroploca filamentosa	12.5		1
Tectus spp.	7.0		1
Thais aculeata	4.0		1
Vasum turbinellum	4.0		1
Linckia laevigata			1046
Echinometra mathaei			643
Beguina semiorbiculata			33
Culcita novaeguineae			32
Arca spp.			29
Bohadschia graeffei			29
Protoreaster nodosus			20
Echinothrix diadema			16
Holothuria hilla			14
Acanthaster planci			12
Choriaster granulatus			10
Stichodactyla spp.			10
Cassiopea spp.			8
Synapta spp.			8
Cypraea caputserpensis			5
Lysiosquillina maculata			5
Panulirus versicolor			4
Pinna spp.			4
Lopha cristagalli			3
Panulirus spp.			3
Cassiopea andromeda			2

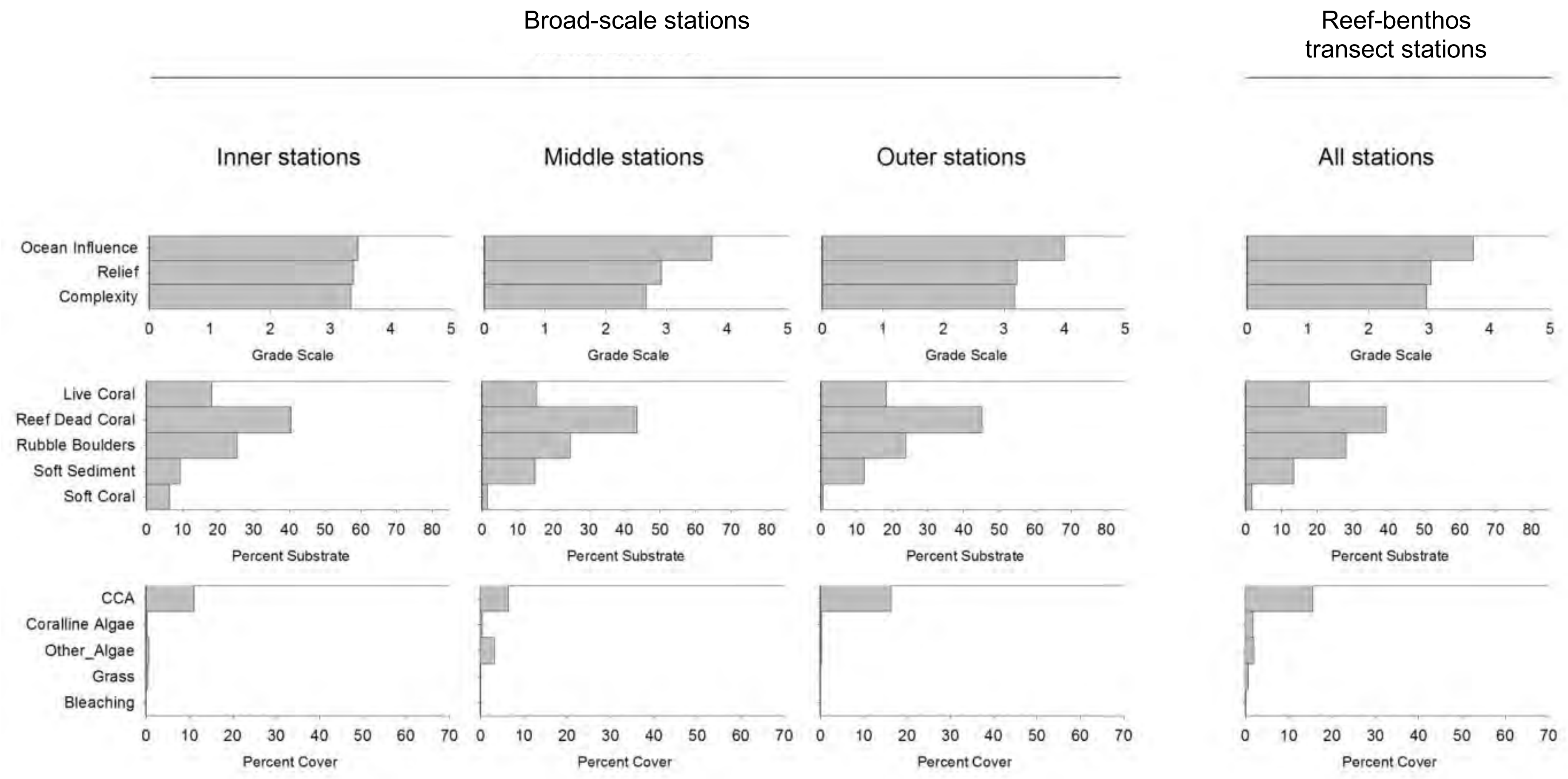
SE = Standard error; n = number.

4.1.10 Ngarchelong species size review – all survey methods (continued)

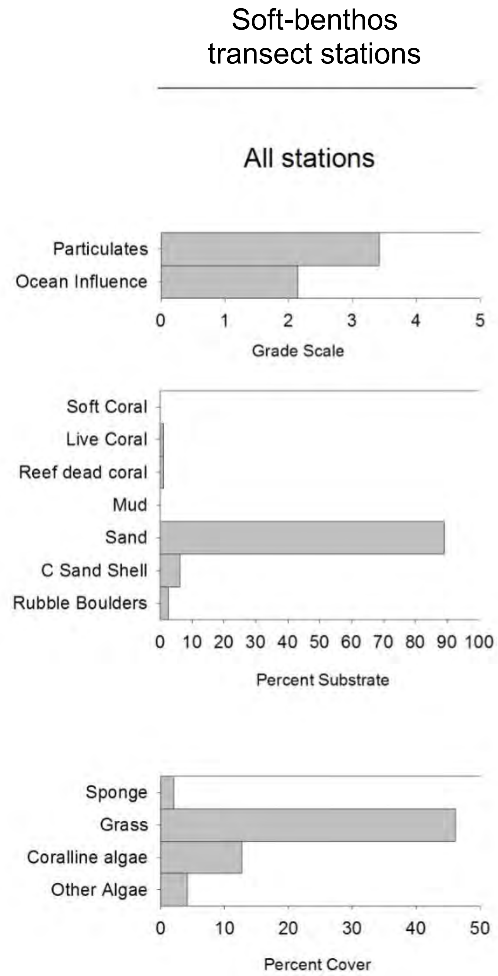
Species	Mean length (cm)	SE	n
Drupa grossularia			2
Echinothrix calamaris			2
Ovula ovum			2
Pteria penguin			2
Saron spp.			2
Stenopus hispidus			2
Thalassina spp.			2
Atrina spp.			1
Bursa bufonia			1
Conus imperialis			1
Cypraea moneta			1
Cypraea talpa			1
Heterocentrotus mammillatus			1
Holothuria spp.			1
Linckia guildingi			1
Octopus cyanea			1

SE = Standard error; n = number.

4.1.11 Habitat descriptors for independent assessments – Ngarchelong



4.1.11 Habitat descriptors for independent assessments – Ngarchelong (continued)



4.2 Ngatpang invertebrate survey data

4.2.1 Invertebrate species recorded in different assessments in Ngatpang

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga echinites*			+	
Bêche-de-mer	*Actinopyga lecanora*		+		+
Bêche-de-mer	*Actinopyga mauritiana*	+	+		+
Bêche-de-mer	*Actinopyga miliaris*	+		+	+
Bêche-de-mer	*Actinopyga palauensis*		+		
Bêche-de-mer	*Actinopyga* spp.			+	
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 flavomaculata*	+	+	+	
Bêche-de-mer	*Holothuria fuscogilva*		+		+
Bêche-de-mer	*Holothuria fuscopunctata*	+	+		+
Bêche-de-mer	*Holothuria hilla*		+		
Bêche-de-mer	*Holothuria nobilis*	+	+	+	+
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	*Stichopus vastus*		+	+	
Bêche-de-mer	*Synapta* spp.			+	
Bêche-de-mer	*Thelenota ananas*	+	+		+
Bêche-de-mer	*Thelenota anax*	+	+		+
Bivalve	*Anadara scapha*			+	
Bivalve	*Anadara* spp.	+			
Bivalve	*Arca* spp.		+		
Bivalve	*Atrina vexillum*	+	+	+	
Bivalve	*Barbatia* spp.		+		
Bivalve	*Beguina semiorbiculata*		+		+
Bivalve	*Chama* spp.	+	+		+
Bivalve	*Gafrarium* spp.			+	
Bivalve	*Hippopus hippopus*	+	+	+	+
Bivalve	*Hippopus porcellanus*	+	+		
Bivalve	*Hyotissa* spp.	+			+
Bivalve	*Malleus* spp.			+	
Bivalve	*Pinctada margaritifera*	+	+		+
Bivalve	*Pinna* spp.		+		
Bivalve	*Pteria penguin*				+
Bivalve	*Spondylus* spp.			+	+
Bivalve	*Tridacna crocea*	+	+		+
Bivalve	*Tridacna derasa*	+			+
Bivalve	*Tridacna gigas*	+	+		+

+ = presence of the species.

4.2.1 Invertebrate species recorded in different assessments in Ngatpang (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna* spp.		+		
Bivalve	*Tridacna squamosa*	+	+		+
Cnidarian	*Cassiopea andromeda*			+	
Cnidarian	*Cassiopea* spp.			+	
Cnidarian	*Entacmaea quadricolor*		+		
Cnidarian	*Stichodactyla* spp.	+	+	+	+
Crustacean	*Lysiosquillina maculata*			+	
Crustacean	*Panulirus* spp.	+			
Crustacean	*Panulirus versicolor*		+		+
Crustacean	*Saron* spp.		+		
Crustacean	*Stenopus hispidus*		+		
Crustacean	*Thalassina* spp.		+	+	
Gastropod	*Astralium* spp.		+		+
Gastropod	*Cerithium nodulosum*		+		
Gastropod	*Charonia tritonis*				+
Gastropod	*Chicoreus brunneus*		+		
Gastropod	*Chicoreus* spp.		+		
Gastropod	*Conus capitaneus*		+		
Gastropod	*Conus distans*		+		
Gastropod	*Conus emaciatus*		+		
Gastropod	*Conus lividus*		+		
Gastropod	*Conus marmoreus*		+		
Gastropod	*Conus miliaris*		+		
Gastropod	*Conus quercinus*			+	
Gastropod	*Conus rattus*		+		
Gastropod	*Conus* spp.		+		+
Gastropod	*Conus striatus*		+		
Gastropod	*Conus vexillum*		+		
Gastropod	*Cypraea annulus*		+		
Gastropod	*Cypraea caputserpensis*				+
Gastropod	*Cypraea lynx*		+	+	
Gastropod	*Cypraea* spp.		+		
Gastropod	*Cypraea tigris*	+	+	+	
Gastropod	*Haliotis asinina*		+		
Gastropod	*Lambis chiragra*		+		+
Gastropod	*Lambis lambis*	+	+	+	
Gastropod	*Lambis truncata*				+
Gastropod	*Latirolagena smaragdula*		+		+
Gastropod	*Ovula ovum*				+
Gastropod	*Strombus lentiginosus*		+		
Gastropod	*Strombus luhuanus*		+		+
Gastropod	*Tectus conus*				+
Gastropod	*Tectus pyramis*		+		+
Gastropod	*Tectus triserialis*		+		
Gastropod	*Trochus maculata*		+		
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Turbo argyrostomus*	+	+		+

+ = presence of the species.

4.2.1 Invertebrate species recorded in different assessments in Ngatpang (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Turbo chrysostomus*				+
Gastropod	*Turbo crassus*				+
Gastropod	*Vasum ceramicum*				+
Gastropod	*Vasum* spp.		+		+
Star	*Acanthaster planci*	+	+		+
Star	*Choriaster granulatus*	+			+
Star	*Culcita novaeguineae*	+	+	+	+
Star	*Linckia laevigata*	+	+	+	+
Star	*Nardoa* spp.		+		
Star	*Protoreaster nodosus*			+	
Urchin	*Diadema savignyi*		+		
Urchin	*Diadema* spp.		+		
Urchin	*Echinometra mathaei*	+	+		+
Urchin	*Mespilia globulus*			+	
Urchin	*Toxopneustes pileolus*		+		
Urchin	*Tripneustes gratilla*			+	

+ = presence of the species.

4.2.2 Ngatpang 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	2.3	0.8	72	18.5	1.9	9	4.4	2.2	13	11.4	4.1	5
Actinopyga mauritiana	0.2	0.2	72	16.7		1	0.2	0.2	13	2.8		1
Actinopyga miliaris	0.7	0.4	72	16.7	0.0	3	0.6	0.3	13	2.8	0.0	3
Anadara spp.	0.2	0.2	72	16.7		1	0.2	0.2	13	2.8		1
Atrina vexillum	0.7	0.4	72	16.7	0.0	3	0.6	0.5	13	4.2	1.4	2
Bohadschia argus	18.1	3.8	72	46.4	6.9	28	16.6	4.9	13	24.0	5.5	9
Bohadschia graeffei	10.9	2.4	72	30.1	4.6	26	16.0	5.4	13	20.8	6.3	10
Bohadschia vitiensis	0.2	0.2	72	16.7		1	0.2	0.2	13	2.7		1
Chama spp.	3.5	1.5	72	25.0	8.3	10	9.2	5.4	13	14.9	8.3	8
Choriaster granulatus	0.5	0.3	72	16.7	0.0	2	1.2	0.7	13	5.1	1.7	3
Culcita novaeguineae	5.1	1.2	72	21.6	1.9	17	7.7	2.6	13	11.1	3.1	9
Cypraea tigris	0.7	0.4	72	16.7	0.0	3	0.6	0.3	13	2.8	0.0	3
Echinometra mathaei	4.9	2.8	72	87.5	30.7	4	4.5	3.3	13	19.4	11.6	3
Hippopus hippopus	4.4	1.1	72	21.0	2.0	15	4.0	0.9	13	5.8	0.7	9
Hippopus porcellanus	0.7	0.4	72	16.7	0.0	3	1.4	0.7	13	4.5	1.3	4
Holothuria atra	17.7	4.2	72	57.9	9.0	22	26.8	10.4	13	38.7	13.3	9
Holothuria coluber	0.9	0.6	72	22.2	5.6	3	0.9	0.7	13	5.6	2.8	2
Holothuria edulis	23.1	4.8	72	49.0	8.1	34	45.3	21.2	13	58.9	26.2	10
Holothuria flavomaculata	1.6	1.1	72	38.9	14.7	3	1.5	1.5	13	19.4		1
Holothuria fuscopunctata	13.1	3.5	72	58.9	9.4	16	12.1	4.4	13	22.5	5.9	7
Holothuria nobilis	6.2	1.9	72	40.4	5.1	11	5.7	3.0	13	18.6	6.0	4
Hyotissa spp.	4.6	1.2	72	23.8	2.9	14	4.3	1.5	13	7.9	1.8	7
Lambis lambis	0.5	0.3	72	16.7	0.0	2	0.4	0.3	13	2.8	0.0	2
Linckia laevigata	103.1	20.5	72	168.8	29.7	44	107.4	35.2	13	126.9	38.9	11
Panulirus spp.	0.2	0.2	72	16.7		1	0.2	0.2	13	2.8		1
Pinctada margaritifera	3.7	0.9	72	18.8	1.5	14	4.2	1.0	13	6.0	0.9	9
Stichodactyla spp.	1.8	0.7	72	18.8	2.4	7	1.7	0.7	13	3.7	0.9	6
Stichopus chloronotus	13.2	6.2	72	67.9	28.3	14	38.4	23.8	13	71.2	41.4	7

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.2 Ngatpang 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
Stichopus hermanni	11.8	2.3	72	33.9	3.5	25	13.9	3.5	13	20.0	3.4	9
Thelenota ananas	9.9	4.3	72	51.1	18.7	14	9.2	4.5	13	17.0	7.3	7
Thelenota anax	4.4	1.9	72	45.2	10.7	7	4.1	2.8	13	13.2	7.7	4
Tridacna crocea	842.4	137.7	72	947.7	149.8	64	1109.7	314.4	13	1109.7	314.4	13
Tridacna derasa	0.7	0.4	72	16.7	0.0	3	1.4	0.7	13	4.5	1.3	4
Tridacna gigas	0.2	0.2	72	16.7		1	0.2	0.2	13	2.8		1
Tridacna maxima	63.1	13.7	72	94.6	19.0	48	62.3	20.9	13	67.5	22.0	12
Tridacna squamosa	10.2	2.2	72	30.6	4.0	24	14.6	4.6	13	19.0	5.3	10
Trochus niloticus	0.2	0.2	72	16.7		1	0.2	0.2	13	2.8		1
Turbo argyrostomus	1.2	0.7	72	27.8	5.6	3	1.0	1.0	13	13.6		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.3 Ngatpang reef-benthos transect (RBt) assessment data review
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Actinopyga lecanora	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Actinopyga mauritiana	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Actinopyga palauensis	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Arca spp.	166.7	50.7	114	863.6	207.2	22	166.7	76.3	19	316.7	129.9	10
Astralium spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Atrina vexillum	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Barbatia spp.	46.1	46.1	114	5250.0		1	46.1	46.1	19	875.0		1
Beguina semiorbiculata	846.5	192.2	114	2838.2	503.0	34	846.5	396.6	19	1462.1	631.7	11
Bohadschia argus	81.1	20.1	114	462.5	66.1	20	81.1	26.4	19	171.3	37.0	9
Bohadschia graeffei	17.5	6.8	114	285.7	35.7	7	17.5	9.7	19	83.3	29.5	4

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.3 Ngatpang 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
Cerithium nodulosum	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Chama spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Chicoreus brunneus	17.5	6.8	114	285.7	35.7	7	17.5	5.8	19	47.6	6.0	7
Chicoreus spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus capitaneus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus distans	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus emaciatus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus lividus	4.4	4.4	114	500.0		1	4.4	4.4	19	83.3		1
Conus marmoreus	6.6	3.8	114	250.0	0.0	3	6.6	3.6	19	41.7	0.0	3
Conus miliaris	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus rattus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus spp.	6.6	3.8	114	250.0	0.0	3	6.6	4.8	19	62.5	20.8	2
Conus striatus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus vexillum	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Culcita novaeguineae	19.7	7.1	114	281.3	31.3	8	19.7	6.7	19	53.6	7.7	7
Cypraea annulus	21.9	18.0	114	1250.0	750.0	2	21.9	21.9	19	416.7		1
Cypraea lynx	6.6	4.9	114	375.0	125.0	2	6.6	6.6	19	125.0		1
Cypraea spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea tigris	19.7	6.3	114	250.0	0.0	9	19.7	6.7	19	53.6	7.7	7
Diadema savignyi	11.0	7.9	114	625.0	125.0	2	11.0	11.0	19	208.3		1
Diadema spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Echinometra mathaei	138.2	33.4	114	525.0	97.6	30	138.2	52.9	19	218.8	75.2	12
Entacmaea quadricolor	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Haliotis asinina	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Hippopus hippopus	61.4	13.1	114	318.2	29.3	22	61.4	18.9	19	116.7	25.5	10
Hippopus porcellanus	4.4	3.1	114	250.0	0.0	2	4.4	4.4	19	83.3		1
Holothuria atra	87.7	22.7	114	454.5	80.0	22	87.7	41.9	19	208.3	84.4	8
Holothuria coluber	11.0	4.8	114	250.0	0.0	5	11.0	8.9	19	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; SE = standard error.

4.2.3 Ngatpang reef-benthos transect (RBt) assessment data review (continued)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria edulis	105.3	26.2	114	480.0	85.3	25	105.3	59.9	19	153.8	85.1	13
Holothuria flavomaculata	13.2	8.1	114	500.0	144.3	3	13.2	13.2	19	250.0		1
Holothuria fuscogilva	30.7	17.9	114	700.0	300.0	5	30.7	26.4	19	291.7	208.3	2
Holothuria fuscopunctata	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Holothuria hilla	17.5	9.7	114	500.0	144.3	4	17.5	15.4	19	166.7	125.0	2
Holothuria nobilis	26.3	11.0	114	375.0	94.5	8	26.3	12.0	19	83.3	26.4	6
Holothuria spp.	4.4	4.4	114	500.0		1	4.4	4.4	19	83.3		1
Lambis chiragra	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Lambis lambis	52.6	14.8	114	400.0	58.8	15	52.6	17.7	19	111.1	26.0	9
Latirolagena smaragdula	13.2	9.3	114	500.0	250.0	3	13.2	11.1	19	125.0	83.3	2
Linckia laevigata	219.3	41.5	114	568.2	84.2	44	219.3	65.8	19	347.2	84.6	12
Nardoa spp.	8.8	4.3	114	250.0	0.0	4	8.8	4.0	19	41.7	0.0	4
Panulirus versicolor	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Pinctada margaritifera	8.8	4.3	114	250.0	0.0	4	8.8	5.1	19	55.6	13.9	3
Pinna spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Saron spp.	8.8	6.9	114	500.0	250.0	2	8.8	6.8	19	83.3	41.7	2
Stenopus hispidus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Stichodactyla spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Stichopus chloronotus	19.7	7.1	114	281.3	31.3	8	19.7	12.1	19	125.0	41.7	3
Stichopus hermanni	6.6	4.9	114	375.0	125.0	2	6.6	4.8	19	62.5	20.8	2
Stichopus horrens	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Stichopus vastus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Strombus lentiginosus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Strombus luhuanus	4.4	4.4	114	500.0		1	4.4	4.4	19	83.3		1
Tectus pyramis	21.9	8.0	114	312.5	40.9	8	21.9	13.7	19	104.2	49.6	4
Tectus triserialis	4.4	3.1	114	250.0	0.0	2	4.4	4.4	19	83.3		1
Thalassina spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Thelenota ananas	26.3	9.5	114	333.3	58.9	9	26.3	17.2	19	166.7	72.2	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.3 Ngatpang reef-benthos transect (RBt) assessment data review (continued)
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Thelenota anax	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Toxopneustes pileolus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Tridacna crocea	3392.5	315.9	114	4250.0	341.3	91	3392.5	701.8	19	3392.5	701.8	19
Tridacna gigas	4.4	3.1	114	250.0	0.0	2	4.4	4.4	19	83.3		1
Tridacna maxima	263.2	51.5	114	714.3	109.6	42	263.2	85.5	19	357.1	105.6	14
Tridacna spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Tridacna squamosa	15.4	6.4	114	291.7	41.7	6	15.4	5.7	19	48.6	6.9	6
Trochus maculata	8.8	5.3	114	333.3	83.3	3	8.8	6.8	19	83.3	41.7	2
Trochus niloticus	17.5	8.1	114	333.3	83.3	6	17.5	11.6	19	111.1	50.1	3
Turbo argyrostomus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Vasum spp.	6.6	3.8	114	250.0	0.0	3	6.6	3.6	19	41.7	0.0	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.4 Ngatpang 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	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Actinopyga miliaris	108.3	45.4	90	1 083.3	311.8	9	108.3	94.1	15	541.7	439.0	3
Actinopyga spp.	4494.4	1826.9	90	10,112.5	3959.9	40	4494.4	3422.0	15	7490.7	5599.0	9
Anadara scapha	19.4	9.9	90	350.0	100.0	5	19.4	14.0	15	97.2	55.6	3
Atrina vexillum	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Bohadschia argus	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Bohadschia similis	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Bohadschia vitiensis	16.7	6.6	90	250.0	0.0	6	16.7	7.9	15	62.5	12.0	4
Cassiopea spp.	13.9	6.1	90	250.0	0.0	5	13.9	6.6	15	52.1	10.4	4
Cassiopea andromeda	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; SE = standard error.

4.2.4 Ngatpang 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
Conus quercinus	8.3	6.2	90	375.0	125.0	2	8.3	6.0	15	62.5	20.8	2
Culcita novaeguineae	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Cypraea lynx	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Cypraea tigris	5.6	5.6	90	500.0		1	5.6	5.6	15	83.3		1
Gafrarium spp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Hippopus hippopus	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Holothuria atra	3247.2	624.7	90	4953.4	876.1	59	3247.2	1393.5	15	3746.8	1567.8	13
Holothuria coluber	55.6	34.2	90	625.0	340.7	8	55.6	39.4	15	208.3	128.4	4
Holothuria edulis	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Holothuria flavomaculata	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Holothuria nobilis	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Holothuria scabra	594.4	157.5	90	2972.2	482.9	18	594.4	350.7	15	2972.2	878.1	3
Lambis lambis	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Linckia laevigata	55.6	18.0	90	416.7	77.4	12	55.6	34.9	15	208.3	103.5	4
Lysiosquillina maculata	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Malleus spp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Mespilia globulus	8.3	6.2	90	375.0	125.0	2	8.3	6.0	15	62.5	20.8	2
Protoreaster nodosus	25.0	14.3	90	562.5	187.5	4	25.0	25.0	15	375.0		1
Spondylus spp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Stichodactyla spp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Stichopus vastus	783.3	192.5	90	2136.4	436.7	33	783.3	458.7	15	1175.0	663.2	10
Synapta spp.	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Thalassina spp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Tripneustes gratilla	11.1	6.7	90	333.3	83.3	3	11.1	11.1	15	166.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.5 Ngatpang reef-front search (RFs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Actinopyga mauritiana	14.1	4.6	30	38.5	8.6	11	14.1	6.2	5	23.5	3.9	3
Actinopyga miliaris	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Bohadschia graeffei	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Chama spp.	18.0	12.1	30	135.3	72.8	4	18.0	17.1	5	45.1	41.2	2
Conus spp.	4.7	2.1	30	28.2	4.7	5	4.7	2.3	5	7.8	2.3	3
Cypraea caputserpensis	1.6	1.6	30	47.1		1	1.6	1.6	5	7.8		1
Echinometra mathaei	126.3	29.3	30	199.4	37.2	19	126.3	46.9	5	157.8	44.7	4
Holothuria atra	1.6	1.1	30	23.5	0.0	2	1.6	1.6	5	7.8		1
Holothuria fuscogilva	1.6	1.1	30	23.5	0.0	2	1.6	1.6	5	7.8		1
Holothuria fuscopunctata	3.1	2.2	30	47.1	0.0	2	3.1	3.1	5	15.7		1
Holothuria nobilis	3.1	1.9	30	31.4	7.8	3	3.1	2.3	5	7.8	3.9	2
Lambis chiragra	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Lambis truncata	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Latirolagena smaragdula	3.9	2.0	30	29.4	5.9	4	3.9	2.5	5	9.8	2.0	2
Linckia laevigata	29.8	16.9	30	223.5	79.5	4	29.8	29.8	5	149.0		1
Ovula ovum	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Pinctada margaritifera	1.6	1.1	30	23.5	0.0	2	1.6	1.0	5	3.9	0.0	2
Stichopus hermanni	7.8	4.4	30	58.8	20.4	4	7.8	7.8	5	39.2		1
Tectus conus	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Tectus pyramis	5.5	2.2	30	27.5	3.9	6	5.5	2.0	5	6.9	1.9	4
Thelenota ananas	15.7	5.1	30	47.1	9.3	10	15.7	9.4	5	26.1	12.5	3
Thelenota anax	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Tridacna crocea	45.5	14.4	30	91.0	23.8	15	45.5	21.0	5	45.5	21.0	5
Tridacna maxima	136.5	19.6	30	136.5	19.6	30	136.5	15.1	5	136.5	15.1	5
Trochus niloticus	8.6	2.6	30	28.8	3.5	9	8.6	3.1	5	10.8	2.9	4
Turbo argyrostomus	5.5	1.8	30	23.5	0.0	7	5.5	2.4	5	9.2	1.3	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.5 Ngatpang reef-front search (RFs) assessment data review (continued)
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
Turbo chrysostomus	1.6	1.1	30	23.5	0.0	2	1.6	1.0	5	3.9	0.0	2
Turbo crassus	0.8	0.8	30	23.5		1	0.8	0.8	5	3.9		1
Vasum ceramicum	2.4	1.7	30	35.3	11.8	2	2.4	2.4	5	11.8		1
Vasum spp.	2.4	1.7	30	35.3	11.8	2	2.4	2.4	5	11.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.6 Ngatpang mother-of-pearl search (MOPs) assessment data review
Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga lecanora	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Actinopyga mauritiana	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Astralium spp.	3.0	2.1	30	45.5	0.0	2	3.0	1.9	5	7.6	0.0	2
Charonia tritonis	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Conus spp.	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Culcita novaeguineae	10.6	5.6	30	79.5	21.8	4	10.6	10.6	5	53.0		1
Echinometra mathaei	28.8	16.9	30	215.9	85.8	4	28.8	25.2	5	72.0	56.8	2
Holothuria atra	4.5	3.3	30	68.2	22.7	2	4.5	3.0	5	11.4	3.8	2
Holothuria edulis	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Holothuria nobilis	16.7	8.3	30	83.3	29.7	6	16.7	9.4	5	20.8	10.9	4
Hyotissa spp.	6.1	4.7	30	90.9	45.5	2	6.1	6.1	5	30.3		1
Latirolagena smaragdula	7.6	7.6	30	227.3		1	7.6	7.6	5	37.9		1
Panulirus versicolor	3.0	3.0	30	90.9		1	3.0	3.0	5	15.2		1
Pinctada margaritifera	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Stichodactyla spp.	6.1	2.9	30	45.5	0.0	4	6.1	3.7	5	15.2	0.0	2
Stichopus hermanni	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Tectus conus	3.0	3.0	30	90.9		1	3.0	3.0	5	15.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.6 Ngatpang mother-of-pearl search (MOPs) assessment data review (continued)
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	12.1	4.3	30	51.9	6.5	7	12.1	3.9	5	15.2	3.1	4
Thelenota ananas	9.1	3.4	30	45.5	0.0	6	9.1	4.4	5	15.2	4.4	3
Tridacna crocea	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Tridacna maxima	69.7	13.4	30	110.0	14.5	19	69.7	21.3	5	69.7	21.3	5
Trochus niloticus	19.7	7.1	30	73.9	14.7	8	19.7	11.6	5	32.8	15.4	3
Turbo argyrostomus	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1
Turbo chrysostomus	1.5	1.5	30	45.5		1	1.5	1.5	5	7.6		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.7 Ngatpang 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	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Bohadschia argus	22.2	10.3	12	66.7	13.3	4	22.2	13.3	2	22.2	13.3	2
Bohadschia similis	22.2	12.2	12	88.9	17.8	3	22.2	22.2	2	44.4		1
Bohadschia vitiensis	702.2	259.3	12	1053.3	325.0	8	702.2	684.4	2	702.2	684.4	2
Echinometra mathaei	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Hippopus hippopus	13.3	9.6	12	80.0	26.7	2	13.3	13.3	2	26.7		1
Holothuria atra	62.2	37.6	12	248.9	88.9	3	62.2	62.2	2	124.4		1
Holothuria edulis	8.9	6.0	12	53.3	0.0	2	8.9	8.9	2	17.8		1
Holothuria nobilis	22.2	13.9	12	88.9	35.6	3	22.2	22.2	2	44.4		1
Linckia laevigata	17.8	12.0	12	106.7	0.0	2	17.8	17.8	2	35.6		1
Strombus luhuanus	8.9	8.9	12	106.7		1	8.9	8.9	2	17.8		1
Thelenota ananas	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Tridacna crocea	22.2	13.9	12	88.9	35.6	3	22.2	22.2	2	44.4		1
Tridacna gigas	8.9	6.0	12	53.3	0.0	2	8.9	0.0	2	8.9	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.8 Ngatpang 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
Actinopyga miliaris	0.8	0.6	36	14.3	0.0	2	0.8	0.5	6	2.4	0.0	2
Beguina semiorbiculata	9.1	9.1	36	328.6		1	9.1	9.1	6	54.8		1
Bohadschia argus	2.4	1.5	36	28.6	8.2	3	2.4	1.6	6	7.1	2.4	2
Choriaster granulatus	0.8	0.6	36	14.3	0.0	2	0.8	0.8	6	4.8		1
Culcita novaeguineae	0.8	0.6	36	14.3	0.0	2	0.8	0.8	6	4.8		1
Holothuria fuscogilva	2.0	1.0	36	17.9	3.6	4	2.0	1.1	6	4.0	1.6	3
Holothuria fuscopunctata	2.8	1.0	36	14.3	0.0	7	2.8	1.4	6	5.6	1.6	3
Holothuria nobilis	0.8	0.8	36	28.6		1	0.8	0.8	6	4.8		1
Hyotissa spp.	0.4	0.4	36	14.3		1	0.4	0.4	6	2.4		1
Pteria penguin	0.4	0.4	36	14.3		1	0.4	0.4	6	2.4		1
Spondylus spp.	0.8	0.6	36	14.3	0.0	2	0.8	0.5	6	2.4	0.0	2
Stichopus hermanni	2.8	1.4	36	25.0	3.6	4	2.8	2.3	6	8.3	6.0	2
Thelenota ananas	2.4	1.1	36	17.1	2.9	5	2.4	1.2	6	4.8	1.4	3
Thelenota anax	8.7	2.7	36	28.6	5.1	11	8.7	6.4	6	13.1	9.1	4
Tridacna derasa	0.4	0.4	36	14.3		1	0.4	0.4	6	2.4		1
Tridacna squamosa	0.4	0.4	36	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.

Appendix 4: Invertebrate survey data
Ngatpang

4.2.9 Ngatpang species size review – all survey methods

Species	Mean length (cm)	SE	n
Tridacna crocea	5.9	0.1	5265
Actinopyga spp.	9.8	0.1	1618
Holothuria atra	13.9	0.3	1305
Tridacna maxima	12.2	0.4	616
Stichopus vastus	15.2	0.4	283
Holothuria scabra	16.2	0.2	214
Bohadschia vitiensis	19.7	1.0	165
Holothuria edulis	16.2	0.7	152
Bohadschia argus	31.7	0.7	128
Thelenota ananas	38.8	1.3	88
Stichopus hermanni	36.2	2.0	72
Holothuria fuscopunctata	39.1	1.7	69
Stichopus chloronotus	16.6	2.1	66
Holothuria nobilis	28.6	0.5	62
Bohadschia graeffei	25.4	1.5	56
Tridacna squamosa	27.9	1.2	52
Hippopus hippopus	24.2	0.9	52
Actinopyga miliaris	29.2	0.6	45
Thelenota anax	47.3	1.6	43
Trochus niloticus	9.5	0.2	33
Holothuria coluber	28.5	13.5	29
Lambis lambis	12.7	0.5	27
Tectus pyramis	6.2	0.2	25
Pinctada margaritifera	13.5	0.6	23
Holothuria fuscogilva	35.6	0.9	21
Actinopyga mauritiana	20.0	0.0	21
Holothuria flavomaculata	21.8	3.6	14
Turbo argyrostomus	3.4	0.5	14
Cypraea tigris	7.4	0.4	14
Conus spp.	6.0	1.4	10
Holothuria hilla	10.2	2.1	8
Chicoreus brunneus	6.0	0.5	8
Anadara scapha	6.2	0.1	7
Bohadschia similis	18.3	2.4	6
Vasum spp.	7.8	1.3	6
Tridacna gigas	51.6	3.7	5
Atrina vexillum	19.5	2.5	5
Hippopus porcellanus	25.2	1.3	5
Tridacna derasa	41.0	5.4	4
Strombus luhuanus	5.3	0.3	4
Tripneustes gratilla	5.9	0.1	4
Trochus maculata	2.9	0.1	4
Nardoa spp.	6.5	0.0	4
Mespilia globulus	4.0	2.0	3
Conus quercinus	5.9	0.9	3
Conus marmoreus	6.6	0.3	3
Astralium spp.	3.7	0.2	3
Tectus conus	5.1	0.1	3

SE = Standard error; n = number.

4.2.9 Ngatpang species size review – all survey methods (continued)

Species	Mean length (cm)	SE	n
Holothuria spp.	26.0	4.0	2
Conus vexillum	6.0	2.5	2
Actinopyga lecanora	18.5	0.5	2
Conus lividus	3.8	0.3	2
Tectus triserialis	3.4	0.2	2
Cerithium nodulosum	8.6	0.1	2
Lambis chiragra	20.0		2
Charonia tritonis	32.0		1
Actinopyga palauensis	19.0		1
Actinopyga echinites	17.0		1
Toxopneustes pileolus	15.0		1
Stichopus horrens	11.5		1
Conus distans	9.8		1
Turbo crassus	7.8		1
Strombus lentiginosus	7.1		1
Tridacna spp.	5.5		1
Conus striatus	5.0		1
Conus emaciatus	4.1		1
Chicoreus spp.	4.1		1
Conus miliaris	2.5		1
Linckia laevigata			611
Beguina semiorbiculata			409
Echinometra mathaei			265
Arca spp.			76
Culcita novaeguineae			42
Chama spp.			39
Hyotissa spp.			25
Barbatia spp.			21
Latirolagena smaragdula			16
Stichodactyla spp.			14
Acanthaster planci			13
Cypraea annulus			10
Protoreaster nodosus			9
Cassiopea spp.			5
Diadema savignyi			5
Cypraea lynx			4
Choriaster granulatus			4
Saron spp.			4
Turbo chrysostomus			3
Vasum ceramicum			3
Spondylus spp.			3
Panulirus versicolor			3
Synapta spp.			2
Cypraea caputserpensis			2
Thalassina spp.			2
Cassiopea andromeda			2
Gafrarium spp.			1
Stenopus hispidus			1

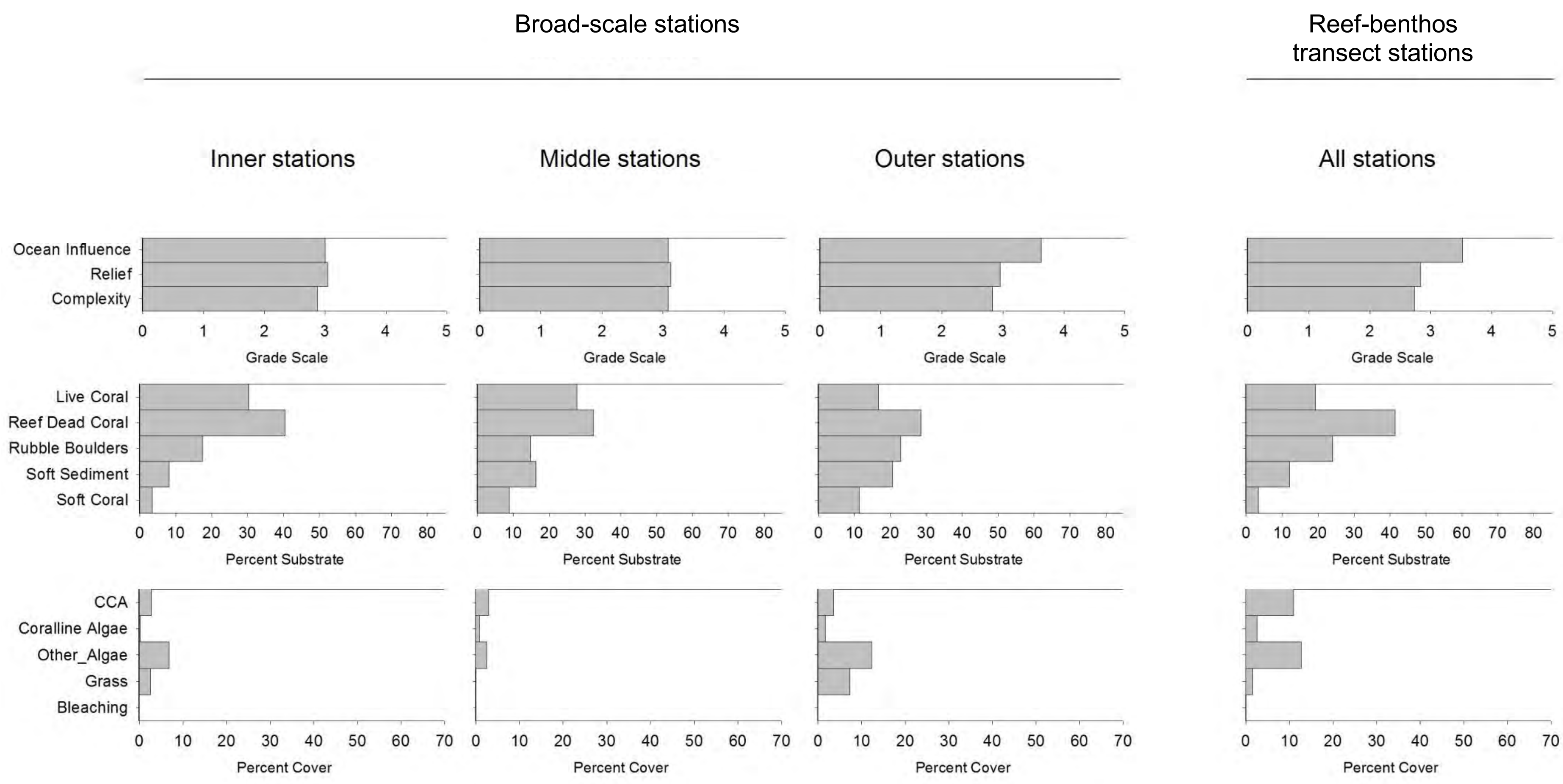
SE = Standard error; n = number.

4.2.9 Ngatpang species size review – all survey methods (continued)

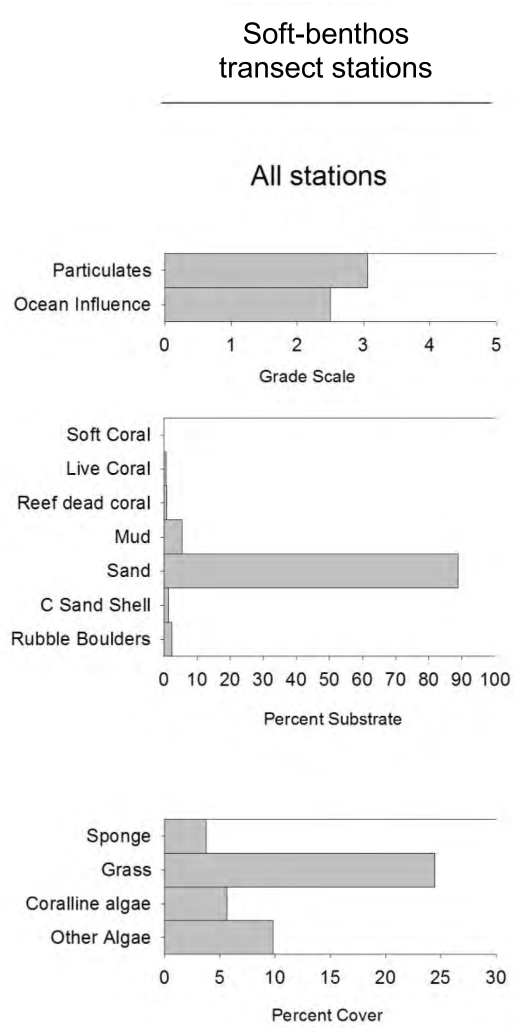
Species	Mean length (cm)	SE	n
Panulirus spp.			1
Anadara spp.			1
Malleus spp.			1
Entacmaea quadricolor			1
Lysiosquillina maculata			1
Haliotis asinina			1
Diadema spp.			1
Pteria penguin			1
Pinna spp.			1
Ovula ovum			1
Conus capitaneus			1
Cypraea spp.			1
Conus rattus			1
Lambis truncata			1

SE = Standard error; n = number.

4.2.10 Habitat descriptors for independent assessments – Ngatpang



4.2.10 Habitat descriptors for independent assessments – Ngatpang (continued)



4.3 Airai invertebrate survey data

4.3.1 Invertebrate species recorded in different assessments in Airai

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga echinites*	+		+	
Bêche-de-mer	*Actinopyga lecanora*			+	
Bêche-de-mer	*Actinopyga mauritiana*	+	+		+
Bêche-de-mer	*Actinopyga miliaris*	+	+	+	
Bêche-de-mer	*Actinopyga* spp.		+	+	
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 flavomaculata*	+	+	+	
Bêche-de-mer	*Holothuria fuscogilva*				+
Bêche-de-mer	*Holothuria fuscopunctata*	+			+
Bêche-de-mer	*Holothuria hilla*		+	+	
Bêche-de-mer	*Holothuria nobilis*	+	+		+
Bêche-de-mer	*Holothuria pervicax*			+	
Bêche-de-mer	*Holothuria scabra*	+		+	
Bêche-de-mer	*Stichopus chloronotus*	+	+	+	+
Bêche-de-mer	*Stichopus hermanni*	+		+	+
Bêche-de-mer	*Stichopus horrens*		+	+	
Bêche-de-mer	*Stichopus vastus*	+	+	+	
Bêche-de-mer	*Synapta maculata*			+	
Bêche-de-mer	*Synapta* spp.			+	
Bêche-de-mer	*Thelenota ananas*	+	+		+
Bêche-de-mer	*Thelenota anax*	+			+
Bivalve	*Anadara scapha*			+	
Bivalve	*Atrina vexillum*	+			
Bivalve	*Beguina semiorbiculata*		+		
Bivalve	*Chama* spp.	+	+	+	+
Bivalve	*Hippopus hippopus*	+	+	+	+
Bivalve	*Hippopus porcellanus*	+		+	+
Bivalve	*Pinctada margaritifera*	+	+		+
Bivalve	*Spondylus* spp.	+	+	+	
Bivalve	*Tridacna crocea*	+	+	+	+
Bivalve	*Tridacna derasa*	+			+
Bivalve	*Tridacna gigas*	+	+		+
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+	+		+
Cnidarian	*Cassiopea andromeda*			+	+
Cnidarian	*Stichodactyla* spp.	+		+	+
Crustacean	*Lysiosquillina* spp.		+		
Crustacean	*Panulirus* spp.	+			+
Crustacean	*Panulirus versicolor*		+		+
Crustacean	*Periclimenes* spp.			+	

+ = presence of the species.

4.3.1 Invertebrate species recorded in different assessments in Airai (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Crustacean	*Portunus* spp.		+		
Crustacean	*Thalassina* spp.		+	+	
Gastropod	*Astralium* spp.		+		+
Gastropod	*Cerithium nodulosum*	+	+		
Gastropod	*Charonia tritonis*				+
Gastropod	*Chicoreus brunneus*		+		
Gastropod	*Chicoreus* spp.		+		
Gastropod	*Conus bandanus*		+		
Gastropod	*Conus consors*		+		
Gastropod	*Conus distans*		+		
Gastropod	*Conus flavidus*		+		
Gastropod	*Conus imperialis*		+		
Gastropod	*Conus litteratus*		+		
Gastropod	*Conus lividus*		+		
Gastropod	*Conus marmoreus*		+		
Gastropod	*Conus miles*		+		+
Gastropod	*Conus miliaris*		+		
Gastropod	*Conus pulicarius*			+	
Gastropod	*Conus quercinus*			+	
Gastropod	*Conus* spp.		+	+	+
Gastropod	*Conus vexillum*				+
Gastropod	*Coralliophila* spp.		+		
Gastropod	*Cypraea annulus*		+		
Gastropod	*Cypraea arabica*		+		
Gastropod	*Cypraea caputserpensis*		+		
Gastropod	*Cypraea erosa*		+	+	
Gastropod	*Cypraea helvola*		+		
Gastropod	*Cypraea isabella*		+		
Gastropod	*Cypraea lynx*		+		
Gastropod	*Cypraea moneta*		+		
Gastropod	*Cypraea talpa*		+		
Gastropod	*Cypraea tigris*		+	+	+
Gastropod	*Drupa rubusidaeus*		+		
Gastropod	*Lambis lambis*	+	+	+	+
Gastropod	*Lambis truncata*	+			
Gastropod	*Latirolagena smaragdula*				+
Gastropod	*Ovula ovum*		+		+
Gastropod	*Pleuroploca* spp.		+		
Gastropod	*Strombus gibberulus gibbosus*			+	
Gastropod	*Strombus lentiginosus*		+		
Gastropod	*Strombus luhuanus*	+	+		
Gastropod	*Tectus conus*				+
Gastropod	*Tectus pyramis*	+	+	+	+
Gastropod	*Tectus* spp.		+		
Gastropod	*Tectus triserialis*		+		
Gastropod	*Thais aculeata*		+		
Gastropod	*Trochus maculata*		+	+	
Gastropod	*Trochus niloticus*	+	+		+

+ = presence of the species.

4.3.1 Invertebrate species recorded in different assessments in Airai (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Turbo argyrostomus*	+	+		+
Gastropod	*Turbo chrysostomus*		+		
Gastropod	*Tutufa bubo*	+	+		
Gastropod	*Tutufa rubeta*				+
Gastropod	*Vasum ceramicum*		+		+
Gastropod	*Vasum turbinellum*		+	+	
Octopus	*Octopus* spp.	+			
Star	*Acanthaster planci*	+	+		
Star	*Choriaster granulatus*				+
Star	*Culcita novaeguineae*	+	+	+	+
Star	*Linckia laevigata*	+	+	+	+
Star	*Protoreaster nodosus*	+		+	+
Urchin	*Echinometra mathaei*	+	+		+
Urchin	*Echinothrix calamaris*		+		
Urchin	*Echinothrix diadema*	+	+		+
Urchin	*Heterocentrotus mammillatus*	+	+		
Urchin	*Mespilia globulus*		+		
Urchin	*Tripneustes gratilla*			+	

+ = presence of the species.

4.3.2 Airai 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	1.2	0.5	72	16.7	0.0	5	1.1	0.5	12	3.4	0.7	4
Actinopyga echinites	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Actinopyga mauritiana	5.0	2.2	72	59.5	12.3	6	4.9	4.0	12	29.6	18.5	2
Actinopyga miliaris	2.3	1.0	72	27.8	5.6	6	2.3	1.2	12	6.9	2.4	4
Atrina vexillum	0.2	0.2	72	16.7		1	0.2	0.2	12	2.7		1
Bohadschia argus	16.0	4.7	72	52.5	12.2	22	15.9	8.9	12	21.2	11.5	9
Bohadschia graeffei	11.6	4.5	72	76.0	21.6	11	11.8	8.6	12	35.3	23.0	4
Bohadschia vitiensis	14.1	7.3	72	169.4	61.2	6	14.1	12.2	12	56.5	45.6	3
Cerithium nodulosum	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Chama spp.	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Culcita novaeguineae	11.1	3.1	72	34.7	7.9	23	11.1	4.3	12	14.8	5.2	9
Echinometra mathaei	1.6	1.2	72	38.9	22.2	3	1.6	1.2	12	6.5	3.7	3
Echinothrix diadema	1.2	0.8	72	41.7	8.3	2	1.2	0.8	12	6.9	1.4	2
Heterocentrotus mammillatus	0.4	0.3	72	15.4	1.3	2	0.4	0.3	12	2.7	0.0	2
Hippopus hippopus	4.8	1.2	72	23.0	2.3	15	4.8	1.2	12	7.1	1.1	8
Hippopus porcellanus	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Holothuria atra	384.9	197.2	72	554.2	281.4	50	384.6	203.8	12	461.5	238.7	10
Holothuria coluber	2.8	1.0	72	25.0	3.1	8	2.8	1.5	12	11.1	1.6	3
Holothuria edulis	61.0	22.6	72	219.6	70.9	20	60.8	31.1	12	146.0	57.4	5
Holothuria flavomaculata	18.8	13.7	72	192.9	131.5	7	18.8	16.8	12	75.0	64.1	3
Holothuria fuscopunctata	5.6	3.9	72	133.3	67.4	3	5.6	5.6	12	66.7		1
Holothuria nobilis	9.2	1.9	72	26.5	3.4	25	9.1	2.6	12	13.6	2.8	8
Holothuria scabra	0.5	0.5	72	33.3		1	0.5	0.5	12	5.6		1
Lambis lambis	1.2	0.6	72	20.8	4.2	4	1.1	0.5	12	3.4	0.6	4
Lambis truncata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Linckia laevigata	152.8	29.3	72	261.9	42.9	42	153.0	54.3	12	166.9	57.5	11
Octopus spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Panulirus spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.2 Airai 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	1.6	0.7	72	19.0	2.9	6	1.6	0.8	12	4.7	1.2	4
Protoreaster nodosus	2.3	1.4	72	41.7	16.0	4	2.3	2.1	12	13.9	11.1	2
Spondylus spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Stichodactyla spp.	3.0	0.8	72	18.1	1.4	12	3.0	1.4	12	7.2	2.3	5
Stichopus chloronotus	13.9	5.5	72	66.7	22.1	15	13.5	7.8	12	26.9	14.1	6
Stichopus hermanni	6.3	3.6	72	75.0	33.5	6	6.2	3.4	12	18.5	7.3	4
Stichopus vastus	31.5	27.8	72	323.8	280.1	7	31.5	30.5	12	125.9	120.4	3
Strombus luhuanus	3.9	3.4	72	93.2	76.5	3	4.7	4.2	12	18.9	16.1	3
Tectus pyramis	3.5	1.1	72	22.9	3.5	11	3.6	1.4	12	7.2	1.8	6
Thelenota ananas	3.5	1.3	72	31.3	4.9	8	3.4	2.1	12	13.6	5.5	3
Thelenota anax	0.5	0.5	72	33.3		1	0.5	0.5	12	5.6		1
Tridacna crocea	515.8	91.9	72	663.2	110.6	56	513.1	158.3	12	513.1	158.3	12
Tridacna derasa	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Tridacna gigas	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Tridacna maxima	52.0	10.7	72	93.7	16.5	40	51.6	18.7	12	61.9	21.1	10
Tridacna squamosa	1.9	0.7	72	19.0	2.4	7	1.8	0.7	12	3.7	0.9	6
Trochus niloticus	10.1	3.2	72	52.1	10.6	14	10.1	5.7	12	24.3	11.4	5
Turbo argyrostomus	1.4	1.0	72	50.0	16.7	2	1.4	1.4	12	16.7		1
Tutufa bubo	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.3 Airai reef-benthos transect (RBt) assessment data review
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Actinopyga mauritiana	19.7	8.3	114	321.4	71.4	7	19.7	11.2	19	125.0	24.1	3
Actinopyga miliaris	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Actinopyga spp.	4.4	4.4	114	500.0		1	4.4	4.4	19	83.3		1
Astralium spp.	4.4	4.4	114	500.0		1	4.4	4.4	19	83.3		1
Beguina semiorbiculata	160.1	61.6	114	2281.3	426.4	8	160.1	98.6	19	1013.9	348.9	3
Bohadschia argus	52.6	16.0	114	352.9	74.4	17	52.6	25.5	19	125.0	51.6	8
Cerithium nodulosum	11.0	5.7	114	312.5	62.5	4	11.0	5.4	19	52.1	10.4	4
Chama spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Chicoreus brunneus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Chicoreus spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus bandanus	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Conus consors	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus distans	26.3	9.0	114	333.3	41.7	9	26.3	12.8	19	100.0	31.2	5
Conus flavidus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus imperialis	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus litteratus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus lividus	11.0	4.8	114	250.0	0.0	5	11.0	6.2	19	69.4	13.9	3
Conus marmoreus	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Conus miles	35.1	10.7	114	363.6	39.4	11	35.1	17.8	19	133.3	46.4	5
Conus miliaris	37.3	16.0	114	472.2	141.0	9	37.3	23.8	19	177.1	89.0	4
Conus spp.	41.7	16.2	114	431.8	117.2	11	41.7	24.7	19	263.9	73.5	3
Coralliophila spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Culcita novaeguineae	13.2	5.3	114	250.0	0.0	6	13.2	5.6	19	50.0	8.3	5
Cypraea annulus	24.1	20.2	114	1 375.0	875.0	2	24.1	24.1	19	458.3		1
Cypraea arabica	6.6	4.9	114	375.0	125.0	2	6.6	4.8	19	62.5	20.8	2
Cypraea caputserpensis	8.8	5.3	114	333.3	83.3	3	8.8	5.1	19	55.6	13.9	3
Cypraea erosa	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.3 Airai reef-benthos transect (RBt) assessment data review (continued)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Cypraea helvola	6.6	3.8	114	250.0	0.0	3	6.6	4.8	19	62.5	20.8	2
Cypraea isabella	6.6	6.6	114	750.0		1	6.6	6.6	19	125.0		1
Cypraea lynx	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea moneta	11.0	7.2	114	416.7	166.7	3	11.0	11.0	19	208.3		1
Cypraea talpa	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea tigris	15.4	7.8	114	350.0	100.0	5	15.4	7.3	19	58.3	16.7	5
Drupa rubusidaeus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Echinometra mathaei	129.4	28.6	114	491.7	77.2	30	129.4	36.5	19	204.9	45.1	12
Echinothrix calamaris	4.4	3.1	114	250.0	0.0	2	4.4	4.4	19	83.3		1
Echinothrix diadema	59.2	14.7	114	421.9	37.6	16	59.2	27.8	19	160.7	59.9	7
Heterocentrotus mammillatus	6.6	3.8	114	250.0	0.0	3	6.6	3.6	19	41.7	0.0	3
Hippopus hippopus	32.9	11.0	114	340.9	61.0	11	32.9	16.1	19	89.3	35.7	7
Holothuria atra	440.8	142.4	114	1 435.7	421.3	35	440.8	340.6	19	697.9	533.1	12
Holothuria coluber	37.3	17.7	114	708.3	198.1	6	37.3	37.3	19	708.3		1
Holothuria edulis	26.3	9.5	114	333.3	58.9	9	26.3	13.2	19	125.0	29.5	4
Holothuria flavomaculata	4.4	3.1	114	250.0	0.0	2	4.4	4.4	19	83.3		1
Holothuria hilla	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Holothuria nobilis	30.7	7.7	114	250.0	0.0	14	30.7	9.5	19	72.9	10.4	8
Lambis lambis	32.9	9.6	114	312.5	32.6	12	32.9	16.4	19	104.2	39.9	6
Linckia laevigata	425.4	58.4	114	808.3	84.5	60	425.4	105.2	19	577.4	118.6	14
Lysiosquillina spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Mespilia globulus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Ovula ovum	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Panulirus versicolor	8.8	8.8	114	1000.0		1	8.8	8.8	19	166.7		1
Pinctada margaritifera	6.6	3.8	114	250.0	0.0	3	6.6	3.6	19	41.7	0.0	3
Pleuroploca spp.	13.2	6.1	114	300.0	50.0	5	13.2	7.8	19	83.3	24.1	3
Portunus spp.	15.4	7.2	114	350.0	61.2	5	15.4	9.7	19	97.2	36.7	3
Spondylus spp.	8.8	4.3	114	250.0	0.0	4	8.8	5.1	19	55.6	13.9	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.3 Airai 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
Stichopus chloronotus	116.2	21.6	114	427.4	45.2	31	116.2	41.2	19	245.4	64.2	9
Stichopus horrens	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Stichopus vastus	11.0	5.7	114	312.5	62.5	4	11.0	8.9	19	104.2	62.5	2
Strombus lentiginosus	4.4	4.4	114	500.0		1	4.4	4.4	19	83.3		1
Strombus luhuanus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Tectus pyramis	133.8	21.6	114	401.3	37.2	38	133.8	32.7	19	158.9	35.5	16
Tectus spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Tectus triserialis	4.4	3.1	114	250.0	0.0	2	4.4	4.4	19	83.3		1
Thais aculeata	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Thalassina spp.	13.2	11.2	114	750.0	500.0	2	13.2	13.2	19	250.0		1
Thelenota ananas	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Tridacna crocea	1210.5	170.5	114	1769.2	222.6	78	1210.5	339.6	19	1352.9	364.6	17
Tridacna gigas	4.4	3.1	114	250.0	0.0	2	4.4	4.4	19	83.3		1
Tridacna maxima	184.2	28.6	114	488.4	47.8	43	184.2	40.2	19	233.3	42.6	15
Tridacna squamosa	13.2	5.3	114	250.0	0.0	6	13.2	4.6	19	41.7	0.0	6
Trochus maculata	26.3	8.5	114	300.0	33.3	10	26.3	8.6	19	71.4	7.7	7
Trochus niloticus	133.8	33.0	114	525.9	99.5	29	133.8	56.1	19	231.1	86.7	11
Turbo argyrostomus	54.8	14.5	114	390.6	50.9	16	54.8	19.7	19	130.2	30.9	8
Turbo chrysostomus	21.9	8.6	114	357.1	50.5	7	21.9	12.1	19	104.2	36.1	4
Tutufa bubo	4.4	4.4	114	500.0		1	4.4	4.4	19	83.3		1
Vasum ceramicum	11.0	4.8	114	250.0	0.0	5	11.0	6.2	19	69.4	13.9	3
Vasum turbinellum	11.0	4.8	114	250.0	0.0	5	11.0	6.2	19	69.4	13.9	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.4 Airai 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	53.6	26.5	84	642.9	230.5	7	53.6	44.4	14	250.0	187.9	3
Actinopyga lecanora	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Actinopyga miliaris	20.8	9.7	84	350.0	61.2	5	20.8	14.3	14	145.8	20.8	2
Actinopyga spp.	113.1	39.6	84	1 055.6	165.5	9	113.1	86.3	14	791.7	375.0	2
Anadara scapha	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Bohadschia similis	1381.0	419.8	84	6444.4	1447.7	18	1381.0	1027.9	14	3866.7	2685.4	5
Bohadschia vitiensis	943.5	203.5	84	2264.3	393.2	35	943.5	444.3	14	1886.9	747.4	7
Cassiopea andromeda	8.9	5.1	84	250.0	0.0	3	8.9	4.7	14	41.7	0.0	3
Chama spp.	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Conus pulicarius	8.9	6.6	84	375.0	125.0	2	8.9	8.9	14	125.0		1
Conus quercinus	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Conus spp.	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Culcita novaeguineae	8.9	5.1	84	250.0	0.0	3	8.9	6.4	14	62.5	20.8	2
Cypraea erosa	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Cypraea tigris	17.9	8.2	84	300.0	50.0	5	17.9	12.1	14	125.0	0.0	2
Hippopus hippopus	8.9	5.1	84	250.0	0.0	3	8.9	6.4	14	62.5	20.8	2
Hippopus porcellanus	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Holothuria atra	3360.1	615.7	84	4090.6	720.6	69	3360.1	1164.6	14	3360.1	1164.6	14
Holothuria coluber	50.6	26.0	84	531.3	218.8	8	50.6	25.2	14	141.7	50.3	5
Holothuria edulis	544.6	145.6	84	1577.6	352.0	29	544.6	340.3	14	953.1	566.3	8
Holothuria flavomaculata	1104.2	487.1	84	15,458.3	3280.3	6	1104.2	1104.2	14	15,458.3		1
Holothuria hilla	32.7	11.8	84	343.8	45.7	8	32.7	19.6	14	152.8	50.1	3
Holothuria pervicax	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Holothuria scabra	44.6	20.4	84	535.7	158.4	7	44.6	31.0	14	208.3	110.2	3
Lambis lambis	35.7	12.1	84	333.3	41.7	9	35.7	15.7	14	83.3	26.4	6
Linckia laevigata	8.9	5.1	84	250.0	0.0	3	8.9	6.4	14	62.5	20.8	2
Periclimenes spp.	6.0	6.0	84	500.0		1	6.0	6.0	14	83.3		1
Protoreaster nodosus	35.7	12.8	84	333.3	58.9	9	35.7	20.4	14	166.7	41.7	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.

4.3.4 Airai 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
Spondylus spp.	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Stichodactyla spp.	11.9	7.2	84	333.3	83.3	3	11.9	9.2	14	83.3	41.7	2
Stichopus chloronotus	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Stichopus hermanni	14.9	8.8	84	416.7	83.3	3	14.9	10.3	14	104.2	20.8	2
Stichopus horrens	14.9	8.8	84	416.7	83.3	3	14.9	14.9	14	208.3		1
Stichopus vastus	3163.7	712.2	84	10,221.2	1598.6	26	3163.7	1689.4	14	6327.4	3005.3	7
Strombus gibberulus gibbosus	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Synapta maculata	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Synapta spp.	8.9	6.6	84	375.0	125.0	2	8.9	6.4	14	62.5	20.8	2
Tectus pyramis	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Thalassina spp.	142.9	73.9	84	2000.0	724.6	6	142.9	127.7	14	1000.0	791.7	2
Tridacna crocea	23.8	18.3	84	666.7	416.7	3	23.8	18.4	14	166.7	83.3	2
Tripneustes gratilla	11.9	5.8	84	250.0	0.0	4	11.9	9.2	14	83.3	41.7	2
Trochus maculata	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Vasum turbinellum	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.5 Airai reef-front search (RFs) assessment data review
Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	20.9	3.8	54	43.4	5.0	26	20.9	6.2	9	23.5	6.4	8
Astralium spp.	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Bohadschia argus	4.4	2.0	54	47.1	7.4	5	4.4	3.0	9	19.6	3.9	2
Bohadschia graeffei	2.2	1.6	54	58.8	11.8	2	2.2	2.2	9	19.6		1
Chama spp.	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Charonia tritonis	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.5 Airai reef-front search (RFs) assessment data review (continued)

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.	2.2	1.1	54	29.4	5.9	4	2.2	1.2	9	6.5	1.3	3
Culcita novaeguineae	0.9	0.6	54	23.5	0.0	2	0.9	0.6	9	3.9	0.0	2
Cypraea tigris	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Echinometra mathaei	3.5	2.0	54	62.7	7.8	3	3.5	1.8	9	10.5	1.3	3
Echinothrix diadema	1.7	0.8	54	23.5	0.0	4	1.7	0.9	9	5.2	1.3	3
Hippopus porcellanus	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Holothuria atra	13.9	4.9	54	94.1	12.6	8	13.9	11.3	9	62.7	39.2	2
Holothuria edulis	3.5	2.5	54	94.1	23.5	2	3.5	3.5	9	31.4		1
Holothuria fuscogilva	0.9	0.9	54	47.1		1	0.9	0.9	9	7.8		1
Holothuria fuscopunctata	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Holothuria nobilis	5.7	2.0	54	34.0	5.7	9	5.7	3.1	9	12.7	5.2	4
Lambis lambis	0.4	0.4	54	23.5	-	1	0.4	0.4	9	3.9		1
Linckia laevigata	2.2	1.1	54	29.4	5.9	4	2.2	1.3	9	6.5	2.6	3
Panulirus spp.	2.2	1.8	54	58.8	35.3	2	2.2	1.7	9	9.8	5.9	2
Panulirus versicolor	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Stichodactyla spp.	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Stichopus chloronotus	8.3	2.9	54	44.7	8.9	10	8.3	4.5	9	18.6	7.4	4
Stichopus hermanni	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Tectus pyramis	12.2	4.8	54	73.2	19.0	9	12.2	5.1	9	18.3	6.3	6
Thelenota ananas	1.3	0.7	54	23.5	0.0	3	1.3	0.9	9	5.9	2.0	2
Tridacna crocea	29.2	11.5	54	105.1	35.2	15	29.2	17.1	9	65.7	30.8	4
Tridacna gigas	1.3	1.0	54	35.3	11.8	2	1.3	0.9	9	5.9	2.0	2
Tridacna maxima	32.2	4.5	54	52.8	4.6	33	32.2	6.1	9	32.2	6.1	9
Tridacna squamosa	0.9	0.6	54	23.5	0.0	2	0.9	0.6	9	3.9	0.0	2
Trochus niloticus	87.6	11.7	54	100.6	12.3	47	87.6	16.7	9	87.6	16.7	9
Turbo argyrostomus	6.5	1.7	54	27.1	2.5	13	6.5	2.1	9	8.4	2.2	7
Tutufa rubeta	0.4	0.4	54	23.5		1	0.4	0.4	9	3.9		1
Vasum ceramicum	0.9	0.9	54	47.1		1	0.9	0.9	9	7.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.6 Airai mother-of-pearl search (MOPs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	7.6	7.6	6	45.5		1	7.6		1	7.6		1
Latirolagena smaragdula	7.6	7.6	6	45.5		1	7.6		1	7.6		1
Tectus pyramis	22.7	15.5	6	68.2	22.7	2	22.7		1	22.7		1
Tridacna crocea	7.6	7.6	6	45.5		1	7.6		1	7.6		1
Tridacna maxima	37.9	24.7	6	113.6	22.7	2	37.9		1	37.9		1
Trochus niloticus	60.6	27.9	6	90.9	32.1	4	60.6		1	60.6		1
Turbo argyrostomus	30.3	15.2	6	60.6	15.2	3	30.3		1	30.3		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.7 Airai 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
Actinopyga mauritiana	55.6	20.3	54	214.3	62.1	14	55.6	20.8	9	71.4	23.6	7
Astralium spp.	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Bohadschia argus	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Bohadschia graeffei	4.6	3.2	54	125.0	0.0	2	4.6	4.6	9	41.7		1
Chama spp.	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Conus miles	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Conus spp.	16.2	9.9	54	218.8	93.8	4	16.2	11.4	9	48.6	27.8	3
Conus vexillum	6.9	3.9	54	125.0	0.0	3	6.9	4.9	9	31.3	10.4	2
Culcita novaeguineae	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Echinometra mathaei	18.5	7.7	54	166.7	26.4	6	18.5	8.1	9	41.7	8.5	4
Echinothrix diadema	25.5	10.1	54	196.4	37.2	7	25.5	18.3	9	76.4	45.5	3
Hippopus hippopus	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Holothuria atra	9.3	5.6	54	166.7	41.7	3	9.3	7.0	9	41.7	20.8	2
Holothuria edulis	9.3	7.3	54	250.0	125.0	2	9.3	9.3	9	83.3		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.7 Airai mother-of-pearl transect (MOPt) assessment data review (continued)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria nobilis	11.6	5.0	54	125.0	0.0	5	11.6	5.0	9	26.0	5.2	4
Latirolagena smaragdula	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Linckia laevigata	9.3	4.5	54	125.0	0.0	4	9.3	7.0	9	41.7	20.8	2
Ovula ovum	6.9	6.9	54	375.0		1	6.9	6.9	9	62.5		1
Panulirus spp.	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Panulirus versicolor	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Pinctada margaritifera	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Stichopus chloronotus	113.4	49.3	54	612.5	207.9	10	113.4	88.7	9	340.3	236.4	3
Tectus conus	4.6	3.2	54	125.0	0.0	2	4.6	3.1	9	20.8	0.0	2
Tectus pyramis	57.9	15.7	54	195.3	34.2	16	57.9	17.6	9	74.4	18.1	7
Tridacna crocea	4.6	3.2	54	125.0	0.0	2	4.6	3.1	9	20.8	0.0	2
Tridacna derasa	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Tridacna gigas	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Tridacna maxima	57.9	13.5	54	173.6	22.9	18	57.9	17.3	9	65.1	17.8	8
Trochus niloticus	608.8	83.9	54	764.5	91.2	43	608.8	160.9	9	608.8	160.9	9
Turbo argyrostomus	76.4	17.3	54	217.1	28.4	19	76.4	23.5	9	85.9	24.4	8
Vasum ceramicum	11.6	6.0	54	156.3	31.3	4	11.6	5.0	9	26.0	5.2	4

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.8 Airai sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	2.4	1.4	24	19.0	4.8	3	2.4	1.4	4	4.8	0.0	2
Bohadschia vitiensis	1.2	0.8	24	14.3	0.0	2	1.2	1.2	4	4.8		1
Cassiopea andromeda	0.6	0.6	24	14.3		1	0.6	0.6	4	2.4		1
Choriaster granulatus	0.6	0.6	24	14.3		1	0.6	0.6	4	2.4		1
Culcita novaeguineae	0.6	0.6	24	14.3		1	0.6	0.6	4	2.4		1
Holothuria atra	1.2	0.8	24	14.3	0.0	2	1.2	1.2	4	4.8		1
Holothuria edulis	3.0	1.5	24	17.9	3.6	4	3.0	3.0	4	11.9		1
Holothuria fuscogilva	2.4	1.6	24	28.6	0.0	2	2.4	2.4	4	9.5		1
Holothuria fuscopunctata	7.7	3.9	24	37.1	12.5	5	7.7	5.1	4	15.5	6.0	2
Holothuria nobilis	1.2	0.8	24	14.3	0.0	2	1.2	1.2	4	4.8		1
Pinctada margaritifera	0.6	0.6	24	14.3		1	0.6	0.6	4	2.4		1
Protoreaster nodosus	1.2	0.8	24	14.3	0.0	2	1.2	1.2	4	4.8		1
Stichodactyla spp.	0.6	0.6	24	14.3		1	0.6	0.6	4	2.4		1
Stichopus hermanni	1.2	1.2	24	28.6		1	1.2	1.2	4	4.8		1
Thelenota ananas	1.2	0.8	24	14.3	0.0	2	1.2	0.7	4	2.4	0.0	2
Thelenota anax	9.5	3.5	24	28.6	6.6	8	9.5	5.4	4	12.7	6.2	3
Tridacna derasa	0.6	0.6	24	14.3		1	0.6	0.6	4	2.4		1
Tridacna maxima	0.6	0.6	24	14.3		1	0.6	0.6	4	2.4		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.9 Airai species size review – all survey methods

Species	Mean length (cm)	SE	n
Holothuria atra	14.7	0.3	3035
Tridacna crocea	6.9	0.1	2905
Stichopus vastus	11.8	0.3	1204
Trochus niloticus	9.6	0.1	578
Holothuria edulis	15.9	0.5	476
Bohadschia similis	18.0	0.4	464
Holothuria flavomaculata	29.9	0.9	454
Tridacna maxima	15.5	0.5	418
Bohadschia vitiensis	26.7	0.4	380
Stichopus chloronotus	16.8	0.7	182
Tectus pyramis	5.5	0.1	134
Bohadschia argus	27.9	1.0	109
Actinopyga mauritiana	20.0	0.6	104
Turbo argyrostomus	6.6	0.2	83
Holothuria nobilis	26.4	0.8	74
Bohadschia graeffei	37.0	1.0	59
Holothuria coluber	36.0	4.0	46
Hippopus hippopus	21.7	1.0	40
Actinopyga spp.	13.0	0.4	40
Holothuria fuscopunctata	44.0	1.9	38
Stichopus hermanni	26.3	3.6	35
Lambis lambis	12.8	0.7	33
Conus spp.	3.8	0.3	32
Strombus luhuanus	6.0	0.0	23
Thelenota ananas	46.7	4.8	22
Actinopyga echinites	14.4	0.9	19
Thelenota anax	50.6	1.3	18
Actinopyga miliaris	27.7	1.2	18
Holothuria scabra	16.8	0.6	17
Conus miles	3.8	0.3	17
Conus miliaris	2.5	0.0	17
Tridacna squamosa	23.8	2.4	16
Cypraea tigris	7.0	0.2	14
Trochus maculata	3.2	0.3	13
Pinctada margaritifera	11.9	0.9	12
Vasum ceramicum	7.9	0.7	12
Conus distans	7.4	0.2	12
Turbo chrysostomus	4.8	0.4	10
Tridacna gigas	33.9	6.7	7
Stichopus horrens	7.1	1.2	7
Holothuria fuscogilva	35.5	2.9	6
Spondylus spp.	11.0	2.5	6
Cerithium nodulosum	8.8	0.6	6
Panulirus versicolor	22.5	0.5	6
Vasum turbinellum	5.1	0.5	6
Pleuroploca spp.	6.1	0.3	6
Conus lividus	6.0	2.0	5
Tridacna derasa	44.5	7.5	4

SE = Standard error; n = number.

4.3.9 Airai species size review – all survey methods (continued)

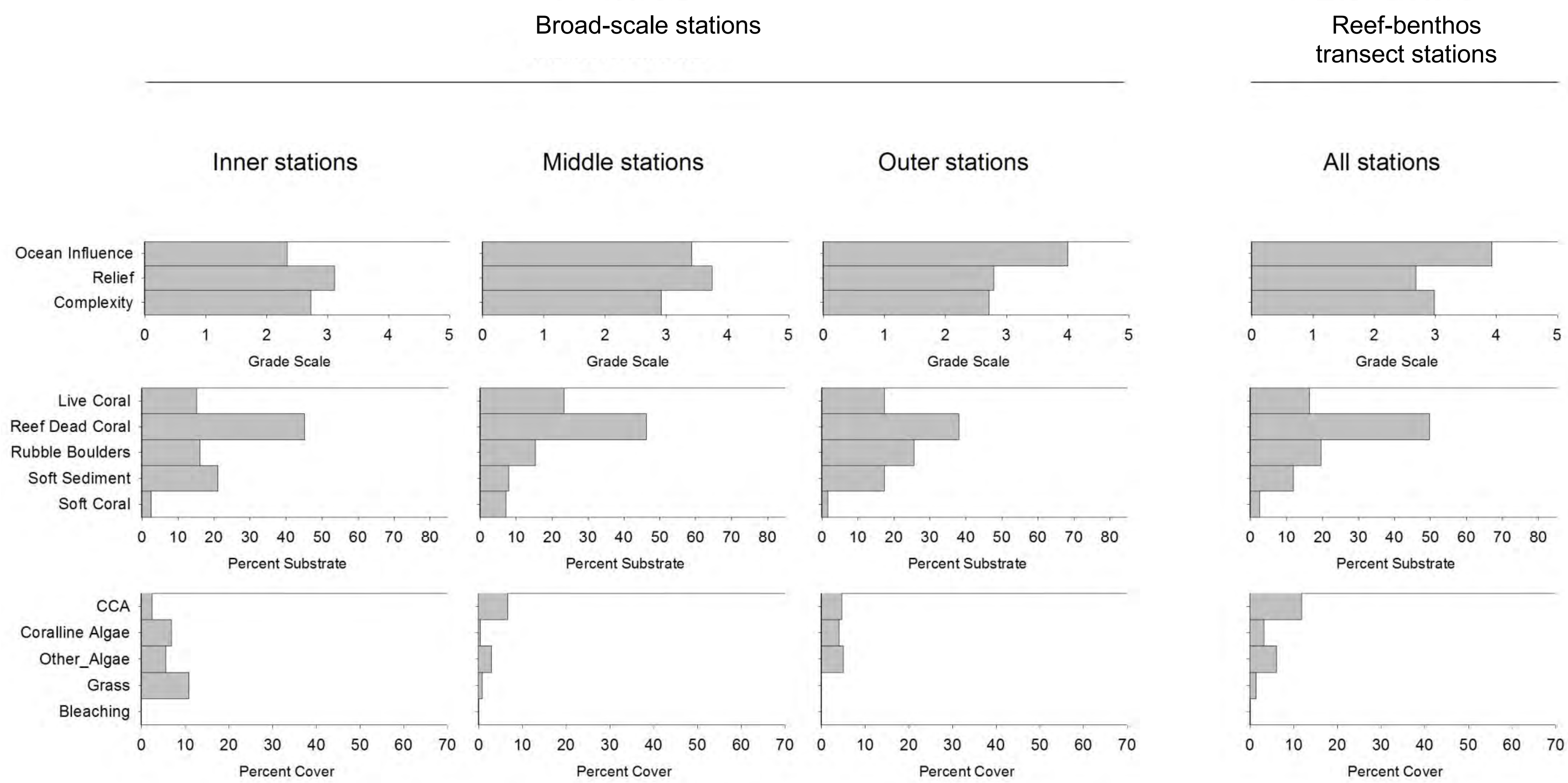
Species	Mean length (cm)	SE	n
Hippopus porcellanus	23.0	2.5	4
Tripneustes gratilla	7.5	0.2	4
Ovula ovum	8.0	0.0	4
Astralium spp.	3.2	0.0	4
Cypraea caputserpensis	3.0	0.0	4
Tutufa bubo	21.3	0.7	3
Conus vexillum	6.8	0.2	3
Conus pulicarius	4.2	0.2	3
Cypraea arabica	4.8	0.0	3
Conus marmoreus	7.5	2.0	2
Tectus triserialis	2.8	0.6	2
Strombus lentiginosus	7.9	0.4	2
Tectus conus	3.9	0.4	2
Conus bandanus	7.7	0.2	2
Thais aculeata	3.5		2
Charonia tritonis	29.0		1
Lambis truncata	24.0		1
Actinopyga lecanora	12.5		1
Conus litteratus	9.7		1
Anadara scapha	8.0		1
Chicoreus spp.	7.0		1
Tectus spp.	6.9		1
Conus quercinus	6.0		1
Conus imperialis	5.3		1
Conus consors	4.5		1
Strombus gibberulus gibbosus	4.3		1
Conus flavidus	4.1		1
Linckia laevigata			875
Echinometra mathaei			82
Beguina semiorbiculata			73
Culcita novaeguineae			61
Thalassina spp.			54
Echinothrix diadema			47
Protoreaster nodosus			24
Stichodactyla spp.			19
Holothuria hilla			13
Cypraea annulus			11
Panulirus spp.			8
Portunus spp.			7
Acanthaster planci			6
Chama spp.			6
Heterocentrotus mammillatus			5
Cypraea moneta			5
Cassiopea andromeda			4
Cypraea helvola			3
Latirolagena smaragdula			3
Cypraea isabella			3
Synapta spp.			3

SE = Standard error; n = number.

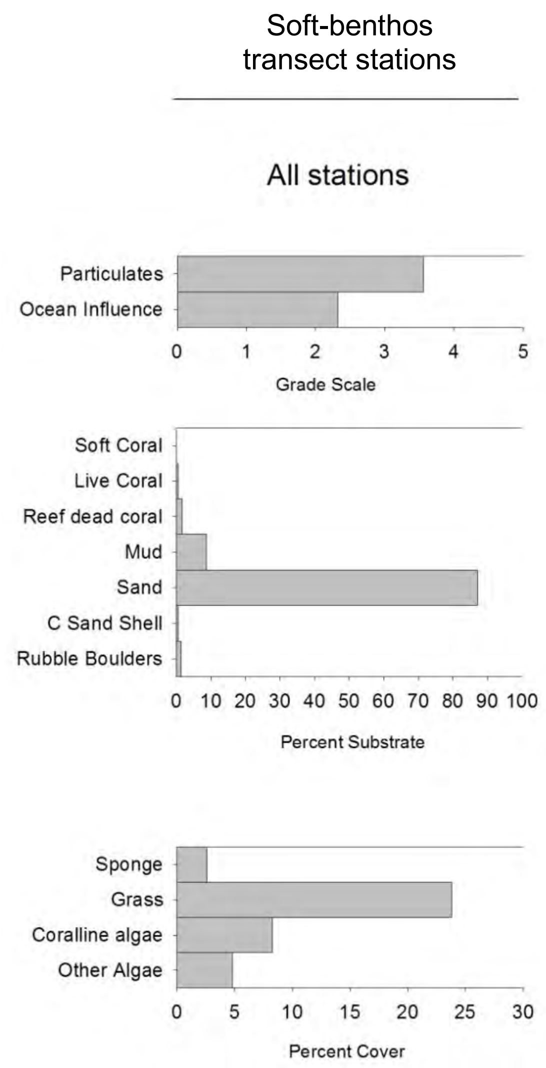
4.3.9 Airai species size review – all survey methods (continued)

Species	Mean length (cm)	SE	n
Cypraea erosa			3
Periclimenes spp.			2
Echinothrix calamaris			2
Synapta maculata			2
Atrina vexillum			1
Coralliophila spp.			1
Choriaster granulatus			1
Mespilia globulus			1
Cypraea lynx			1
Holothuria pervicax			1
Lysiosquillina spp.			1
Tutufa rubeta			1
Chicoreus brunneus			1
Cypraea talpa			1
Drupa rubusidaeus			1
Octopus spp.			1

4.3.10 Habitat descriptors for independent assessments – Airai



4.3.10 Habitat descriptors for independent assessments – Airai (continued)



4.4 Koror invertebrate survey data

4.4.1 Invertebrate species recorded in different assessments in Koror

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	*Actinopyga* spp.			+	+
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 flavomaculata*	+	+	+	+
Bêche-de-mer	*Holothuria fuscogilva*	+			+
Bêche-de-mer	*Holothuria fuscopunctata*	+	+		+
Bêche-de-mer	*Holothuria hilla*			+	
Bêche-de-mer	*Holothuria nobilis*	+	+		+
Bêche-de-mer	*Stichopus chloronotus*	+	+		+
Bêche-de-mer	*Stichopus hermanni*	+	+		+
Bêche-de-mer	*Stichopus horrens*			+	+
Bêche-de-mer	*Stichopus vastus*	+		+	+
Bêche-de-mer	*Synapta maculata*			+	
Bêche-de-mer	*Synapta* spp.			+	
Bêche-de-mer	*Thelenota ananas*	+	+		+
Bêche-de-mer	*Thelenota anax*	+			+
Bivalve	*Arca* spp.		+		
Bivalve	*Atrina vexillum*	+			
Bivalve	*Beguina semiorbiculata*	+	+		
Bivalve	*Chama* spp.	+	+	+	
Bivalve	*Hippopus hippopus*	+	+		+
Bivalve	*Hippopus porcellanus*	+			
Bivalve	*Hyotissa* spp.	+	+		
Bivalve	*Lopha cristagalli*				+
Bivalve	*Malleus* spp.			+	
Bivalve	*Pinctada margaritifera*	+	+		+
Bivalve	*Spondylus* spp.	+	+	+	+
Bivalve	*Tridacna crocea*	+	+	+	+
Bivalve	*Tridacna derasa*	+	+		+
Bivalve	*Tridacna gigas*				+
Bivalve	*Tridacna maxima*	+	+	+	+
Bivalve	*Tridacna squamosa*	+	+	+	+
Cnidarian	*Cassiopea andromeda*	+		+	
Cnidarian	*Cassiopea* spp.			+	
Cnidarian	*Entacmaea quadricolor*			+	
Cnidarian	*Stichodactyla* spp.	+	+	+	+
Crustacean	*Etisus splendidus*				+
Crustacean	*Lysiosquillina maculata*	+			

+ = presence of the species.

4.4.1 Invertebrate species recorded in different assessments in Koror (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Crustacean	*Panulirus penicillatus*				+
Crustacean	*Panulirus* spp.	+			+
Crustacean	*Panulirus versicolor*		+		+
Crustacean	*Saron* spp.		+		
Gastropod	*Astralium* spp.				+
Gastropod	*Cassis cornuta*				+
Gastropod	*Cerithium nodulosum*		+		
Gastropod	*Cerithium* spp.			+	
Gastropod	*Charonia tritonis*				+
Gastropod	*Conus distans*		+		+
Gastropod	*Conus emaciatus*		+		
Gastropod	*Conus leopardus*				+
Gastropod	*Conus lividus*		+		+
Gastropod	*Conus miliaris*		+		
Gastropod	*Conus* spp.	+	+	+	+
Gastropod	*Conus vexillum*		+		
Gastropod	*Cypraea annulus*		+		
Gastropod	*Cypraea caputserpensis*		+		
Gastropod	*Cypraea erosa*		+		
Gastropod	*Cypraea lynx*		+		
Gastropod	*Cypraea moneta*		+	+	
Gastropod	*Cypraea* spp.			+	
Gastropod	*Cypraea tigris*	+	+	+	+
Gastropod	*Drupa rubusidaeus*		+		+
Gastropod	*Lambis chiragra*	+			+
Gastropod	*Lambis lambis*	+	+	+	
Gastropod	*Lambis truncata*		+		
Gastropod	*Latirolagena smaragdula*		+		+
Gastropod	*Pleuroploca filamentosa*		+		+
Gastropod	*Strombus gibberulus gibbosus*			+	
Gastropod	*Tectus conus*		+		+
Gastropod	*Tectus pyramis*	+	+		+
Gastropod	*Tectus triserialis*	+	+		
Gastropod	*Trochus maculata*	+	+		+
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Trochus* spp.			+	+
Gastropod	*Turbo argyrostomus*	+	+		+
Gastropod	*Turbo chrysostomus*		+		
Gastropod	*Tutufa bubo*				+
Gastropod	*Vasum ceramicum*	+	+		+
Gastropod	*Vasum* spp.		+		
Gastropod	*Vasum turbinellum*	+		+	+
Octopus	*Octopus* spp.	+			
Star	*Acanthaster planci*	+	+		+
Star	*Choriaster granulatus*	+	+		+
Star	*Culcita novaeguineae*	+	+		+
Star	*Linckia guildingi*				+
Star	*Linckia laevigata*	+	+		+

+ = presence of the species.

4.4.1 Invertebrate species recorded in different assessments in Koror (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Star	*Protoreaster nodosus*	+	+	+	+
Urchin	*Diadema setosum*				+
Urchin	*Diadema* spp.				+
Urchin	*Echinometra mathaei*	+	+	+	+
Urchin	*Echinothrix calamaris*		+		
Urchin	*Echinothrix diadema*	+	+		+

+ = presence of the species.

4.4.2 Koror 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	7.2	3.0	72	47.0	14.9	11	7.2	4.9	12	21.5	12.5	4
Actinopyga lecanora	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Actinopyga mauritiana	1.1	0.7	72	27.1	5.2	3	1.1	0.9	12	6.9	4.1	2
Actinopyga miliaris	2.0	1.0	72	29.3	8.5	5	2.1	1.1	12	6.2	2.1	4
Atrina vexillum	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Beguina semiorbiculata	86.3	28.4	72	478.2	104.3	13	86.0	55.6	12	343.8	154.2	3
Bohadschia argus	6.0	1.5	72	26.9	3.4	16	6.0	2.3	12	9.0	2.9	8
Bohadschia graeffei	3.7	2.0	72	33.3	14.4	8	3.7	2.3	12	8.9	4.8	5
Bohadschia vitiensis	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Cassiopea andromeda	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Chama spp.	0.7	0.4	72	16.7	0.0	3	0.7	0.4	12	2.8	0.0	3
Choriaster granulatus	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Conus spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Culcita novaeguineae	8.8	1.9	72	27.4	3.7	23	8.8	3.3	12	17.6	4.1	6
Cypraea tigris	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Echinometra mathaei	3.8	1.8	72	45.7	12.5	6	3.9	2.0	12	11.6	3.8	4
Echinothrix diadema	1.4	0.5	72	16.7	0.0	6	1.4	0.5	12	3.3	0.6	5
Hippopus hippopus	2.1	0.8	72	21.4	3.1	7	2.1	0.8	12	5.0	1.0	5
Hippopus porcellanus	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Holothuria atra	36.3	7.1	72	58.0	10.0	45	36.2	7.2	12	36.2	7.2	12
Holothuria coluber	2.3	1.3	72	55.6	5.6	3	2.3	2.3	12	27.5		1
Holothuria edulis	45.6	13.7	72	126.2	32.6	26	45.5	21.0	12	60.7	26.4	9
Holothuria flavomaculata	3.4	1.5	72	41.1	9.1	6	3.4	3.0	12	13.8	11.0	3
Holothuria fuscogilva	0.7	0.4	72	16.7	0.0	3	0.7	0.4	12	2.8	0.0	3
Holothuria fuscopunctata	5.3	4.0	72	76.7	51.8	5	5.3	3.9	12	16.0	10.5	4
Holothuria nobilis	15.2	4.7	72	54.8	13.7	20	15.2	9.8	12	30.4	18.1	6
Hyotissa spp.	1.2	0.6	72	20.8	4.2	4	1.2	0.9	12	6.9	4.2	2
Lambis chiragra	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.2 Koror 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
Lambis lambis	0.2	0.2	72	15.9		1	0.2	0.2	12	2.7		1
Linckia laevigata	75.0	12.3	72	135.0	16.9	40	74.7	24.9	12	89.6	27.6	10
Lysiosquillina maculata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.7		1
Octopus spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Panulirus spp.	1.6	1.1	72	38.9	14.7	3	1.6	1.2	12	9.7	4.2	2
Pinctada margaritifera	0.7	0.4	72	16.7	0.0	3	0.7	0.4	12	2.8	0.0	3
Protoreaster nodosus	40.5	20.9	72	416.9	164.0	7	40.4	39.2	12	242.5	228.6	2
Spondylus spp.	1.2	0.6	72	20.8	4.2	4	1.2	0.5	12	3.5	0.7	4
Stichodactyla spp.	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Stichopus chloronotus	49.3	15.7	72	147.8	40.5	24	48.9	27.6	12	73.4	39.3	8
Stichopus hermanni	3.5	1.3	72	27.6	5.5	9	3.5	2.3	12	10.4	5.9	4
Stichopus vastus	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Tectus pyramis	1.6	0.8	72	29.2	4.2	4	1.6	1.0	12	6.4	2.4	3
Tectus triserialis	0.2	0.2	72	16.7		1	0.2	0.2	12	2.7		1
Thelenota ananas	5.3	2.1	72	34.8	10.4	11	5.3	2.0	12	10.6	2.5	6
Thelenota anax	1.4	0.9	72	33.3	9.6	3	1.4	0.8	12	5.5	1.6	3
Tridacna crocea	1007.4	132.4	72	1051.2	135.7	69	1007.0	262.8	12	1007.0	262.8	12
Tridacna derasa	1.2	0.8	72	27.8	11.1	3	1.2	0.9	12	6.9	4.2	2
Tridacna maxima	64.7	19.3	72	126.0	34.8	37	64.6	29.7	12	86.1	37.2	9
Tridacna squamosa	5.3	1.2	72	22.5	2.0	17	5.3	1.4	12	7.1	1.5	9
Trochus maculata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.7		1
Trochus niloticus	12.5	4.1	72	52.9	13.4	17	12.5	6.9	12	29.9	13.5	5
Turbo argyrostomus	1.4	0.8	72	25.0	8.3	4	1.4	1.4	12	16.7		1
Vasum ceramicum	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Vasum turbinellum	1.1	0.6	72	20.7	4.2	4	1.2	0.6	12	4.6	0.9	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.3 Koror 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	11.0	5.7	114	312.5	62.5	4	11.0	11.0	19	208.3		1
Actinopyga mauritiana	11.0	5.7	114	312.5	62.5	4	11.0	6.2	19	69.4	13.9	3
Arca spp.	142.5	44.3	114	1160.7	218.6	14	142.5	65.2	19	451.4	143.7	6
Beguina semiorbiculata	1320.2	397.9	114	6270.8	1531.3	24	1320.2	650.4	19	4180.6	1559.1	6
Bohadschia argus	19.7	6.3	114	250.0	0.0	9	19.7	7.4	19	62.5	9.3	6
Bohadschia graeffei	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Cerithium nodulosum	8.8	6.9	114	500.0	250.0	2	8.8	6.8	19	83.3	41.7	2
Chama spp.	8.8	6.9	114	500.0	250.0	2	8.8	6.8	19	83.3	41.7	2
Choriaster granulatus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus distans	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Conus emaciatus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus lividus	4.4	3.1	114	250.0	0.0	2	4.4	4.4	19	83.3		1
Conus miliaris	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus vexillum	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Culcita novaeguineae	13.2	7.5	114	375.0	125.0	4	13.2	7.2	19	62.5	20.8	4
Cypraea annulus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea caputserpensis	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea erosa	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea lynx	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea moneta	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea tigris	6.6	3.8	114	250.0	0.0	3	6.6	3.6	19	41.7	0.0	3
Drupa rubusidaeus	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Echinometra mathaei	81.1	20.3	114	462.5	68.5	20	81.1	29.6	19	154.2	45.7	10
Echinothrix calamaris	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Echinothrix diadema	19.7	8.3	114	321.4	71.4	7	19.7	8.0	19	62.5	14.2	6
Hippopus hippopus	17.5	6.0	114	250.0	0.0	8	17.5	8.6	19	83.3	17.0	4
Holothuria atra	94.3	18.3	114	398.1	38.3	27	94.3	35.0	19	199.1	56.7	9

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.3 Koror reef-benthos transect (RBt) assessment data review (continued)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria coluber	21.9	9.1	114	416.7	52.7	6	21.9	15.4	19	208.3	41.7	2
Holothuria edulis	59.2	15.7	114	355.3	58.4	19	59.2	27.7	19	140.6	55.1	8
Holothuria flavomaculata	21.9	9.1	114	357.1	74.3	7	21.9	15.4	19	104.2	62.5	4
Holothuria fuscopunctata	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Holothuria nobilis	43.9	15.0	114	454.5	88.0	11	43.9	23.9	19	166.7	68.5	5
Hyotissa spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Lambis lambis	13.2	6.1	114	300.0	50.0	5	13.2	6.4	19	62.5	12.0	4
Lambis truncata	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Latirolagena smaragdula	11.0	5.7	114	312.5	62.5	4	11.0	8.9	19	104.2	62.5	2
Linckia laevigata	392.5	54.6	114	699.2	78.2	64	392.5	86.2	19	532.7	90.6	14
Panulirus versicolor	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Pinctada margaritifera	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Pleuroploca filamentosa	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Protoreaster nodosus	250.0	104.0	114	4750.0	605.5	6	250.0	250.0	19	4750.0		1
Saron spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Spondylus spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Stichodactyla spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Stichopus chloronotus	206.1	45.3	114	783.3	121.5	30	206.1	94.4	19	435.2	172.8	9
Stichopus hermanni	8.8	4.3	114	250.0	0.0	4	8.8	5.1	19	55.6	13.9	3
Tectus conus	6.6	3.8	114	250.0	0.0	3	6.6	4.8	19	62.5	20.8	2
Tectus pyramis	144.7	31.3	114	660.0	82.8	25	144.7	65.5	19	458.3	141.9	6
Tectus triserialis	4.4	4.4	114	500.0		1	4.4	4.4	19	83.3		1
Thelenota ananas	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Tridacna crocea	2129.4	226.5	114	2667.6	254.4	91	2129.4	455.6	19	2129.4	455.6	19
Tridacna derasa	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Tridacna maxima	114.0	24.8	114	520.0	66.0	25	114.0	43.9	19	197.0	66.0	11
Tridacna squamosa	46.1	10.6	114	291.7	22.6	18	46.1	10.0	19	67.3	10.1	13
Trochus maculata	17.5	6.0	114	250.0	0.0	8	17.5	7.3	19	55.6	13.9	6

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.3 Koror 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	230.3	66.0	114	1 250.0	264.5	21	230.3	151.1	19	729.2	433.1	6
Turbo argyrostomus	19.7	7.1	114	281.3	31.3	8	19.7	10.7	19	93.8	31.3	4
Turbo chrysostomus	11.0	7.2	114	416.7	166.7	3	11.0	8.9	19	104.2	62.5	2
Vasum ceramicum	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Vasum spp.	6.6	3.8	114	250.0	0.0	3	6.6	3.6	19	41.7	0.0	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.4 Koror soft-benthos transect (SBt) assessment data review
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga spp.	12.8	7.8	78	333.3	83.3	3	12.8	9.9	13	83.3	41.7	2
Bohadschia similis	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Bohadschia vitiensis	125.0	46.2	78	1083.3	220.5	9	125.0	111.5	13	541.7	459.0	3
Cassiopea spp.	9.6	7.1	78	375.0	125.0	2	9.6	6.9	13	62.5	20.8	2
Cassiopea andromeda	16.0	8.3	78	312.5	62.5	4	16.0	8.9	13	69.4	13.9	3
Cerithium spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Chama spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Conus spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Cypraea moneta	6.4	6.4	78	500.0		1	6.4	6.4	13	83.3		1
Cypraea spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Cypraea tigris	16.0	7.0	78	250.0	0.0	5	16.0	8.9	13	69.4	13.9	3
Echinometra mathaei	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Entacmaea quadricolor	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Holothuria atra	7689.1	687.3	78	7689.1	687.3	78	7689.1	1653.8	13	7689.1	1653.8	13
Holothuria coluber	51.3	30.7	78	666.7	327.0	6	51.3	41.4	13	222.2	160.2	3
Holothuria edulis	384.6	108.6	78	1 153.8	271.1	26	384.6	260.0	13	714.3	460.4	7

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.4 Koror 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
Holothuria flavomaculata	16.0	10.5	78	416.7	166.7	3	16.0	13.0	13	104.2	62.5	2
Holothuria hilla	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Lambis lambis	32.1	10.6	78	277.8	27.8	9	32.1	11.7	13	69.4	13.9	6
Malleus spp.	28.8	15.8	78	562.5	157.3	4	28.8	19.7	13	125.0	63.6	3
Protoreaster nodosus	70.5	21.3	78	423.1	71.5	13	70.5	43.8	13	305.6	118.7	3
Spondylus spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Stichodactyla spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Stichopus horrens	19.2	10.0	78	375.0	72.2	4	19.2	13.8	13	125.0	41.7	2
Stichopus vastus	586.5	137.1	78	1236.5	249.8	37	586.5	333.7	13	953.1	510.3	8
Strombus gibberulus gibbosus	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Synapta maculata	41.7	15.4	78	406.3	65.8	8	41.7	21.6	13	135.4	42.9	4
Synapta spp.	64.1	26.4	78	500.0	149.1	10	64.1	38.5	13	166.7	85.4	5
Tridacna crocea	54.5	31.5	78	850.0	358.8	5	54.5	34.8	13	236.1	100.2	3
Tridacna maxima	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Tridacna squamosa	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Trochus spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Vasum turbinellum	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.5 Koror reef-front search (RFs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	0.8	0.4	90	23.5	0.0	3	0.8	0.4	15	3.9	0.0	3
Actinopyga mauritiana	6.8	1.8	90	34.0	5.5	18	6.8	2.7	15	14.6	4.3	7
Bohadschia argus	17.5	7.6	90	98.5	37.1	16	17.5	14.0	15	65.7	48.8	4
Bohadschia graeffei	1.0	0.5	90	23.5	0.0	4	1.0	0.8	15	7.8	3.9	2
Bohadschia vitiensis	0.8	0.8	90	70.6		1	0.8	0.8	15	11.8		1
Cassis cornuta	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Charonia tritonis	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Conus lividus	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Conus spp.	1.3	0.7	90	29.4	5.9	4	1.3	0.9	15	9.8	2.0	2
Culcita novaeguineae	0.8	0.8	90	70.6		1	0.8	0.8	15	11.8		1
Cypraea tigris	1.0	0.5	90	23.5	0.0	4	1.0	0.5	15	3.9	0.0	4
Echinometra mathaei	2.9	1.6	90	64.7	20.1	4	2.9	2.1	15	14.4	8.6	3
Holothuria atra	22.7	6.3	90	66.0	15.6	31	22.7	9.1	15	42.6	13.8	8
Holothuria edulis	8.9	2.7	90	53.3	10.9	15	8.9	4.9	15	33.3	12.0	4
Holothuria fuscogilva	5.5	3.0	90	98.8	34.4	5	5.5	5.5	15	82.4		1
Holothuria fuscopunctata	10.7	5.5	90	160.8	56.8	6	10.7	9.9	15	80.4	68.6	2
Holothuria nobilis	15.2	4.5	90	80.3	16.0	17	15.2	7.8	15	32.5	14.4	7
Lambis chiragra	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Latirolagena smaragdula	0.8	0.6	90	35.3	11.8	2	0.8	0.8	15	11.8		1
Linckia guildingi	4.2	2.4	90	75.3	31.0	5	4.2	3.2	15	20.9	13.3	3
Linckia laevigata	31.6	7.0	90	91.8	15.3	31	31.6	11.4	15	52.7	15.4	9
Panulirus spp.	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Panulirus versicolor	0.5	0.4	90	23.5	0.0	2	0.5	0.4	15	3.9	0.0	2
Pinctada margaritifera	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Pleuroploca filamentosa	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Protoreaster nodosus	1.0	1.0	90	94.1		1	1.0	1.0	15	15.7		1
Stichodactyla spp.	1.0	0.6	90	31.4	7.8	3	1.0	0.8	15	7.8	3.9	2
Stichopus chloronotus	40.8	9.4	90	135.9	22.8	27	40.8	17.3	15	87.4	28.5	7

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.5 Koror reef-front search (RFs) assessment data review (continued)

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 hermanni	5.2	2.7	90	78.4	27.6	6	5.2	5.0	15	39.2	35.3	2
Tectus pyramis	10.5	2.2	90	39.2	4.8	24	10.5	3.0	15	15.7	3.4	10
Thelenota ananas	6.8	2.6	90	40.8	12.5	15	6.8	3.1	15	14.6	5.3	7
Thelenota anax	8.1	5.6	90	145.9	87.9	5	8.1	8.1	15	121.6		1
Tridacna crocea	25.6	7.1	90	96.1	21.1	24	25.6	12.1	15	48.0	19.9	8
Tridacna derasa	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Tridacna maxima	116.3	27.3	90	205.3	44.4	51	116.3	55.2	15	145.4	66.9	12
Trochus maculata	1.3	0.6	90	23.5	0.0	5	1.3	1.1	15	9.8	5.9	2
Trochus niloticus	76.1	11.4	90	124.5	15.4	55	76.1	22.3	15	95.1	25.0	12
Trochus spp.	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1
Turbo argyrostomus	9.2	2.6	90	48.4	9.1	17	9.2	4.3	15	27.5	8.2	5
Vasum ceramicum	1.3	1.1	90	58.8	35.3	2	1.3	1.3	15	19.6		1
Vasum turbinellum	0.3	0.3	90	23.5		1	0.3	0.3	15	3.9		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.6 Ngatpang mother-of-pearl search (MOPs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga miliaris	1.9	1.9	24	45.5		1	1.9	1.9	4	7.6		1
Astralium spp.	3.8	2.6	24	45.5	0.0	2	3.8	3.8	4	15.2		1
Holothuria atra	1.9	1.9	24	45.5		1	1.9	1.9	4	7.6		1
Holothuria nobilis	1.9	1.9	24	45.5		1	1.9	1.9	4	7.6		1
Linckia laevigata	1.9	1.9	24	45.5		1	1.9	1.9	4	7.6		1
Panulirus spp.	1.9	1.9	24	45.5		1	1.9	1.9	4	7.6		1
Panulirus versicolor	7.6	7.6	24	181.8		1	7.6	7.6	4	30.3		1
Spondylus spp.	1.9	1.9	24	45.5		1	1.9	1.9	4	7.6		1
Stichodactyla spp.	11.4	4.9	24	54.5	9.1	5	11.4	4.9	4	15.2	4.4	3
Tectus pyramis	3.8	3.8	24	90.9		1	3.8	3.8	4	15.2		1
Thelenota ananas	1.9	1.9	24	45.5		1	1.9	1.9	4	7.6		1
Tridacna crocea	5.7	4.2	24	68.2	22.7	2	5.7	5.7	4	22.7		1
Tridacna maxima	367.4	102.6	24	400.8	109.3	22	367.4	207.1	4	367.4	207.1	4
Tridacna squamosa	1.9	1.9	24	45.5		1	1.9	1.9	4	7.6		1
Trochus niloticus	7.6	3.5	24	45.5	0.0	4	7.6	3.1	4	10.1	2.5	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.7 Koror 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
Actinopyga lecanora	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Actinopyga mauritiana	16.2	6.6	54	145.8	20.8	6	16.2	8.3	9	48.6	6.9	3
Bohadschia argus	9.3	5.6	54	166.7	41.7	3	9.3	9.3	9	83.3		1
Bohadschia graeffei	6.9	3.9	54	125.0	0.0	3	6.9	6.9	9	62.5		1
Charonia tritonis	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Conus distans	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Cypraea tigris	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Drupa rubusidaeus	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Echinometra mathaei	13.9	7.1	54	187.5	36.1	4	13.9	9.8	9	62.5	20.8	2
Echinothrix diadema	4.6	3.2	54	125.0	0.0	2	4.6	4.6	9	41.7		1
Hippopus hippopus	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Holothuria atra	13.9	9.7	54	250.0	125.0	3	13.9	13.9	9	125.0		1
Holothuria edulis	18.5	6.9	54	142.9	17.9	7	18.5	9.5	9	55.6	6.9	3
Holothuria nobilis	23.1	8.1	54	156.3	20.5	8	23.1	10.1	9	52.1	10.4	4
Lambis chiragra	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Linckia guildingi	6.9	5.1	54	187.5	62.5	2	6.9	6.9	9	62.5		1
Linckia laevigata	37.0	16.1	54	285.7	75.8	7	37.0	24.3	9	111.1	54.2	3
Panulirus penicillatus	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Panulirus versicolor	6.9	3.9	54	125.0	0.0	3	6.9	4.9	9	31.3	10.4	2
Pleuroploca filamentosa	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Stichopus chloronotus	48.6	16.7	54	291.7	46.6	9	48.6	31.1	9	145.8	67.0	3
Tectus conus	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Tectus pyramis	99.5	21.5	54	224.0	34.5	24	99.5	24.5	9	99.5	24.5	9
Thelenota ananas	6.9	5.1	54	187.5	62.5	2	6.9	4.9	9	31.3	10.4	2
Tridacna crocea	99.5	27.9	54	335.9	63.2	16	99.5	50.6	9	224.0	78.1	4
Tridacna gigas	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1
Tridacna maxima	111.1	17.7	54	206.9	19.9	29	111.1	24.8	9	142.9	17.3	7
Tridacna squamosa	2.3	2.3	54	125.0		1	2.3	2.3	9	20.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.7 Koror mother-of-pearl transect (MOPt) 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 maculata	13.9	7.1	54	187.5	36.1	4	13.9	6.0	9	31.3	6.0	4
Trochus niloticus	613.4	68.5	54	649.5	69.2	51	613.4	97.4	9	613.4	97.4	9
Trochus spp.	6.9	5.1	54	187.5	62.5	2	6.9	6.9	9	62.5		1
Turbo argyrostomus	101.9	22.4	54	289.5	34.5	19	101.9	33.4	9	114.6	35.0	8

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.8 Koror 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	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Actinopyga miliaris	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Actinopyga spp.	191.1	25.0	12	191.1	25.0	12	191.1	48.9	2	191.1	48.9	2
Diadema setosum	22.2	15.3	12	133.3	26.7	2	22.2	22.2	2	44.4		1
Diadema spp.	84.4	33.1	12	168.9	44.4	6	84.4	13.3	2	84.4	13.3	2
Echinometra mathaei	275.6	67.9	12	330.7	68.8	10	275.6	17.8	2	275.6	17.8	2
Etisus splendidus	48.9	15.3	12	83.8	15.9	7	48.9	22.2	2	48.9	22.2	2
Holothuria coluber	13.3	7.0	12	53.3	0.0	3	13.3	4.4	2	13.3	4.4	2
Holothuria edulis	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Holothuria flavomaculata	400.0	57.4	12	400.0	57.4	12	400.0	26.7	2	400.0	26.7	2
Linckia laevigata	8.9	8.9	12	106.7		1	8.9	8.9	2	17.8		1
Stichopus horrens	17.8	10.0	12	71.1	17.8	3	17.8	8.9	2	17.8	8.9	2
Stichopus vastus	13.3	7.0	12	53.3	0.0	3	13.3	4.4	2	13.3	4.4	2
Tectus pyramis	26.7	10.4	12	64.0	10.7	5	26.7	8.9	2	26.7	8.9	2
Trochus niloticus	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.9 Koror 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
Actinopyga miliaris	1.4	0.8	30	14.3	0.0	3	1.4	1.4	5	7.1		1
Bohadschia argus	4.3	1.4	30	16.1	1.8	8	4.3	1.9	5	7.1	1.4	3
Bohadschia graeffei	1.9	0.9	30	14.3	0.0	4	1.9	1.4	5	4.8	2.4	2
Choriaster granulatus	13.3	4.2	30	33.3	7.3	12	13.3	8.2	5	16.7	9.7	4
Conus leopardus	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Holothuria atra	3.3	2.1	30	33.3	12.6	3	3.3	3.3	5	16.7		1
Holothuria edulis	7.1	3.3	30	35.7	10.9	6	7.1	6.6	5	17.9	15.5	2
Holothuria fuscogilva	23.8	9.9	30	79.4	25.2	9	23.8	21.5	5	59.5	50.0	2
Holothuria fuscopunctata	3.3	1.8	30	25.0	6.8	4	3.3	2.2	5	5.6	3.2	3
Holothuria nobilis	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Lambis chiragra	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Linckia guildingi	6.7	2.6	30	28.6	6.2	7	6.7	5.6	5	16.7	11.9	2
Linckia laevigata	15.7	3.8	30	31.4	5.1	15	15.7	5.1	5	19.6	4.3	4
Lopha cristagalli	1.0	1.0	30	28.6		1	1.0	1.0	5	4.8		1
Panulirus spp.	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Panulirus versicolor	1.4	1.1	30	21.4	7.1	2	1.4	1.0	5	3.6	1.2	2
Protoreaster nodosus	17.6	7.4	30	48.1	16.8	11	17.6	10.1	5	29.4	13.0	3
Stichopus hermanni	7.1	2.1	30	23.8	2.4	9	7.1	2.6	5	8.9	2.5	4
Tectus pyramis	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Thelenota ananas	4.8	1.7	30	20.4	2.9	7	4.8	2.3	5	7.9	2.1	3
Thelenota anax	10.5	3.6	30	28.6	6.9	11	10.5	5.2	5	17.5	5.6	3
Tridacna squamosa	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Tutufa bubo	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	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.

4.4.10 Koror species size review – all survey methods

Species	Mean length (cm)	SE	n
Tridacna crocea	7.3	0.1	5501
Holothuria atra	14.2	0.2	2700
Tridacna maxima	14.5	0.3	1020
Trochus niloticus	9.6	0.1	720
Stichopus chloronotus	17.8	0.4	484
Holothuria edulis	15.2	0.3	402
Stichopus vastus	13.7	0.4	187
Tectus pyramis	5.4	0.1	165
Holothuria nobilis	27.7	0.4	157
Holothuria flavomaculata	26.4	2.4	120
Bohadschia argus	25.4	0.8	115
Turbo argyrostomus	6.3	0.2	94
Holothuria fuscogilva	32.8	0.6	74
Holothuria fuscopunctata	40.4	2.2	72
Thelenota ananas	42.9	2.0	65
Thelenota anax	51.6	2.4	59
Stichopus hermanni	28.1	1.0	54
Tridacna squamosa	20.6	1.2	48
Actinopyga spp.	13.7	1.4	47
Bohadschia vitiensis	22.9	0.5	44
Actinopyga mauritiana	18.9	0.4	43
Holothuria coluber	37.0	2.0	39
Bohadschia graeffei	27.4	1.4	29
Trochus maculata	3.2	0.3	20
Hippopus hippopus	22.8	1.0	18
Lambis lambis	13.7	0.5	17
Actinopyga miliaris	25.8	1.4	14
Cypraea tigris	6.8	0.4	14
Stichopus horrens	10.0	0.9	10
Conus spp.	8.1	1.5	8
Latirolagena smaragdula	4.7	0.1	8
Spondylus spp.	6.9	0.0	8
Tridacna derasa	28.7	5.2	7
Vasum ceramicum	8.3	0.6	7
Vasum turbinellum	7.0	0.0	7
Pinctada margaritifera	15.7	2.3	5
Turbo chrysostomus	3.6	1.1	5
Trochus spp.	3.7	0.1	5
Cerithium nodulosum	8.6	0.5	4
Tectus conus	4.2	0.3	4
Conus distans	6.8	0.9	3
Conus lividus	7.5	0.3	3
Pleuroploca filamentosa	10.8	0.2	3
Vasum spp.	2.1	0.0	3
Charonia tritonis	23.0	9.0	2
Hippopus porcellanus	28.5	3.5	2
Tutufa bubo	20.3	3.3	2
Conus vexillum	6.3	2.1	2
Actinopyga lecanora	19.5	0.5	2
Astralium spp.	3.5	0.1	2

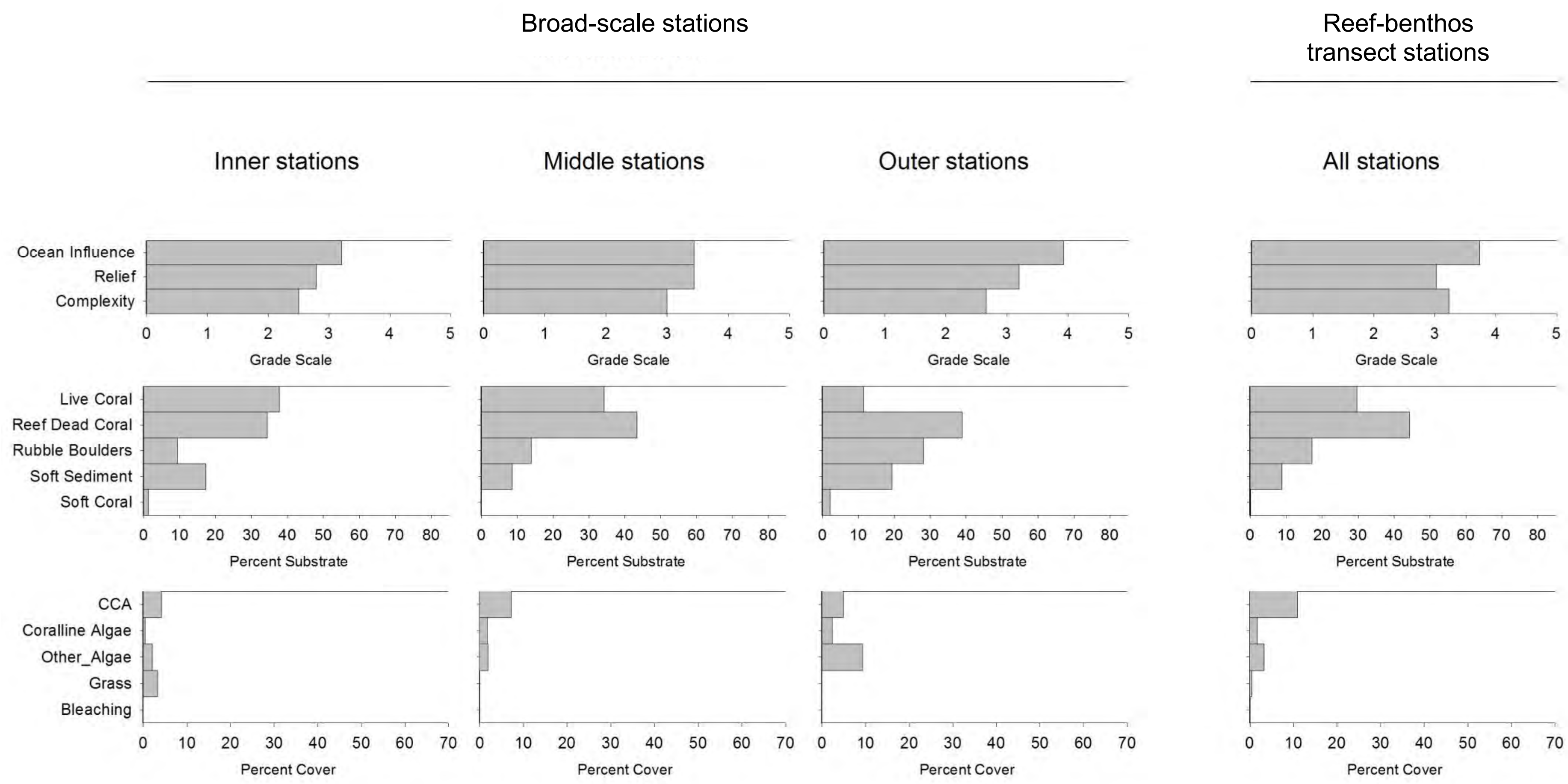
SE = Standard error; n = number.

4.4.10 Koror species size review – all survey methods (continued)

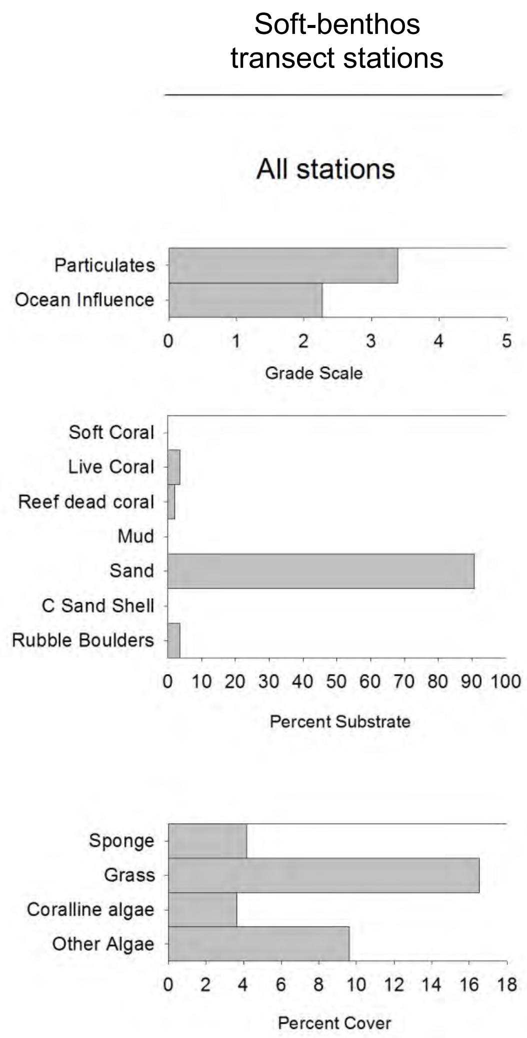
Species	Mean length (cm)	SE	n
Drupa rubusidaeus	3.3		2
Tridacna gigas	60.0		1
Lambis truncata	23.0		1
Cassis cornuta	21.5		1
Holothuria hilla	15.5		1
Bohadschia similis	13.0		1
Conus leopardus	9.5		1
Strombus gibberulus gibbosus	4.9		1
Conus emaciatus	4.6		1
Cypraea lynx	3.9		1
Cypraea erosa	3.1		1
Beguina semiorbiculata			975
Linckia laevigata			678
Protoreaster nodosus			353
Echinometra mathaei			134
Arca spp.			65
Culcita novaeguineae			47
Acanthaster planci			40
Linckia guildingi			33
Choriaster granulatus			30
Synapta spp.			20
Diadema spp.			19
Echinothrix diadema			17
Stichodactyla spp.			14
Panulirus versicolor			13
Synapta maculata			13
Etisus splendidus			11
Panulirus spp.			10
Malleus spp.			9
Chama spp.			8
Hyotissa spp.			6
Cassiopea andromeda			6
Diadema setosum			5
Lambis chiragra			4
Cypraea moneta			3
Tectus triserialis			3
Cassiopea spp.			3
Lopha cristagalli			2
Cerithium spp.			1
Cypraea annulus			1
Saron spp.			1
Atrina vexillum			1
Cypraea caputserpensis			1
Conus miliaris			1
Echinothrix calamaris			1
Octopus spp.			1
Lysiosquillina maculata			1
Cypraea spp.			1
Entacmaea quadricolor			1
Panulirus penicillatus			1

SE = Standard error; n = number.

4.4.11 Habitat descriptors for independent assessments – Koror



4.4.11 Habitat descriptors for independent assessments – Koror (continued)



APPENDIX 5: MILLENNIUM CORAL REEF MAPPING PROJECT – PALAU

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
Palau

(May 2009)

The Institute for Marine Remote Sensing (IMaRS) of University of South Florida (USF) was funded in 2002 by the Oceanography Program of the National Aeronautics and Space Administration (NASA) to characterize, map and estimate the extent of shallow coral reef ecosystems worldwide using high-resolution satellite imagery (Landsat 7 images at 30 meters resolution). Since mid-2003, the project is a partnership between Institut de Recherche Pour le Développement (IRD, France) and USF. The program aims to highlight similarities and differences between reef structures at a scale never considered so far by traditional work based on field studies. It provides a reliable, spatially well constrained data set for biogeochemical budgets, biodiversity assessment, coral reef conservation programs and fisheries. The PROCFish/Coastal project has been using Millennium products in the last four years to optimize sampling strategy, access reliable reef maps, and further help in fishery data interpretation for all targeted countries. PROCFish/C is using Millennium maps only for the fishery grounds surveyed for the project.

For further inquiries regarding the status of the coral reef mapping of Palau and data availability, please contact:

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Reference: Andréfouët S. *et al.* 2006. Global assessment of modern coral reef extent and diversity for regional science and management applications: a view from space. Proc 10th Int. Coral Reef Symposium, Okinawa 2004, Japan: pp. 1732-1745.