PACIFIC REGIONAL OCEANIC AND

COASTAL FISHERIES DEVELOPMENT PROGRAMME

(PROCFish/C/CoFish)

REGIONAL ASSESSMENT REPORT:

PROFILES AND RESULTS FROM SURVEY WORK AT 63 SITES ACROSS 17 PACIFIC ISLAND COUNTRIES AND TERRITORIES

(1 March 2002 to 31 December 2009)

by

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

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The team, over the years, has been made up of:

- Lindsay Chapman, CFP Manager and PROCFish/C coordinator (March 2006 to December 2009)
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- Franck Magron, Reef Fisheries Information Manager (March 2002 to September 2009)
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- Marie-Therese Bui, Project Administrator (March 2002 to December 2009)
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- Sarah Langi, Report Editor (July to December 2008 plus consultancies April to December 2009)
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- Pierre Labrosse, PROCFish/C coordinator and senior finfish scientist (March 2002 to August 2003).

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EXECUTIVE SUMMARY

The Pacific Regional Coastal Fisheries Development Programme (CoFish) and its associated programme PROCFish/C (the coastal component of the Pacific Regional Oceanic and Coastal Fisheries Development Programme)[1] conducted fieldwork in 63 sites across 17 Pacific Island countries and territories over a seven-year period from 2002 to 2009.

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 covered three disciplines (finfish, invertebrate and socioeconomic) in each site, with a team of 4–8 programme scientists and several local counterparts from the participating country or territory, usually from the fisheries or conservation department, with some NGOs participating in some locations. 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.

Usually, four sites were selected for the survey in each country or territory. These sites were selected based on specific criteria, which included:

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

[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 this report and all country reports.

Habitat and finfish assessment

The extensive geographical variation observed during this survey has been taken into account in the study of the relationship between resources and use in both the search for indicators and the identification of fishing impacts. The very large scale of the project is reflected in the high level of control exerted by the geographical location on the fish presence, production and association: longitude and latitude influence the geomorphology of islands and reef composition and the fish communities both directly, through variation of the biota, and indirectly, through the geographical variation of habitat.

Four major geomorphological types of islands are defined: high oceanic islands of volcanic origins; islands with small lagoons at an intermediate geological development between a high island and an atoll; complex islands, which are intermediate between the two extreme geological stages of 'atoll' and 'high island' and present a large range of terrestrial and marine habitats; and atolls, the final geological development of an island.

Coral reef composition is defined by summarising reef types into four main coralline geomorphologic structures found in the Pacific: sheltered coastal reef along the shores; intermediate lagoon reef identified by patch reef that is located inside a lagoon or a pseudo-lagoon; back-reef, which is the inner/lagoon side of outer reef; and outer reef, the ocean side of fringing or barrier reefs. This composition of different reefs is related mostly to the geomorphological configuration of the islands, and changes considerably throughout the region. Total reef area varies greatly from site to site, from reef surfaces as small as 1 km^2 to much larger reef surfaces reaching almost 200 km^2. Total reef areas per site are larger at complex islands and atolls compared to islands with small lagoons, and oceanic islands.

At a smaller scale, substrate composition varies widely: the average percentage cover of live coral is higher at atolls and complex islands and lower at oceanic islands. Percentages of dead coral and rubble are higher at complex islands. There are larger differences among different reef types at a site than among the same reef types of all sites, making generalisation about an 'average' site substrate not very meaningful. Live-coral and bedrock cover are significantly higher, and sand significantly lower, at outer reefs.

In terms of fish resources, the 63 sites studied were found to be mediocre when considered as a whole. Less than one-third (27%) of the sites were in good condition. Most sites (54%) were in average-to-low or poor condition. The average value of biomass throughout the region equalled 118 t/km^2, a value that is in the range of good quality reef fishing around the world. However, as many as 41 sites (65% of total) were found below this average value. The trophic composition of a fish community was found to reflect its health: a high ratio proportion of carnivores to herbivores indicates a healthy fish community. Fish size was also identified as a major signal of fish community status and, possibly, also of fishing pressure: large fish indicate a healthy community and a lower fishing pressure. These parameters were, therefore, chosen as strong indicators of status.

The fish community on average was dominated by small sizes. Fish were in general of small size: 96% of the whole commercial fish community was composed of fish smaller than 35 cm (FL) in size. Fish smaller than 20 cm made up on average 68% of the total fish abundance. Thirty-six per cent of all commercial fish (maximum frequency) were 15 cm in body length (FL).

When sites were grouped into four levels of resource status (from level I healthy/good to level IV depleted/poor), the following trend in size-frequency distribution of whole fish communities was observed. As conditions declined, there were fewer fish of all sizes, a reduction in numbers of large-sized fish, and a few smaller-sized species dominated the fish community. Sites in poorer condition, with a high biomass of small fish and a low ratio of carnivores to herbivores, occurred more frequently towards the east of the region, at islands with small lagoons, intermediate, complex, and oceanic islands and at locations with large areas of coastal reefs. Sites in healthier condition, with high ratios of piscivores, a wider range of sizes with large fish present and in greater abundance, and a greater presence of large-sized species were more frequent at high latitude, at atoll sites, and at locations with highly complex habitat and large surface areas of outer, back- and lagoon reefs. Sites with larger areas of coastal reefs compared to back- and outer reefs appeared to be among the naturally poorest habitats.

The impact from fishing measured on the fish community was significant given that the spatial scale was so large and that only a few components describing fishing were taken into account for the analysis. Sites with large areas of coastal reefs compared to other reef types were found to be the most impacted by fishing: these sites contained a low abundance of piscivores, a low abundance of large-sized fish, a higher proportion of small fish, and communities increasingly dominated by opportunistic fish species that dominated the biomass as well as the numbers. Easier access for fishers could be a cause of the poorer conditions of fish communities in coastal reefs due to fishing impact. The intermediate and complex islands appeared to be naturally rich but showed impact from fishing pressure, visible by a noted decrease of large-sized species.

At high people-density (the best parameter for measuring fishing pressure) there was found to be a higher proportion of biomass of herbivores over carnivores, a higher relative density and biomass of Acanthuridae compared to other fish (and high relative importance of *Acanthurus triostegus*, *Naso lituratus* and *Ctenochaetus striatus)* and lower relative density and biomass of Scaridae (*Chlorurus sordidus* displayed high numbers but small size, making their overall biomass low). Moreover, Serranidae sizes were smaller. Carangidae, sharks and *Bolbometopon muricatum* were rarer at sites where people-density was high.

The large differences in habitat across the vast Pacific Island region control most of the variability in the fish community in terms of density, biomass and size, at the level of species, family and trophic guild. However, despite these differences, only three indicators of fishing stress were found to explain almost 20% of the variability in the fish community. These three factors were: population density, fish consumption, and catch for sale. About half of this variation can be accounted for by differences in the nature of fishing activities related to location and island type (differences in fishing techniques, cultural differences, etc.), while the other half is correlated with the direct effects of population density, fish consumption, and catch for sale on the fish community composition.

Invertebrate assessment

Invertebrate export fisheries in the Pacific have a long history dating back to pre-European settlement. These fisheries are primarily based on the sale of bêche-de-mer (sea cucumbers), mother-of-pearl shell or ‘MOP’ (trochus and pearl oysters) but, more recently, also the export of dead coral products, live molluscs, crustaceans, and corals for the ornamental trade and aquarium industry. Additionally, a vastly larger number of other species and species groups are targeted for artisanal and subsistence use. A variety of commercially valuable invertebrates are associated with a range of mainly lagoonal (reef, sand and mud, mangroves and seagrass meadows) and reef-slope coral reef habitats in the Pacific.

Defining the status of the sea cucumber fishery in PICTs is complicated by the fact that it is a multi-species fishery. Although we can lump together abundance results across species groups for some very basic comparisons, the amalgamated species data disguise important differences in species complements among countries, as different species have different life characteristics and so cannot be meaningfully compared. There are almost no cases where these commercial stocks are still in their virgin or un-impacted condition in the Pacific. In fact, many sites surveyed were severely depleted, especially for the higher-value species.

Managers who are able to control harvest periods for sea cucumber, by only opening a commercial fishery for small, pulse-fishing events, with regular monitoring (pre-fishing and post-fishing surveys) will be able to understand stock changes and refine management understanding of stock recovery. This 'closure – pulse fishing – closure' approach based on population metrics taken from these surveys can be adopted for many species or a subset of sea cucumber species. The metrics can become refined over time through sharing information and advice gleaned from the joint experiences of managers across the region. Continued research on the basic biology and ecology of sea cucumbers, which is slowly emerging for a few species, will provide a valuable complementary dataset to inform community members about growth and reproduction, as will genetic studies that highlight isolation or connectivity between neighbouring populations.

As in the fishery for sea cucumbers, trochus stocks were found to be depleted at many of the sites surveyed, based on the densities recorded. Results varied among sites and countries where stocks are under differing fishing pressures and forms of fishery management.

Management considerations for mother-of-pearl resources may benefit from looking at the factors that were used to control fishing at sites that maintained average densities of stocks above the threshold of 500 per ha. Invariably these locations were managed through only allowing a limited number of active fishing periods, and ensuring these were short 'pulses' of commercial fishing, interspersed with longer periods when stocks were 'closed' to fishing. The mechanism for closing and opening the fishery was mostly controlled through centralised management, or a combination of centralised management and community input and instruction. In no case was community management alone used to maintain average density of stocks at or >500 per ha.

To allow stocks and, therefore, fishery productivity to rebuild at places where stocks are depleted, underperforming (and declining) fisheries need to be closed. In some cases live shells need to be aggregated within key fishery grounds to assist spawning success and to 'kick-start' a return to productivity. To maintain stocks at reasonably high levels of abundance, community negotiations need to take place where local and Pacific-wide information is presented and discussed, and thresholds to determine what stock densities should be before any harvesting is considered should be agreed between centralised government and community leaders.

Clams are a common food staple and a cash crop in the Pacific, occasionally being used for artisanal or commercial fishing (shell and meat products). However, in the majority of cases today clams are taken for food. Declines related to fishing have been widely noted for these species, especially with resource stocks that have been impacted by fishing pressure over generational time scales. As a result, what we can strive for across the Pacific is to hold stocks above a sustainable target reference point or threshold that we believe will ensure that the stock remains viable and resilient to natural pressures, but that also is able to provide an opportunity for periodic harvest. Although clam densities for high-status sites are higher than for low-status sites, and we need to formulate a 'target reference density' for harvested species groups, this must include some reference to a site's capacity to support the resource in question. There will be differences in this capacity, which means that in some cases a site which has a low capacity may never be able to reach the density of a site which has better habitat, incoming recruitment, and adequate food resources for the stock in question.

Giant clams are a useful keystone species for encouraging community involvement in resource management. These colourful species are easy to locate and count, and changes in abundance and size are easily measured when setting and testing management targets. Giant clams are also useful species for teaching communities the complexity of life histories of invertebrate species, and how resource species are impacted by fishing and management decisions. In general, we found villagers were not generally aware of the life cycle and age of most resource species; giant clams, which are broadcast spawners with a short-lived planktonic larvae, are good examples for showing how spawning occurs and how small clams need to settle and grow to reach maturity. As they are protandrous hermaphrodites (begin as males and later become females), only the larger clams are female (*Tridacna maxima* develop as females from about 8 cm, *T. squamosa* from 15 cm and *T. gigas* from about 50 cm, or as old as ten years.). Knowing this will help communities develop strategies for protecting some of the larger stock or for establishing protected areas and rules around allowable sizes for sustainable harvest in the interest of conserving populations.

Socioeconomic assessment

The region's per capita annual consumption of marine products was found to be high, with a regional average of 67.8 kg fresh fish, 7.5 kg of invertebrates (edible meat only) and 8.9 kg canned fish (net weight). Income dependency on fisheries as compared to salaries varied significantly, with a regional average of 29.5% and 20.2% of all households earning primary and secondary income from fisheries, and 32.5% and 6.5% from salaries respectively. These results confirm that dependency on marine resources for both subsistence and income determines the level of resource exploitation for finfish and most invertebrates.

The main drivers determining high commercial finfish and small-scale artisanal invertebrate catches are factors that represent limited opportunities for earning alternative income, and difficulties in meeting living costs, combined with easy access to and good choice of fishing grounds, and easy marketability. As expected, demographic pressure and food dependency on marine produce are the main drivers for finfish and invertebrate subsistence fisheries. A close relationship exists between exploitation, hence fishing pressure, and economic factors, possibly poverty. Households depending on fishing for primary income are financially disadvantaged as compared to those that have primary income sources other than fisheries.

Results confirm that even low finfish fishing intensity can cause cascading effects and also that these effects increase with increasing fishing pressure. The socioeconomic, fishery, and resource data gathered during these surveys need to be combined to identify the cause-and-effect of fishing pressure. To achieve sustainable resource-use management of small-scale artisanal fisheries in Pacific Island Countries and Territories, management should shift from the long-established goals to embrace a wider rural-development approach that fosters the development of alternative-income opportunities and that restricts the use of fishing techniques with high impact.

The future of the artisanal fishery sector and the livelihood of coastal communities in the Pacific Islands region will depend to a large extent on access to and potential of alternative subsistence and income sources. These are necessary to reduce fishing pressure to a sustainable level to maintain ecosystem services and food security. The harmonisation of objectives for resource use and development requires the promotion of diversification, including alternatives to coastal wild-caught fisheries, and demands management strategies that make artisanal coastal fisheries an integral part of domestic rural development. Artisanal fisheries can no longer be managed independently of other resource uses and their environmental and socioeconomic impacts. The adoption of an approach that integrates development strategies in other sectors will be an effective means of reducing dependence on marine resources, reducing fishing pressure, and making restrictive management easier or less controversial for the affected stakeholders.

The above objectives may require adaptive capacity assessments to tailor specific development programmes to the available resources and the communities' and households' capabilities. A gender lens also needs to be applied beyond fisheries to tailor strategies to males' and females' contributions to the household's food and income security and their possibilities and limitations in exploring alternatives. The implications of livelihood diversification programmes on gender participation and responsibilities must also be considered, taking into account that female fishers are a vulnerable group and may risk becoming over-burdened as the responsibilities imposed by gender-defined roles may be maintained within traditional and cultural value systems. In response to economic stress, female fishers have already expanded their traditional roles to increasingly contribute to household cash income (particularly in Melanesia).

Recommendations

Due to the strong response of the fish community to fishing pressure in terms of small sizes and low biomass, a thorough and cautious management regime should be applied throughout the region for finfish species:

- ***Restrictions to fishing tools*** should be applied, especially for night-diving and non-selective gillnetting.

- ***Catch quotas*** should be established at each site relative to both the conditions and risk level of each site, as determined by this study.

- ***Alternative fisheries*** should be sought and established: users should look into exploiting alternative resources. Acanthuridae appeared to be less impacted and the most opportunistic feeders and, therefore, the most resilient fish family to fishing pressure. Diet preferences should be re-directed towards more sustainable resources. As another example, in some places, offshore or deep-water species could be targeted. Preferences should be given to herbivorous fish (Acanthuridae, Scaridae, Siganidae).

- ***Protection of spawning aggregation sites*** should be applied everywhere, regardless of the conditions and risk levels. Such locations are the sources of replenishing all coastal, lagoonal and outer-reef resources.

- ***Community-managed 'no fishing' areas*** should be applied everywhere to provide sources of replenishing fish stock throughout the sites.

- ***Monitoring programmes*** should be established everywhere, on both resources and catches. For underwater resource assessment a new, locally manageable method is currently being designed; however, some rules and indicators to be measured at regular times can be summarised:
  - maintain the same design over time, in the same locations;
  - measure the sizes of all edible fish;
  - identify and count target families: Acanthuridae, Scaridae, Siganidae, Serranidae, at the level of species, focusing on locally preferred and highly targeted species;
  - measure live coral cover and complexity at *in situ* dive sites. Satellite images can be requested.

The following points are provided in support of the sustainable management of bêche-de-mer or sea cucumber fisheries:

- ***Continue to define the fisheries:***
  - focus understanding on relevant species groups rather than the whole fishery;
  - map their distribution – determine how big and where are the fishery grounds;
  - examine the Pacific dataset and decide what numbers (densities/sizes) need to be left in the water to retain breeding capacity.

- ***Control the fisheries:***
  - set in place an agreed monitoring strategy;
  - simplify management – use an 'on/off' switch to manage harvests;
  - educate fishers in fishery understanding and post-harvest processing;
  - control access to the fishery by the marine product sector;
  - institute comprehensive export inspection and reporting.

- ***Grow the business:***
  - monitor and share understanding of productivity and responses in the fishery;
  - monitor and share market information;
  - focus on market development.

The following points are provided in support of the sustainable management of mother-of-pearl fisheries.

- ***Continue to define the fisheries:***
  - map their distribution – determine how big and where are the key fishery grounds;
  - examine the Pacific dataset and decide what numbers (densities/sizes) need to be left in the water to retain breeding capacity.

- ***Control the fisheries:***
  - set in place an agreed monitoring strategy;
  - simplify management – use an 'on/off' switch to manage harvests;
  - educate fishers in fishery understanding and post-harvest processing;
  - control access to the fishery by the marine product sector;
  - institute comprehensive export inspection and reporting.

- ***Grow the business:***
  - monitor and share understanding of productivity and responses in the fishery;
  - assist and facilitate translocation among areas with suitable habitat for trochus;
  - monitor and share market information;
  - focus on synchronising market access and on developing the markets.

The following points are provided in support of the sustainable management of giant clam fisheries.

- ***Continue to define the fisheries:***
  - map the distribution – determine how big and where are the key fishery grounds;
  - examine the Pacific dataset and decide what numbers and sizes need to be left in the water to retain breeding capacity.

- ***Control the fisheries:***
  - set in place an agreed monitoring strategy (Use the Pacific dataset and sampling strategy advice.);
  - educate fishers in fishery understanding;
  - decide on some 'no-take' areas, where fishing is banned to protect mature clams as a broodstock.

- ***Grow the understanding:***
  - monitor and share understanding of productivity and responses in the fishery among participating communities and countries who share the same resources.

RÉSUMÉ

Le projet de développement de la pêche côtière (CoFish) et son projet connexe PROCFish/C (composante côtière du Programme régional de développement des pêches océaniques et côtières dans les PTOM français et pays ACP du Pacifique)[2] ont mené des enquêtes sur 63 sites à travers dix-sept États et Territoires insulaires océaniens durant une période de sept ans allant de 2002 à 2009.

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

Les autres résultats escomptés du projet étaient notamment :

- première évaluation exhaustive et comparative des pêcheries récifales (poissons, invertébrés et paramètres socioéconomiques de leur exploitation) jamais entreprise dans 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 des informations, dont des bases de données régionales et nationales.

Les enquêtes comprenaient trois volets (poissons, invertébrés et aspects socioéconomiques) sur chaque site avec une équipe de 4 à 8 scientifiques du programme et de plusieurs agents locaux, habituellement du service de la pêche ou du département de la conservation, et certaines ONG sur quelques sites. Durant les travaux de terrain, l'équipe a également formé des agents locaux aux méthodes d'enquête et d'inventaire utilisées dans chaque volet d'étude, notamment la collecte de données et leur saisie dans la base de données du projet.

En règle générale, quatre sites ont été retenus pour la conduite des enquêtes dans chaque pays et Territoire. Ces sites ont été sélectionnés selon des critères précis. Ils devaient notamment avoir les caractéristiques suivantes :

- existence d'une pêcherie récifale active,
- représentativité,
- systèmes relativement fermés (les habitants du site pêchent dans des zones bien définies),
- superficie appropriée,
- habitat diversifié,

[2] CoFish et PROCFish/C sont les deux composantes d'un même programme, CoFish couvrant les pays ACP pouvant prétendre aux financements du 9e fed, à savoir niue, nauru, les états fédérés de micronésie, palau, les îles marshall et les îles cook, tandis que procfish/c concerne les pays financés au titre du 8e fed (les pays acp : fidji, tonga, papouasie-nouvelle-guinée, îles salomon, vanuatu, samoa, tuvalu et kiribati, et les pays et territoires d'outre-mer français (ptom) : nouvelle-calédonie, polynésie française et wallis et futuna). les appellations cofish et procfish/c sont donc utilisées indifféremment dans ce rapport et dans tous les rapports sur les pays.

- absence de gros problème logistique,
- n'avoir jamais été encore étudiés, et
- intérêt particulier pour les autorités.

Évaluation des poissons et de leur habitat

Dans l'étude des liens existant entre les ressources et leur exploitation, il a été tenu compte des grandes variations géographiques observées, tant pour la recherche d'indicateurs que pour la détermination des incidences de la pêche. On peut mesurer l'ampleur de l'échelle du projet à la très grande influence exercée par la localisation géographique sur la présence de poissons, leur production et leur association : la longitude et la latitude influencent la géomorphologie des îles et la composition des récifs, ainsi que les regroupements de poissons, directement, par la variété des biotes, et indirectement par les différences géographiques des habitats.

On distingue quatre grands types géomorphologiques d'îles : les îles hautes océaniques d'origine volcanique, les îles comprenant de petits lagons, au stade de développement géologique intermédiaire entre une île haute et un atoll, des îles complexes, se situant à un stade intermédiaire entre les deux stades géologiques extrêmes de « l'atoll » et de « l'île haute » et présentant un vaste éventail d'habitats terrestres et marins, et les atolls, état ultime de développement géologique d'une île.

On peut définir la composition des récifs coralliens en résumant schématiquement les types de récifs à quatre principales structures géomorphologiques coralliennes présentes dans le Pacifique : les récifs côtiers abrités le long des rivages, les récifs lagonaires intermédiaires se présentant sous forme de pâtés de corail situés à l'intérieur d'un lagon ou d'un pseudo-lagon, les « *back reefs* », situés à l'arrière des récifs, du côté intérieur de la barrière de corail dans le lagon, et le « récif extérieur », côté océanique des récifs frangeants ou de la barrière de corail. Cette différence de composition des récifs est principalement due à la configuration géomorphologique des îles, et accuse des variations considérables à travers la région. La superficie totale des récifs varie grandement d'un site à l'autre. Certains s'étendent sur 1 km^2, d'autres peuvent atteindre une superficie de près de 200 km^2. Les récifs des sites étudiés s'étendent sur des superficies plus grandes quand il s'agit d'îles complexes ou d'atolls que lorsqu'il s'agit de petits lagons ou d'îles océaniques.

Sur une plus petite échelle, la composition du substrat présente de grandes variations: en moyenne, le couvert de corail vivant est plus étendu sur les atolls et les îles complexes que sur les îles océaniques. En proportion, le couvert de coraux morts et de blocaille est plus important sur les îles complexes. On note de plus grandes différences entre les types de récif sur un seul site qu'entre les mêmes types de récif observés sur tous les sites, ce qui rend peu significative toute généralisation quant à un substrat « moyen » d'un site. Les récifs extérieurs se caractérisent par un couvert de coraux vivants et de substrats rocheux important, tandis que les étendues sablonneuses y sont plus réduites.

Pour ce qui est des ressources en poissons, les 63 sites étudiés, pris dans leur ensemble, se sont révélés pauvres. Les sites en bon état représentent moins d'un tiers des sites (27%). La plupart (54%) sont plutôt dans un état moyen à pauvre, ou médiocre. La biomasse moyenne de la région tout entière est évaluée à 118 t/km^2, grandeur qui se situe dans la fourchette des pêcheries récifales de bonne qualité dans le monde. Toutefois, on a constaté que 41 sites (soit 65% du total) ont une biomasse inférieure à cette valeur moyenne. On sait que la composition trophique d'une colonie de poissons reflète son état de santé : une proportion élevée de carnivores par rapport aux herbivores indique que cette colonie est en bonne santé. La taille des poissons est aussi un signe révélateur de la condition de la colonie de poissons, et, sans doute aussi, de la pression de pêche : la présence de gros poissons laisse penser que la colonie est prospère et la pression halieutique faible. Ces paramètres ont donc été choisis comme des indicateurs significatifs de l'état de la ressource.

En moyenne, les poissons de petite taille prédominent dans la ressource en poissons. D'une manière générale, les poissons observés étaient de petite taille: 96% de l'ensemble des colonies de poissons pouvant faire l'objet d'une exploitation commerciale étaient composés de poissons ne dépassant pas 35 cm de la tête à la queue (FL). Les poissons dont la taille était inférieure à 20 cm composaient en moyenne 68% de l'abondance totale en poissons. Sur l'ensemble des poissons faisant l'objet d'une pêche commerciale, 36% (fréquence maximale) mesuraient 15 cm (FL).

Suivant une classification des sites par niveau de ressources (du niveau I « bon état », au niveau IV « épuisé/mauvais état »), la distribution des fréquences de taille de l'ensemble des colonies de poissons s'est présentée comme suit. Lorsque les conditions se détérioraient, le nombre de poissons, de toutes tailles, diminuait, les poissons de grosse taille étaient moins nombreux et quelques poissons de plus petite taille prédominaient. Les sites plus pauvres, pourvus d'une biomasse composée essentiellement de petits poissons et où le rapport carnivores/herbivores était faible, se situaient plutôt vers l'est de la région, vers les îles dotées de petits lagons, les îles intermédiaires et complexes, les îles océaniques, et dans des lieux pourvus de vastes surfaces de récifs côtiers. Les sites en meilleur état, où les proportions de piscivores étaient plus élevées, où les tailles s'échelonnaient sur un éventail plus large, avec des poissons de grosse taille et en plus grande abondance, étaient plus fréquents à des latitudes plus élevées, dans les atolls et dans des lieux dotés d'un habitat plus diversifié et de plus grandes étendues de récifs extérieurs, intérieurs et lagonaires. Les sites comprenant des récifs côtiers plus étendus semblaient offrir les habitats les moins riches naturellement, en comparaison avec les *back-reefs* et les récifs extérieurs.

Les conséquences de la pêche mesurées à l'aune des colonies de poissons ont semblé importantes compte tenu de la dispersion des ressources dans l'espace et du fait que seules quelques composantes de la pêche ont été prises en compte dans l'analyse. On a constaté que les sites le plus affectés par la pêche étaient ceux qui comprenaient une grande superficie de récifs côtiers, par rapport à ceux caractérisés par d'autres types de récifs: ces sites abritaient peu de poissons piscivores, peu de poissons de grande taille, une forte proportion de petits poissons, et des colonies de poissons où prédominaient des espèces opportunistes constituant la majeure partie de la biomasse et des effectifs. Les mauvaises conditions des colonies de poissons vivant sur les récifs côtiers découlant de la pêche sont peut-être dues à la facilité d'accès à ces zones par les pêcheurs. Les îles intermédiaires et les îles complexes semblaient naturellement riches mais étaient néanmoins marquées par la pression de pêche, vu le déclin notable des espèces de grosse taille.

Lorsque la densité démographique était élevée (le meilleur paramètre pour déterminer la pression de pêche), on a constaté que la biomasse était davantage composée d'herbivores que de carnivores, qu'il y avait une densité et une biomasse relativement plus importantes d'Acanthuridae que d'autres poissons (et une forte abondance relative de *Acanthurus triostegus*, *Naso lituratus* et *Ctenochaetus striatus)* et des densité et biomasse relatives faibles de Scaridae (il y avait de nombreux *Chlorurus sordidus* mais de petite taille, ce qui expliquait la pauvreté de leur biomasse générale). En outre, la taille des Serranidae était petite. Les Carangidae, les requins et les *Bolbometopon muricatum* étaient peu nombreux dans les sites à forte densité de population humaine.

Les grandes différences d'habitat à travers la vaste région insulaire du Pacifique déterminent pour l'essentiel la variabilité des colonies de poissons en termes de densité, de biomasse et de taille, au niveau des espèces, des familles et de leur guilde trophique. Toutefois, malgré ces différences, on n'a décelé que trois indicateurs de perturbation due à la pêche pouvant expliquer près de 20% de la variabilité des colonies de poissons. Ces trois facteurs sont: la densité démographique, la consommation de poisson et les prises à destination commerciale. À peu près la moitié de ces variations est imputable aux différences relatives aux activités halieutiques liées à la localisation et au type d'île (différences de techniques de pêche, différences culturelles, etc.), l'autre moitié étant liée aux effets directs de la densité démographique, de la consommation de poissons et des prises commerciales sur la composition des colonies de poissons.

Évaluation des invertébrés

La pêche des invertébrés pour l'exportation en Océanie a un long passé qui remonte aux peuplements humains antérieurs à l'arrivée des Européens. Cette pêche est principalement destinée à la vente de bêches-de-mer (concombres de mer), de coquillages à nacre, à savoir trocas et huîtres perlières. Plus récemment, s'est ajoutée l'exportation de produits coralliens morts, de mollusques vivants, de crustacés et de coraux pour le commerce de produits d'ornements et d'aquariophilie. En outre, d'autres espèces et groupes d'espèces sont ciblés en bien plus grand nombre pour l'artisanat et les besoins alimentaires. Dans le Pacifique, divers invertébrés d'un intérêt commercial sont associés à une variété d'habitats principalement lagonaires (récifs, étendues sablonneuses et vaseuses, mangroves et herbiers) et offerts par les pentes récifales coralliennes.

Décrire l'état de la pêcherie du concombre de mer dans les ETIO est compliqué par le fait que cette pêche s'inscrit dans une pêche polyvalente. Même s'il est possible d'établir des chiffres globaux concernant l'abondance de groupes d'espèces à des fins de comparaisons très élémentaires, cette pondération des données relatives aux espèces occulte d'importantes différences dans les regroupements d'espèces entre les pays, chaque espèce ayant des caractéristiques propres et ne pouvant être comparée à bon escient à d'autres espèces. En Océanie, il n'y a quasiment pas d'espèce dont le stock commercial soit encore à l'état vierge ou indemne. En fait, de nombreux sites étudiés étaient très appauvris, dépourvus des espèces très prisées.

Les gestionnaires qui sont en mesure de réguler les périodes de récolte des concombres de mer, en n'autorisant qu'une pêche commerciale occasionnelle, de type artisanale ou pulsatoire, avec des contrôles réguliers (par des inventaires avant et après la pêche) sont plus à même de comprendre l'évolution des stocks et d'affiner le mode de gestion au bénéfice de la reconstitution du stock. Il est possible de décider de cette alternance de périodes de fermeture et de pêche pulsatoire en fonction de l'effectif de la population dénombré grâce à ces inventaires, pour de nombreuses espèces ou pour un sous-ensemble d'espèces de concombre de mer. Ce dénombrement s'affinera avec le temps si les divers gestionnaires de la région s'échangent les connaissances et les conseils qu'ils auront tirés de leurs expériences respectives. La poursuite des travaux de recherche sur les rudiments de la biologie et de l'écologie des concombres de mer, qui émergent progressivement de l'étude de quelques espèces, permettra de constituer une précieuse base de données complémentaire grâce à laquelle les habitants des sites concernés connaîtront les modes de croissance et de reproduction de ces espèces, tout comme les études génétiques qui mettent en évidence l'isolement des populations voisines ou leurs interactions.

De même que pour la ressource en concombres de mer, l'inspection de nombre des sites explorés a révélé que les stocks de trocas étaient également épuisés, au vu des densités enregistrées. Les résultats variaient suivant les sites et les pays, les stocks étant soumis à des pressions de pêche et à des modes de gestion différents.

La gestion des ressources en coquillages à nacre bénéficie sans doute de la prise en compte des facteurs utilisés pour réguler la pêche dans des sites où les densités moyennes des stocks se maintiennent à un niveau supérieur au seuil de 500 par ha. Invariablement, ces sites étaient gérés suivant une approche n'autorisant qu'un nombre limité de périodes de pêche active et faisant en sorte que celles-ci soient de brèves périodes de pêche commerciale « pulsatoire », entrecoupées de périodes plus longues de fermeture de la pêche. Il appartenait principalement à une autorité de gestion, ou à une combinaison de gestion centralisée et de gestion communautaire sous forme d'avis et d'instructions, de veiller au respect de ce système de fermeture et d'ouverture de la pêche. En aucun cas la gestion communautaire n'était la seule responsable du maintien de la densité moyenne des stocks à 500 ou à plus de 500 par ha.

Afin de permettre la reconstitution des stocks et, partant, la reprise de la rentabilité de la pêche dans les endroits où les stocks sont épuisés, il faut fermer les pêcheries aux résultats médiocres (et en déclin). Il faudrait éventuellement replacer des coquillages vivants sur des sites de pêche clés pour leur permettre de frayer avec succès et de relancer la productivité. Dans le but de maintenir les stocks à un niveau d'abondance raisonnablement élevé, il y aurait lieu d'organiser des réunions de village au cours desquelles des informations locales et à l'échelle du Pacifique tout entier, seraient communiquées et examinées, et des seuils, établissant les densités de stock à enregistrer avant toute récolte, seraient fixés d'un commun accord entre les autorités gouvernementales et les chefs de village.

Les praires sont une denrée de base et une espèce récoltée à des fins commerciales en Océanie. Occasionnellement, elles sont employées pour des produits d'artisanat ou la pêche commerciale (coquille et chair). Toutefois, elles sont surtout récoltées pour être mangées. On a noté un appauvrissement général de cette ressource lié à la pêche, surtout lorsque les stocks ont subi une pression de pêche depuis plusieurs générations. En conséquence, ce que nous pouvons essayer de faire à l'échelle du Pacifique, c'est de maintenir les stocks à un niveau supérieur à une référence ou seuil cible durable, qui, croit-on, assurera la viabilité du stock et sa résistance aux agressions naturelles, mais qui, également, offrira de quoi permettre une récolte périodique. Même si les densités de praires dans les sites en bon état sont plus élevées que dans les sites en mauvais état, il nous faudra établir une « densité cible de référence » pour les groupes d'espèces récoltés, en tenant compte d'une manière ou d'une autre de la capacité du site de faire vivre la ressource concernée. Cette capacité aura tendance à varier, du fait que dans certains cas, un site, pourvu d'une faible capacité, risquera de ne jamais atteindre la densité associée à un site offrant un meilleur habitat, des ressources trophiques adéquates pour le stock en question et accueillant un recrutement de l'extérieur.

Les bénitiers appartiennent à une espèce qui se prête bien à une intervention auprès des populations locales pour encourager celles-ci à s'employer à gérer les ressources. Cette espèce colorée est facile à localiser et à inventorier, et il est facile d'en évaluer les changements d'abondance et de taille lorsqu'on vérifie la réalisation des objectifs de leur gestion. Les bénitiers sont aussi utiles lorsqu'on veut montrer aux villageois la complexité des cycles de vie des invertébrés et la façon dont la pêche et les modes de gestion choisis influent sur ces ressources. Nous nous sommes aperçus qu'en général les villageois ne connaissent ni les cycles de vie ni l'âge de la plupart des espèces de ces ressources ; les bénitiers, qui dispersent leur semence et ont une vie larvaire planctonique brève, sont de bons exemples pour montrer comment ils frayent et comment les petits bénitiers doivent se fixer et grossir pour atteindre leur maturité. Comme ce sont des hermaphrodites protérandriques (ils parviennent d'abord à maturité en tant que mâles puis en tant que femelles), seuls les bénitiers de grande taille sont femelles (*Tridacna maxima* devient femelle dès qu'il mesure environ 8 cm, *T. squamosa* 15 cm, et *T. gigas* 50 cm, ou qu'il atteint l'âge de dix ans.). Sachant cela, les villageois peuvent élaborer des stratégies pour protéger une partie du stock de grande taille, ou pour établir des zones protégées et des règles déterminant les tailles à partir desquelles autoriser une récolte durable, dans l'intérêt de la conservation de la ressource.

Évaluation socioéconomique

Il est apparu que la consommation annuelle par Océanien de produits de la mer est forte. Elle s'élève en moyenne à 67,8 kg de poisson frais, à 7,5 kg d'invertébrés (chair comestible seulement) et à 8,9 kg de conserves de poisson (poids net). La part des revenus issus de la pêche comparée à ceux des emplois salariés varie énormément, la moyenne régionale étant de 29,5%, de 20,2% pour l'ensemble des ménages percevant des revenus primaires et secondaires de la pêche, et de 32,5% et 6,5% des revenus des salaires, respectivement. Ces chiffres confirment que la dépendance à l'égard des ressources marines, tant à des fins vivrières que financières, détermine le degré d'exploitation des ressources en poissons et de la plupart des invertébrés.

Les principales motivations sous-tendant d'importantes captures commerciales de poissons et des récoltes d'invertébrés à l'échelle artisanale sont le manque de possibilités de gagner de l'argent par d'autres moyens et la difficulté de faire face au coût de la vie, auxquels s'ajoutent la bonne accessibilité et la qualité des sites de pêche et la facilité de commercialisation des produits de la mer. Comme on s'y attendait, la pression démographique et la dépendance alimentaire à l'égard des produits de la mer sont ce qui motive essentiellement la pêche vivrière des poissons et des invertébrés. Il existe des liens étroits entre l'exploitation, et, donc, la pression de pêche, et les facteurs économiques, éventuellement, la pauvreté. Les ménages pour qui la pêche est une source de revenus primaire sont financièrement défavorisés par rapport à ceux qui ont une source de revenus primaire autre que la pêche.

Les chiffres confirment que même une pêche de poissons de faible intensité peut causer des effets en cascade et que ces effets s'aggravent à mesure que la pression de pêche augmente. Il y a lieu de combiner les données socioéconomiques, halieutiques et relatives à la ressource, recueillies lors de ces études, pour déterminer les relations de cause à effet de la pression de pêche. Pour réaliser une gestion durable de l'exploitation de la ressource dans le domaine de la petite pêche artisanale dans les États et Territoires insulaires océaniens, il faudrait ne plus se situer par rapport à des objectifs fixés de longue date mais embrasser une vision plus large du développement rural, qui favorise l'offre d'autres moyens de gagner sa vie et qui prône une limitation des techniques de pêche ayant un impact élevé sur l'environnement.

L'avenir du secteur de la pêche artisanale et des moyens de subsistance des populations côtières dans les pays insulaires océaniens dépendra dans une grande mesure de l'accessibilité et du potentiel de sources de revenus et de moyens de subsistance de substitution. Il faudra en effet en trouver pour réduire la pression de pêche à un degré supportable et conserver ainsi la sécurité alimentaire et les services rendus par l'écosystème. L'harmonisation des objectifs relatifs à l'exploitation des ressources, d'une part, et des objectifs de développement, d'autre part, exige que l'on promeuve la diversification, y compris des activités de substitution à la pratique de la pêche côtière dans le milieu naturel, ainsi que la mise en œuvre de stratégies de gestion qui fassent de la petite pêche côtière une partie intégrante du développement rural local. La pêche artisanale ne peut plus se gérer indépendamment de l'exploitation des autres ressources et sans égard à ses conséquences écologiques et socioéconomiques. On ne parviendra à réduire effectivement la dépendance à l'égard des ressources marines, à diminuer la pression de pêche, et à rendre les mesures de gestion restrictives plus acceptables ou moins sujettes à controverse pour les parties prenantes affectées, qu'en adoptant une approche qui intègre les stratégies de développement établies pour d'autres secteurs.

Cette approche nécessitera sans doute des évaluations des capacités d'adaptation pour l'élaboration sur mesure de programmes de développement spécifiques, correspondant aux ressources disponibles et aux aptitudes des ménages et des communautés villageoises. Il faudra également adopter une optique sensible aux sexospécificités, au-delà du domaine de la pêche, pour concevoir des modes de contribution à la sécurité alimentaire et financière propres aux hommes et aux femmes, en fonction de leurs aptitudes, ou inaptitudes respectives, à explorer des solutions de remplacement. Il faudra aussi prendre en compte les incidences des programmes de diversification des moyens de subsistance sur les participations et responsabilités respectives des hommes et des femmes, sachant que les femmes qui pratiquent la pêche constituent un groupe vulnérable qui risque de se voir submerger de travail si les responsabilités relevant de la répartition des tâches selon le sexe restent les mêmes que celles imposées par les systèmes de valeur traditionnels et culturels. Pour faire face aux difficultés économiques, les femmes pratiquant la pêche ont déjà débordé de leur rôle traditionnel en contribuant de plus en plus à la perception de revenus en espèces du ménage (en particulier en Mélanésie).

Recommandations

Vu les fortes répercussions de la pression de pêche sur les colonies de poissons, qui se traduisent par une prépondérance des poissons de petite taille et la pauvreté de la biomasse, il convient d'appliquer aux espèces de poissons un régime de gestion prudent et exhaustif dans toute la région :

- ***Limiter les engins de pêche***, en particulier la chasse sous-marine de nuit et l'emploi de filets maillants non sélectifs.

- ***Établir des quotas*** de capture pour chaque site, en fonction de son état et du degré de risque auquel il est exposé, déterminés par cette étude.

- ***Trouver et établir d'autres cibles pour la pêche***: les pêcheurs devraient envisager d'exploiter d'autres ressources. Les Acanthuridae semblent avoir subi moins de dommage et ce sont les plus opportunistes en matière de nourriture. C'est pourquoi ils appartiennent à la famille de poissons qui résiste le mieux à la pression de pêche. Il faudrait orienter les préférences alimentaires vers des ressources plus durables. Autre exemple, à certains endroits, on pourrait cibler les espèces au large et en eaux profondes. La préférence devrait être donnée aux poissons herbivores (Acanthuridae, Scaridae, Siganidae).

- ***Protéger partout les sites de concentration pour le frai***, quels que soient leur état et les risques qu'ils encourent. Ces lieux sont des sources de reconstitution de toutes les ressources, côtières, lagonaires et de haute mer.

- ***Délimiter partout des aires où la pêche est interdite, gérées par les villageois,*** pour prévoir des sources de reconstitution des stocks de poissons sur tous les sites.

- ***Concevoir des programmes de surveillance*** partout, à la fois des ressources et des captures. Pour l'évaluation des ressources sous-marines, une nouvelle méthode, gérable au niveau local, est en cours de conception; on peut néanmoins en résumer certains indicateurs et règles à l'aune desquels des mesures devront être faites périodiquement :
  - conserver le même modèle au fil du temps dans les mêmes endroits ;
  - mesurer les tailles de tous les poissons comestibles ;
  - identifier et compter les familles cibles: Acanthuridae, Scaridae, Siganidae, Serranidae, au niveau des espèces, en prêtant particulièrement attention aux espèces prisées localement et ciblées de préférence ;
  - mesurer le couvert de corail vivant et sa complexité sur place, dans les sites de plongée. S'aider pour cela des images satellite.

La gestion durable de la pêche de la bêche-de-mer, ou concombre de mer, devrait s'appuyer sur les mesures suivantes :

- ***Continuer de définir cette pêche :***
  - s'efforcer de recueillir des informations sur les groupes d'espèces concernés plutôt que sur cette ressource halieutique dans son ensemble ;
  - cartographier leur distribution – localiser les sites de pêche et en déterminer l'abondance ;
  - examiner les ensembles de données les concernant dans l'ensemble du Pacifique et décider du nombre de spécimens (densité et taille) à laisser dans l'eau pour que les espèces conservent leur capacité de reproduction.

- ***Surveiller la pêche :***
  - mettre en place par consensus une méthode de contrôle ;
  - simplifier la gestion – employer un système de fermeture/ouverture pour gérer les récoltes ;
  - apprendre aux pêcheurs toutes les composantes de cette pêche et comment les produits sont traités après la récolte ;
  - réglementer l'accès à cette pêche par le secteur des produits de la mer ;
  - instituer un système exhaustif d'inspection et de déclaration des exportations.

- ***Favoriser la croissance de ce secteur d'activité :***
  - suivre la productivité et les répercussions de cette pêche et diffuser des informations à ce sujet ;
  - suivre l'évolution du marché et diffuser des informations à son sujet ;
  - centrer ses efforts sur le développement du marché.

La gestion durable de la pêche des coquillages à nacre devrait s'appuyer sur les mesures suivantes :

- ***Continuer de définir cette pêche :***
  - cartographier la distribution des coquillages – localiser les sites de pêche et en déterminer l'abondance ;
  - examiner les ensembles de données les concernant dans l'ensemble du Pacifique et décider du nombre de spécimens (densité et taille) à laisser dans l'eau pour que les espèces conservent leur capacité de reproduction.

- ***Surveiller la pêche :***
  - mettre en place par consensus une méthode de contrôle ;
  - simplifier la gestion – employer un système de fermeture/ouverture pour gérer les récoltes ;
  - apprendre aux pêcheurs toutes les composantes de cette pêche et comment les produits sont traités après la récolte ;
  - réglementer l'accès à cette pêche par le secteur des produits de la mer ;
  - instituer un système exhaustif d'inspection et de déclaration des exportations.

- ***Favoriser la croissance de ce secteur d'activité :***
  - suivre la productivité et les répercussions de cette pêche et diffuser des informations à ce sujet ;
  - prêter assistance en facilitant la transplantation des trocas dans des zones leur offrant un habitat qui leur convienne mieux ;
  - suivre l'évolution du marché et diffuser des informations à ce sujet ;
  - s'employer à favoriser en même temps l'accès au marché et l'ouverture de débouchés commerciaux.
  - La gestion durable des bénitiers devrait s'appuyer sur les mesures suivantes :

- ***Continuer de définir cette pêche :***
  - cartographier la distribution des bénitiers – localiser les sites de pêche et en déterminer l'abondance ;
  - examiner les ensembles de données les concernant dans l'ensemble du Pacifique et décider du nombre de spécimens (densité et taille) à laisser dans l'eau pour que les espèces conservent leur capacité de reproduction.

- ***Surveiller la pêche :***
  - mettre en place par consensus une méthode de contrôle (exploiter la base de données océanienne et les conseils sur les techniques d'échantillonnage) ;
  - apprendre aux pêcheurs toutes les composantes de cette pêche ;
  - délimiter des aires fermées, où leur prélèvement est interdit, pour protéger les bénitiers parvenus à maturité et constituant le stock reproducteur.

- ***Favoriser la croissance de ce secteur d'activité :***
  - suivre la productivité et les répercussions de cette pêche et diffuser des informations auprès des communautés villageoises et des pays ayant ces mêmes ressources.

ACRONYMS

ACP	African, Caribbean and Pacific Group of States
AIMS	Australian Institute of Marine Science
ANOVA	analysis of variance
BdM	bêche-de-mer (or sea cucumber)
CANOCO	canonical community ordination
CAP	canonical analysis of principal coordinates
CITES	Convention of International Trade in Endangered Species
CNMI	Commonwealth of the Northern Marianas
CoB	centre of biodiversity
CoFish	Pacific Regional Coastal Fisheries Development Programme
CPI	Consumer price index
CPUE	catch per unit effort
DFID	Department for International Development
Ds	day search
D-UVC	distance-sampling underwater visual census
DWs	Deep-water SCUBA search
EDF	European Development Fund
EEZ	exclusive economic zone
EU/EC	European Union/European Commission
FAD	fish aggregating device
FAO	Food and Agricultural Organization of the United Nations
FL	fork length
FSM	Federated States of Micronesia
GDP	gross domestic product
GIS	geographic information system
GNS	GEONet Names Server
GPS	global positioning system
ha	hectare
HH	household
H_b/C_b	biomass ratio of herbivores over carnivores
H_s/C_s	catch ratio of herbivores over carnivores
HP	horse power
ICES	International Council for the Exploration of the Sea
ICLARM	International Center for Living Aquatic Resources Management (now WorldFish Center)
IUCN	International Union for Conservation of Nature
MCRMP	Millennium Coral Reef Mapping Project
MIRAB	Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations)

MOP	mother-of-pearl
MOPs	mother-of-pearl search
MOPt	mother-of-pearl transect
MPA	marine protected area
MSA	medium-scale approach
NASA	National Aeronautics and Space Administration
NCA	nongeniculate coralline algae
Ns	night search
OCT	Overseas Countries and Territories
PCA	principal component analysis
PERMANOVA	permutational multivariate analysis of variance
PGR	population growth rate
PICTs	Pacific Island countries and territories
PNG	Papua New Guinea
PRDA	partial redundancy analysis
PROCFish	Pacific Regional Oceanic and Coastal Fisheries Development Programme
PROCFish/C	Pacific Regional Oceanic and Coastal Fisheries Development Programme (coastal component)
RB_{LS}	relative biomass of all major piscivores (Lutjanidae and Serranidae)
RBt	reef-benthos transect
RB_{20}	relative biomass of fish of size <20 cm
RDA	redundancy analysis
RDL_{52}	relative density of species of maximum size 52 cm
RFID	Reef Fisheries Integrated Database
RFO	Reef Fisheries Observatory
RFs	reef-front search by swimming
RFs_w	reef-front search by walking
SBq	soft-benthos quadrat
SBt	soft-benthos transect
SCUBA	self-contained underwater breathing apparatus
SE	standard error
SEMCoS	Socioeconomic manual companion software
SES	social-ecological system
SiQ	soft-infaunal quadrat
SLA	Sustainable Livelihoods Approach
SPC	Secretariat of the Pacific Community
SSR	spawning stock recruitment
SWs	Shallow-water timed SCUBA search
SWt	Shallow-water SCUBA transect
t	tonnes (metric)

UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USD	United States dollar(s)
UVC	underwater visual census
WCPO	Western and Central Pacific Ocean
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 two-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 Pacific Regional 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 Cook Islands, Federated States of Micronesia, Marshall Islands, Nauru, Niue and Palau, and is funded under EDF 9.

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

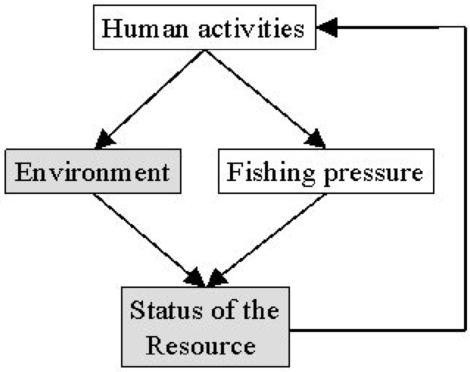


Figure 1.1: Synopsis of the PROCFish/C* multidisciplinary approach.
PROCFish/C conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the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

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

Expected outputs of the project include:

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

1.2 PROCFish/C and CoFish methodologies

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

1.2.1 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 1.1 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).

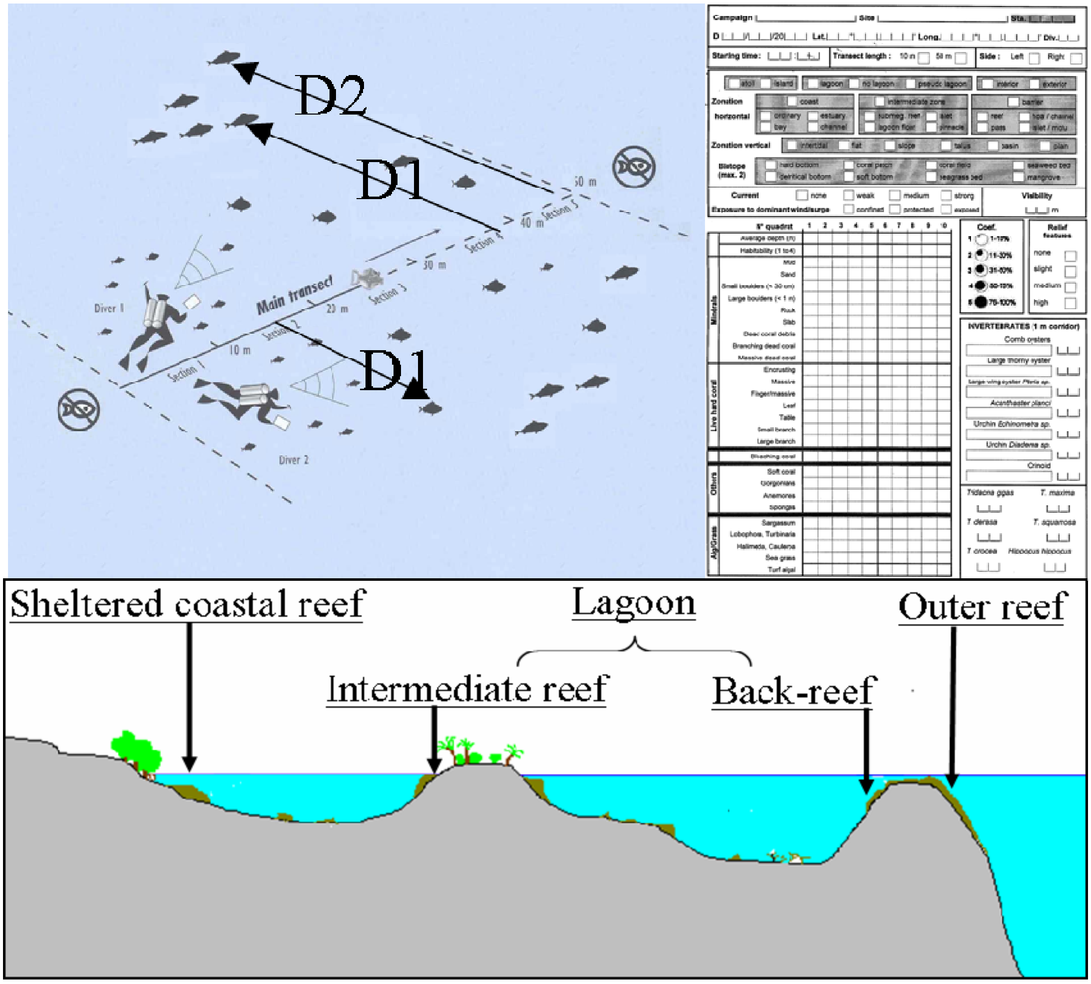


Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

1.2.2 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).).[3]

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 Figure 1.3 (5) and (6).); and using SCUBA (Figure 1.3 (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 1.2 for complete methods.).

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

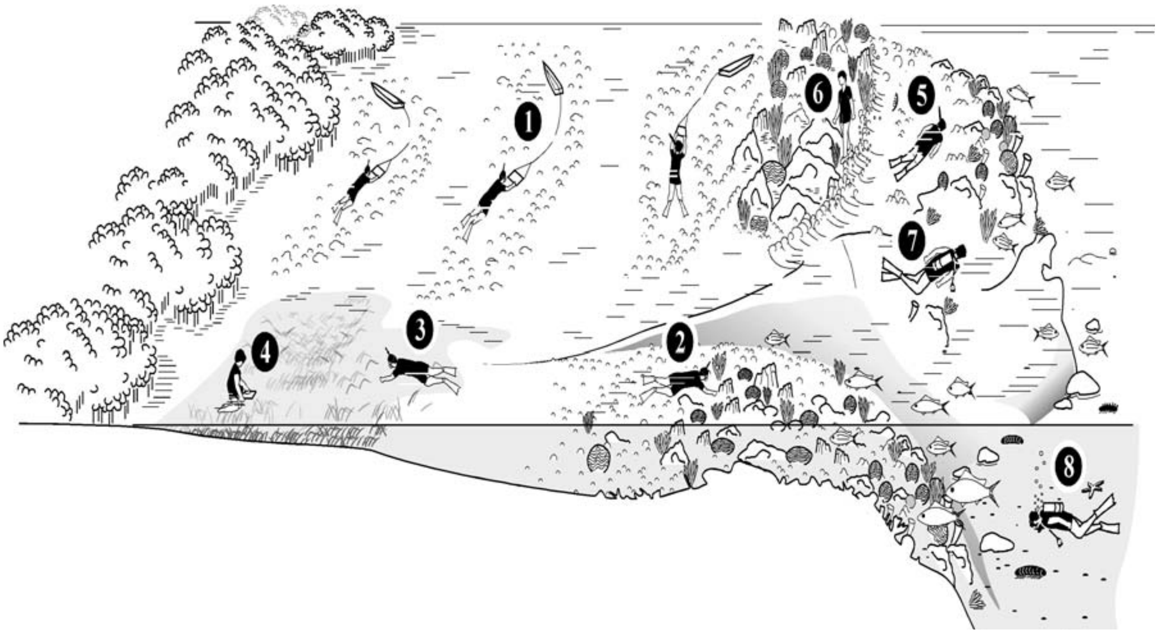


Figure 1.3: Assessment of invertebrate resources and associated environments.
Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epi-benthic resources and potential indicator species (2) and (3); quadrats to count targeted infaunal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

1.2.3 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.

1.3 The Pacific region

1.3.1 General

The Pacific region (Figure 1.4) is made up of 22 Pacific Island countries and territories (PICTs). The total population of the region is around 9.5 million (Table 1.1), with around 68% of the total population in one country, Papua New Guinea.

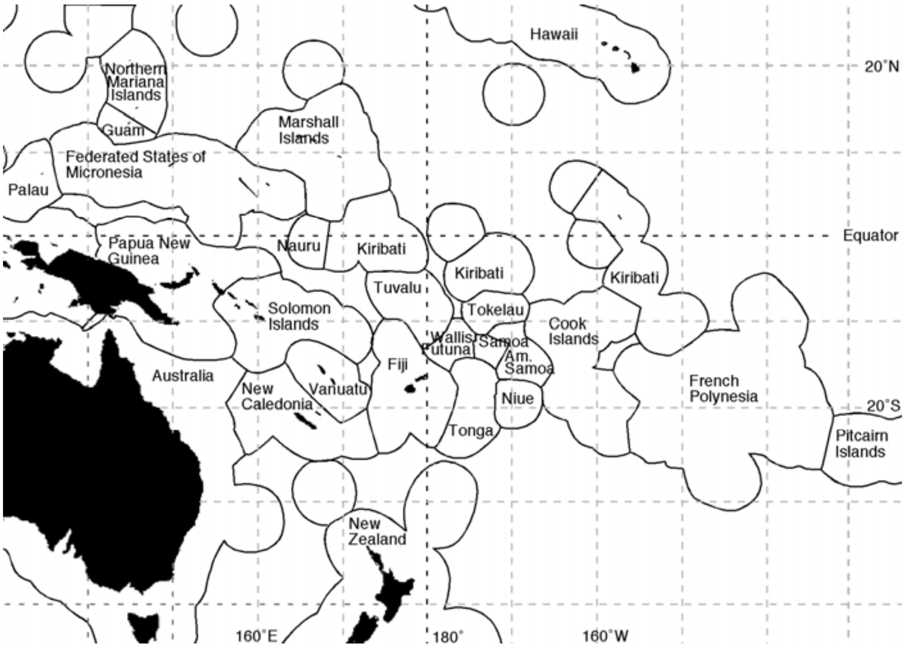


Figure 1.4: The Pacific region showing all 22 PICTs and their EEZs.

The total land area of the 22 PICTs amounts to around 551,424 km^2 (SPC 2008a, Table 1.1), with over 83% of the land located in Papua New Guinea. In contrast, the total area of ocean under the jurisdiction of PICTs amounts to over 29 million km^2. The high ratio of ocean area to land area (roughly 53:1) highlights the importance of the ocean and its resources to the people of the PICTs.

Table 1.1: Summary of the population, approximate land area (SPC 2008a) and approximate ocean area for each PICT

Country/Territory	Population (2008 mid-year estimate)	Approximate land area (km^2)	Approximate ocean or EEZ area (km^2)
American Samoa	66,107	199	390,000
Cook Islands	15,537	237	1,830,000
Federated States of Micronesia	110,443	701	2,780,000
Republic of the Fiji Islands	839,324	18,272	1,290,000
French Polynesia	263,267	3521	5,030,000
Guam	178,980	541	218,000
Republic of Kiribati	97,231	811	3,550,000
Republic of the Marshall Islands	53,236	181	2,131,000
Republic of Nauru	10,163	21	320,000
New Caledonia	246,614	18,576	1,740,000
Niue	1549	259	390,000
Commonwealth of the Northern Mariana Islands	62,969	457	777,000
Republic of Palau	20,279	444	629,000
Papua New Guinea	6,473,910	462,840	3,120,000
Pitcairn Islands	66	39	800,000
Samoa	179,645	2935	120,000
Solomon Islands	517,455	28,370	1,340,000
Tokelau	1170	12	290,000
Kingdom of Tonga	102,724	650	700,000
Republic of Tuvalu	9729	26	900,000
Republic of Vanuatu	233,026	12,190	680,000
Wallis and Futuna	15,472	142	300,000
TOTAL	**9,498,896**	**551,424**	**29,325,000**

1.3.2 The fisheries sector

The total regional fishery and aquaculture production in 2007 within the EEZs of the 22 PICTs was 1,330,345 t plus 305,336 pieces (from aquaculture production). The majority of this catch (1,148,781 t valued at USD 1,513,418,176) was tuna as part of the industrial tuna fishery. The balance of 181,564 t (valued at USD 536,045,411) was made up of subsistence, small-scale coastal commercial, freshwater and aquaculture production (Gillett 2009), which the people of the PICTs rely on for food security and livelihoods. Therefore, the fisheries sector in the Pacific can be categorised into three broad groups: the offshore tuna fishery, the inshore fishery (including small-scale nearshore activities and reef fisheries) and aquaculture/mariculture (including culture in rivers and inland waters).

Offshore tuna fishery

The offshore tuna fishery in the western and central Pacific Ocean (WCPO) targets four species of tuna: skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*T. obesus*) and albacore (*T. alalunga*). The three main fishing methods used are purse seining, longlining and pole-and-line fishing. The catch of tuna in the WCPO area in 2008 was 2.4 million t (estimated delivered value of USD 4.4 billion), or 56% of the global tuna catch (OFP 2009a, b). This was the highest tuna catch recorded in the WCPO (Figure 1.5), with purse seining the main method and skipjack making up the majority of the catch

(OFP 2009a). Approximately half of the catch (1.2 million t) comes from the EEZs of PICTs (OFP 2009a).

A growing proportion of the WCPO offshore tuna catch is being taken by PICTs, and Papua New Guinea is establishing several tuna canneries and loining facilities to maximise the economic return and employment opportunities for its people. At the same time, the historical distant water fishing nations want to retain their share of the catch (OFP 2009a) and more tuna is going to be needed domestically for food security given the estimated population increase of 50% by the year 2030 (Bell 2008). Therefore, there is an urgent need for the PICTs to take the lead in the long-term conservation and sustainable use of the tuna resource in the region.

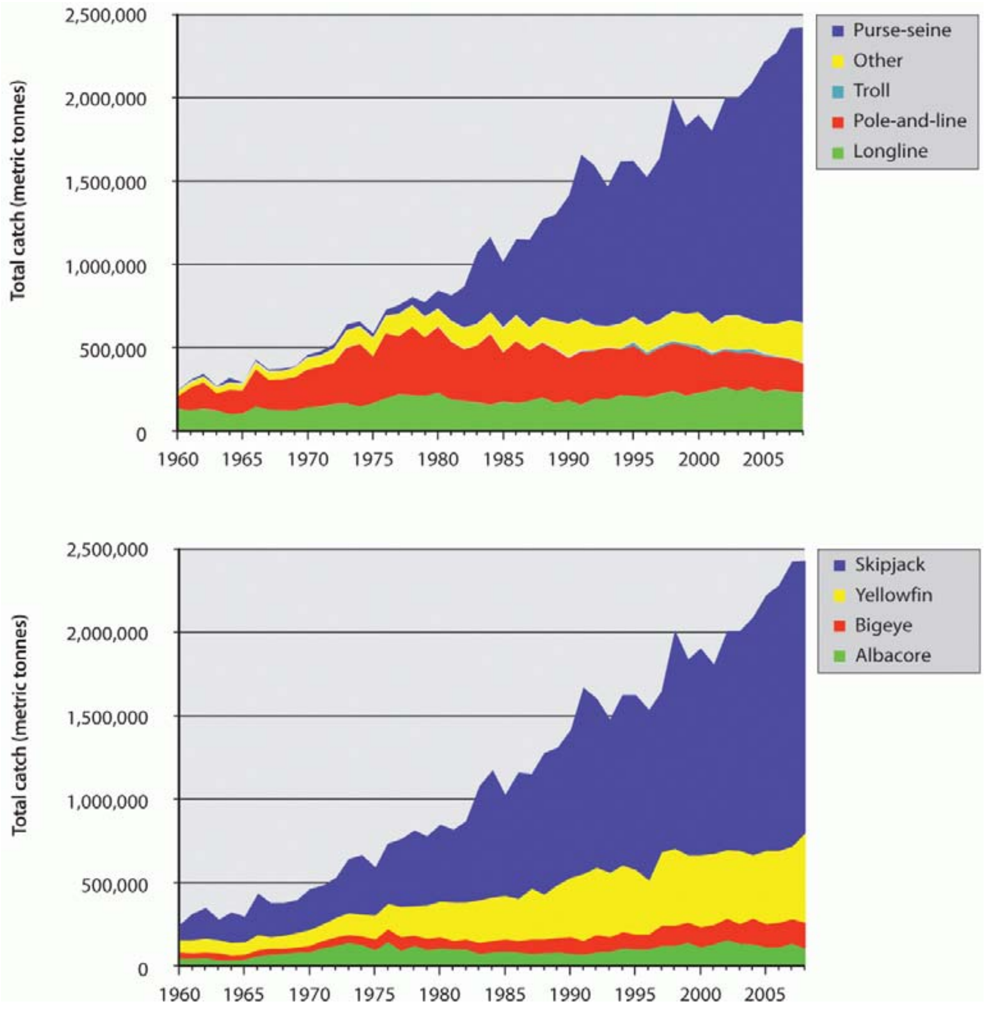


Figure 1.5: Total catch of tuna (skipjack, yellowfin, bigeye and albacore) in the WCPO by longline, pole-and-line, purse-seine, troll and other gear types (OFP 2009a).

The inshore (coastal) fishery

Coastal fisheries, including reef finfish and invertebrate resources as well as coastal pelagics, provide the major source of national food security and rural income. Bell (2008) estimates that an additional 115,000 t of fish will be needed in 2030 to maintain traditional patterns of consumption. Given that many coastal or reef resources are fully exploited, or over exploited in the case of commercial invertebrate species, food security is at risk given the estimated population growth and the need to increase fish production. There are also the added effects of climate change, which will only add to the vulnerability of PICTs with regard to maintaining sustainable subsistence production.

Commercial invertebrates appear to be the most heavily fished according to the early results of the PROCFish/C work (SPC 2008b). Figure 1.6 shows that many survey sites had stocks of the high-value/low-density indicator species black teatfish (*Holothuria whitmaei*) at levels well below the threshold needed for a healthy fishery. The same is true for many other species of sea cucumber and also for trochus.

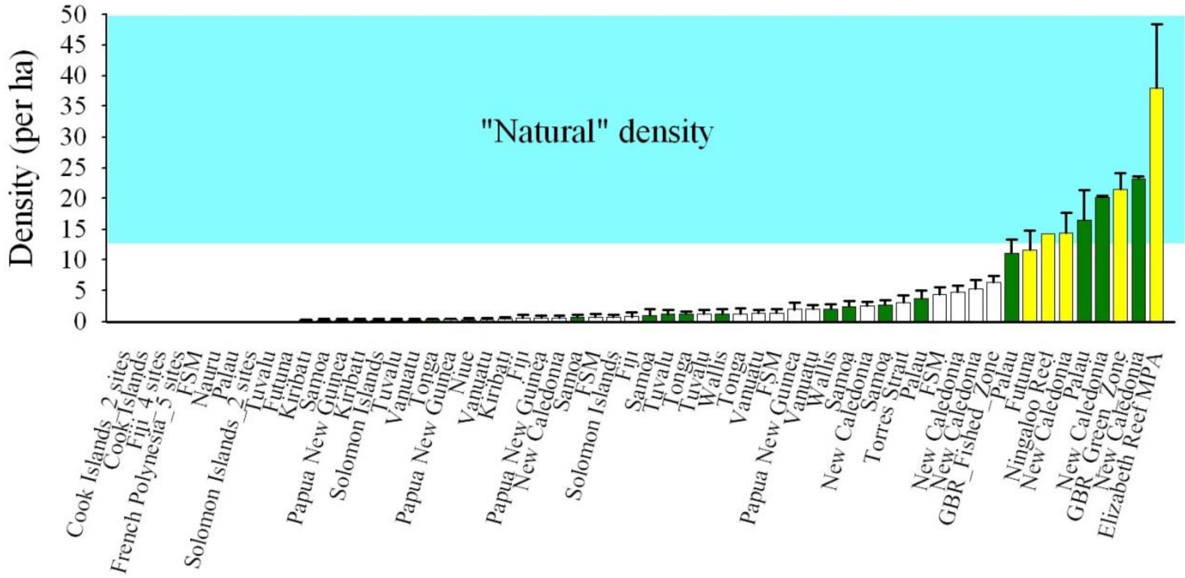


Figure 1.6: Density of the high-value/low density sea cucumber indicator species black teatfish (*Holothuria whitmaei)* across the 63 PROCFish/C sites plus several sites in northern Australia and the Torres Straits (SPC 2008b). Remote marine protected areas, and unfished sites are presented as yellow bars, while green bars represent areas where fishing has been halted for a decade or more. For this indicator species, densities over 12.5 animals/ha are considered to be the "Natural" density and the threshold for fishing/non-fishing activity. For countries where this species was not recorded, the number of sites is indicated.

Other coastal fisheries of importance include the export aquarium trade (fish, corals, invertebrates, etc.), the reef finfish fishery for domestic consumption (subsistence and small-scale commercial), the deep-water snapper fishery (export and domestic) and small-scale pelagic fisheries. Several countries want to expand, or in some cases enter the wild-caught aquarium fish trade, and there does seem to be scope for expansion of this fishery, provided it is done sustainably and remains economically viable. Reef finfish fisheries, on the other hand, are showing signs of overfishing, especially around main urban centres, and urgent management is needed to ensure the harvesting of these resources is sustainable (SPC 2008b).

Deep-water snapper fishing has been tried across the region over the last 30 plus years with varying degrees of success, mainly due to stock limitations and high transportation costs to export markets. Ongoing fisheries have developed in Samoa, Tonga, New Caledonia and French Polynesia while, in many other PICTs, this fishery is more *ad hoc* (McCoy 2009), with limited scope for further development. One area for future development is the nearshore pelagic fishery for tuna and associated species. The use of fish aggregating devices assists small-scale fishers to increase catches through both targeting the surface-swimming tuna (for the domestic market) and fishing deep in the water column for the larger tuna (for the domestic market and possibly export).

Aquaculture and mariculture

There has been a large increase in aquaculture globally with almost 50% of the world's food fish now coming from aquaculture (Figure 1.7). Based on figures from the Food and Agriculture Organization of the United Nations (FAO), the aquaculture production in 2004 was around 60 million t, worth USD 70 billion, compared to less than one million tonnes in the early 1950s (SPC 2008b).

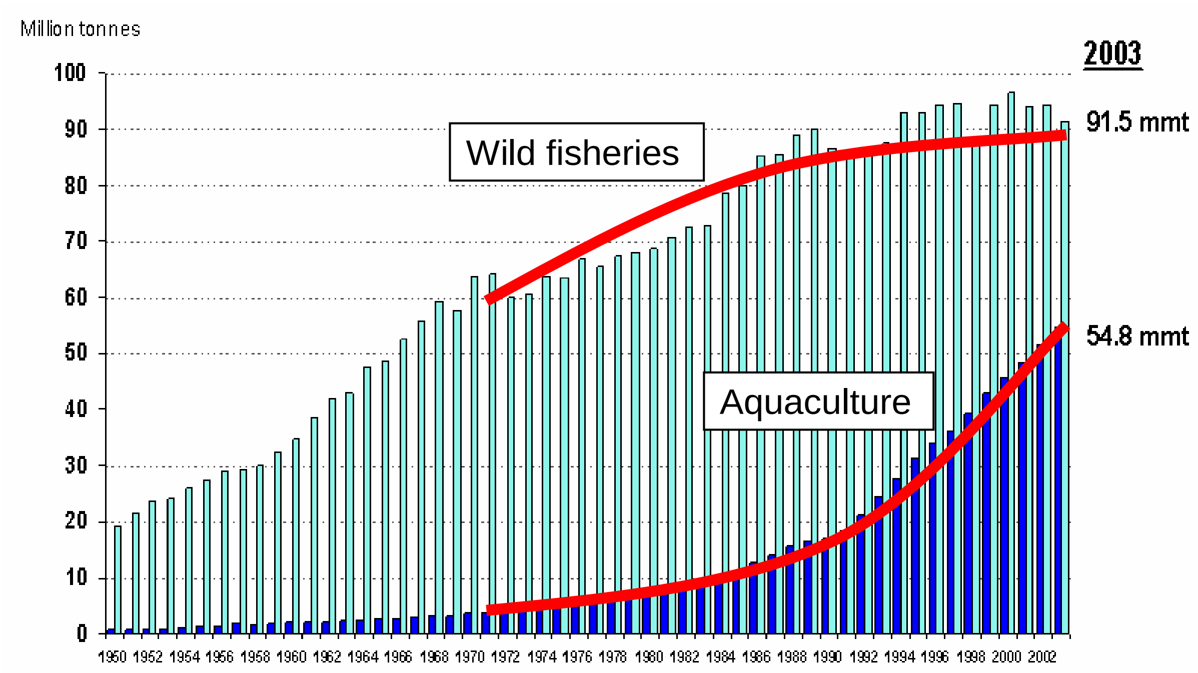


Figure 1.7: FAO figures for world production of fisheries and aquaculture (quoted in SPC 2008b).

In the Pacific, the value of aquaculture production has fluctuated over the last decade or more from USD 140 million in 2003 to highs of USD 222 million in 1999 and 2005, and the 2007 value estimated at USD 211 million (Ponia 2010). The main aquaculture production, in terms of financial value, is the pearl production of French Polynesia (USD 180 million in 2005) and shrimp production in New Caledonia (USD 37 million in 2005), with all other commodities making up the difference (Ponia 2010).

The latest production and value figures are for 2007, with pearls being the most valuable; French Polynesia produces 98% of these, valued at USD 173 million. Other Pacific countries producing pearls are Tonga, Papua New Guinea (PNG), Marshall Islands, Fiji Islands, Federated States of Micronesia (FSM) and Cook Islands, with a total value of USD 3.9 million in 2007 (Ponia 2010). Shrimp is the second most valuable aquaculture product in the region; New Caledonia produced 1800 t or 90% of regional production in 2007, valued at USD 28 million. Other Pacific countries producing shrimp are Vanuatu, Solomon Islands, PNG, Northern Mariana Islands, Guam, French Polynesia and Fiji Islands, with a total production of 204 t, valued at USD 2.7 million (Ponia 2010).

Other main aquaculture commodities include giant clams and corals farmed for the ornamental trade, *Kappaphycus* seaweed, and tilapia. The main countries culturing clams for the aquarium trade are FSM, Marshall Islands, and Tonga, with 69,000 pieces exported in 2007. Corals were exported from Solomon Islands, Marshall Islands and Fiji Islands. The combined value of clam and coral exports in 2007 was USD 470,000 (Ponia 2010). While production of some commodities is expanding, the production of seaweed has greatly reduced from over 1800 t in 2000 to less than 200 t in 2007, due to high freight costs, warm water temperatures and poor currency exchange. Tilapia production has also fluctuated; around 450 t were produced in 1999, dropping to almost zero in 2003, and rising to around 370 t in 2007, with the main countries being Vanuatu, Samoa, American Samoa, Cook Islands, Northern Mariana Islands, Guam, and PNG (Ponia 2010).

1.4 Selection of sites in the region

In total, 63 sites were surveyed by the PROCFish/C and CoFish projects (Figure 1.8 and Table 1.2). Each of these sites was selected for two reasons.

First, sites shared most of the required characteristics for our study:
- they had active reef fisheries;
- they were representative of the country/territory;
- they were relatively closed systems[4];
- they were appropriate in size;
- they possessed diverse habitats;
- they presented no major logistical limitations that would make fieldwork unfeasible;
- they had been investigated by previous studies; and
- they presented particular interest for the fisheries department in each country or territory.

Second, there was a mix of marketing arrangements for the non-subsistence catch: road-side sales; exports to the capital city and/or other main urban centre for sale; and export of some species, such as trochus, to overseas markets.

Table 1.2 also provides the approximate timing of the in-country fieldwork.

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

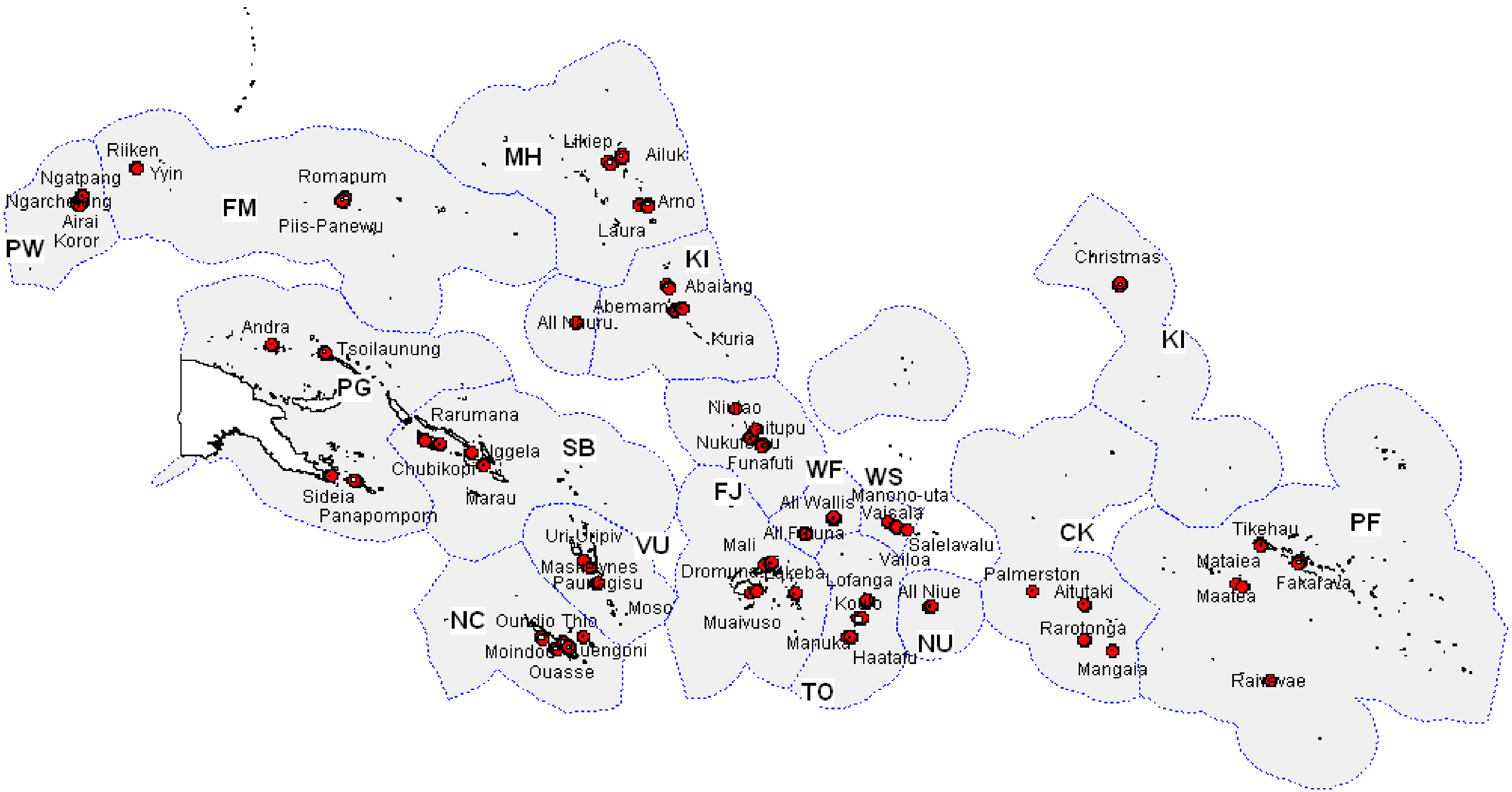


Figure 1.8: Map of the 63 sites selected for survey across the region.
For names of sites and country and territory abbreviations refer to Table 1.2 and Appendix 2.2.
Note: Christmas Is. is referred to as 'Kiritimati' throughout the text.

Table 1.2: Countries with corresponding abbreviations, sites and approximate timing of in-country fieldwork

Country/Territory	Sites	Approximate timing of fieldwork
Cook Islands (CK)	Aitutaki, Mangaia, Palmerston, Rarotonga	February and October 2007
Fiji Islands (FJ)	Dromuna, Lakeba, Muaivuso, Mali	September to November 2002; April to June 2003; Re-survey June and July 2007; February 2009
French Polynesia (FP)	Fakarava, Maatea, Mataiea, Raivavae, Tikehau	September to October 2003; January to March 2004; May to June 2006
Federated States of Micronesia (FM)	Piis-Panewu, Riiken, Yyin, Romanum	April and May 2006
Kiribati (KI)	Abaiang, Abemama, Kiritimati (Christmas), Kuria	May to November 2004
Marshall Islands (MI)	Ailuk, Arno, Laura, Likiep	August and September 2007
Nauru (NR)	Nauru	October and November 2005
New Caledonia (NC)	Luengoni, Moindou, Ouassé, Oundjo, Thio	March, April and November 2003; January, February, April, June, August and November 2004; April and May 2005; January to March 2006; January and February 2007
Niue (NU)	Niue	May and June 2005
Palau (PW)	Airai, Koror, Ngarchelong, Ngatpang	April to June 2007
Papua New Guinea (PG)	Andra, Panapompom, Sideia, Tsoilaunung	June to November 2006
Samoa (WS)	Manono-uta, Salelavalu, Vailoa, Vaisala	June and August/September 2005
Solomon Islands (SB)	Chubikopi, Marau, Nggela, Rarumana	June to September and December 2006
Tonga (TO)	Ha'atafu, Koulo, Lofanga, Manuka	November and December 2001; March to June 2002; Re-survey April to June, September and October 2008
Tuvalu (TV)	Funafuti, Niutao, Nukufetau, Vaitupu	October to November 2004; March to April 2005
Vanuatu (VU)	Maskelynes, Moso, Paunagisu, Uri-Uripiv	July to December 2003
Wallis and Futuna (WF)	Futuna, Halalo, Vailala	August to December 2005; March 2006

2. PROFILE AND RESULTS FOR FINFISH ASSESSMENT

2.1 Summary of finfish survey approach and method

Underwater visual census (Labrosse *et al.* 2002) was used to assess commercial finfish resources. This method consists in recording the species name, abundance, body length and distance to the 50 m transect line of each fish or group of fish observed. For the purpose of evaluating density and biomass, calculations were done from the counts considering a corridor area of 5 m distance each side of the tape, for a total volume of water assessed of 50 m x 10 m. Only reef fish of interest for consumption or sale and species that could potentially serve as indicators of coral reef health were surveyed. For size analysis, all data to the maximum distance were included in calculations. At the same time, a description of the substrate was done along the same surface determining, among many other variables, the area of coverage of the following substrate categories: live coral, dead coral, rubble (coral debris), bedrock, and sand. More detailed information on substrate was collected at the transect (station) level, but only average values of some of such assessed categories were analysed to detect differences among reef types and sites.

Fish and associated habitat parameters were generally recorded along 24 transects per site, with a balanced design among the main geomorphologic structures or reef types present at a given site (at least six transects in each of the reef types present). For the specific needs of the finfish resource assessment, reef types were grouped into the four main coralline geomorphologic structures found in the Pacific: sheltered coastal reef, intermediate lagoon reef (patch reef that is located inside a lagoon or a pseudo-lagoon), back-reef (inner/lagoon side of outer reef), and outer reef (ocean side of fringing or barrier reefs). Maps from the NASA MCRMP (Andréfouët *et al*. 2006), satellite images, and *in situ* observation at dive sites allowed identification of these habitats and calculation of reef areas in each site studied.

Composition and diversity of habitat at a larger scale (large-scale habitat complexity, at the scale of 10 km) were summarised by a computed variable, L4, equivalent to the average number of substrate pixels obtained by satellite photos describing substrate composition in a 10 km radius around each site.

Islands were grouped into four major morphological types, as a function of their geological development and distribution of reefs, based on a description compiled by South *et al.* (2004); this classification is defined in Table 2.1, with all habitat descriptors given in Table 2.2.

Table 2.1: Definition of four types of island based on geomorphology and composition of reefs

Island type and number of sites	Atoll (13)	Complex island (28)	Island with small lagoon (7)	Oceanic island (15)
Description of characteristic	Latest stage of a tropical island. No more native rocks; land is old reef or beach rock. Barrier reef with some *motu*, central lagoon	Includes barrier reef, back-reef, intermediate reef, deep lagoon, large-fringing reef, might include sea grass beds, mangroves	Intermediate reef complexity with no full-sized lagoon between a barrier reef and a fringing reef; might hold some parts of deep lagoon	Young fringing reef, almost exposed at low tide, sometimes with shallow and very limited pools; includes systems with lagoon in formation
Site examples	Likiep (MI), Piis-Panewu (FSM)	Chubikopi (SB)	Maatea (FP)	Niue, Mangaia (CK)
	Age of formation ←			

Table 2.2: List of selected large-scale habitat variables used in the analysis, including transformed variables (in order to linearise some of them)

Definition and number of transformed parameters	Abbreviation	Unit of measure
Latitude (2)	lat1, lat2	Described by two values each for linearisation of the variable
Longitude (2)	long1, long2	Described by two values each for linearisation of the variable
Island types (4)	as in Table 2.1	Described by binary values (presence/absence for each site)
Large-scale substrate diversity (1)	L4_10 km	Average number of categories describing substrate diversity of substrate pixels from satellite photos in a 10 km radius from site
Importance of coastal reef (1)	Coastal	Surface area in km^2 covered by coastal reefs
Importance of lagoon reef (1)	Lagoon	Surface area in km^2 covered by lagoon reefs
Importance of back-reef (1)	Back	Surface area in km^2 covered by back-reefs
Importance of outer reef (1)	Outer	Surface area in km^2 covered by outer reefs

lat = latitude; long = longitude; L4 = computed variable equivalent to the average number of substrate pixels obtained by satellite photos describing substrate composition in a 10 km radius around each site.

Data from the 63 sites and 1459 transects sampled from all the 17 countries were analysed. A total of 91 commercial genera and 392 species were counted, belonging to the 15 major commercial and indicator families: Acanthuridae, Balistidae, Chaetodontidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Nemipteridae, Pomacanthidae, Scaridae, Serranidae, Siganidae and Zanclidae. No Mugilidae were included in the underwater assessment due to their typical habitat (shallow turbid waters) not being adapted for diving and counting. Carangidae are too mobile and not strictly associated with coral reefs, therefore too difficult to properly sample using the UVC method (Kulbicki *et al.* 2007).

For analysis, fish were also assigned trophic guilds according to their most common diet, as recorded on FishBase (Froese and Pauly 1997) and from Kulbicki *et al.* (2005). Trophic categories were simplified as four major classes: herbivores, invertebrate-feeders, planktivores and piscivores. The total sample size for fish was 571,254, recorded in 162,436 observations. Only 11 families, 76 genera and 251 species were considered in this analysis due to the presence of too many missing values for Kyphosidae and Nemipteridae and to the low and rare commercial importance of Chaetodontidae and Pomacanthidae (counted for further types of reef-health assessment).

A more detailed description of the survey approach, analysis methodology and variables can be found in Appendix 2.1.

2.2 General description of finfish resource distribution throughout the region

Although many studies have been conducted to determine the state of commercial fisheries resources and the level of their impact (for example Costello *et al.* 2008, Daan *et al*. 2005, Hilborn 2002, Jackson *et al.* 2001, Mullon *et al.* 2005, Myers and Worm 2003, Pauly *et al.* 1998, Pauly 2002, Pauly *et al.* 2003, Rosenberg 2003), very little attention has been given to the assessment of tropical coastal resources in the Pacific, probably due to the low cash flow related to them (Kulbicki *et al*. 2004). Some of the missing information on the status of fish resources in the Pacific Islands region is being filled by this first large-scale study on reef fish conditions at sites that support artisanal fisheries for mostly self-subsistence reasons.

In order to present the results from these assessments, it is firstly essential to understand how resources naturally change in time and space, before analysing any possible effect from fishing, to make sure that general variations due to natural causes are identified as well as human impacts. Fish stocks vary on a temporal scale as well as on a spatial scale (Caley 1993, Friedman and Wolff 2008, Kulbicki *et al.* 2007), due to the variation of environmental conditions as well as the variation in ecological interactions, such as larval supply, recruitment and predation of fish (Doherty and Williams 1988, Talbot *et al.* 1978). Unfortunately, we do not have access to historical data for the entire region; therefore, changes on a temporal scale are to be disregarded.

The difficulty of defining status and extracting indicators of the level of fishing impact already implied in the multi-species and multi-gear nature of these fisheries is amplified in this study by the very large geographical scale. As many of the habitat variables vary along geographical gradients, latitudinal and longitudinal effects are analysed as primary inducers of variability on coral-reef communities. The 9000 by 4000 km surface bears in itself wide differences of habitat relevance: the seventeen countries are characterised by a high diversity of geomorphologic types of island, which are under the effect of different terrestrial as well as oceanographic conditions and nutrient inputs. Differences in nutrients induce different ecological responses on the associated coral reefs as well as different levels of production of the whole trophic web, both directly and indirectly: insufficient levels of nutrients limit standing stocks and affect the number and quality of species that co-exist, which in turn affect biomass production in itself (Cardinale *et al.* 2009).

The parameters used here to define the habitat at a large scale are only a very limited selection of the possible causes of distribution and production of coral reef resources. Variables such as currents and upwellings, temperature, nutrient inputs, sedimentation, and bathymetric complexity would help improve the understanding of natural variability. However, for such a large-scale and large-scope research and due to the limitation of time and means, all such measurements could not be taken into account.

In addition to the extensive latitudinal and longitudinal range to be considered, the geology and morphology of islands (identified as types of islands at different ages of formation and different physical structures) are considered to be basic drivers of the fish communities at an intermediate scale. In addition, reef complexity at a smaller scale (the scale of the reefs at the fishing villages studied) is tested as having a possible influence on the fish community composition. Such complexity is summarised by the number of types of substrate obtained from satellite images (Millennium Coral Reef Mapping Project (MCRMP), Andréfouët *et al.* 2006) at a scale of 10 km around the fishing village and by the area covered by the four main reef types assessed. At an even smaller scale (the transect level), the reef complexity is represented by the composition of substrate descriptors. All these indicators describe the spatial heterogeneity of coral reefs, which is of extreme relevance in resource assessment due to the high patchiness and discontinuity of reef presence and coverage and the specific association of fish to them (Medley *et al.* 1993).

Not including habitat variability in resource studies can lead to wrong estimations of resource status and impact from fishing. Moreover, environmental variability is closely related to climate change, a variable that is currently considered a crucial prerequisite for any resource managerial decision (Friedman and Wolff 2008).

The association of species and the production of an ecosystem at a specific location are not the only variables changing in relation to geography and habitat; fishing practices are also highly related to the environment. To the variability of the geomorphology of islands and reefs, a high diversity of conditions at a social level is added: different customs drive different fishing requirements, practices and target species.

Therefore, it is necessary to study how the variation due to the natural conditions shapes both the ecology of fish and humans in order to assess the status of resources (Figure 2.1).

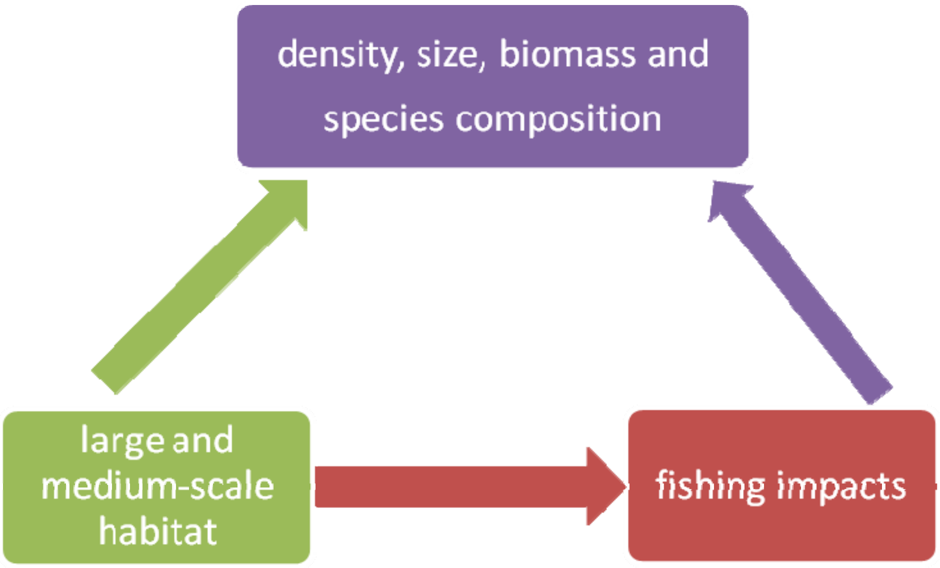


Figure 2.1: Relation among the different components of this study.
Habitat diversity influences both fishing practices and fish community ecology (species composition, density and size of the components of the system). Fishing practices have a direct influence on the ecological community.

2.2.1 Geographical variation of habitat

Latitude and, to a lesser extent, longitude influence the fish stock in an important way, both directly as well as by being the cause of habitat differences. Latitude has an influence on the distribution of different types of islands (See Appendix 2.3 for island-type classifications.): whereas oceanic islands of volcanic origins and islands with small lagoons are mostly found closer to the equator, complex islands are more concentrated to the west, and atolls to the north and east (Figure 2.2).

Total reef area varies greatly from site to site, from reef surfaces as small as 1 km^2 in front of a single village to much larger reef surfaces covering almost 200 km^2 (Appendix 2.4 provides a percentage split of area for reef types.). Total reef area per site is higher at complex islands and atolls compared to islands with small lagoons and oceanic islands ($P_{ANOVA} < 0.01$).

Another source of spatial complexity is the composition of reef types, related mostly to the geomorphological configuration of the islands: presence as well as percentage composition of the main four classes of reef defined and used in this study, i.e. coastal, lagoon, back- and outer reefs (Tables 2.1 and 2.2) vary greatly throughout the region. Atolls have comparatively large areas of outer reefs but no coastal reefs; therefore, they are characterised by no terrigenous inputs from land, but by a high influence of nutrients coming from the outer ocean through currents and upwellings. Complex islands have a large area of coastal, lagoon and back-reef and are also characterised by the highest complexity of habitats and substrate diversity. Oceanic islands have large areas of outer as well as back-reefs (Figure 2.3). Larger reef areas are associated with coastal, back- and lagoon reefs compared with outer reefs ($P_{ANOVA} < 0.01$, Figure 2.4).

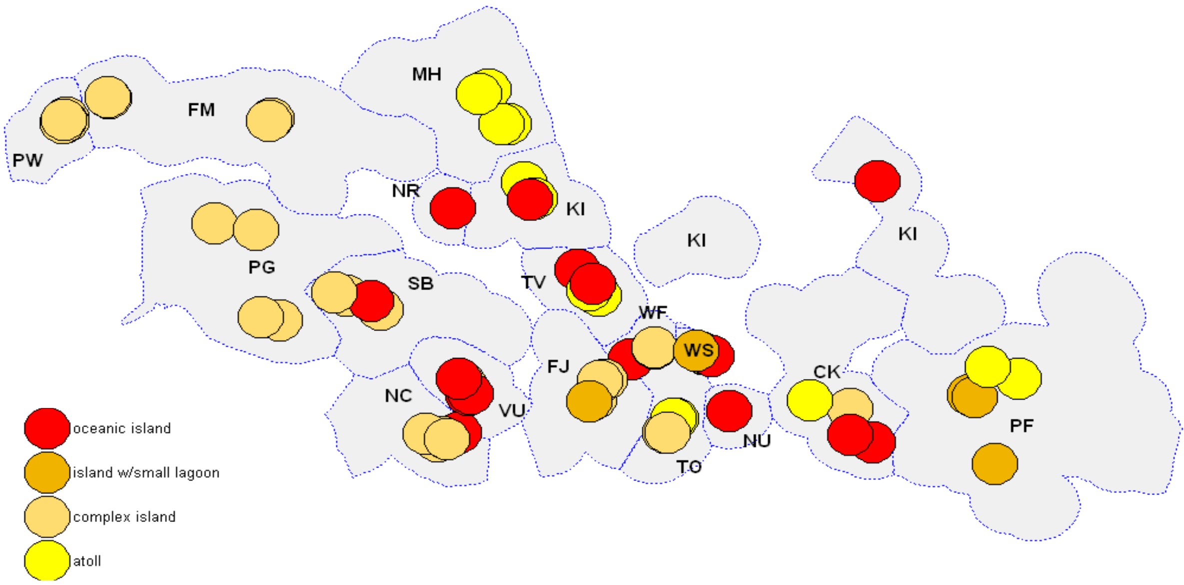


Figure 2.2: Sites identified by island type.
In order of decreasing age: atoll, complex islands, islands with small lagoons, oceanic islands.

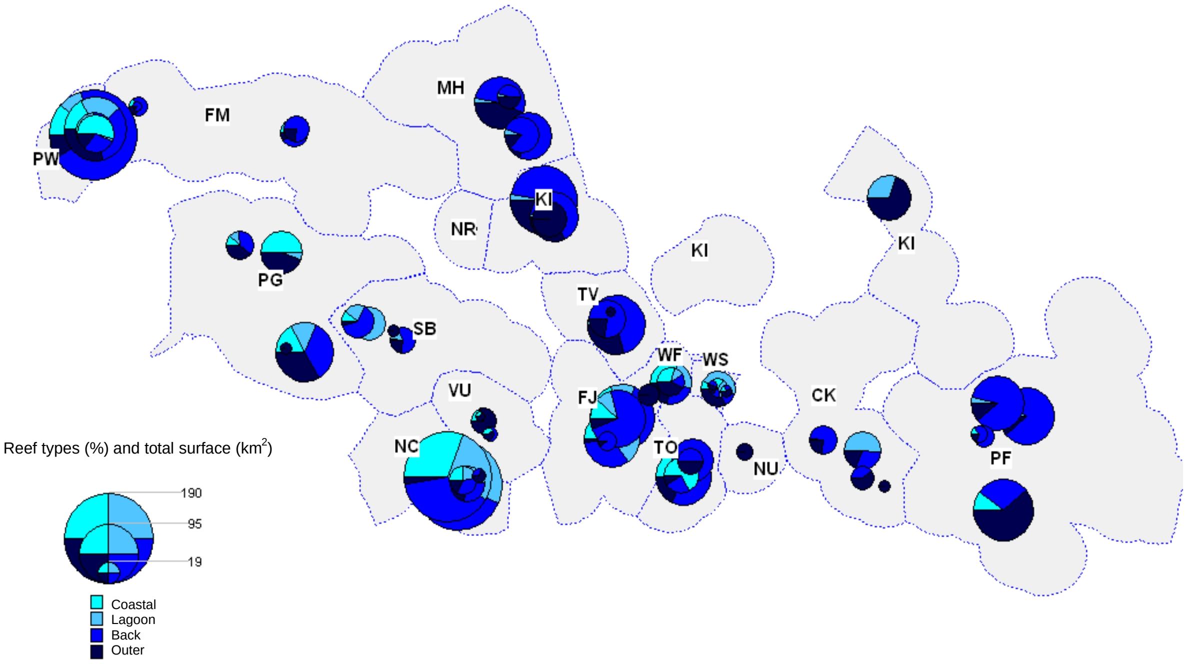


Figure 2.3: Percentage cover of surface area of each of the four reef types in each site and total cover of selected reef.

Substrate composition varies widely among different types of islands. Percentage of average live coral is higher at atolls and complex islands and lower at oceanic islands (P_{ANOVA} = 0.02). Dead coral (P_{ANOVA} = 0.02) and coral debris (rubble, P_{ANOVA} <0.01) are higher at complex islands.

Variation of percentage cover of coral and other major substrate descriptors is higher among reef types (σ^2 = 0.18; P_{ANOVA} <0.01) than among sites (σ^2 = 0.05; P_{ANOVA} = 0.02), indicating larger differences among different reef types at a site than among sites for the same reef type. This makes any generalisation about the average substrate of a site not very meaningful.

Live coral and rock (bedrock) cover is significantly higher and sand significantly lower at outer reefs (Figure 2.4 and Table 2.3). Variation of live coral cover is also higher at outer reefs (σ^2 = 0.04; cover ranging between 6 and 62% of total substrate) and back-reefs (σ^2 = 0.04; cover range: 4–48%), less at lagoon reefs (σ^2 = 0.03; range: 7–36%), and least at coastal reefs (σ^2 = 0.02; range: 10–43%). Soft algae do not show any significant differences among the four reef types; however, encrusting algae are more extensive at ocean reefs than at back-reefs, and less extensive at lagoon and coastal reefs.

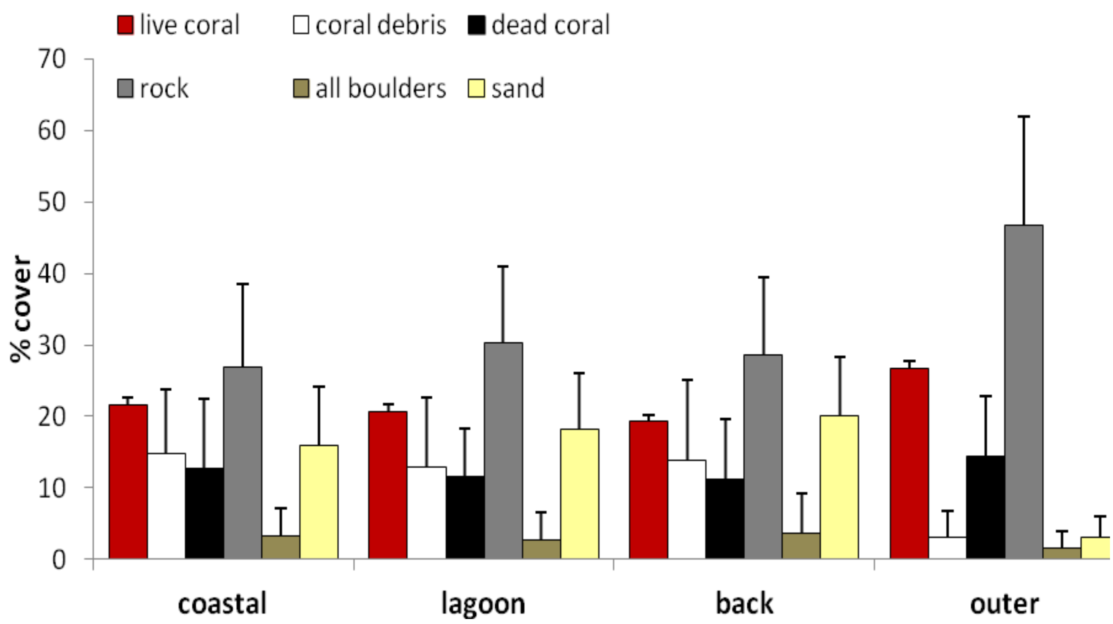


Figure 2.4: Proportion of different substrates among the four reef types, with average and standard error (SE) among sites.

Table 2.3: Results from ANOVA test of significant differences of substrate cover among the four reef types: coastal, lagoon, back- and outer reefs

Substrate cover	P_{ANOVA}	Reef type			
		Coastal	Lagoon	Back-reef	Outer
Live coral	<0.01		-	-	+
Sand	<0.01	+	+	+	-
Coral debris	<0.01	+	+	+	-
Rock	<0.01	-	-	-	+
Dead coral	Not significant				
All boulders	Not significant				

+ = positive association; - = negative association.

Fish presence and community composition are highly associated with reefs and their structures and are thus subject to all such highlighted morphological differences; in fact, differences among islands, reef types and substrate composition act as important causes of variability in fish community among sites.

2.2.2 Geographical variation of fish

The mean number of species (species richness) per transect across the entire region was 37, with extreme values at 21 species per transect (Raivavae - FP) and 60 species per transect (Koror - PW). Average species richness by site was 152 species per site (93 species per site at Manuka - TO and 239 species per site at Koror - PW). The map indicates a relative decrease from west to east as expected from the knowledge of rarefaction of species with increasing distance from the centre of biodiversity (Figure 2.5). This makes comparisons of faunal compositions very hard, considering that only less than 1% of all species (four species: *Ctenochaetus striatus*, *Naso lituratus*, *Parupeneus multifasciatus* and *Zanclus cornutus)* is shared by all sites.

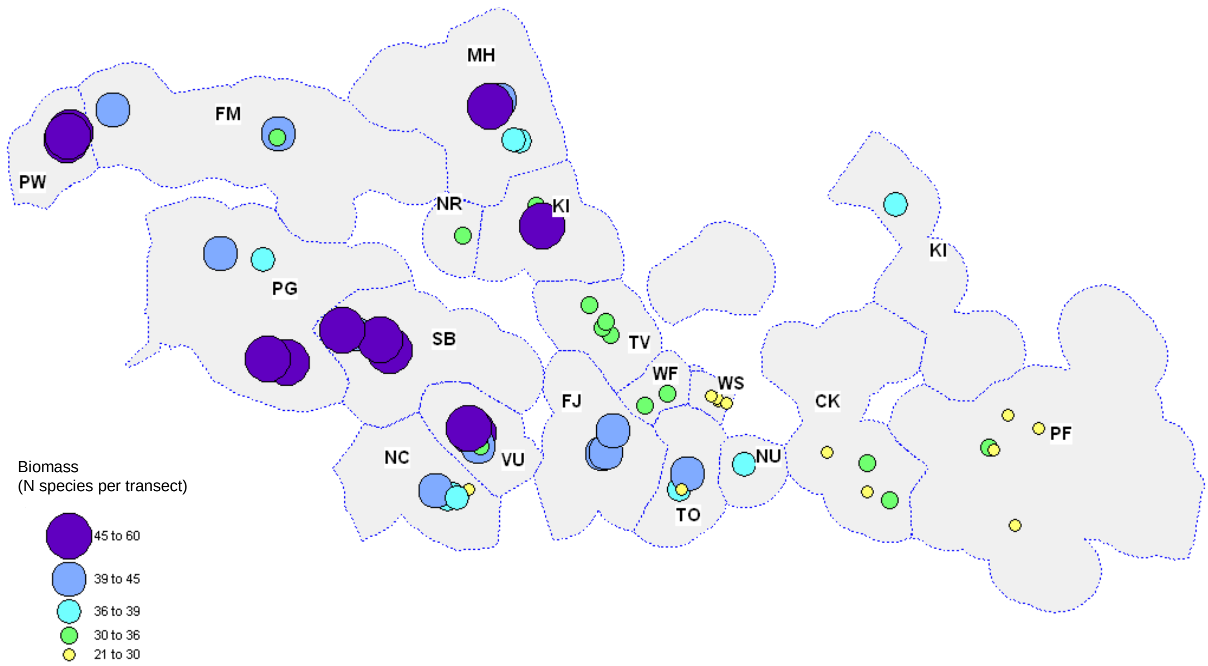


Figure 2.5: Map of regional variation of species richness (N species per transect) calculated as an average per site.
A transect represents 500 m² (50 x 10 m).

Fish density varies almost an order of magnitude between the poorest and the highest extremes: 0.2 N/m^2 at Manuka (TO) and 1.8 N/m^2 at Kuria (KI), with a regional average of 0.6 N/m^2 (Figure 2.6).

Fish biomass was 20 times higher at the richest site compared to the poorest one: the minimum value of 17 g/m^2 was recorded at Manuka (TO) and the maximum value of 363 g/m^2 found at Kiritimati (KI), with a regional average of 118 g/m^2 (Figure 2.7). Overall, mean fish size was 17 cm fork length (FL), with the minimum at 11 cm recorded at Palmerston (CK) and the maximum at 23 cm recorded at Kiritimati (KI).

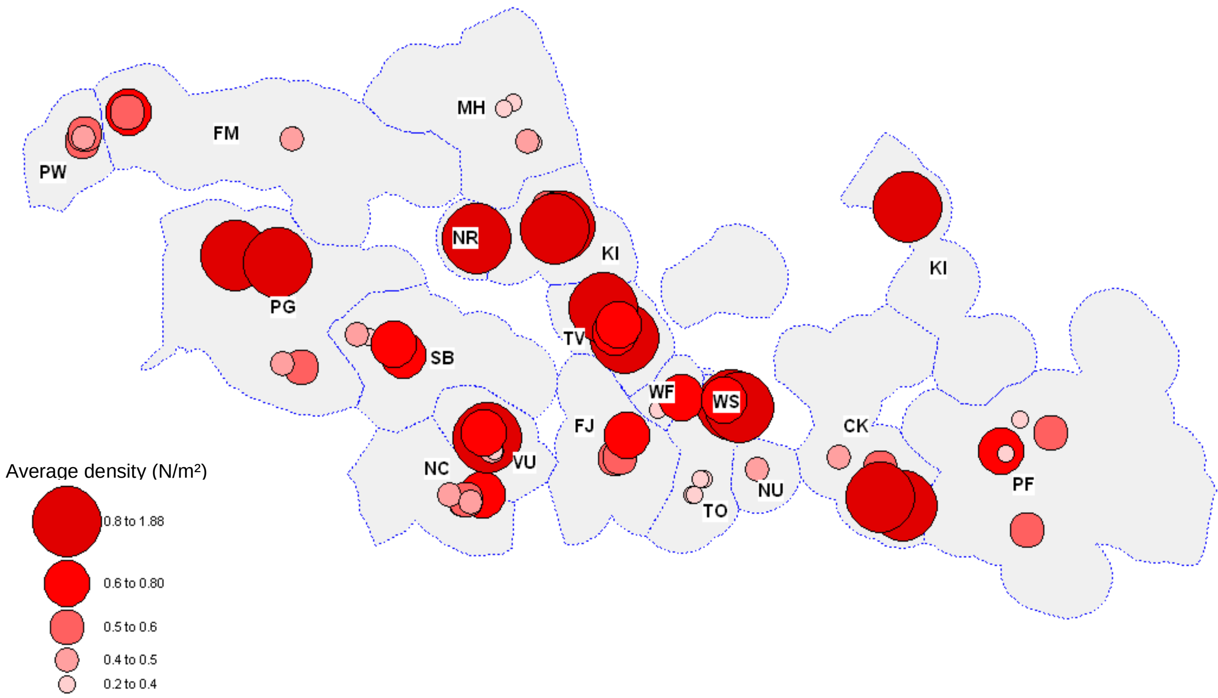


Figure 2.6: Values of weighted average density (N/m^2) of all commercial fish for all sites.
N/m² = number of species per square metre.

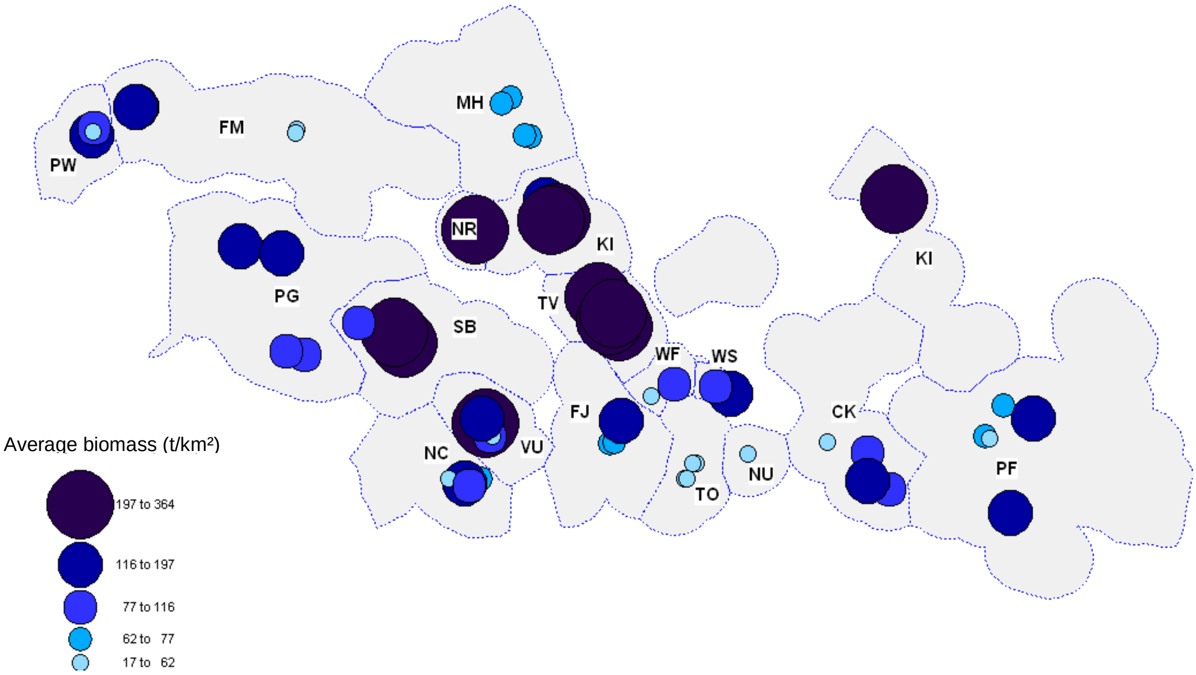


Figure 2.7: Values of weighted average biomass (t/km^2) of all commercial fish for all sites.
t/km^2 = tonnes per square kilometre.

2.2.3 Fish community association

In addition to spatial variation in the total abundance of fish, interactions among species, families (Table 2.4) and trophic groups are also highly important for determining the diversity and production of fish communities and in order to identify the level of resource status. Any prediction of population size or stock is of limited relevance if done without consideration of the effects of species on each other (Medley *et al.* 1993). Therefore, our study took into consideration the association among individuals, species, families and trophic guilds and among these and the large-scale habitat before assessing any conditions related to fishing. Trophic guilds were simplified into four major ones indicating the predominant diet of a fish: herbivores, invertebrate feeders, planktivores and piscivores (The three latter groups were classified as 'carnivores'.).

Table 2.4: Target commercial finfish families analysed according to their dominant diet
In addition to these 11 target commercial finfish families, data for finfish from other major families, e.g. Chaetodontidae, Pomacanthidae, Kyphosidae and Nemipteridae, were also collected.

Herbivores	Invertebrate feeders	Plankton-feeders	Piscivores

Family	N spp		Family	N spp	
Acanthuridae	61		Mullidae	15	
Balistidae	19		Scaridae	35	
Holocentridae	21		Serranidae	47	
Labridae	79		Siganidae	17	
Lethrinidae	19		Zanclidae	1	
Lutjanidae	24				

Throughout the region, the dominant trophic group, in terms of density, was the herbivores, with an average of 65% of total fish counted (Figure 2.8), ranging from 18% in Abemama (KI) to 92% in Mangaia (CK). The second group was the invertebrate-feeders (average 27%, ranging from 4% in Mangaia (CK) to 50% in Abemama (KI)), followed by planktivores (average 5%, ranging from <1% in Raivavae (FP) to 50% in Kuria (KI)) and piscivores (average 3%, ranging from <1% in Koulo (TO) to 10% in Nukufetau (TV)). All carnivores together represented on average 35% of the total density for all commercial fishes, ranging from 8% (Mangaia - CK) to 82% (Abemama - KI).

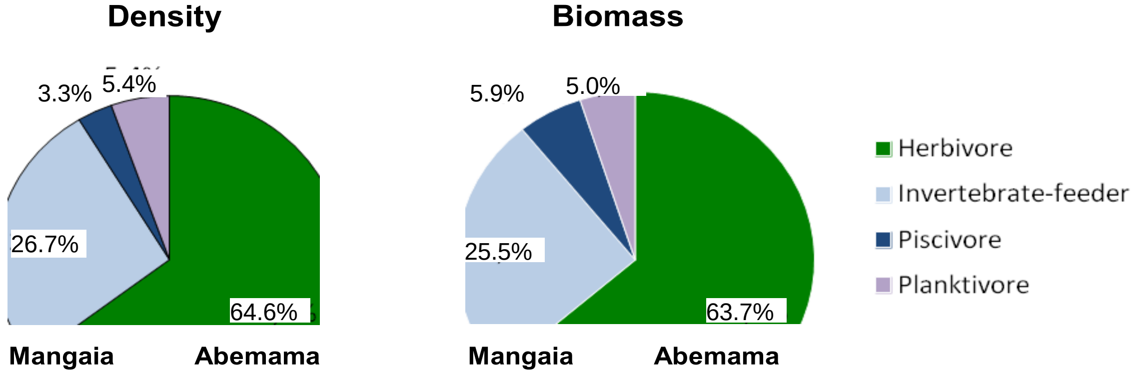


Figure 2.8: Weighted average relative density and biomass of the four trophic guilds and selected sites of highest and lowest herbivore percentage.

Herbivores also dominated the biomass composition with an average of 64% of the total fish biomass (Figures 2.8 and 2.9), ranging from 20% in Abemama (KI) to 89% in Mangaia (CK); second in importance were the invertebrate-feeders, with 25% on average (ranging from 6% in Mangaia (CK) to 60% in Abemama (KI)), then piscivores (average 6%, ranging from <1% in Koulo (TO) to 15% in Ailuk (MI)) and planktivores (average 5%, ranging from <1% in Raivavae (FP) to 21% in Marau (SB)). All carnivores considered together were around 36% of the total average biomass (Figure 2.10), with extreme values at 11% (at Mangaia - CK) and 81% (at Abemama - KI).

As for any animal community, generally a fish community highly dominated by herbivores (as in the extreme case of Mangaia) is considered either to be impacted or stressed, or in a very immature state of development, which is not the case in these very established communities. A fish community with high values of carnivores and especially piscivores is considered to be healthier and less impacted by fishing. The ratio between herbivores and carnivores (H_b/C_b), a first, broad indication of complexity and health of a fish community, varies largely throughout the region, with extreme values between 0.2 and 7.8 (Figure 2.11).

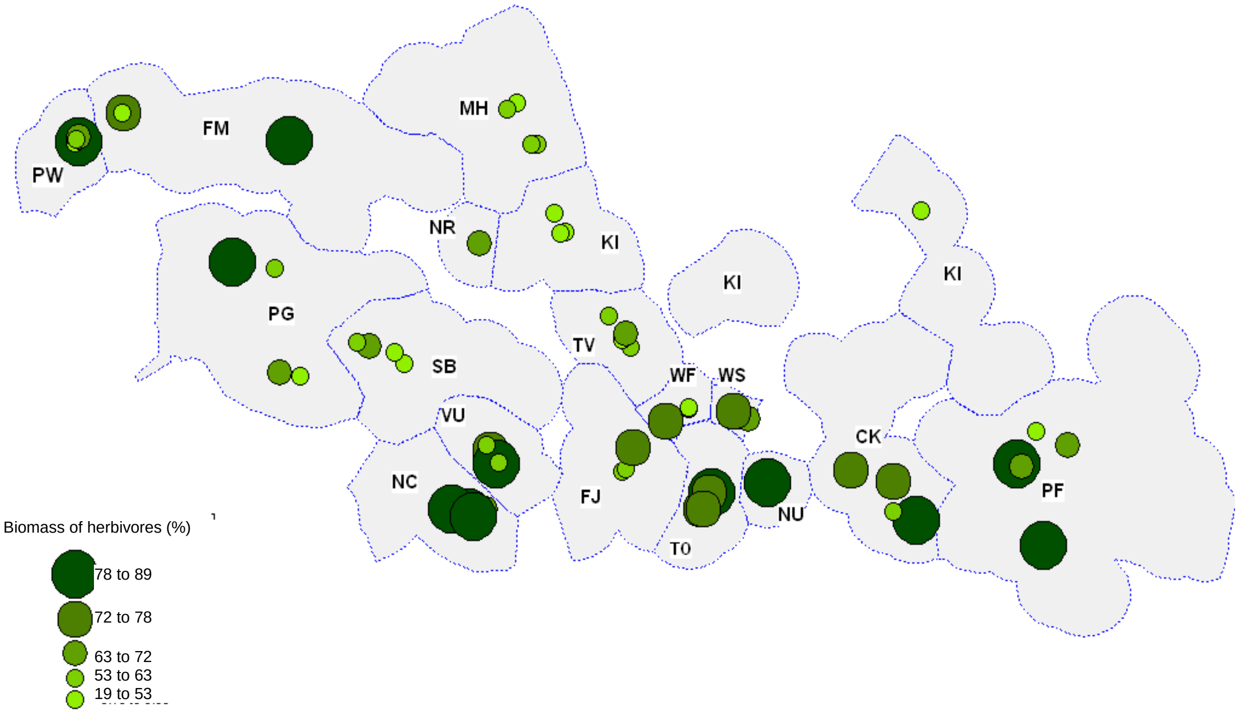


Figure 2.9: Relative biomass of herbivores (%) for all sites.

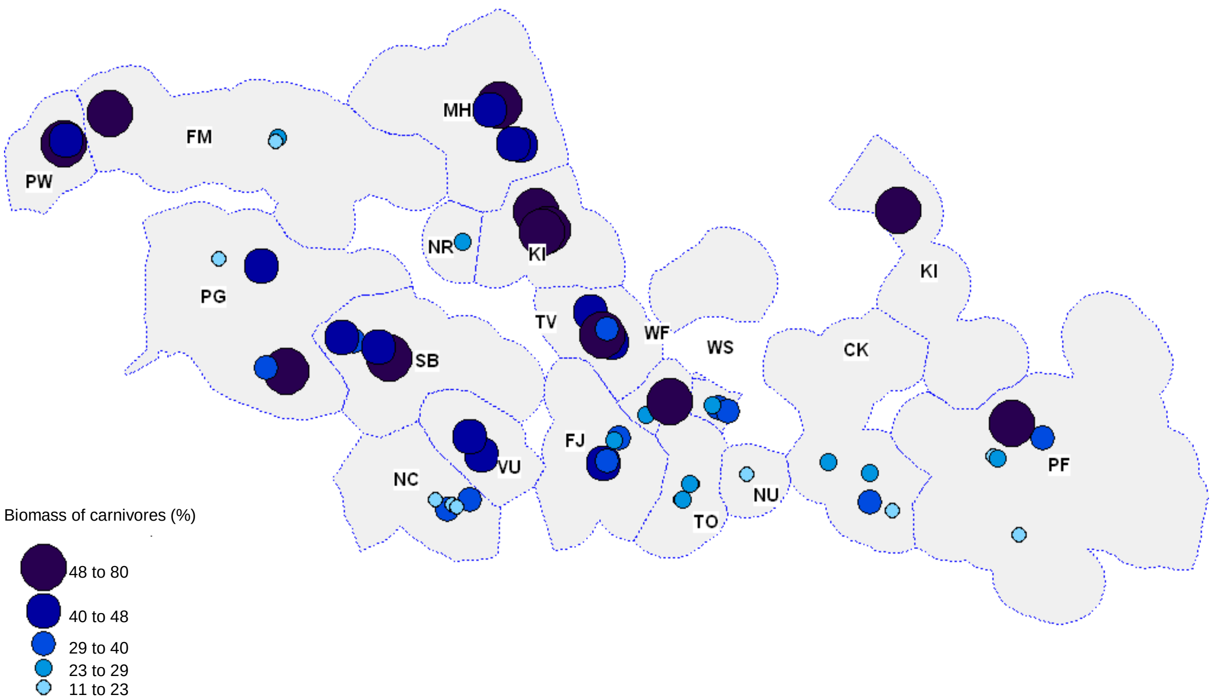


Figure 2.10: Relative biomass of carnivores (%) for all sites.

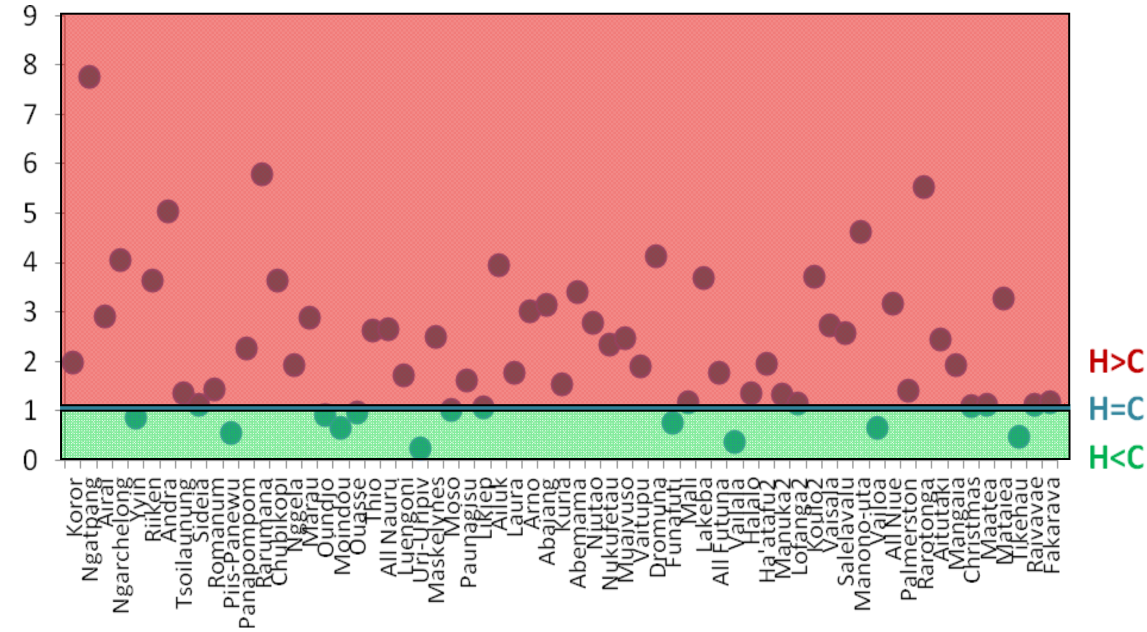


Figure 2.11: Ratio between the biomass of herbivores (H_b) and carnivores (C_b) for all sites.
Sites with H_b/C_b <1 are in the minority.

The 11 most important families composing the fish community had very different importance in terms of density and abundance (Figure 2.12). The most important families in terms of relative density and biomass, when considering the regional average, were the Acanthuridae, Scaridae and Lutjanidae (Figures 2.13 to 2.15). The community composition, in terms of relative density and biomass of families, was also highly variable from site to site.

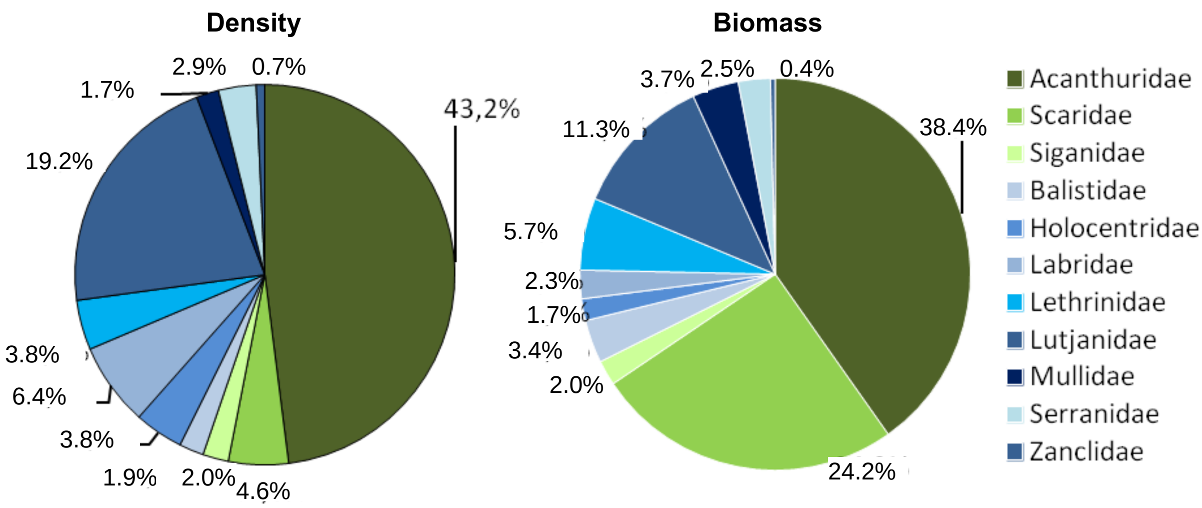


Figure 2.12: Relative proportions of density and biomass (%) for the 11 selected commercial families.
Values are calculated as regional mean of weighted average by site.
Density = number of fish per square metre (N/m²); Biomass = grams per square metre (g/m²).

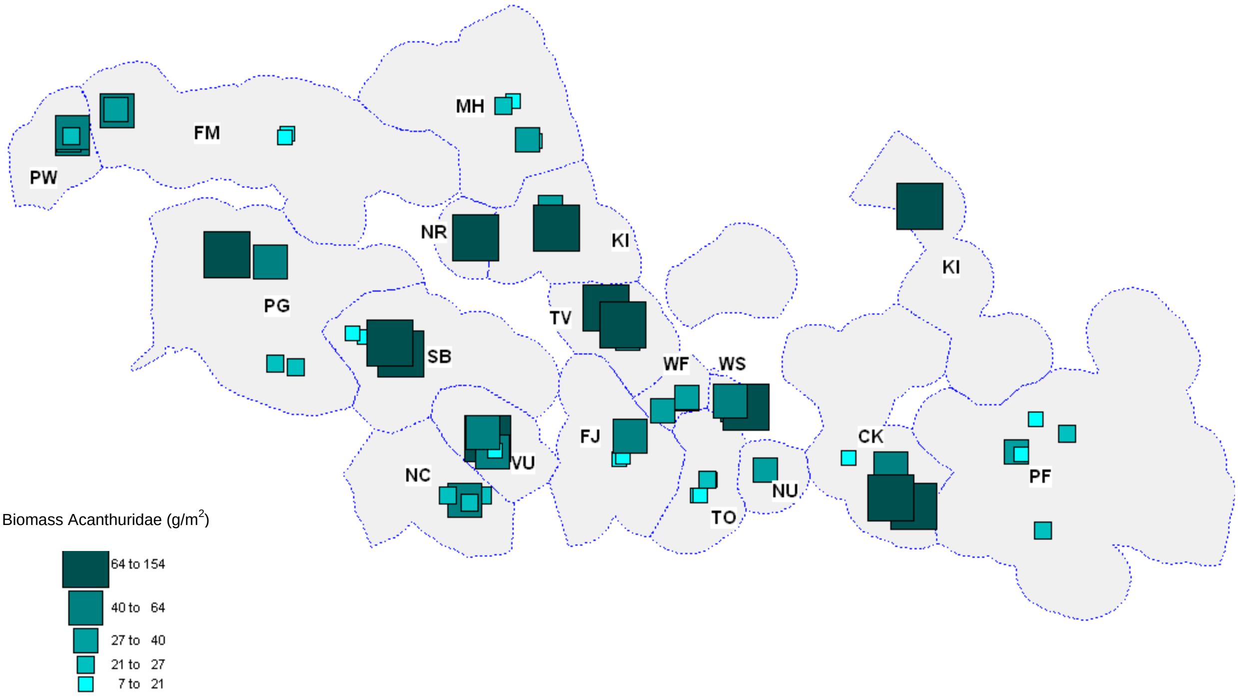


Figure 2.13: Biomass (g/m²) for Acanthuridae at all sites.

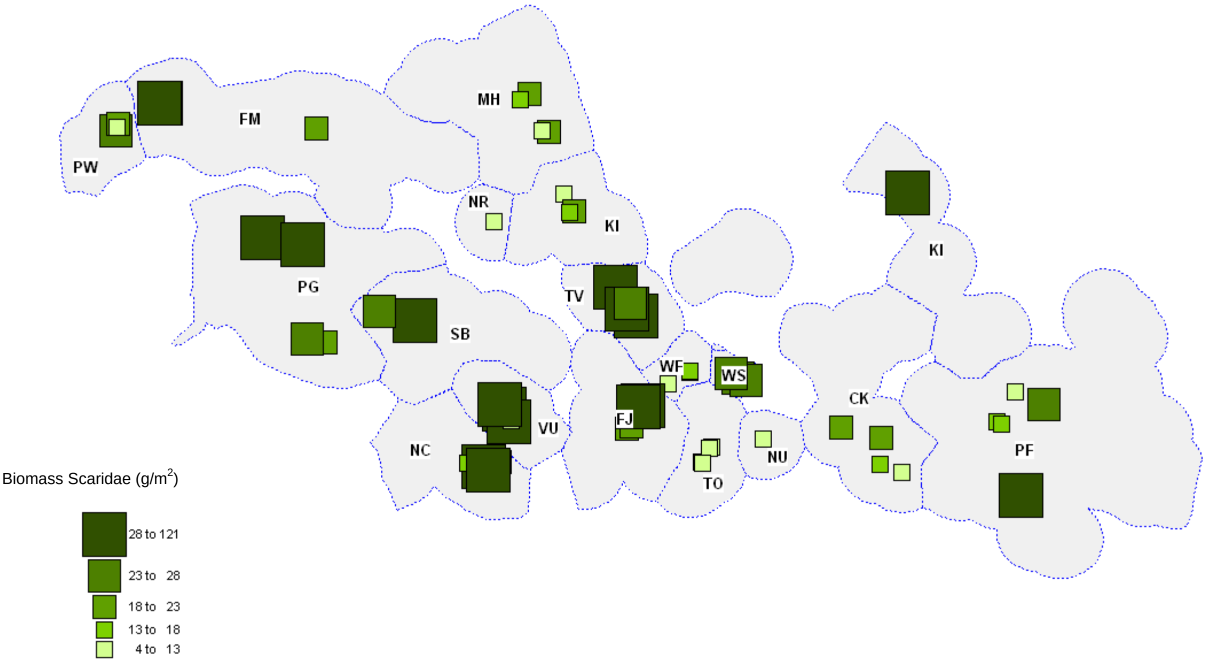


Figure 2.14: Biomass (g/m²) for Scaridae at all sites.

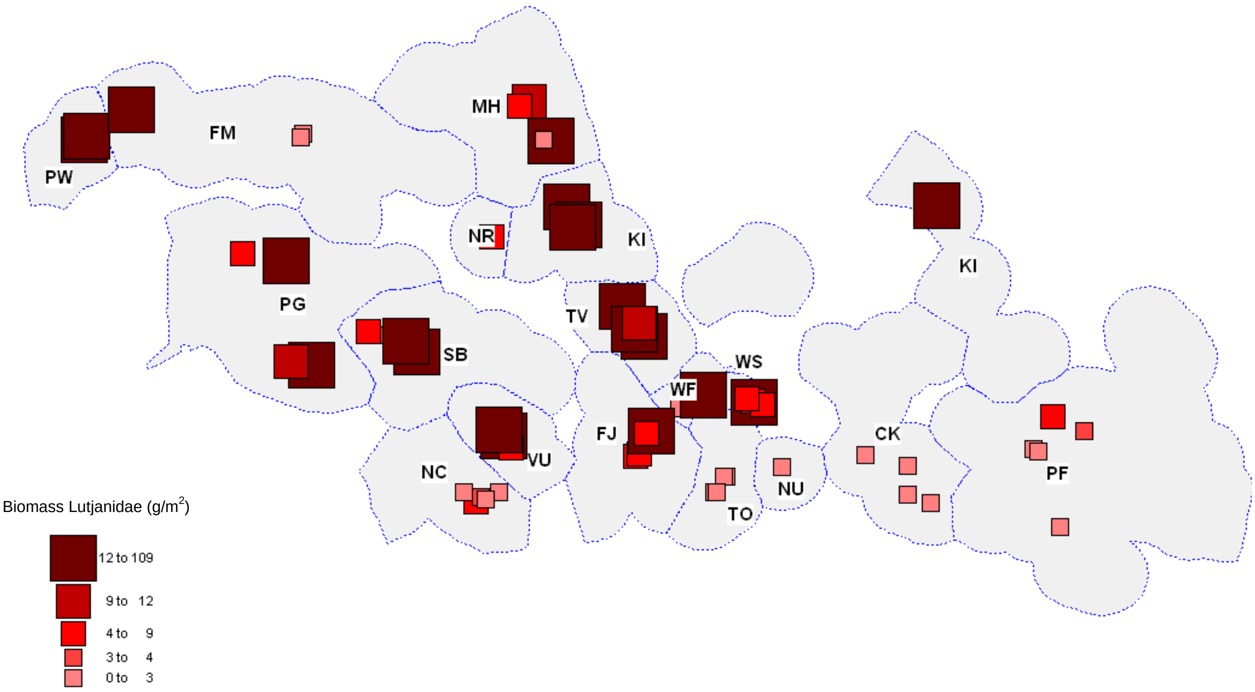


Figure 2.15: Biomass (g/m^2) for Lutjanidae at all sites.

Longitude controls the distribution of some groups of fish: invertebrate-feeders are negatively related to longitude (i.e. they display a higher density and biomass in the western part of the region), while herbivores are positively related to longitude (more abundant to the east, Table 2.5). However, Scaridae are negatively related to longitude (higher abundance at western sites) as well as latitude (higher density further from the equator), while Acanthuridae are positively related to longitude (more abundant at eastern sites, Table 2.6).

Table 2.5: Association of diet groups to habitat variables

		Herbivores		Invertebrate-feeders		Planktivores		Piscivores	
		D.	B.	D.	B.	D.	B.	D.	B.
	Latitude								
	Longitude	+			-				
Island type	Oceanic islands	+	+		-			+	-
	Islands with small lagoon	+	+			-		-	-
	Complex islands	+	+		-	-		-	-
	Atolls	-	-		+	+		+	+
Substrate Complexity	Number satellite pixels (L4)*				+	-	-	-	-
Reef type	Coastal			+		-	-	-	
	Lagoon	-		+	+				
	Back	+		-		-			
	Outer			-		+	+	+	

D. = density; B. = biomass; + = positive association; - = negative association; L4 = computed variable equivalent to the average number of substrate pixels obtained by satellite photos describing substrate composition in a 10 km radius around each site;
* see Table 2.2.

Table 2.6: Main associations of major families to large-scale habitat descriptors (results from analysis on relative density and biomass of the 11 selected families)

		Scaridae		Acanthuridae		Siganidae		Balistidae		Lutjanidae		Serranidae	
		D.	B.	D.	B.	D.	B.	D.	B.	D.	B.	D.	B.
	Latitude	-		+									
	Longitude	-	-	+	+					-	-		
Island type	Oceanic islands	-						-	-	-	-		-
	Islands with small lagoon	+	+					-		-	-		-
	Complex islands	+	+					-	-	-	-		-
	Atolls	-	-					+	+	+	+		+
Substrate Complexity	Number satellite pixels (L4)*	+	+						-				
Reef type	Coastal			-		+	+					-	
	Lagoon			-		-	-						
	Back			+		-	-					-	
	Outer			+		-	-					+	

D. = density; B. = biomass; + = positive association; - = negative association; L4 = computed variable equivalent to the average number of substrate pixels obtained by satellite photos describing substrate composition in a 10 km radius around each site;
* See Table 2.2.

The most abundant species throughout the region: *Cheilinus chlorourus*, *Chlorurus microrhinos*, *Scarus niger* (Figure 2.16), *S. psittacus*, *S. schlegeli*, *S. frenatus*, *Ctenochaetus striatus*, *Acanthurus lineatus* (Figure 2.17), *A. nigricauda*, *A. triostegus*, *Naso lituratus* (Figure 2.18), *Cephalopholis argus*, *Monotaxis grandoculis*, *Mulloidichthys flavolineatus* and *Lutjanus bohar* (Figure 2.19) are also highly associated, either positively or negatively, to longitude and latitude (See Appendix 2.5 for more details.).

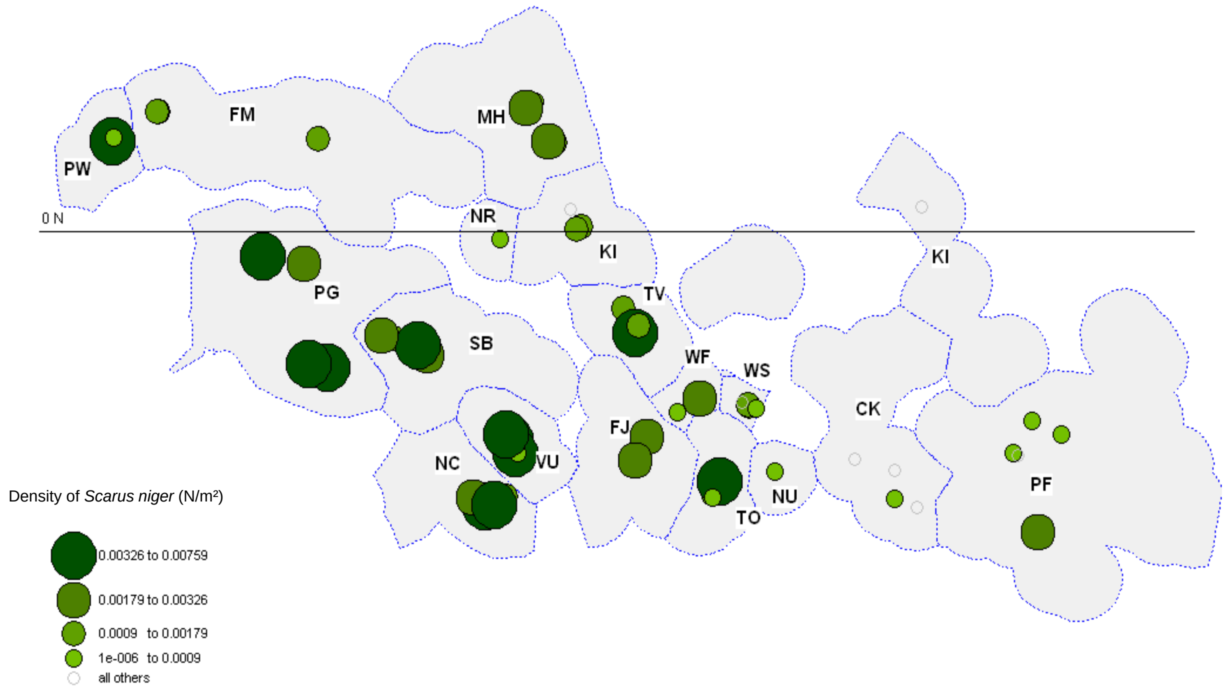


Figure 2.16: Geographic variation of the density (N/m²) of *Scarus niger*.
N/m² = number of fish per square metre; the line represents the equator.

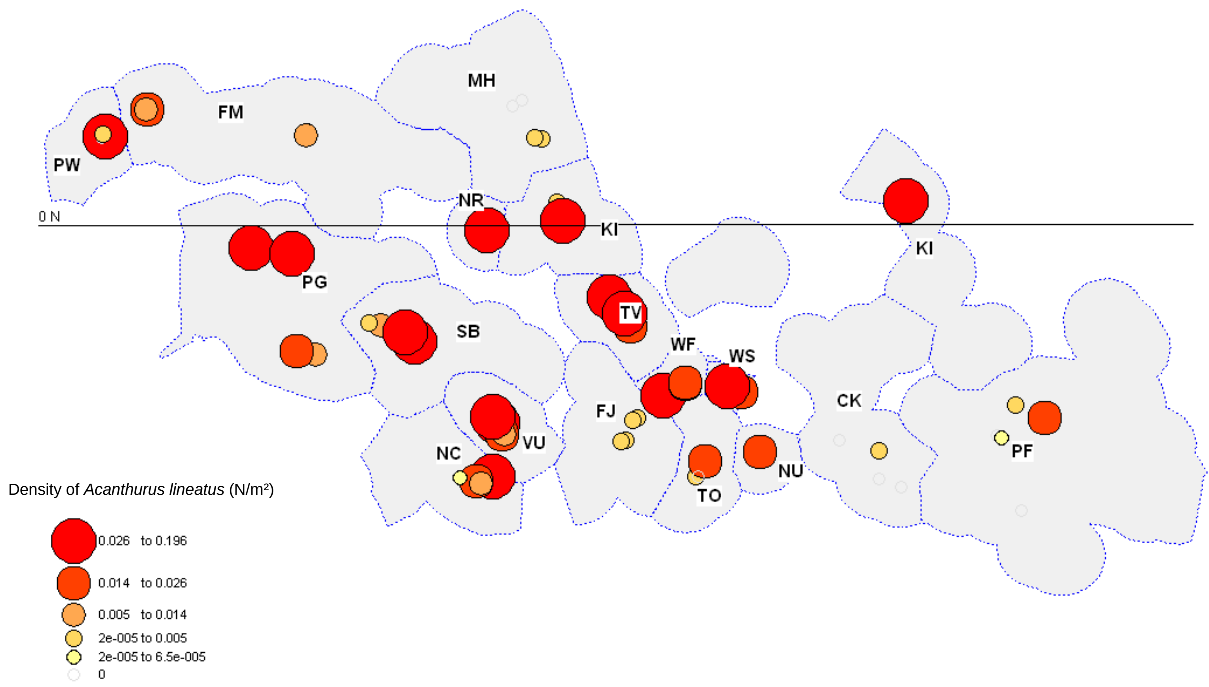


Figure 2.17: Geographic variation of the density (N/m²) of *Acanthurus lineatus*.
N/m² = number of fish per square metre; the line represents the equator.

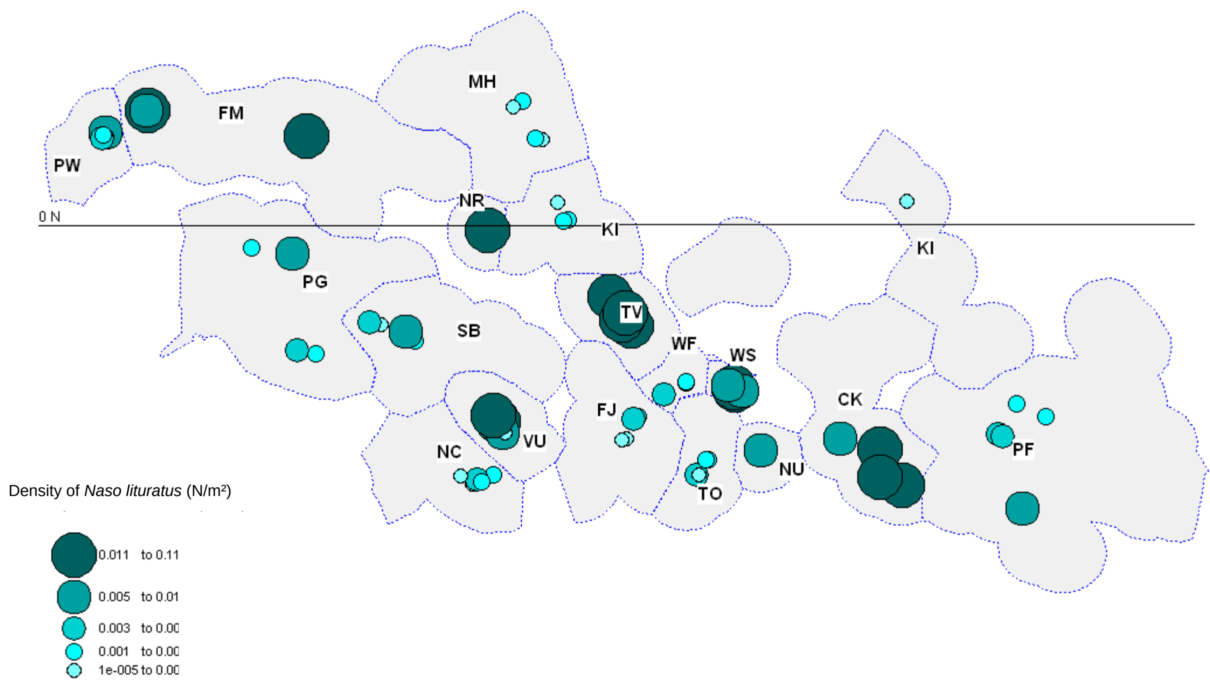


Figure 2.18: Geographic variation of the density (N/m²) of *Naso lituratus*.
N/m² = number of fish per square metre; the line represents the equator.

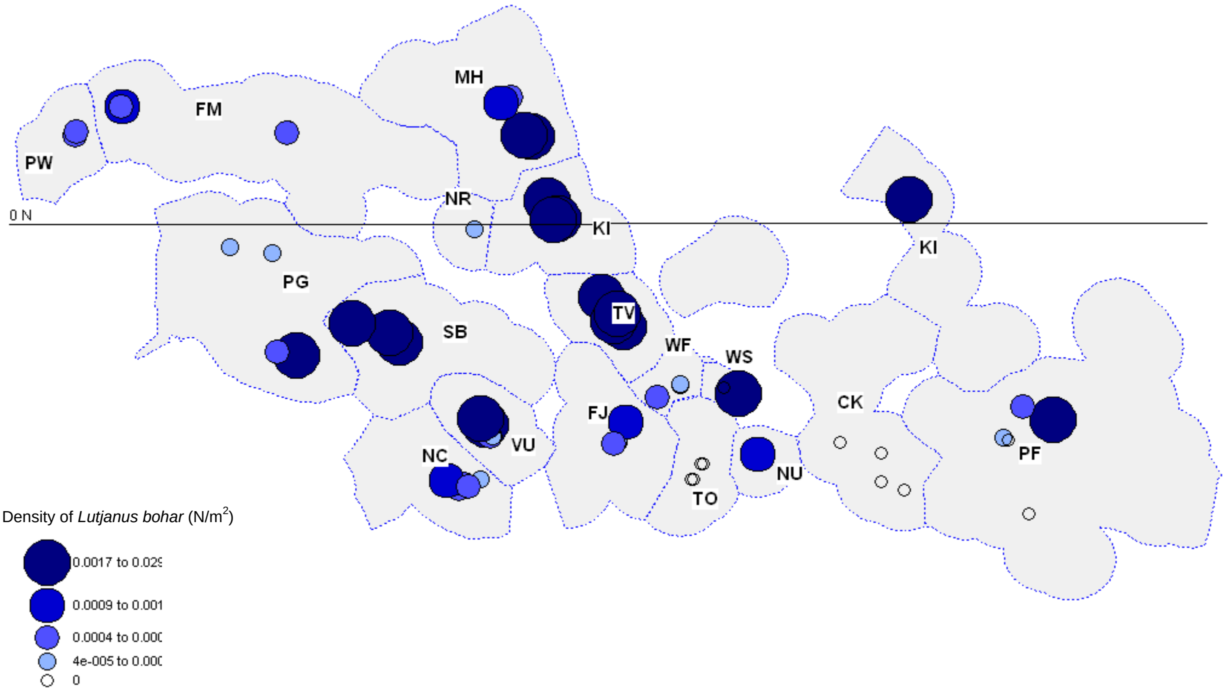


Figure 2.19: Geographic variation of the density (N/m²) of *Lutjanus bohar*.
N/m² = number of fish per square metre; the line represents the equator.

The fish community is dominated by herbivores in the oceanic islands, the islands with small lagoon and the complex islands, where Scaridae are significantly more important (Figures 2.20 and 2.21; Table 2.5). Some species of Scaridae show clear association with islands with small lagoon: *Chlorurus sordidus*, *Scarus niger* and *S. psittacus*. Fish communities in atoll sites, on the contrary, are dominated by carnivores and especially Lutjanidae, Serranidae and Balistidae.

Herbivores are slightly more abundant at back-reefs. Acanthuridae and Siganidae have different smaller-scale spatial distribution (Figures 2.22 and 2.23; Table 2.6). Acanthuridae are more important at outer and back-reefs (the preferred habitat for *Acanthurus lineatus*), while Siganidae are more important at coastal reefs. Invertebrate-feeders are associated with lagoon and coastal reefs, and planktivores and piscivores, including Serranidae, with outer reefs.

Without any further measures of other variables identifying the characteristics of sites, such as primary productivity, turbidity, currents, or temperature, which may be directly responsible for the distribution and preference of some families or species, it is difficult to explain these disparities. However, one needs to keep in mind that geographical and other habitat differences contribute only one part of the causes of the differences that occur in distribution and community composition.

Reef complexity, as measured by the diversity of substrate pixels from satellite photos in a 10 km radius, summarising differences in the composition of small-scale topography, is important in the distribution of some specific groups. Invertebrate-feeders and herbivores are preferentially found at sites of high complexity while planktivores (mainly Balistidae) and some piscivores (Lutjanidae) are negatively associated with reef complexity. This could be explained by the association of invertebrate-feeders and herbivores with corals for their feeding and shelter needs, contrasting with the feeding habit of planktivores and piscivores off the reef.

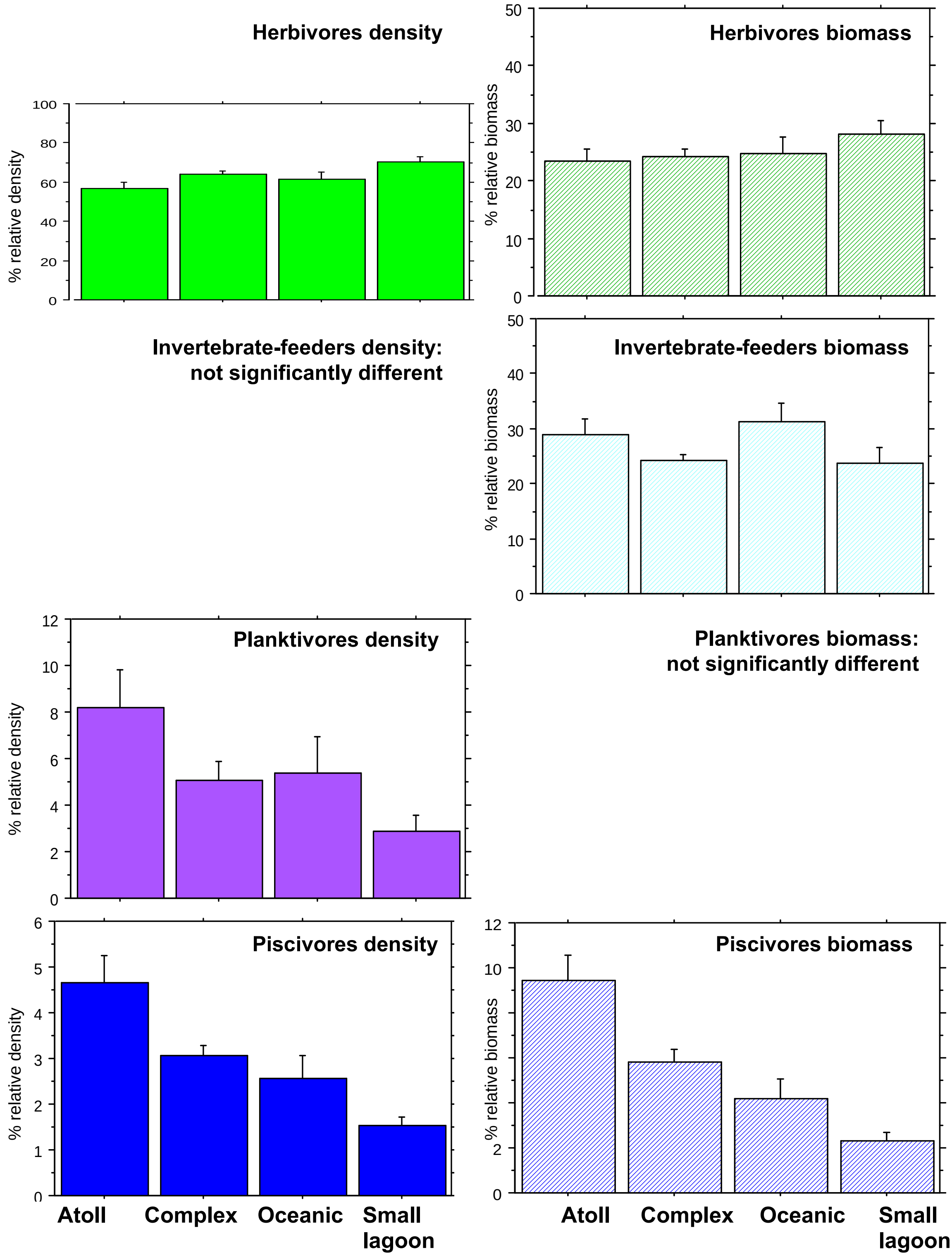


Figure 2.20: Relative density (left) and biomass (right) of herbivores, invertebrate-feeders, planktivores and piscivores among the four island types.

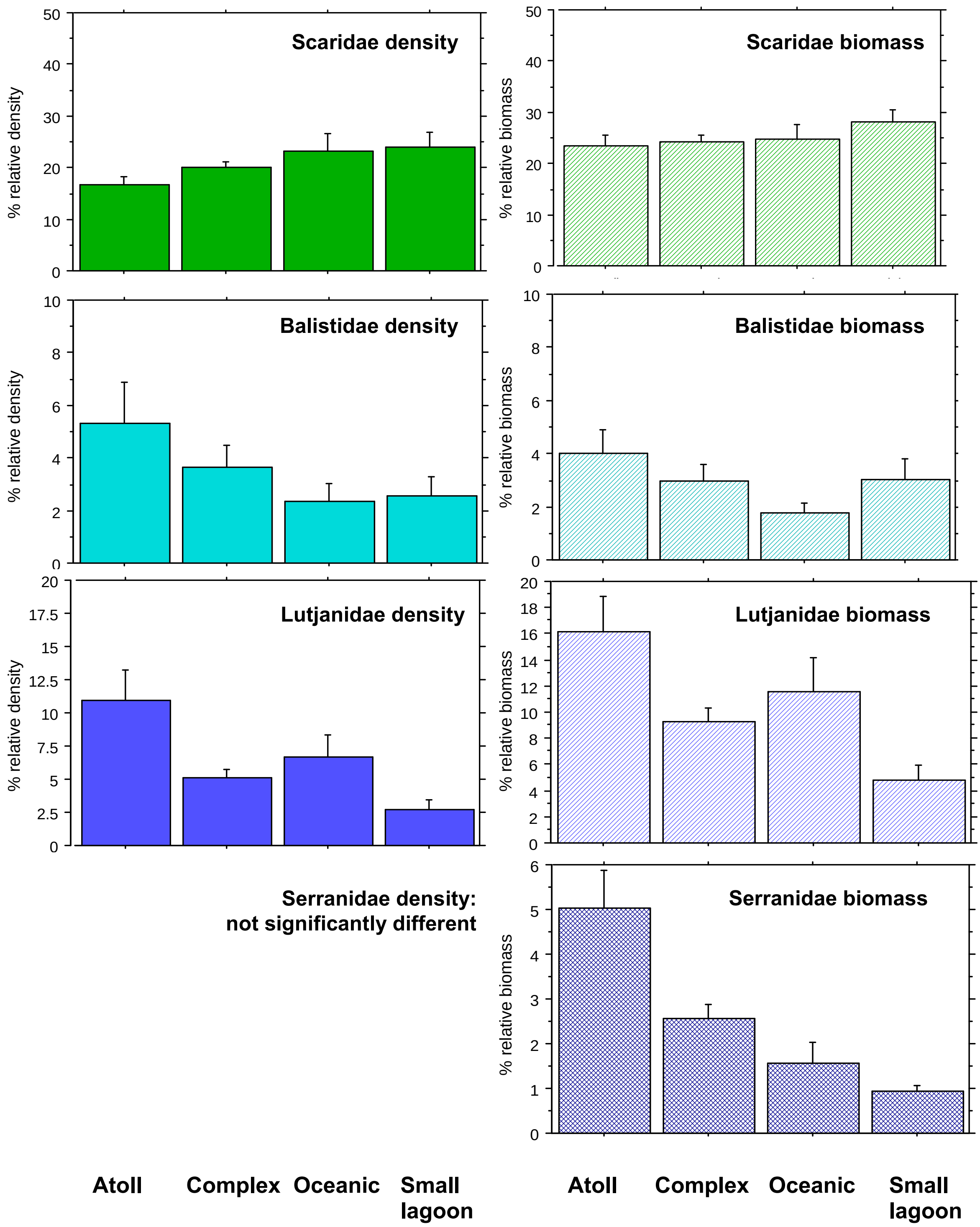


Figure 2.21: Relative density (left) and biomass (right) of some families among the four island types.

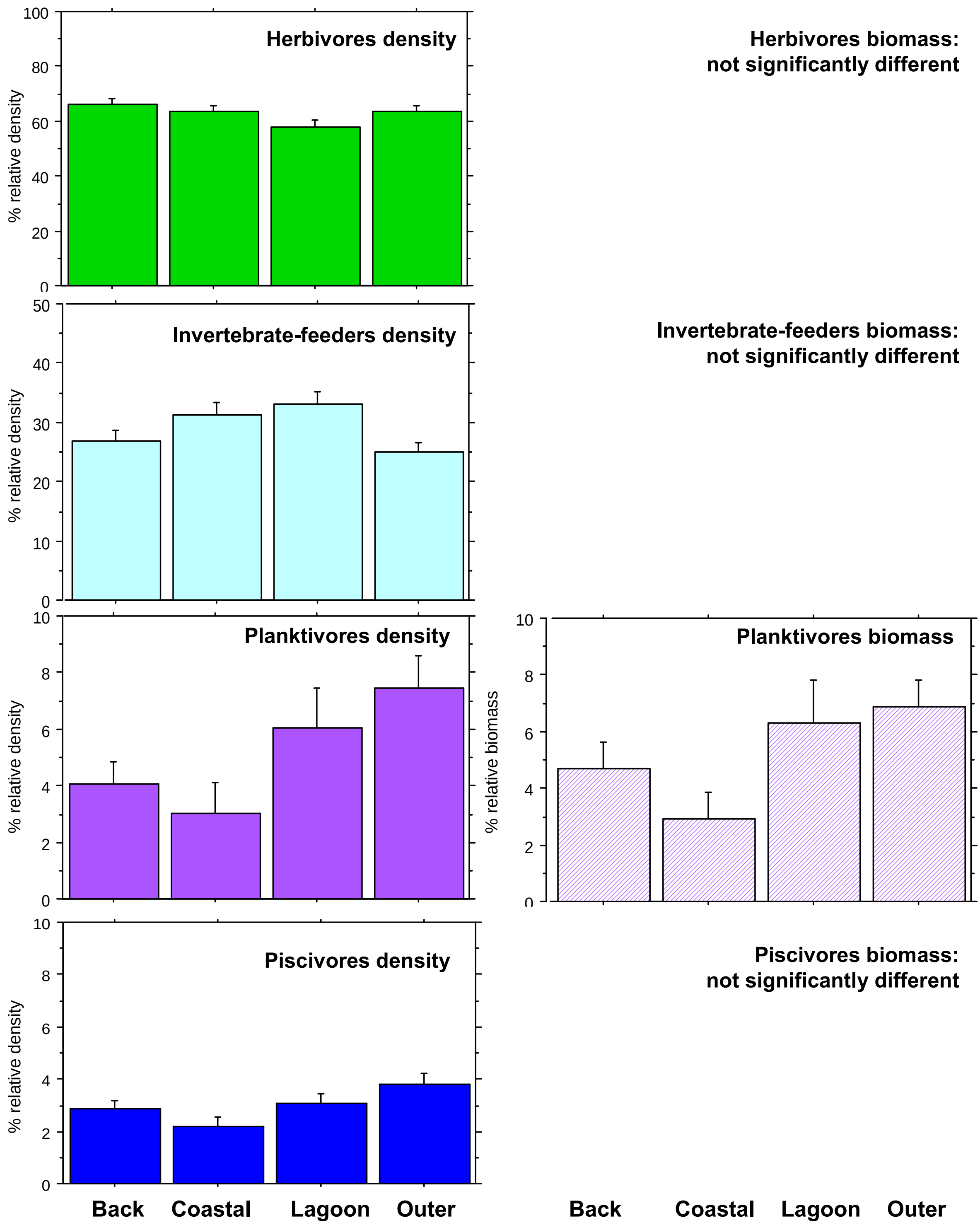


Figure 2.22: Relative density (left) and biomass (right) of herbivores, invertebrate-feeders, planktivores and piscivores among the four reef types.

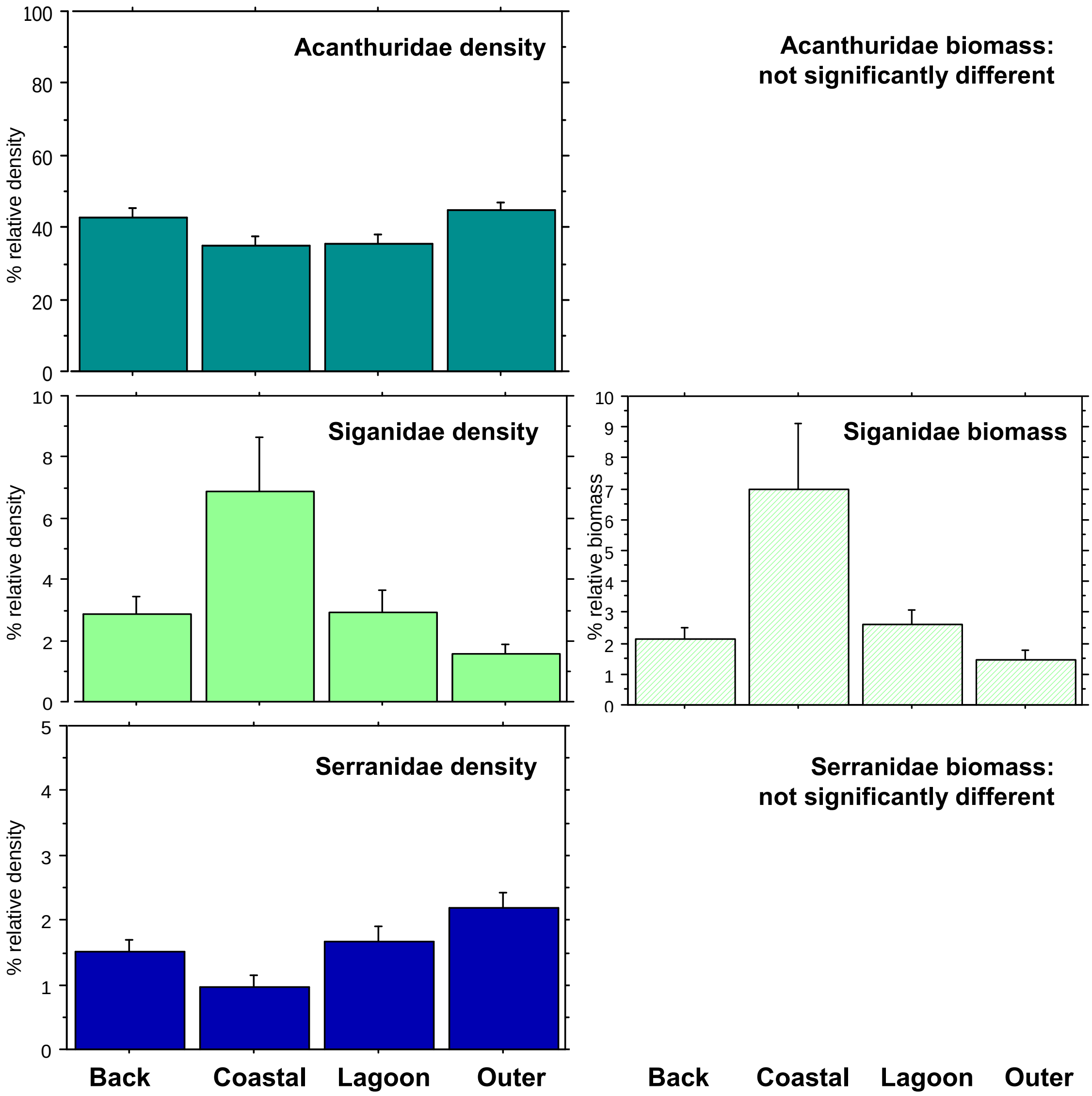


Figure 2.23: Relative density (left) and biomass (right) of Acanthuridae, Siganidae and Serranidae among the four reef types.

2.3 Definition of reef fish status and choice of indicators of fishing impact

In order to overcome the difficulties of the regional assessment due to: 1) the extremely large spatial scale, which carries in itself a large spatial heterogeneity of habitat and faunistic conditions, 2) the lack of time reference point, and 3) the multi-species aspect of such fisheries, we firstly approached the study of the fish communities through a community-sized composition study.

2.3.1 Size importance

Size frequency, distribution of maximum size of fish species (L_{max}) and density/biomass dominance curves were used to define the status levels of fish communities. The double advantage in using this type of information is that these indicators are not a function of specific species present and may be related to levels of disturbance, either due to habitat or externally-induced stress, e.g. fishing pressure. This is useful when comparing locations spread over a large longitudinal scale, and therefore submitted to the law of decline in number of species in the Pacific from west to east.

It has often been demonstrated that detectable effects of selective fishing pressure on coral reefs are a reduction in the average size of the individuals of target species (Craick 1981) and a reduction in the abundance of large-sized and slow-growing species (>30 cm) of large predators or piscivore species (Serranidae, Lutjanidae, Lethrinidae), usually the most favoured targets of male fishers due to their desirability (Bohnsack 1981, Randall 1982, Munro 1983, Munro and Williams 1985, Koslow *et al.* 1988, Russ 1985, Russ and Alcala 1989, Russ 1991, Medley *et al.* 1993, Roberts 1995a, Jennings and Lock 1996, Jennings and Polunin 1997, Jennings and Kaiser 1998, Munro 2003, Daan *et al.* 2005, Kulbicki *et al.* 2007, Clua and Legendre 2008). These are also often the easiest fish to be caught using the cheapest technique, the fishing line, especially at the beginning of the exploitation history of a site. In addition, reduction and loss of keystone species (Munro *et al.* 1987, Huges 1994) as response to fishing contributes to the overall shifting of the fishing community structure.

Fishes at the high end of their size range are an extremely important component of total stock breeding potential due to the greater fecundity of large individuals and higher survivorship of larvae produced by large fish (Birkeland and Dayton 2005, Williams *et al.* 2008). Therefore, selective fishing pressure on larger individuals causes also a decrease in the fecundity of the community by causing a decrease in its average body size (Olsen *et al.* 2004).

In addition to these direct effects, fishing also causes an increase in dominance of small-sized individuals (referred to as Malthusian overfishing), as a result of a direct effect of fishing on large predators, which reduces the predation on small fish, allowing them to increase in number (McManus *et al.* 2000, Pauly 1990).

However, size differences can also be related to regional variability and large-scale habitat differences and not only to fishing. For example, within-species variations in maximum size and age have been correlated with temperature at geographical and local scales (Choat and Robertson 2002, Robertson *et al.* 2005, Ruttenberg *et al.* 2005). In general, individuals tend to reach smaller maximum sizes and have shorter lives in warmer environments, although there are exceptions to this pattern (Williams *et al.* 2003).

Therefore, the study of size composition was carried out by analysing the influence of both large-scale habitat and fishing stress to extract the relative input of these two major drivers on fish community composition and condition. Since regional differences in size spectra are partially related to differences in overall abundances, size and species composition of a local fish community (Rogers *et al.* 1998), we studied differences in densities and biomass of trophic groups, families and species relative to the total amount of density and biomass of all commercial fish.

Analysis of the size distribution of all commercial fish displays a maximum frequency (36%) at 15 cm body length (fork length) (Figure 2.24). Individuals below 20 cm represent an average of 68% of the total fish abundance. Ninety-six per cent of the fish are below 35 cm, which is a rather small size for commercial fish. However, variation is strong throughout the region. Kiritimati (KI), Abaiang (KI) and Koror (PW) had the highest frequency centered around 27 and 25 cm respectively, while Abemama (KI), Luengoni (NC), Maskelynes (VU), Moindou (NC), and Oundjo (NC) had highest frequency around 13 cm and Kuria (KI) only at 9 cm. All other sites had highest frequency between 15 and 17 cm mid-point value.

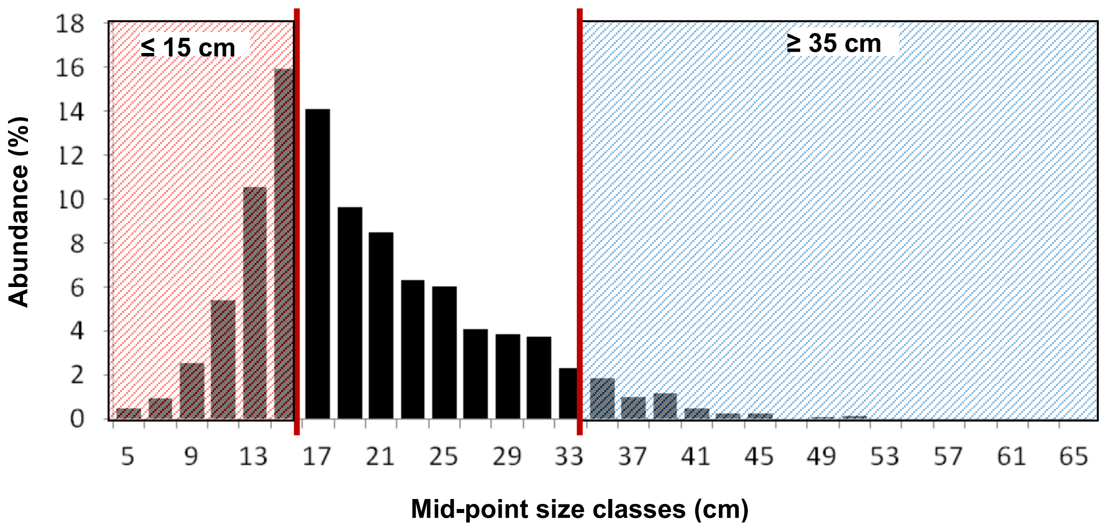


Figure 2.24: Percentage of abundance of size classes throughout the region, limited to the 5–65 cm fork length range.

The highest proportion (32% as average) of the fish assemblage, when taken as a regional average, is composed of species with maximum sizes (L_{max}) ranging between 25 and 30 cm, i.e. medium-sized species (Figure 2.25). To this category belongs a list of 33 species (Appendix 2.6). Classes above 50 cm all contribute together less than 10% of the total counted fish. A second peak is constituted by species of maximum size between 35 and 40 cm (Appendix 2.7). Differences of L_{max} frequency distributions among sites can provide a measure of the indirect effects from fishing (Daan *et al*. 2005, Rogers and Ellis 2000).

There is a large variation among the different sites, subject to wide differences of both habitat conditions and catch intensity. The sites Abaiang (KI), Abemama (KI), Kuria (KI), Lofanga (TO), Luengoni (NC), Moindou (NC), Ouassé (NC) and Thio (NC) present highest abundances for L_{max} between 35 and 40 cm, suggesting a relatively good condition of the community. Chubikopi (SB), Moso (VU) and Panapompom (PG), have highest frequency at L_{max}= 30-35 cm, indicating a dominance of smaller-sized species in the fish community.

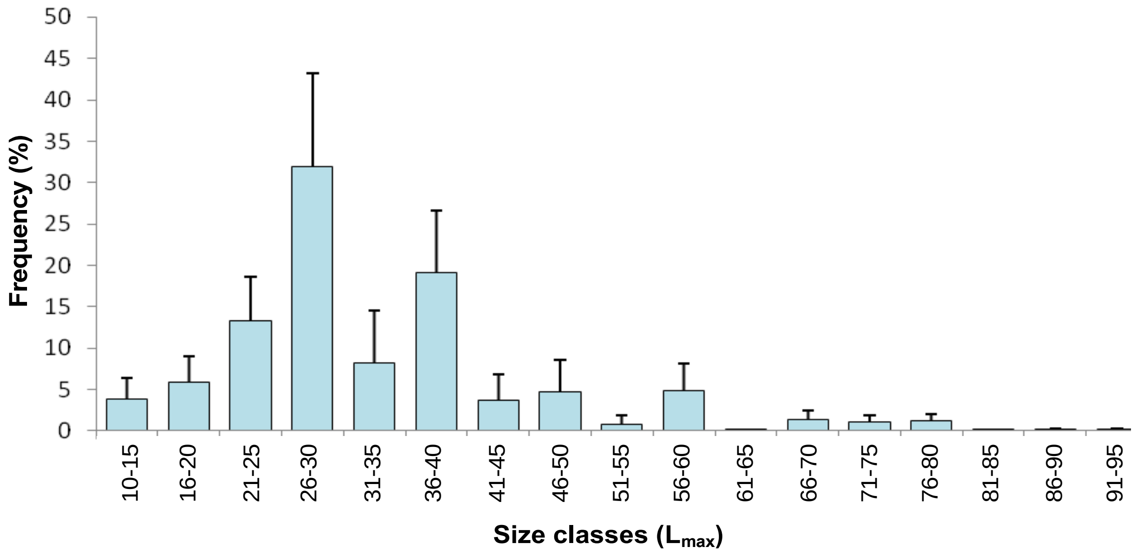


Figure 2.25: Average distribution of frequency per L_{max} size class (fork length, cm) throughout the region.
Highest frequency is in the class 26–30 cm FL.

The majority of fish (96%) do not reach the maximum recorded size for their species (L_{max}). When we take nine representative species from the major families as examples, we can see that none reach the value of maximum size and that 70% of the fish belonging to these species reach only 35 to 60% of the maximum expected size (Figure 2.26).

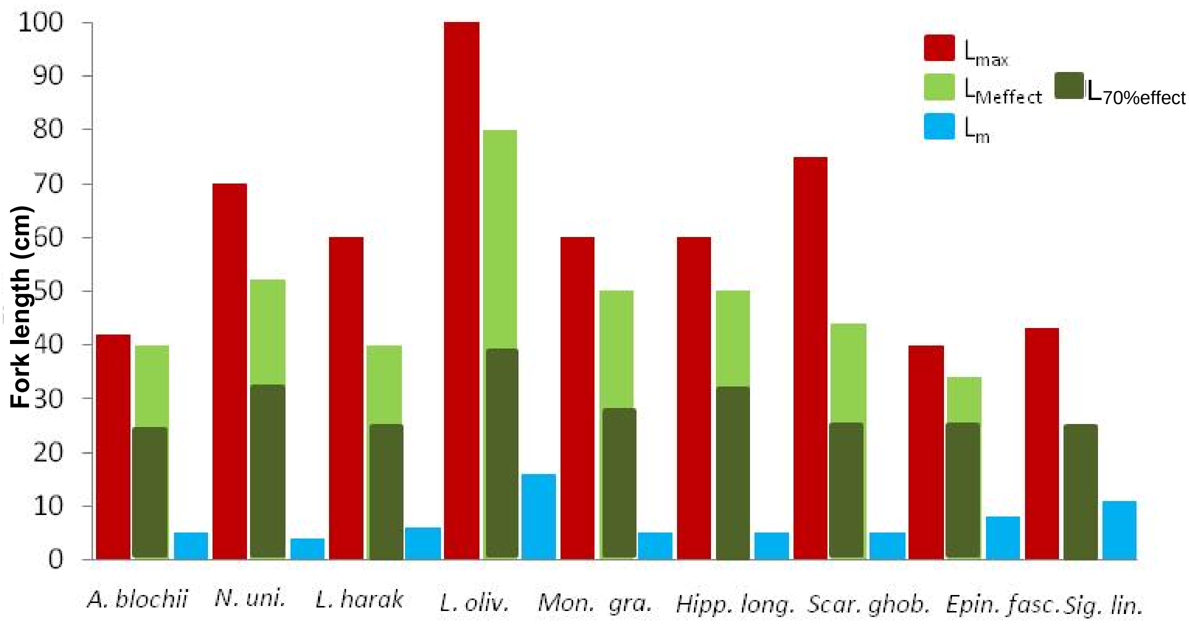


Figure 2.26: Nine selected species of Acanthuridae (*Acanthurus blochii*, *Naso unicornis*), Lethrinidae (*Lethrinus harak*, *L. olivaceus*, *Monotaxis grandoculis*), Scaridae (*Hipposcarus longiceps*, *Scarus ghobban*), Serranidae (*Epinephelus fasciatus*) and Siganidae (*Siganus lineatus*) showing a general trend of low size.
Minimum (blue), maximum (light green) and maximum frequency size (dark green) are plotted versus the maximum size ever recorded for those species; L_{max} = maximum size of fish from literature; $L_{Meffect}$ = maximum recorded size during this study; $L_{70\%effect}$ = 70% of the maximum recorded size during this study; L_m = minimum recorded size during this study; all sizes in cm fork length (FL).

Size-frequency distributions calculated for the whole fish community of each site vary greatly throughout the region. Values of the steepness (slope) of these distributions indicate the narrowness of the size range as well as the amount of dominance of small-sized fish: i.e. a higher negative value of slope would correspond to a smaller range of sizes and a higher dominance of small sizes. Such values range between -1.15 (Manono-uta - WS) and -0.4 (Raivavae - FP) with a mean of -0.75 (Figure 2.27). Even if the value of slopes of the size spectra (the size composition of a fish community; refer Appendix 2.1.2) is often used as a measure of fish intensity effect (McClanahan and Graham 2005, Dulvy *et al.* 2004, Gislason and Rice 1998, Graham *et al.* 2005), the slopes calculated in this study steepen quite irregularly at the increase of catch intensity. This is due to the fact that there is not a direct correlation between intensity of catch and measure of condition at a specific site, when using only information from a determined time at each site without having access to information on previous conditions or responses to older exploitation levels. One site can be poor in resources even if catches are low in intensity because it is a naturally poor site, or because it has been exploited for a long time even at a low intensity of use, or else a place can still be rich in resources even if catch intensity is high because it has a high productivity or because fishing just recently started at this intensity.

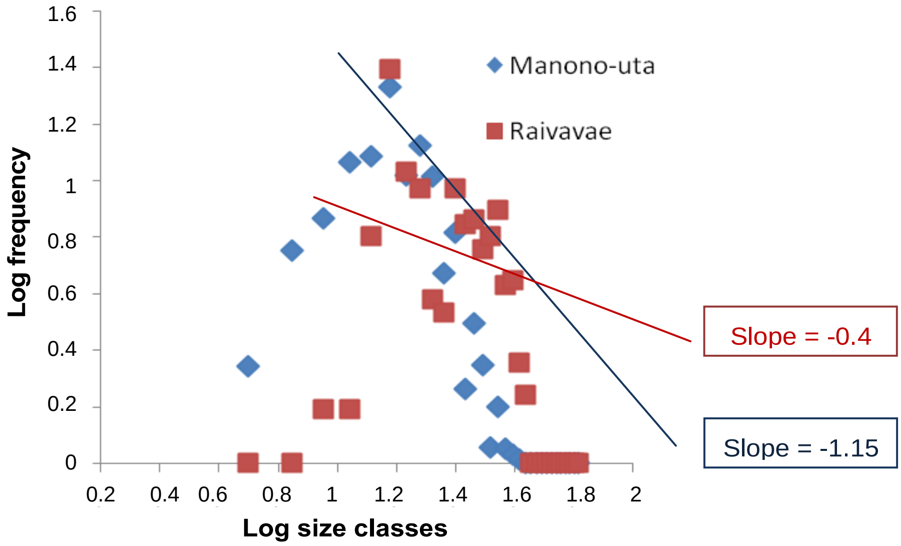


Figure 2.27: Size spectra for two sites at extreme conditions: Raivavae (FP, slope -0.4) and Manono-uta (WS, slope -1.15).
Size spectra = the size composition of a fish community; refer Appendix 2.1.2.

However, when we compared four large groups of sites (I to IV; refer Table 2.7) obtained by association of similar size-spectra shape, we obtained different trends of slope values, average percentage cumulative frequency slopes, steepness at maximum frequency (y_{max}/x_{max}) and at half frequency (y_{50}/x_{50}). Such indicators describe the overall shape of the curves: the slope values of the size frequency distribution decrease (increase in absolute value, i.e. get steeper) from group IV to I, the slope of cumulative frequency decreases (becomes flatter), the ratios between y_{max} and y_{50} and their respective sizes increase (meaning that the trend of the size frequency steepens throughout most of the distribution). All these parameters indicate that the size spectra become steeper and narrower, indicating a decreasing composition of individuals of all sizes, a reduction of large-sized individuals and a domination of few single species of smaller size, therefore suggesting that the level of status of the fish communities decreases from group IV to I (Table 2.7 and Figure 2.28).

Table 2.7: Average value of slope and shape of cumulative percentage frequency described by the slope, y_{50}/x_{50} and y_{max}/x_{max}) for each size frequency group

Groups from size-frequency dendrogram	Average size-frequency slope	Average slope % cumulative frequency	y_{50}/x_{50}	y_{max}/x_{max}	Quality of fish community
IV	-0.59 ±0.09	1.11 ±0.34	38 ±1	14.9 ±4.5	Healthy/Good
III	-0.79 ±0.16	1.23 ±0.47	40 ±3	15.8 ±5.8	Above average
II	-0.73 ±0.11	1.01 ±0.17	39 ±1	15.8 ±3.3	Below average
I	-1.00 ±0.08	0.96 ±0.08	41 ±1	16.3 ±3.3	Low/Depleted

y_{50}/x_{50} = steepness of slope at half frequency; y_{max}/x_{max} = steepness of slope at maximum frequency.

Sites in good conditions (III and IV) were also identified as having significantly high relative density of large-sized species (RD_{L52}), low relative biomass of small-sized animals (RB_{20}), high relative biomass of piscivores (RB_{LS}) and low ratio of herbivores over carnivores (H_b/C_b, Table 2.8). The use of the biomass of piscivores (major top carnivores) and the ratio of herbivores and carnivores biomass is used in relation to the known response of fish communities to removal of top predators with a change in the overall and relative abundance of preys (Beddington and May 1982, Beddington 1984) and the overall change in food webs (Pauly *et al.* 1998).

Table 2.8: Significant differences among the four size-frequency groups from ANOVA results for four major parameters: logarithmically transformed values of relative density of species of max size 52 cm (RD_{L52}), relative biomass of fish of size <20 cm (RB_{20}), relative biomass of all major piscivores (Lutjanidae and Serranidae, RB_{LS}) and relative biomass of herbivores over carnivores (H_b/C_b)

Groups from size-frequency dendrogram	RD_{L52}	RB_{20}	RB_{LS}	H_b/C_b	Quality of fish community
P_{ANOVA}	<0.001	<0.001	<0.001	<0.001	
IV	1.49 ±1.32	0.007 ±0.004	0.018 ±0.010	1.78 ±1.35	Healthy/Good
III	1.04 ±0.89	0.005 ±0.001	0.031 ±0.014	0.82 ±0.46	Above average
II	0.55 ±0.81	0.011 ±0.005	0.013 ±0.007	2.58 ±1.57	Below average
I	0.28 ±0.54	0.013 ±0.003	0.011 ±0.006	3.08 ±0.99	Low/Depleted

RD_{L52} = logarithmically transformed values of relative density of species of maximum size 52 cm; RB_{20} = relative biomass of fish of size <20 cm; RB_{LS} = relative biomass of all major piscivores (Lutjanidae and Serranidae); H_b/C_b = relative biomass of herbivores over carnivores.

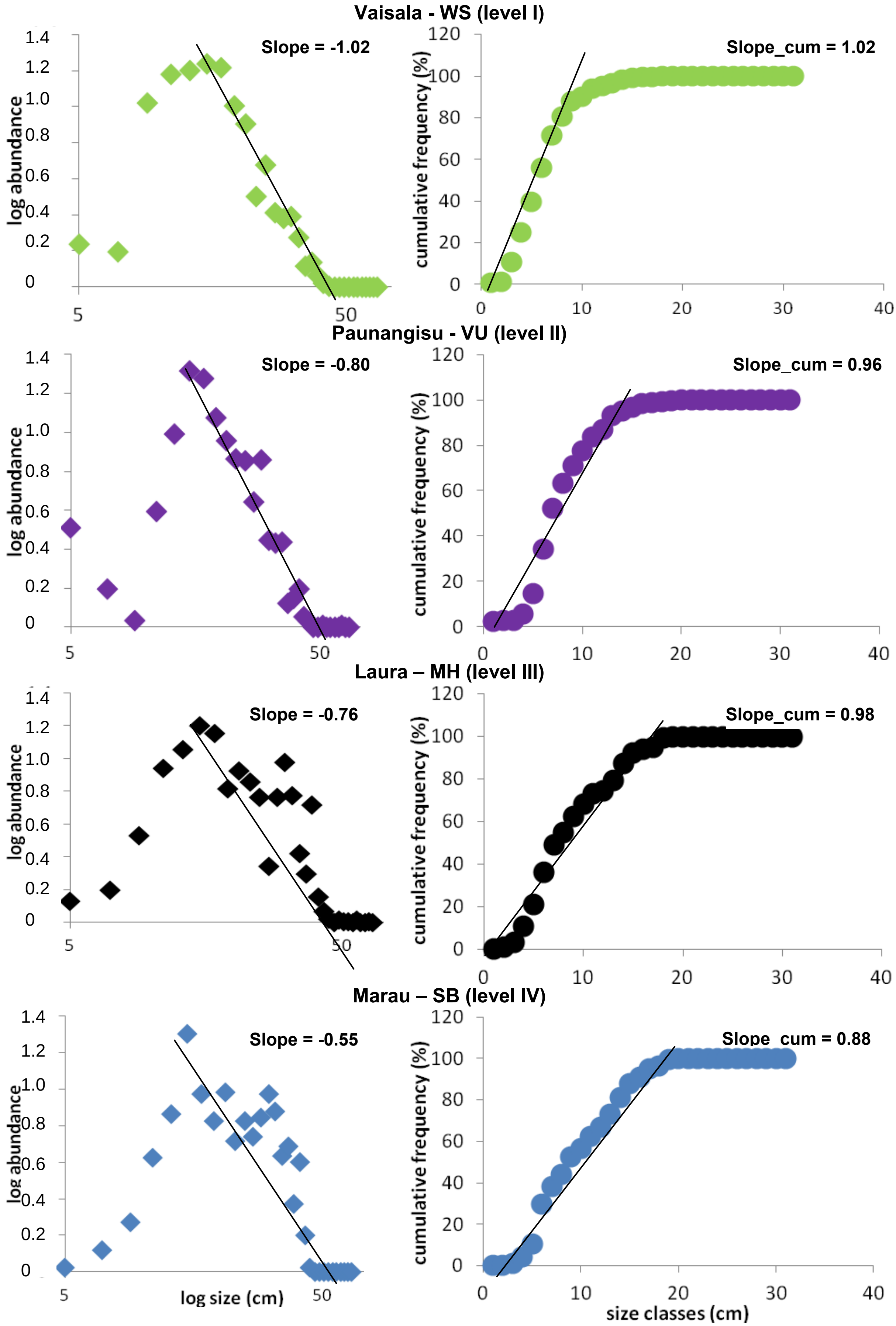


Figure 2.28: Size spectra and cumulative percentage size frequency for representative sites for each of the four levels I to IV.

Slope_cum = average percentage cumulative frequency slope; status I = depleted/low-quality fish community; status IV = healthy/good-quality fish community.

Individual size-frequency distributions were also studied for a few frequently occurring species: two species of herbivores (Scaridae: *Scarus psittacus* and *Chlorurus sordidus*) and two species of carnivores (Serranidae: *Epinephelus merra* and Lethrinidae: *Monotaxis grandoculis*) were represented in the individual size-frequency graphs, showing very different size distribution for sites at level I and level IV. Sites with low-quality status (level I) displayed small maximum values and higher frequency at smaller sizes compared to sites with high-quality status (level IV, Figure 2.29). Although this indication follows the right trend as indicated by the overall fish community size distribution (decrease of size composition from level IV to level I), not many species data distributions are adaptable for such study. The purpose of the extraction of this community indicator is precisely to avoid difficulties linked to the taxonomical identification, the data collection and the difficulty of obtaining statistically relevant information on individual species that are required for a species-based size assessment.

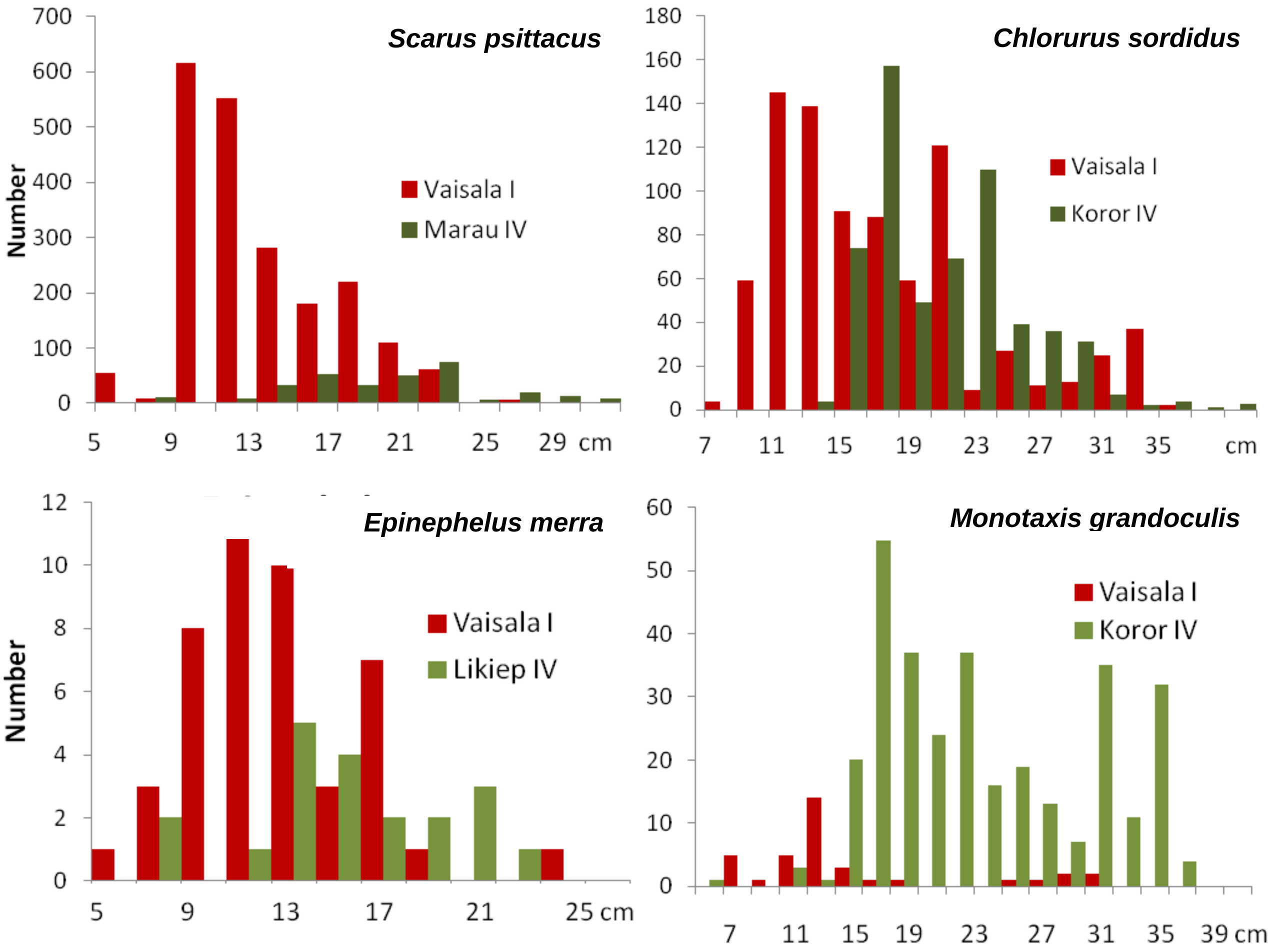


Figure 2.29: Examples of size frequency distributions of two herbivore and two carnivore species from two sites at level of status I and IV respectively.
Status IV displays a wider size range and higher frequency for larger sizes compared to status I; status I = depleted/low-quality fish community; status IV = healthy/good-quality fish community.

We also compared sites by using the W statistics (sum of the differences standardised to a common scale for unequal numbers of species in biomass–density dominance curves; refer Appendix 2.1.2), which standardise the among-sites differences in cumulative biomass and cumulative density to a common scale to correct for a different number of species at different sites (Clarke 1990). The statistics vary between -0.09 (Kuria - KI) and 0.06 (Ouassé - NC, Figure 2.30 and Appendix 2.8). Negative values indicate disturbance.

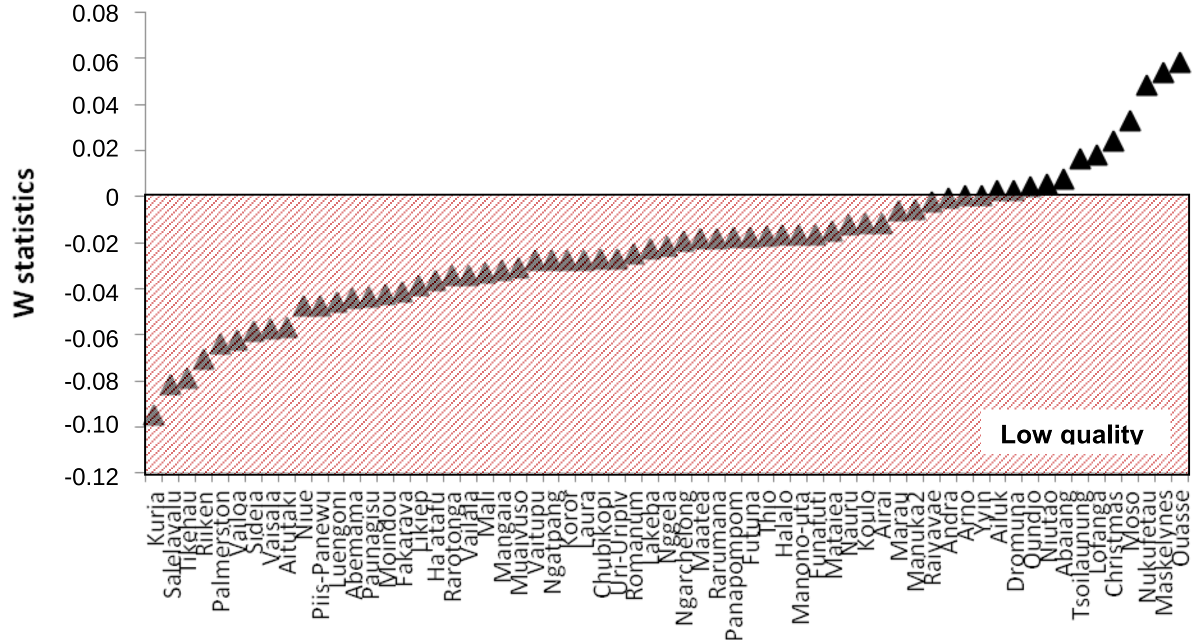


Figure 2.30: W statistics for the 63 sites.
W statistics = sum of the differences standardised to a common scale for unequal numbers of species in biomass-density curves; Refer Appendix 2.1.2.
Negative values indicate disturbance.

The composition of size as described by these major indicators: 1) slope of cumulative size spectra, 2) biomass of selected size as described by RB_{20}, 3) L_{max} of key large species (size selected between 50 and 52 cm, RD_{L52}), and 4) values of W statistics for each site, resulted in a promising set of descriptors of fish community and community status.

2.3.2 Other descriptors for identifying fish community status

These parameters were used together with another two ecological community descriptors based on trophic composition (the relative biomass of major top carnivores RB_{LS} and the ratio of herbivore and carnivore biomass H_b/C_b) for a general study of all sites to detect the influence of large-scale habitat and fishing on community status.

Sites presenting poor conditions (with high RB_{20} and high H_b/C_b) are associated with high longitude (towards the east of the region), islands with small lagoons, intermediate complex islands, and sites with large areas of coastal reefs. Maatea - FP, Mangaia - CK, Mataiea - FP, Ha‘atafu - TO, Manuka - TO and Lofanga - TO are examples of such types of sites (Figure 2.31).

Sites in healthier conditions, with high ratios of piscivores, high cumulative frequency slopes and high biomass compared to density distribution are associated with high latitude, atoll sites, high complexity of habitat, and large surface areas of outer reefs, back-reefs and lagoon reefs. Examples of such sites are Abemama - KI, Abaiang - KI, Likiep - MH, and Ailuk - MH (Table 2.9).

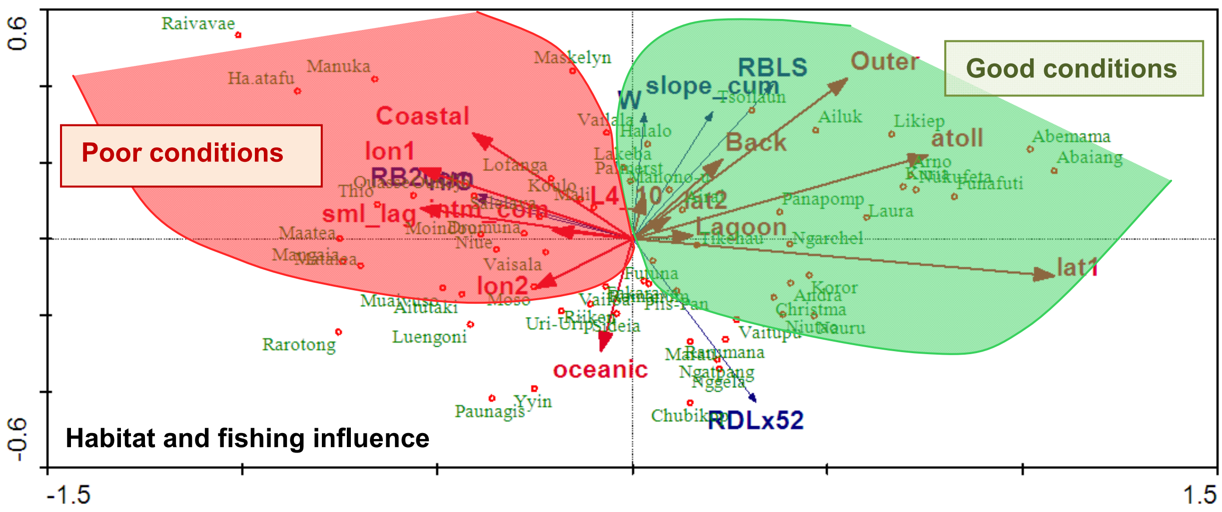


Figure 2.31: Representation of the results of the redundancy analysis (RDA) on the first two axes.

Habitat and fishing pressure are both part of the analysis; RD_{Lx52} = logarithmically transformed values of relative density of species of maximum size 52 cm; RB_{20} = relative biomass of fish of size <20 cm; RB_{LS} = relative biomass of all major piscivores (Lutjanidae and Serranidae); Slope_cum = average percentage cumulative frequency slope; lat = latitude; lon = longitude; W = sum of the differences standardised to a common scale for unequal numbers of species in biomass–density dominance curves–refer Appendix 2.1.2; sml_lag = small lagoon; intm_core = complex island.

Light green colouration represents good condition; red colouration represents poor condition.

Table 2.9: Summary of parameters and their trends describing conditions of fish communities at each site and relation to habitat (RDA on six ecological parameters and 13 habitat parameters)

Green shades are the conditions describing a high level of status, red shades a low level of status. Slope_cum and W are the least sensitive indicators in the list. The two shades of green highlight the different strength of the indicators, with lighter shade for less important ones.

	Long	Lat	*Compl.	Atoll	Small lagoon	*Interm. Compl.	Oceanic	Coastal	Lagoon	Back	Outer
RB_{20}	+	-		-	+	+		+	-	-	-
H_b/C_b	+	-		-	+	+		+	-	-	-
RB_{LS}	-	+	+	+	-		-	-	+	+	+
RD_{L52}						-	+	-			
Slope_cum	-	+	+	+	-		-	-	+	+	+
W	-	+	+	+	-		-	-	+	+	+

*Compl. and *Interm. Compl. combined = complex island; RB_{20} = relative biomass of fish of size <20 cm; H_b/C_b = relative biomass of herbivores over carnivores; RB_{LS} = relative biomass of all major piscivores (Lutjanidae and Serranidae); RD_{L52} = logarithmically transformed values of relative density of species of maximum size 52 cm; Slope_cum = average percentage cumulative frequency slope; W = sum of the differences standardised to a common scale for unequal numbers of species in biomass–density dominance curves–refer Appendix 2.1.2; + = positive association; - = negative association.

A summary of the six major indicators described and analysed and their variation among the four major levels of status is reported in Figure 2.32.

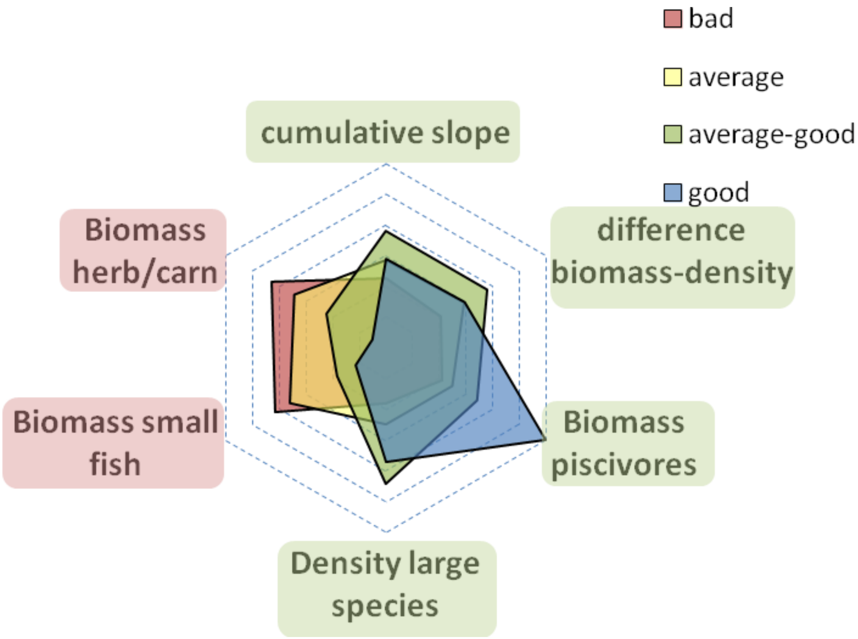


Figure 2.32: Diagram representing differences of values of the six indicators used at the four levels of status.
Values increase from the centre to the perimeter. The red parameters indicate poor conditions, the green good conditions.

An analysis of the sites as described by this set of six variables, computed to measure the relative influence of habitat in the determination of the ecological situation of each site, resulted in a value of variance of status of fish resources equal to 34%. This was obtained after extracting habitat influence from overall variance (Figure 2.33A). 'Other factors' influence 66% of the variability of the fish resource. Such factors are for simplicity considered to be: 1) the influence from demography and fishing and 2) the ecological interactions among the different components of the fish community. However, we should be aware that the habitat influence is not fully described by the 13 variables chosen and that 'other factors' can include other habitat parameters, such as temperature, currents, etc. that were not measured, as well as other descriptors of fishing pressure not used in this analysis.

2.3.3 Measuring fishing pressure

A parallel analysis was done to compute the amount of variance due to fishing stress, here defined simply by: population density per area of reef (people per km^2), yearly consumption of fresh fish (per capita kg of fish per year) and intensity of sale of fish (t/km^2/year). This second test resulted in a variance of status of fish resources due to fishing equal to 19% (Figure 33B).

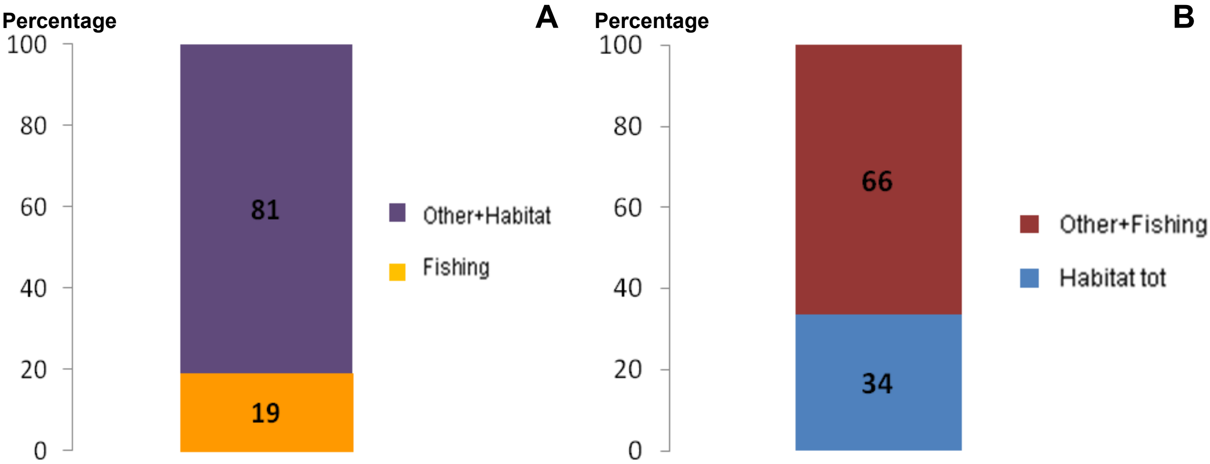


Figure 2.33: Partition of variance among the different drivers of community composition and conditions (six indicators), separating out either habitat (A) or fishing stress (B).
Other + Habitat = variance due to both the habitat influence and the ecological interactions;
Fishing: influence due to the fishing pressure as described by the four parameters selected here;
Other + Fishing = component due to fishing pressure and ecological associations;
Habitat tot = component due to influence of the habitat, both direct and indirect through influence on fishing practices.

Sites in healthy condition, when any influence from fishing is disregarded (i.e., as described only by population density, catches for sale, and consumption) are highly negatively related to longitude (The further to the east, the less rich and healthy the sites are.), and to islands with small lagoons, while they are positively related to: latitude (Better conditions are found at higher latitudes, i.e. further from the equator.), atolls, intermediate and complex islands, substrate complexity, and outer-, back- and lagoon-reef surface areas (Figure 2.34, Table 2.10).

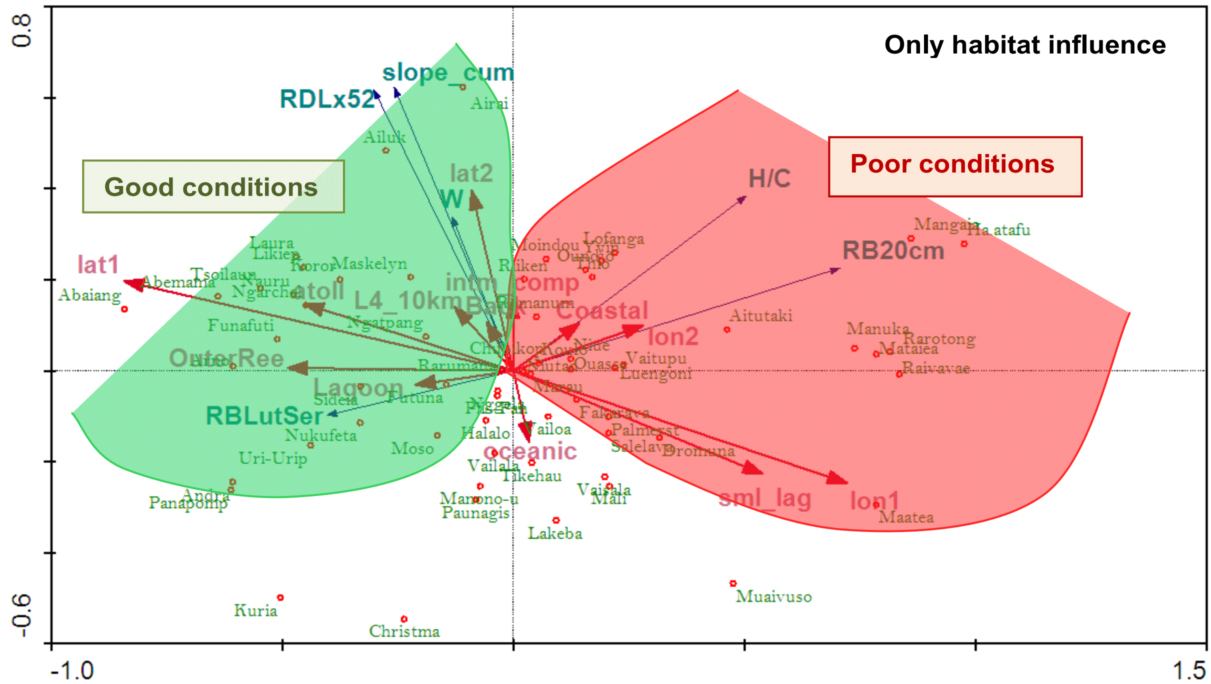


Figure 2.34: Effects of habitat on fish community, when influence from fishing pressure is extracted.
The percentage variance due to habitat and ecological interactions internal to the fish community, after extracting the impact from fishing, is equal to 30%.
Slope_cum = average percentage cumulative frequency slope; RD_{Lx52} = logarithmically transformed values of relative density of species of maximum size 52 cm; RB_{20cm} = relative biomass of fish of size <20 cm; RB_{LutSer} = relative biomass of all major piscivores (Lutjanidae and Serranidae); lat = latitude; lon = longitude; W = sum of the differences standardised to a common scale for unequal numbers of species in biomass–density dominance curves; refer Appendix 2.1.2; sml_lag = small lagoon; intm_comp = intermediate-complex island;
L4_10km = computed variable equivalent to the average number of substrate pixels obtained by satellite photos describing substrate composition in a 10 km radius around each site; H/C = relative biomass of herbivores over carnivores.
Light green colouration represents good condition; red colouration represents poor condition.

Table 2.10: Summary of parameters describing conditions of fish communities at each site and in relation to habitat, after extracting fishing input (three parameters)
In green shades are the conditions describing high level of status, in red, low level of status. In red are the signs (+) that changed from the analysis of both habitat and fishing pressure (Table 2.8)

Parameters	Island type							Reef type			
	Long	Lat	*Compl.	Atoll	Small lagoon	*Interm. compl.	Oceanic	Coastal	Lagoon	Back	Outer
RB_{20}	+	-		-	+			+	-		-
H_b/C_b	+	-		-	+			+	-		-
RB_{LS}	-	+		+	-			-	+	+	+
RB_{L52}	-	+	+	+	-	+	-			+	+
Slope_cum	-	+	+	+	-	+	-			+	+
W	-	+	+	+	-	+	-			+	+

RB_{20} = relative biomass of fish of size <20 cm; H_b/C_b = relative biomass of herbivores over carnivores; RB_{LS} = relative biomass of all major piscivores (Lutjanidae and Serranidae); RD_{L52} = logarithmically transformed values of relative density of species of maximum size 52 cm; Slope_cum = average percentage cumulative frequency slope; W = sum of the differences standardised to a common scale for unequal numbers of species in biomass–density dominance curves; refer Appendix 2.1.2; Long = longitude; Lat = latitude; *Compl. and *Interm. compl. combined = complex island; + = positive association; - = negative association.

In comparison to the relationship pattern resulting when both habitat and fishing are taken into account, when fishing-pressure measures are partitioned out of the analysis (Figure 2.34), large-sized species (RD_{L52}) are associated with the other indicators of good status and related to sites of high complexity, atolls, back- and outer reefs. Moreover, intermediate and complex island sites are not clearly associated with characteristics of poor conditions (high biomass of small fish and high H_b/C_b, and low values of indicators of good conditions). Complex islands could be associated with good fish resources because they host various types of habitats, such as mangroves, seagrass, etc., which increase the nutrient supply to the systems (Medley *et al.* 1993). These results suggest that sites at intermediate-complex islands are naturally in a healthy condition but show a response to fishing pressure, which can be identified by a decrease in large-sized species.

Coastal reefs appeared to be among the naturally poorest habitats and also more impacted by fishing (negative association with RB_{LS}, RD_{L52}, slope, W) while back- and outer reefs are naturally rich but also impacted by fishing. The higher natural poverty of resources in coastal reefs could be related to the input from terrigenous influence that may have an impact on the structure of fish communities. It has been shown, for example, that species richness, fish density and biomass are correlated to runoff gradients; the highest values are found in areas far from the coasts (Letourneur *et al.* 2000). Also, more extensive and complex coral reefs of the outer shelf are apt to provide a higher number of shelters and suitable habitats for more species and fish, making outer reefs richer habitats than internal reefs (Letourneur *et al.* 2000). Finally, easier accessibility for fishers could be a cause of the poorer conditions of fish communities in coastal reefs. In many instances male fishers tend to have less access and less desire to fish on outer reefs, and the lack of vessels can be particularly limiting in some countries (as shown in the socioeconomic report).

When the effect of habitat is extracted and only the relation to fishing impact is studied, the variance due to fishing pressure as described only by population density, catches and fish consumption, was 7% (Figure 2.35). It is interesting that such an impact is measured on the fish community when we consider that the spatial scale is so large and that only a few components of fishing are taken into account. Per capita consumption and catches are related to the biological indicators, while fishing for sale has a much lesser influence. High population density is related to higher proportion of herbivore over carnivore biomass and consumption is related to a high density of small fish.

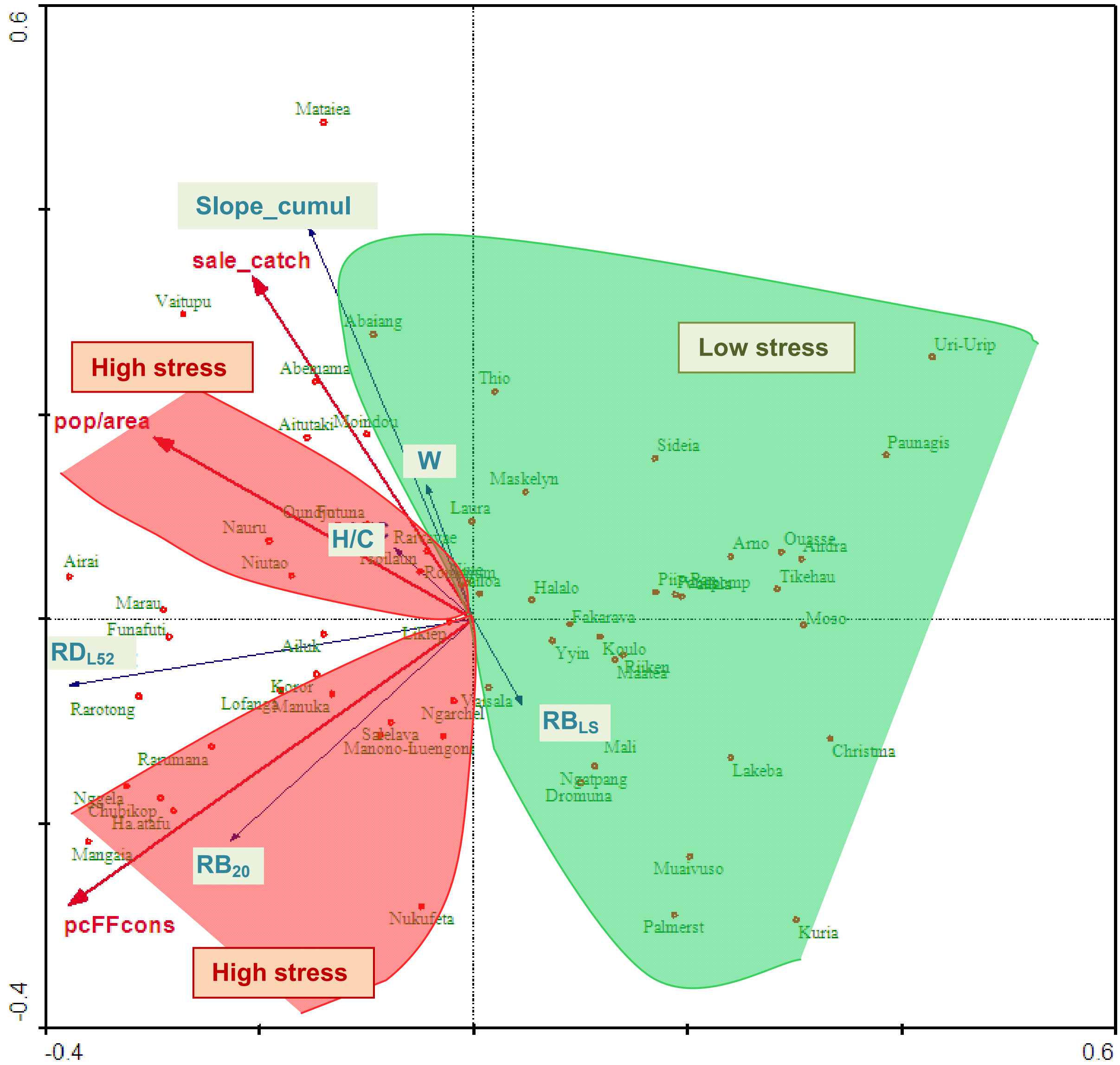


Figure 2.35: Fish composition as related to fishing pressure, when influence from habitat is extracted.
Percentage of variance due to fishing as simplified by three parameters (population density, fish consumption and catch for sale), after extracting the impact from habitat, is equal to 7%.
Slope_cumul = average percentage cumulative frequency slope; sale_catch = catches devoted to sale; pop/area = population per km²; W = sum of the differences standardised to a common scale for unequal numbers of species in biomass–density dominance curves–refer Appendix 2.1.2; H/C = relative biomass of herbivores over carnivores; RD_{L52} = logarithmically transformed values of relative density of species of maximum size 52 cm; RB_{20} = relative biomass of fish of size <20 cm; RB_{LS} = relative biomass of all major piscivores (Lutjanidae and Serranidae); pcFFcons = kg fresh fish consumed per capita per year.
Light green colouration represents low stress; red colouration represents high stress.

The total variance due to fishing impact as described by size and general trophic composition, both direct and indirect (through the variability due to the habitat, Figure 2.36) is equal to 11%; comparatively, the variability due to the habitat alone is equal to 30%, most of it due to the extremely large spatial scale. Unexplained variance amounts to 59%.

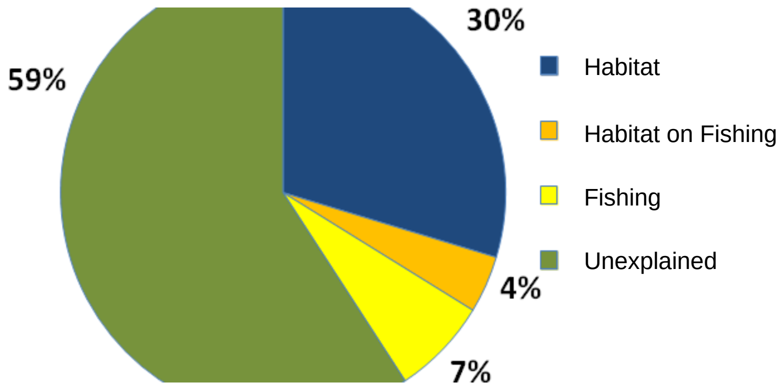


Figure 2.36: Partition of total variance of fish community size and general trophic structure (six indicators) due to causes related to habitat (Habitat), effect of habitat variation on fishing (Habitat on Fishing), and fishing as described by population density, per capita consumption of fresh fish and percentage sale of fish (Fishing).
RDA and PRDA were used to compute the different parts of variance in the fish communities.

2.3.4 Three sub-regions

Fishing stress as measured by the three parameters here considered (population density, fish consumption and catch for sale), appeared not to exert a large influence on the condition of the fish community, as described in terms of size (RD_{20}, RD_{L52}, Slope_cum) and trophic composition (H_b/C_b and RB_{LS}), when compared to the influence of the large-scale habitat. This is due to the distribution of the 63 sites throughout such a vast area so that habitat variability (mainly geographical and topographical) screens the influence of fishing. Moreover, there are many more important social and economic variables that describe the use of the resources that are not considered here. While the impact from fishing is partially obscured by the strong influence of the large spatial scale, it is interesting to note that the response to fishing strengthens when analysing the region on a smaller scale, i.e. at the level of the three ethnic sub-regions in which the Pacific is traditionally divided for representing significant cultural and traditional differences: Melanesia, Micronesia and Polynesia (Figure 2.37). The fishing pressure effects, as measured by human population density, consumption and intensity of catches for sale are higher in Melanesia (38%), followed by Micronesia (29%), and lower in Polynesia (12%), while the direct effect of habitat on fish community studied by size and trophic description is stronger in Polynesia (73%), followed by Melanesia (50%), then Micronesia (43%).

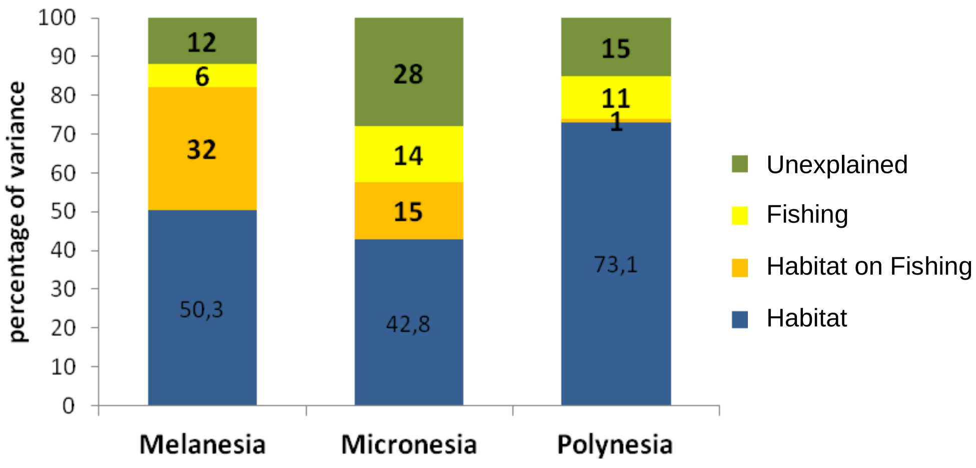


Figure 2.37: Partition of variance of fish composition in terms of size (RB_{20}, RD_{L52}, Slope_cum) and trophic relations (H_b/C_b and RB_{LS}) explained by 13 habitat variables and three fishing stress variables for the three sub-regions.
Fishing stress effects on fish (both direct and indirect through habitat) is highest in Melanesia (38%), lower in Micronesia (29%) and lowest in Polynesia (12%). The direct effect of habitat on fish community is strongest in Polynesia (73%), less in Melanesia (50%), and least in Micronesia (43%). RB_{20} = relative biomass of fish of size <20 cm; RD_{L52} = logarithmically transformed values of relative density of species of maximum size 52 cm; Slope_cum = average percentage cumulative frequency slope; H_b/C_b = relative biomass of herbivores over carnivores; RB_{LS} = relative biomass of all major piscivores (Lutjanidae and Serranidae).

The relative importance of habitat and fishing on variation in density, biomass and size of trophic and specific family composition was also analysed (Figure 2.38).

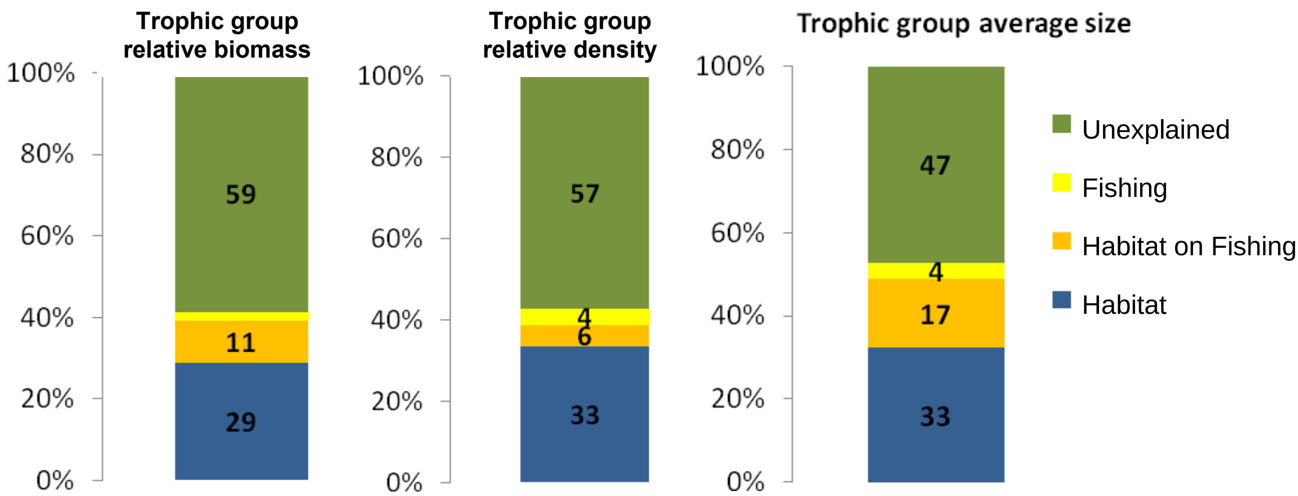


Figure 2.38: Distribution of variance among the two main sets of explanatory variables, large-scale habitat and fishing stress, on the relative biomass, density and average size of the four trophic guilds.
Total habitat effects are stronger than fishing pressure, as described only by three major variables, in explaining variability of density, biomass and size of the four trophic groups.

Trophic groups: The regional variance of relative biomass of trophic groups explained by the three selected fishing pressure factors (population density, fish consumption and catch for sale) was 12% while 29% of the total variance was due to habitat alone directly influencing the fishing community. In terms of density of trophic groups, 10% of the variance was due to fishing and 33% to large-scale habitat. Size appeared to be more influenced by fishing: 21%

of the total variance in average size of the four trophic groups was due to fishing and 33% to direct habitat variability.

Families: In the family analysis, the variance among sites in the relative density and biomass of eleven selected fish families that could be explained by direct fishing pressure was only respectively 18% and 19% of the total (Figure 2.39). At higher human population density (the most important of the three chosen parameters) and fish consumption, relative density and biomass of Acanthuridae are correspondingly higher and relative density and biomass of Scaridae are lower (Figure 2.40). Moreover, Acanthuridae, Scaridae and Lethrinidae sizes are lower at higher fish consumption and Serranidae size is lower at higher population density, confirming the well known response to fishing as a decrease in the average size of the fish population.

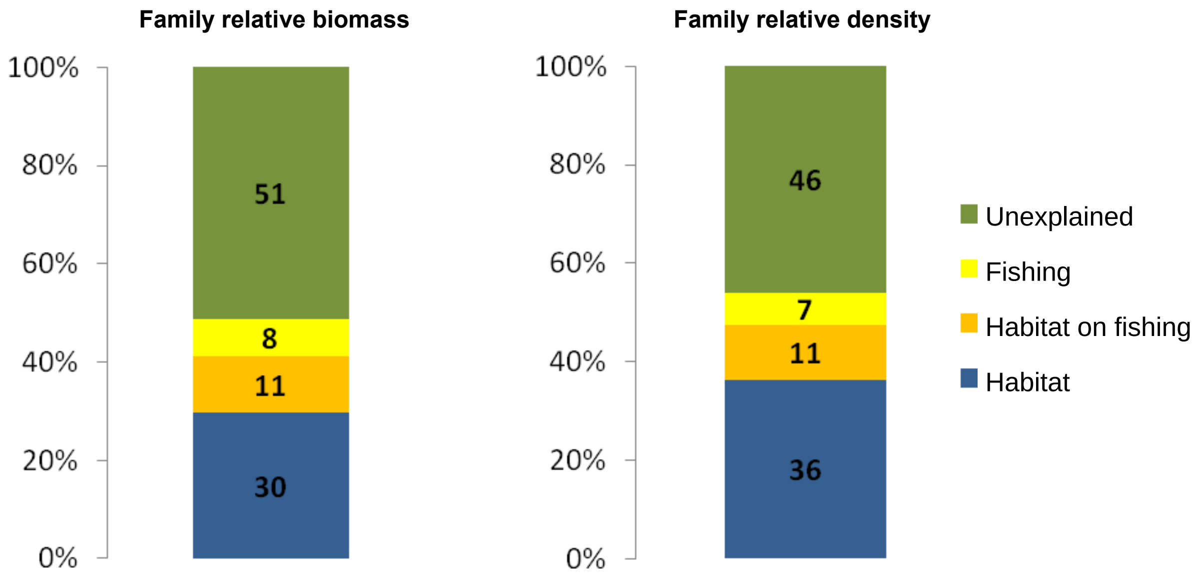


Figure 2.39: Distribution of variance between the two main sets of explanatory variables: large-scale habitat (13 parameters) and fishing stress (three parameters) on the relative biomass and density of the 11 major families.
Total habitat effects are stronger than fishing as described by three major variables in explaining family variance of density and biomass.

Results of the species analysis showed that 6% of the total variance in relative density and 6% of relative biomass of the 16 selected species (*Acanthurus blochii, Acanthurus lineatus, Acanthurus nigricauda, Acanthurus triostegus, Cephalopholis argus, Chaetodon auriga, Chaetodon citrinellus, Cheilinus chlorourus, Chlorurus microrhinos, Chlorurus sordidus, Ctenochaetus striatus, Gnathodentex aureolineatus, Hipposcarus longiceps, Lutjanus bohar, Lutjanus fulvus, Monotaxis grandoculis*) is due to fishing pressure alone. A high human population density and high per capita consumption correspond to a high relative biomass of *Naso lituratus* and a high relative density and biomass of *Ctenochaetus striatus* but a low relative biomass and high relative density of *Chlorurus sordidus* and *Acanthurus triostegus.* These results suggest direct responses from the major groups caught to fishing pressure. However, the large-scale habitat parameters control most of the variability in the fish community in terms of density, biomass and size, at the level of species, family and trophic guild.

The three simple parameters of fishing stress used here (human population density, fish consumption and catch for sale) explain about 20% of the variability of the fish community.

Half of this variability is due to the geographical variability in fishing practices (cultural differences and habits in different sub-regions and countries).

Thirty-three per cent of the variability in average size of family when only seven families are considered (after exclusion of Balistidae, Holocentridae, Siganidae and Zanclidae) was explained by habitat variability, 20% by habitat and fishing together and 4% by fishing only (Figure 2.41). Acanthuridae, Scaridae and Lethrinidae sizes are lower at higher fish consumption; Serranidae size is lower at higher density of people.

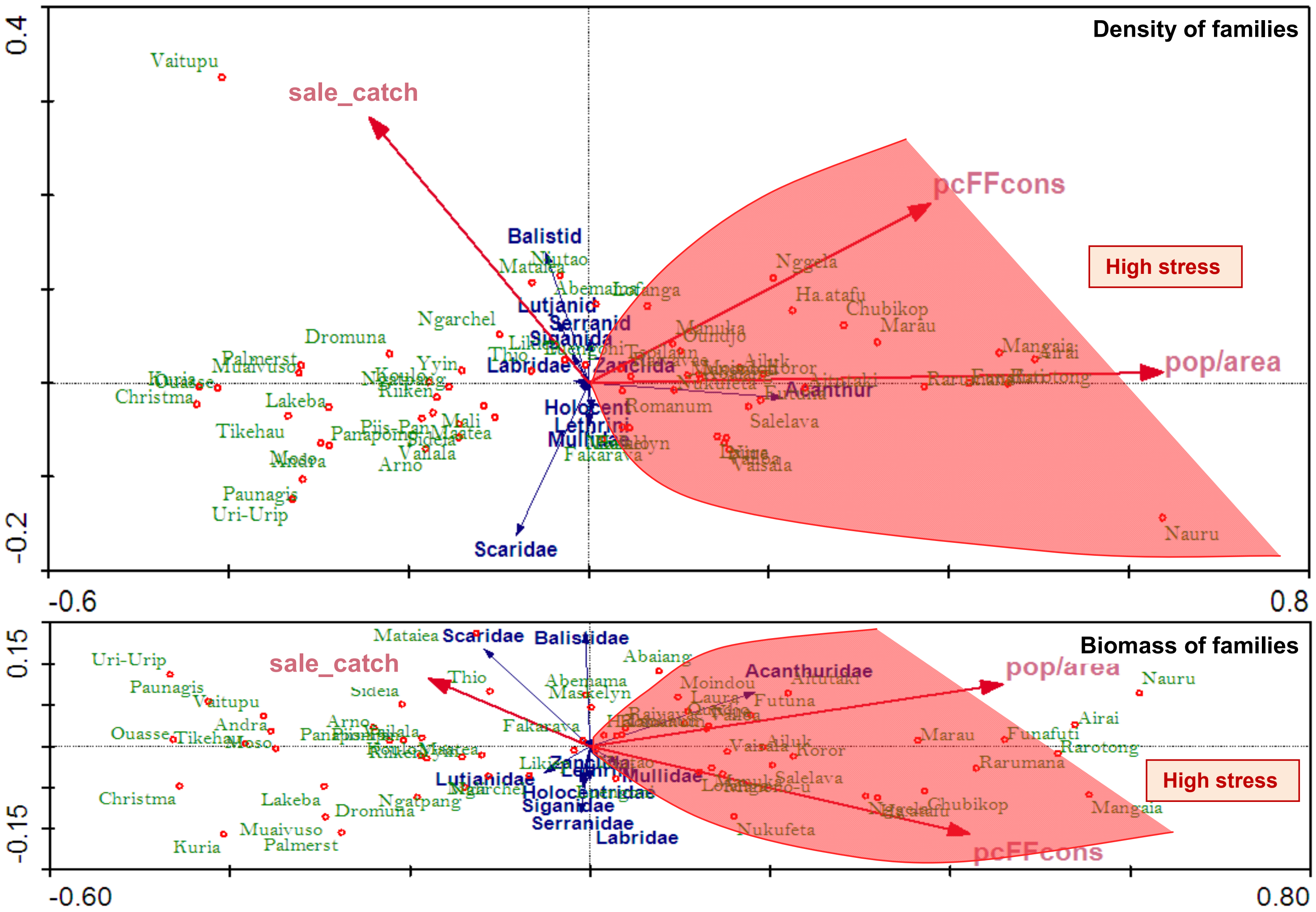


Figure 2.40: Relations to the three fishing impacts are evident in the graphs: Scaridae are negatively related to per capita fish consumed (pcFFcons), Acanthuridae are positively correlated to people density (pop/area).
sale_catch = catches devoted to sale; pop/area = population per km²; pcFFcons = kg fresh fish consumed per capita per year; Balistid = Balistidae; Lutjanid = Lutjanidae; Serranid = Serranidae; Siganida = Siganidae; Zanclida = Zanclidae; Holocent = Holocentridae; Lethrini = Lethrinidae; Acanthur = Acanthuridae. Red colouration represents high stress.

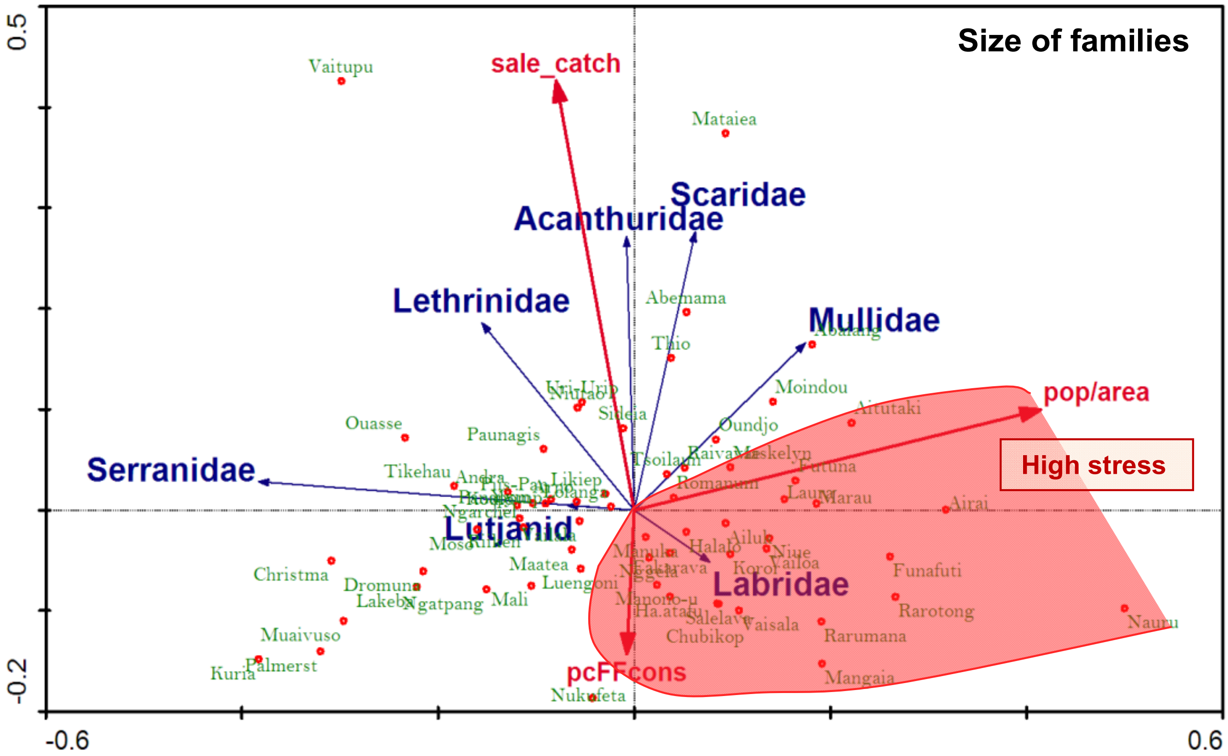


Figure 2.41: Relations to the three fishing impacts are evident in the graph: Acanthuridae, Scaridae, Lethrinidae sizes are negatively correlated to fish consumption; Serranidae size negatively related to density of people.
Lutjanid = Lutjanidae; sale_catch = catches devoted to sale; pop/area = population per km^2; pcFFcons = kg fresh fish consumed per capita per year.
Red colouration represents high stress.

Species: Results from the species analysis showed that 12% of the total variance in relative density and 14% of the variance in relative biomass of the 16 selected species are due to fishing pressure. A high human population density and high per capita consumption correspond to a high relative biomass of *Naso lituratus* and high relative density and biomass of *Ctenochaetus striatus* but a low relative biomass and high relative density of *Chlorurus sordidus* and *Acanthurus triostegus*. These results suggest direct responses from the major groups caught to fishing pressure.

When large-scale habitat is extracted from the matrix of abundance and presence/absence of selected key species (density of Carangidae and presence/absence of Carcharhinidae, *Bolbometopon muricatum* and *Cheilinus undulatus)*, fishing impact determines 5% of the variability. *Cheilinus undulatus* is more often present where consumption of fresh fish is the lowest. Carangidae, sharks and *B. muricatum* are more present where the density of people is low.

Notwithstanding the large differences in habitat across the vast region, which control most of the variability in the fish community in terms of density, biomass and size, at the level of species, family and trophic guild, only three indicators of fishing stress explain almost 20% of the variability of the fish community. These three factors are population density, fish consumption and catch for sale. About half of this variation can be accounted for by differences in the nature of fishing activities related to location and island type (differences in fishing techniques, cultural differences, etc.), while the other half is correlated with the direct effect of population density, fish consumption and catch for sale on the fish community composition.

In order to compare the relative influence of the two sets of factors (habitat and fishing) in determining the size composition, and composition of fish species, family and trophic group, we need to weight the variance of each set by the individual number of factors since the number of variables used in each explanatory matrix is not equal. Habitat plays as much as 2.2–2.8% of cause in the variance per each factor considered (Here 13 factors are retained in the study.), while fishing pressure causes 0.7% to 2.7% of variance for each parameter used (here only three used). However, this is just a rough indication since not all parameters would have the same importance in affecting the total variance of the fish family and trophic composition explained.

Further indicators of fishing impact

We tested the validity of 10 further indicators in identifying status and impact from fishing in addition to the previously tested RD_{L52}, RB_{20}, RB_{LS}, H_b/C_b, W: relative biomass of Acanthuridae, relative biomass of Scaridae, relative density of *Ctenochaetus striatus*, relative density of *Chlorurus sordidus*, relative biomass of *Naso lituratus,* density of Carangidae, presence of *Cheilinus undulatus, Bolbometopon muricatum* and sharks, and the average distance at which a fish keeps away from the divers.

The density of *C. striatus*, biomass of *N. lituratus*, presence of Carcharhinidae and *Cheilinus undulatus*, and average distance of fish from divers did not show differences among groups of sites at different status level (Table 2.11) and were, therefore, eliminated as possible indicators of impact. The relative biomass of Acanthuridae, relative biomass of Scaridae, density of Carangidae and relative density of *Chlorurus sordidus* were significant in the further characterisation of the four site-groups obtained from size-frequency distributions.

Table 2.11: Groups of different levels of status and relative indicators

Group of sites	Slope	RD_{L52}	RB_{20}	RB_{LS}	H_b/C_b	D. Car.	B. Acan.	B. Scar.	D. Chl.
P_{ANOVA}	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	<0.01	<0.05	0.02
IV	++	+	-	+	-	+	--	--	-
III	+	+	-	++	--	++	--	--	
II	+	-	+	-	+	-	-	-	-
I	-	-	+	-	++	-	+	+	+

RD_{L52}: logarithmically transformed values of relative density of species of maximum size 52 cm; RB_{20}: relative biomass of fish of size <20 cm; RB_{LS}: relative biomass of all major piscivores (Lutjanidae and Serranidae); H_b/C_b: relative biomass of herbivores over carnivores; D.: density; B.: biomass; Acan.: Acanthuridae; Scar.: Scaridae; Chr.: *Chlorurus*; status I = depleted/low-quality fish community; status IV = healthy/good-quality fish community.

A classification of sites based on the risk level of use was drawn by Kronen *et al.* (2009), based on fishing pressure and socioeconomic information. Sites are classified from A to D along an increasing level of risk of fishing impact. When comparing the two types of classification: the first based on resource conditions (Table 2.11) and the second on level of risk, similarities as well as some discordances are found (Table 2.12). Some sites are found to have a good status of resource but a high risk, probably meaning that exploitation has been going on for a short time and impacts are not yet visible in the resources. On the other hand, sites with poor resource conditions are considered to be at low risk of fishing pressure, probably meaning that the site is naturally poorly productive and cannot sustain even a low level of catch, or that fishing has been conducted unsustainably over a long time period, causing the collapse of resources and the consequent lower level of catches.

Table 2.12: Groups of sites with good, average, and depleted conditions and, at the same time, with low, average, and high risk of overexploitation
Only sites common to the two groupings are noted.

6 sites; IV-A	Healthy.Good	Ailuk, Fakarava, Koror, Likiep, Ouassé, Raivavae
4 sites; III-B	Above average	Abemama, Funafuti, Kuria, Laura
9 sites; II-B	Below average	Aitutaki, Chubikopi, Mangaia, Maskelynes, Moso, Paunangisu, Piis-Panewu, Sideia, Tsoilaunung
3 sites; I-C	Depleted/Low	Salelavalu, Vailoa, Vaisala

status I = depleted/low-quality fish community; status IV = healthy/good-quality fish community.
A: low risk of fishing impact; D: high risk of fishing impact.

It is important to remember that such a small number of sites per country (four fishing villages only) and a one-off snapshot survey cannot give a true picture of the conditions of fish resources in the entire country. Nor can such a survey reveal the actual state of fish resources, due to a lack of comparative measurements before human impacts or at a previous time. Faunal assemblages found today could already be a consequence of high fishing pressure in the distant past, as long ago as 3000 years (Dalzell 1998, Adams and Dalzell 1998). Estimating a virgin stock biomass is very hard or impossible, especially in multispecies fisheries. If one could determine the original stock, the target catch to maintain production could be established. For example, if the stock is below 10% of its virgin size, no catch should be allowed (Hilborn 2002). However, it was established that biological overfishing occurs already when the stock falls below half of the pristine biomass (Clarke 1985). However, such references are inexistent for these fisheries.

Therefore, the lack of a comparative status or knowledge of the pristine condition limits our capacity to infer the impact of fishing on reef resources. However, comparisons can be made with similar systems in other areas of the world. It was determined that the value 1200 kg/ha (equivalent to 120 t/km^2) provides a good reference of pristine level for estimating the condition of reef fish biomass in Kenya (McClanahan and Graham 2005). Similarly, estimation of biomass in the practically pristine Northwestern Hawaiian Islands gave a value of 2400 kg/ha (equivalent to 240 t/km^2, Friedlander and DeMartini 2002). Comparatively, biomass in unfished areas in Fiji Islands and Seychelles ranged between 500 and 1000 kg/ha (equivalent to 50 to 100 t/km^2, Jennings *et al.* 1995, Jennings and Polunin 1997, Dulvy *et al.* 2004). A low level of exploitation, for example, from a recent study in the Hawaiian islands, can result in a maximum fish biomass of 80 t/km^2 in the lowest populated islands of the chain (Williams *et al.* 2008, McClanahan and Graham 2005). In 1977, Brock calculated 92 kg/km^2 using rotenone in locations at low level of impact in Oahu, Hawai'i (Brock *et al.* 1979). In New Caledonia almost pristine stock was estimated to be at 1.6–3.4 t/ha (160–340 t/km^2, Letourneur *et al.* 2000). Such values give us a rough indication of the level of resources found throughout the region: in the present survey we obtained an average biomass of 118 t/km^2, which suggests resources are generally in rather good conditions when compared to the references cited.

However, the variation in biomass per site is between 17 and 363 t/km^2 (Figure 2.42). Forty-one sites (65% of all sites) are found below the average value (118 t/km^2) and only 22 (35%) above it. A total of 36 sites (57%) displayed biomass <100 t/km^2, a lower limit of unfished areas in the Indian and Pacific oceans. The highest values surpass the estimates previously given by Dalzell *et al.* 1996 (0.8–289 t/km^2) and Adams *et al.* 1997 (mean 7.7 t/km^2) for the

Pacific. However, the average-to-good level of conditions suggested by the present values must be considered with caution, due to the full and large range of values when all sites are considered individually (Table 2.13, Figure 2.42).

Table 2.13: Comparisons of some biomass values for different reef fisheries in the world

Location and level of exploitation	Biomass (t/km^2)	Reference
Unfished Fiji Islands and Seychelles	50–100	Jennings *et al*. 1995, Jennings and Polunin 1997, Dulvy *et al.* 2004
Pristine Kenya	120	McClanahan and Graham 2005
Pristine Northwestern Hawai'ian Islands	240	Friedlander and DeMartini 2002
Hawaiian islands fished at low level (scarcely populated)	80	Williams *et al*. 2008, McClanahan and Graham 2005
Average Pacific (63 sites)	**118**	PROCFish survey
36 sites (of 63 sites)	<100	PROCFish survey
Poorest PROCFish site	17	PROCFish survey

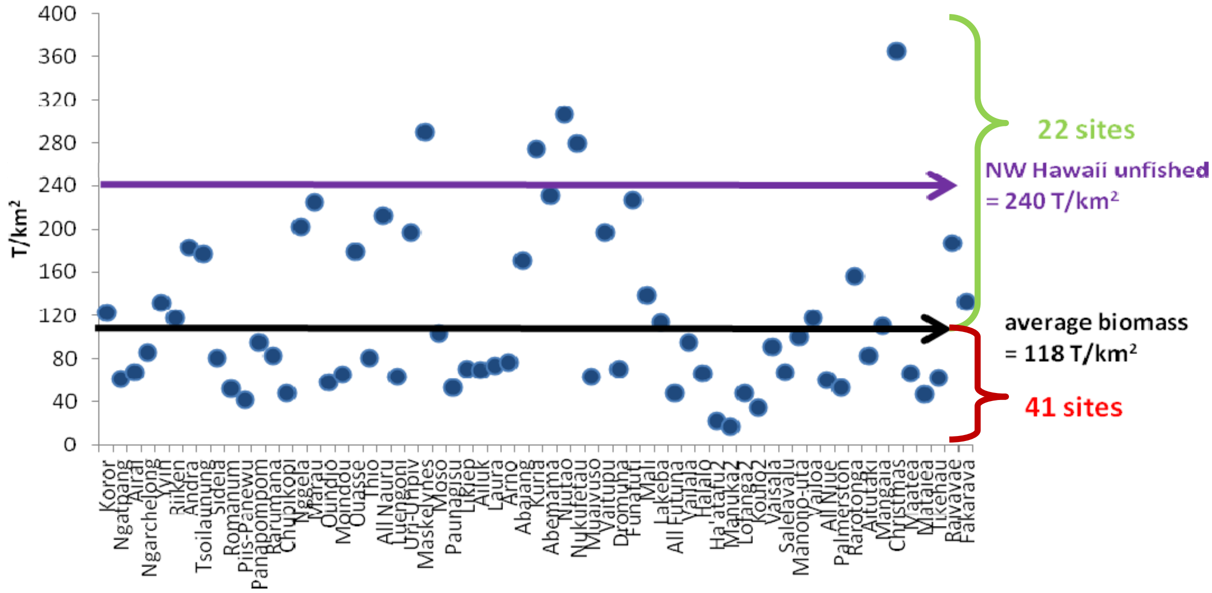


Figure 2.42: Average value of total commercial fish biomass (t/km²) among all sites, and individual values for each site.
Only 22 sites are found with biomass values above average.

2.4 Discussion and conclusion

2.4.1 Levels of status and indicators

The conditions of the 63 sites are rather mediocre in terms of finfish resources when considered as a whole. However, less than 1/3 of all sites (27%) are found in good conditions. The majority of the sites are either in low-average conditions (54% of all sites) or poor conditions (20% of sites).

- The average value of **biomass** throughout the region equals 118 t/km^2, a value which is in the range of good quality reef fishing around the world. However, as many as 41 sites (65% of total) are found below this average value. **Trophic composition** of the fish community helped identify sites of good health (Figure 2.43). **Size** has also been identified as one of the major signals for fish community status and as a possible indicator for fishing pressure. These parameters were, therefore, chosen as strong indicators of status.

- Only 10 sites display a biomass of commercial carnivores higher than herbivores (an index of good condition of a fish community). Twenty-nine sites displayed a herbivore biomass twice as high as carnivore biomass.

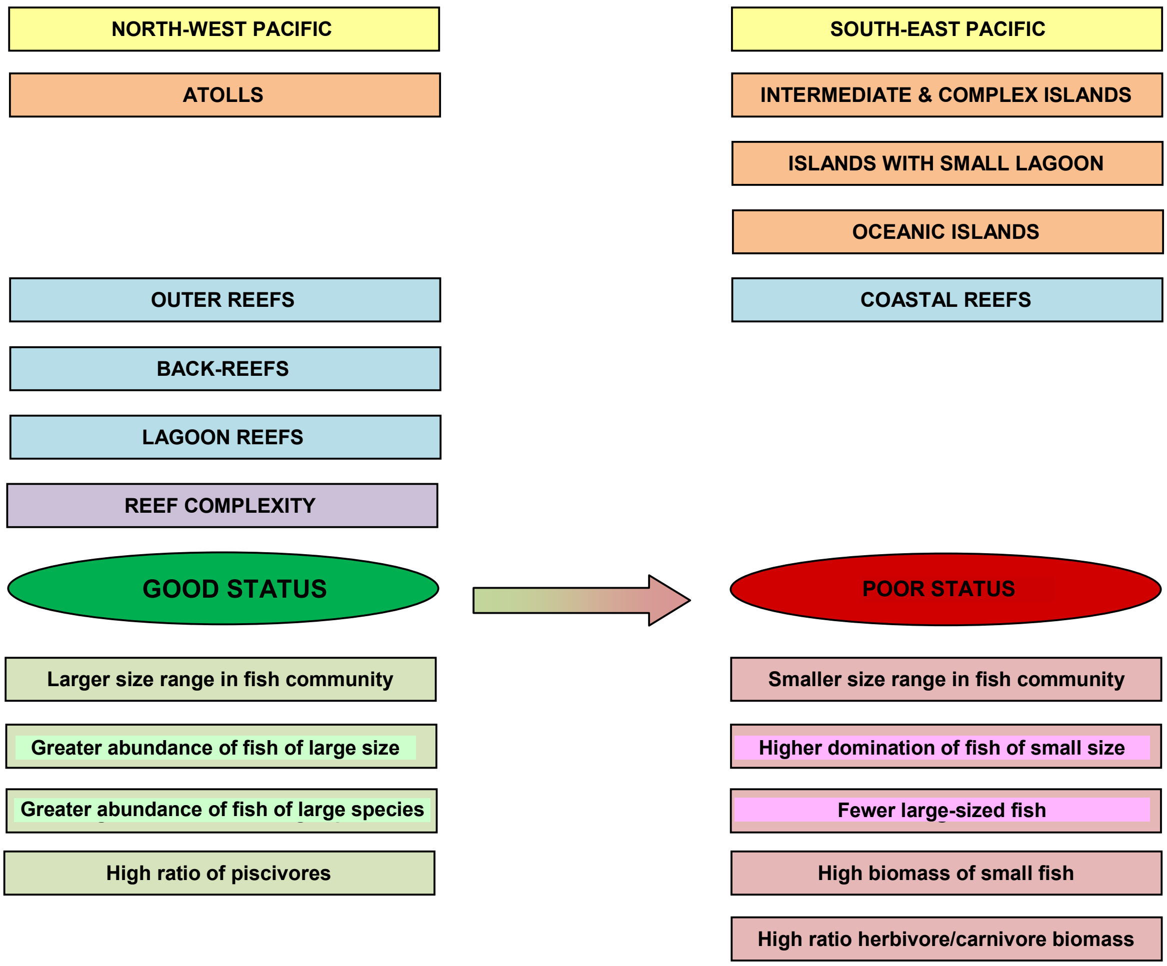


Figure 2.43: Description of sites in good (healthy)/poor (depleted) status based on geographic, geomorphological, topographical and biological parameters.

- **The fish community on average is dominated by small sizes.** Fish are in general of small size: 96% of the whole commercial fish community is composed of fish smaller than 35 cm (FL) in size. Fish smaller than 20 cm represent an average of 68% of the total fish abundance. Thirty-six per cent of all commercial fish (maximum frequency) are 15 cm in body length (fork length).

- The fish community is mainly composed of mid-sized species while **large-sized species are almost absent**: the highest proportion of the fish composition (32%) when taken as a regional average is composed of species that could potentially reach only 25 and 30 cm of body length. Classes above 50 cm of possible maximum length contribute together less than 10% of the total fish counted.

- When sites were grouped into four levels of resource status (level I good to level IV poor), the following trend in size-frequency distribution of whole fish communities was observed. As conditions declined, there were fewer fish of all sizes, a reduction in numbers of large-sized fish, and a few smaller-sized species dominated the fish community.

- Sites presenting **poorer conditions**, with **a high biomass of small fish and high herbivore-to-carnivore ratio,** are more frequent towards the **east** of the region, at **islands with small lagoons, intermediate and complex islands** and **oceanic islands** and at locations with large areas of **coastal reefs**. Maatea (FP), Ha'atafu (TO), Manuka (TO) and Lofanga (TO) are examples of these types of sites.

- Sites in **healthier condition**, with **high ratios of piscivores, a wider range of sizes with presence of large fish and a greater abundance of large fish, and a greater presence of large-sized species** are more frequent at **high latitude**, at **atoll** sites, and at locations with **highly complex habitat** and large surface areas of **outer**, **back-** and **lagoon reefs**. Abaiang (KI), Abemama (KI), Ailuk (MI) and Likiep (MI) are examples of these types of sites.

- **Sites with larger areas of coastal reefs** compared to back- and outer reefs appeared to be among the **naturally poorest habitats.**

- The grouping of sites into four levels of resource conditions seemed to positively correlate with four groups of sites grouped according to risk of fishing pressure (Kronen *et al.* 2009), although some discordances are found. Some sites are found with a good status of resource but at high risk, probably meaning that exploitation has been going on for a short time and impacts are not yet visible in resources; on the other hand, sites with poor resource conditions are considered to be at low fishing pressure risk, probably meaning that the site is naturally poorly productive and cannot even sustain a low level of catch, or that fishing has already been going on for too long, causing the collapse of resources and the consequent lower level of catches.

- **Status level as compared to other regions in the world:** a one-off, snapshot survey of such a small number of sites per country (Four fishing villages, except for Niue, Nauru and Futuna, are hardly representative of the whole country.) cannot give a true picture of the conditions of fish resources in the entire country nor of the actual state of the fish resources, due to lack of comparative measurements before human impacts or at a previous time.

Therefore, the lack of a comparative status or a pristine condition limits our capacity to infer the impact of fishing on reef resources. However, comparisons can be made with similar systems in other areas of the world. If we consider the value 50–240 t/km^2 from other reefs around the world to be a good indicator of reef fish biomass in pristine condition, we could define the conditions of all the sites of the present project taken as a whole (averaging biomass of 118 t/km^2) to be at an **intermediate level of the world pristine state**, i.e. in relatively good condition, when compared to the references cited. However, the variation in biomass per site is 17–363 t/km^2 and a total of 41 sites **(65% of all sites) are found below this average value.** A total of **36 sites (57%) displayed biomass <100 t/km^2.** Therefore, any definition of the resource condition based on the present values has to be considered with caution due to the large range of values when all sites are considered individually.

2.4.2 Fishing impact

A **significant impact from fishing** was measured on the fish community given such a large spatial scale and considering that only a few components describing fishing were taken into account for the analysis.

- **Sites with large areas of coastal reefs** compared to other reef types are the **most impacted by fishing**: these sites present a **low abundance of piscivores, low abundance of large-sized fish, a higher proportion of small fish and fewer large fish, and communities increasingly dominated by opportunistic species** that dominate the biomass as well as the numbers. Easier access could be a cause of poorer conditions of fish communities in coastal reefs due to fishing impact. In many instances, male fishers tend to have less access and less desire to fish on outer reefs and the lack of vessels available can be particularly limiting in some countries.

- **The intermediate and complex islands** appeared to be naturally rich but show **impact from fishing**. They show a decrease of large-sized species under fishing pressure.

- **At high people density** (the best parameter for measuring fishing pressure) **there is a higher proportion of biomass of herbivores over carnivores** (Figure 2.44), a **higher relative density and biomass of Acanthuridae** compared to other fish (and high relative importance of *Acanthurus triostegus*, *Naso lituratus* and *Ctenochaetus striatus)* and **lower relative density and biomass of Scaridae** (*Chlorurus sordidus* display high numbers but small size, making their overall biomass low). Moreover, **Serranidae sizes are smaller**. **Carangidae, sharks and *Bolbometopon muricatum*** are **rarer** when people density is high.

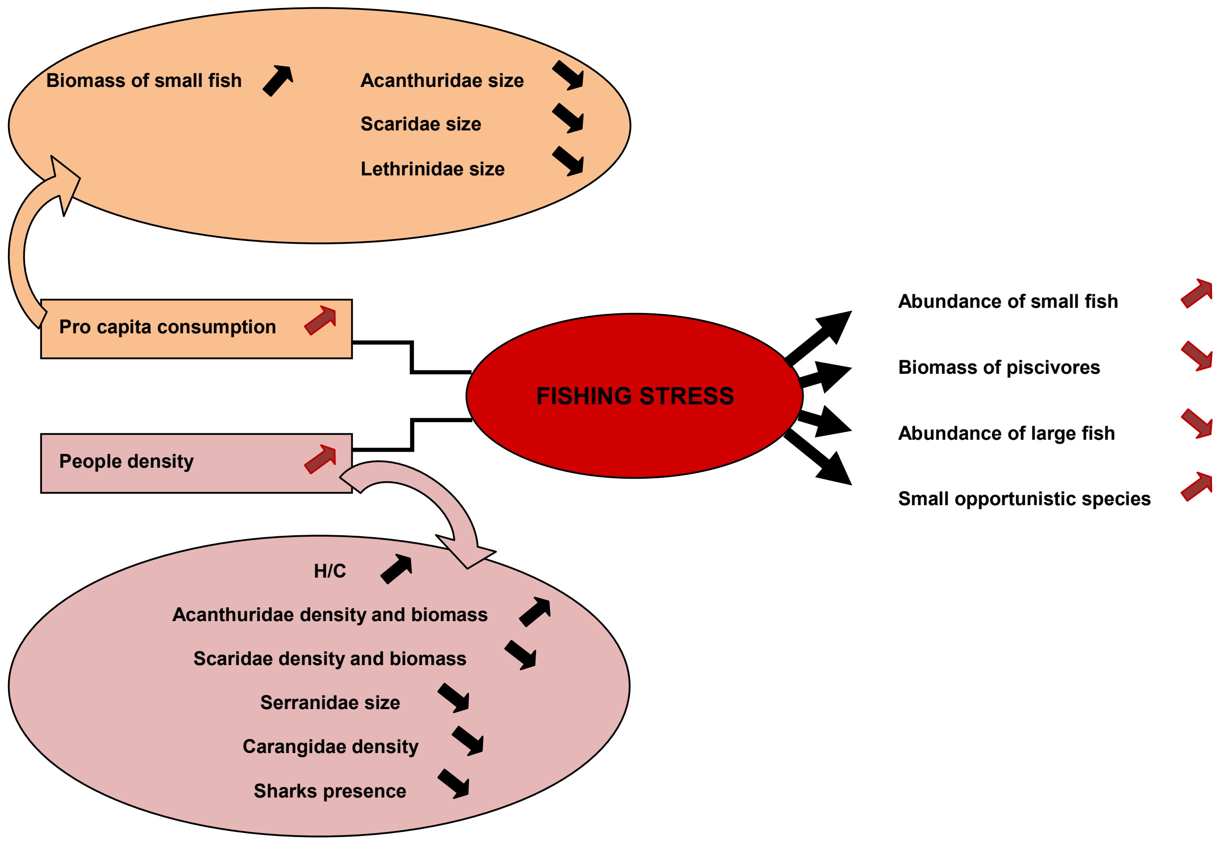


Figure 2.44: Description of fishing stress as influenced by per capita consumption and people density, and its effect on size and abundance of fish.

- At **high per capita consumption of fresh fish** there is a **high density of small fish**. **Sizes of Acanthuridae, Scaridae and Lethrinidae are smaller.** *Cheilinus undulatus* is less present.

- Notwithstanding the large differences in habitat across the vast region, which control most of the variability in the fish community in terms of density, biomass and size, at the level of species, family and trophic guild, only **three indicators of fishing stress explain almost 20%** of the variability of the fish community. **These three factors are population density, fish consumption and catch for sale.** About half of this variation can be accounted for by differences in the nature of fishing activities related to location and island type (differences in fishing techniques, cultural differences, etc.), while the other half is correlated with the direct effect of population density, fish consumption and catch for sale on the fish community composition.

- **Habitat causes** as much as **0.8–2.5% of the variability of the fish community** throughout the region for each of the driving factors considered here (13 factors describing habitat), while **fishing pressure causes 0.7–2.7%** of variance for each parameter used (here only three used). Although this result is just a rough indication, since not all parameters have the same importance for the total variability, it suggests that difference in conditions at the exceptionally large scale exerts only a little more influence than does fishing.

- **Sub-regional fishing and habitat influence:** the direct **effects of geographical location and habit** on fish community studied by size and trophic description is **stronger in**

Polynesia (73%), **less so in Melanesia** (50%), **and least in Micronesia** (43%), while **fishing stress effects**, as measured by human population density, consumption and percentage of catches for sale are **higher in Melanesia** (38%), **lower in Micronesia** (29%) and **lowest in Polynesia** (12%).

2.4.3 Geographical and physical variability driving diversity of conditions of sites

- The tremendous importance of the extensive geographical variation has been taken into account in the study of the relationship between resources and use in both the search for indicators and the identification of fishing impacts.

- The very large scale of the project is reflected in the high level of control on the fish presence, production and association exerted by the geographical location: **longitude and latitude exert an influence on the geomorphology of islands and reef composition** and **on the fish communities,** both directly, through variation of the biota, and indirectly, through the geographical variation of habitat.

- Four major **geomorphological types of islands** are defined:

  - high oceanic islands of volcanic origins,
  - islands with small lagoons at an intermediate geological development between a high island and an atoll,
  - complex islands, which are intermediate between the two extreme geological stages of 'atoll' and 'high island' and present a large range of terrestrial and marine habitats, and
  - atolls, the final geological development of an island. These are differently distributed in the region: **oceanic islands and islands with small lagoon**s are mostly found **closer to the equator**; **complex islands** are **more concentrated to the west; atolls are prevalently found to the north and east** of the region.

- **Total reef area** varies greatly from site to site, from reef surfaces as small as 1 km^2 to much larger reef surfaces reaching almost 200 km^2. Total **reef areas** per site are **higher at complex islands and atolls** compared to islands with small lagoons, and oceanic islands.

- **Coral reef composition** is defined by summarising **reef types** into four main coralline geomorphologic structures found in the Pacific:

  - sheltered coastal reef along the shores,
  - intermediate lagoon reef identified by patch reef that is located inside a lagoon or a pseudo-lagoon,
  - back-reef, which is the inner/lagoon side of outer reef, and
  - outer reef, the ocean side of fringing or barrier reefs.

  This composition of different reefs is related mostly to the geomorphological configuration of the islands, and changes considerably throughout the region. Larger reef areas are associated with coastal, back- and lagoon reefs compared to outer reefs. **Atolls** have comparatively **large areas of outer reefs but no coastal reef**; therefore, they are characterised by no terrigenous inputs from land, but by a high influence of nutrients coming from the outer ocean through currents and upwellings. **Islands with small lagoons and complex islands** have **high cover of coastal, lagoon, back- and outer-reef** areas and are also characterised by the **highest complexity of habitats and**

substrate diversity. **Oceanic** islands have **wide areas of outer reefs as well as back-reefs**.

- **Substrate composition at a smaller scale varies widely:** the average percentage of live coral is higher at atolls and complex islands and lower at oceanic islands. Percentages of dead coral and rubble are higher at complex islands. There are larger differences among different reef types at a site than among the same reef types of all sites, making generalisation about an 'average' site substrate not very meaningful. Live-coral and bedrock cover are significantly higher, and sand significantly lower at outer reefs. Variation in live-coral cover is also greatest at outer reefs and back-reefs, followed by lagoon reefs, and least at coastal reefs. Soft algae do not show any significant differences among the four reef types; however, encrusting algae are most widespread at ocean reefs, less so at back-reefs, and least common at lagoon and coastal reefs.

- **Fish biodiversity**: over such a wide range of longitude, **species diversity in the Pacific region decreases from west to east**, as expected from the rule of rarefaction of species with distance from the centre of biodiversity. The mean number of species per transect was 37, ranging from 21 species per transect (Raivavae - FP) to 60 species per transect (Koror - PW). Average species richness by site was 152 species per site (93 species per site at Manuka - TO and 239 species per site at Koror - PW). Due to the fact that less than 1% of all species (four species: *Ctenochaetus striatus, Naso lituratus*, *Parupeneus multifasciatus* and *Zanclus cornutus)* are common to all sites, any comparison of faunal taxonomical compositions throughout the region is very hard.

- **Fish abundance and composition vary throughout the region.**
  - Fish density varies almost of an order of magnitude between the poorest and the highest extreme: 0.2 N/m^2 (Manuka - TO) and 1.8 N/m^2 (Kuria - KI) respectively, with regional average 0.60 N/m^2. Fish biomass is 20 times higher at the richest site compared to the poorest one: the minimum value at 17 g/m^2 being recorded at Manuka (TO), and the maximum value at 363 g/m^2 at Kiritimati (KI), with a comparative regional average of 118 g/m^2. Overall mean fish size was 17 cm, with minimum at 11 cm recorded at Palmerston (CK) and maximum at 23 cm recorded at Kiritimati (KI).
  - Throughout the region the dominant trophic group is the herbivores, which make up on average 65% of the total fish counted (range 20–90%); second important were invertebrate-eaters (average 25%, range 5–60%), then planktivores (average 5%, range <1–50%) and piscivores (average 6%, range <1–15%).
  - The ratio between herbivores and carnivores, a first broad indication of complexity, productivity and health of a fish community, varies greatly throughout the region, with extreme values between 0.2 and 7.8.

- **Fish abundance and composition varies throughout the region as driven by geography and environment.**
  - Longitude controls the distribution of some groups of fish: invertebrate feeders (e.g. Mullidae, Balistidae, Labridae, Lethrinidae) display a higher relative density and biomass (compared to total density and biomass of commercial fish) to the other trophic groups in the western part of the region, while overall herbivores are more important to the east. However, Scaridae display higher relative density at western sites while Acanthuridae are more important at eastern sites.
  - Diversity of island types also causes differences in fish communities. The fish community is more highly dominated by herbivore fish (Acanthuridae, Scaridae and

Siganidae) at oceanic islands, islands with small lagoon and complex islands; Scaridae are significantly more important at complex and intermediate islands than other families. Some species of Scaridae showed a clear association with islands with small lagoons: *Chlorurus sordidus*, *Scarus niger* and *S. psittacus.* In contrast, fish communities at atoll sites are dominated by carnivores: some invertebrate-feeders (Balistidae, Labridae, Lethrinidae and Mullidae) but mainly planktivores (Holocentridae) and piscivores (Lutjanidae and Serranidae).

- o Reef types with their differences in substrate and complexity, also have an impact on fish composition. Density of herbivores is slightly higher at back-reefs. However, among these, Acanthuridae are more important at outer and back-reefs, while Siganidae are more important at coastal reefs. Invertebrate-feeders are associated with lagoon and coastal reefs. Plankton-feeders and piscivores, and among these Serranidae, are more associated with outer reefs.
- o Invertebrate-feeders (such as species of Balistidae, Labridae, Lethrinidae and Mullidae) and herbivores (most Acanthuridae species, Scaridae and Siganidae) are preferentially found at sites of high complexity, whereas planktivores (most species of Holocentridae, some Acanthuridae), and some piscivores (particularly Lutjanidae) do not show this association. This may be because herbivores and invertebrate feeders are directly dependent on coral reefs for their food and shelter; while planktivores and piscivores feed off the reef but are not strictly linked to it.

2.5 Recommendations

Due to the strong response of the fish community to fishing pressure in terms of small sizes and low biomass, a thorough and cautious management regime should be applied throughout the region.

- ***Restrictions to fishing tools*** should be applied, especially for night-diving and non-selective gillnetting.

- ***Catch quotas*** should be established at each site relative to both the conditions and risk level of each site, as determined by this study.

- ***Alternative fisheries*** should be sought and established: users should look into exploiting alternative resources. Acanthuridae appeared to be less impacted and the most opportunistic feeders and, therefore, the most resilient fish family to fishing pressure. Diet preferences should be re-directed towards more sustainable resources. As another example, in some places, offshore or deep-water species could be targeted. Preferences should be given to herbivorous fish (Acanthuridae, Scaridae, Siganidae).

- ***Protection of spawning aggregation sites:*** this measure should be applied everywhere, regardless of the conditions and risk levels. Such locations are the sources of replenishing all coastal, lagoonal and outer-reef resources.

- ***Community-managed 'no fishing' areas*** should be applied everywhere to provide sources of replenishing fish stock throughout the sites.

- ***Monitoring programmes*** should be established everywhere, on both resources and catches. For underwater resource assessment a new, locally manageable method is currently being designed; however, some rules and indicators to be measured at regular times can be summarised:

- maintain the same design over time, in the same locations;
- measure the sizes of all edible fish;
- identify and count target families: Acanthuridae, Scaridae, Siganidae, Serranidae, at the level of species, focusing on locally preferred and highly targeted species;
- measure live coral cover and complexity at *in situ* dive sites. Satellite images can be requested.

3. PROFILE AND RESULTS FOR INVERTEBRATE ASSESSMENT

3.1 Introduction

3.1.1 General description of invertebrate resource distribution throughout the region

In general, invertebrate reef fisheries in the context of this study are fisheries targeting organisms associated with tropical coral reefs and lagoons – essentially fisheries taking place in Pacific Island waters from 0–50 m depth. The importance of these fisheries to Pacific Island countries and territories (PICTs) cannot be overstated – as mostly everywhere they contribute significantly to the food security, livelihoods and culture of both rural communities and urban populations (Dalzell *et al.* 1996, Anon. 2007, Bell *et al.* 2009, Gillett 2009). Despite the importance of invertebrate resources, most studies in the Pacific have been conducted to determine the state of finfish resources, especially pelagic finfish stocks of commercial and export value, with less emphasis on invertebrates of commercial or subsistence value (Costello *et al.* 2008, Hilborn 2002, Jackson *et al.* 2001, Mullon *et al.* 2005, Myers and Worm 2003, Pauly *et al.* 1998, Pauly 2002, Pauly *et al.* 2003, Rosenberg 2003).

Invertebrate export fisheries in the Pacific have a long history dating back to pre-European settlement. These fisheries are primarily based on the sale of bêche-de-mer (sea cucumbers), mother-of-pearl shell or 'MOP' (trochus and pearl oysters) but, more recently, also the export of dead coral products, live molluscs, crustaceans, and corals for the ornamental trade and aquarium industry. Additionally, a vastly larger number of other species and species groups are targeted for artisanal and subsistence use. These commercial, artisanal and subsistence fisheries are often active in the non-formal economy (without much full-time involvement by professional fishers), are generally not linked to government revenue streams, and have received insufficient scientific or social attention to understand their status and the potential impact should they be lost through overfishing.

Some of the information needed on the methods to use to assess these invertebrate stocks and their relative status across the Pacific region is being provided by this first large-scale study at sites that support export and artisanal invertebrate fisheries. One of the main questions that need to be answered is: 'What level of reef fishing effort is in fact *sustainable*?'. The current survey cannot definitively answer this question immediately but, in this section of the report we supply results that describe a range of status of target stocks (from a snapshot dataset). These results, when defined against fisher and habitat measures, give a preliminary answer to this question. This will need to be refined with time-series information of fisher harvests and in-water stock abundance. With national fisheries agencies and communities themselves initiating management action and establishing agreed targets for healthy stocks, they can build up a series of real-time examples from which to learn and refine production models – in fact the same kind of goal setting and resulting information sharing that our tuna fisheries management relies on. Sharing information across the region will be critical to the speed of development in our understanding of management and, in some cases, re-building of these invertebrate fisheries across the region.

In this benchmark study of invertebrate fisheries, we can gain an increased understanding by reading again the introduction to the finfish chapter, which outlines the complexity found within the simple term of 'status' when looking at resources across such a widely varying range of environments over such a very large geographical scale. In addition to the extensive latitudinal and longitudinal range, the geology and morphology of islands (identified as types of islands at different ages of formation and different physical structure), variability in local factors such as reef make-up, presence of seagrass beds, mangroves, soft sediments and variability of each adds a further level of complexity operating on smaller scales (at the scale of the fishing villages themselves). In a similar way to the results from the finfish study, all these factors drive variation or heterogeneity in where resources are located and their 'strength' (patchiness and discontinuity), which is relevant in resource assessment (Medley *et al.* 1993).

Unlike the case for inshore finfish fisheries, we have not studied invertebrate resources purely according to their habitat (their position on the reef), as invertebrate fishing is generally less easy to define. However, invertebrate fishing is classified according to species (often actually species groups, e.g. 'bêche-de-mer') or, in some cases, activity, such as digging (infaunal fisheries in seagrass beds and shallow-water sand flats), gleaning (shoreline and shallow water), diving, or a combination of activities. Sometimes these activities are linked to finfish fishing activities, for example, in-water spearfishing and collection of topshells, clams and lobsters. Fundamental social differences within the region have also shaped local fisheries over the course of hundreds if not thousands of years and these also need to be integrated into our understanding. Some of these social issues are highlighted in the socioeconomic descriptions given in this report (Chapter 4).

The current study surveyed 63 sites by all three disciplines (finfish, invertebrates and socioeconomics). However, specific invertebrate surveys for some species were conducted in an additional 11 sites. Therefore, for some invertebrate species, results reflect the data and analysis for 74 sites, while the results and analysis of other species are based on 63 sites. In addition, most data were analysed by survey type, and Table 3.1 provides a summary of the survey types used for invertebrate species.

Table 3.1: Survey techniques and abbreviations used

Survey technique	Abbreviation
Manta station (broad-scale)	Manta-tow
Fine-scale reef-benthos transect	RBt
Fine-scale soft-benthos transect	SBt
Shallow-water SCUBA transect	SWt
Shallow-water timed SCUBA search	SWs
Deep-water SCUBA search	DWs
Night search	Ns
Reef-front search by swimming	RFs
Reef-front search by walking	RFs_w
Soft-infaunal quadrat	SiQ

3.1.2 Geographical variation in invertebrate number and richness

Up to eleven different survey methods were conducted to ensure that we could access and measure the full range of invertebrate species targeted in fisheries. Different diurnal/nocturnal time scales and scales of survey were required due to the range of species distributions and the level of their visibility (Invertebrates are often very cryptic, camouflaged or found under cover.). The one technique with a broad-scale view, i.e. the general survey (using a manta-tow board) was conducted at all sites to give an overview of habitats and non-cryptic, large reef resources. This yielded a mean number of 29 species per site, with the species richness ranging from 9 (at Nauru) to 55 species per site (Nggela in Solomon Islands). The results of species presence using data from all survey methods gives a more comprehensive overview of species richness across the wide-ranging study (Figure 3.1).

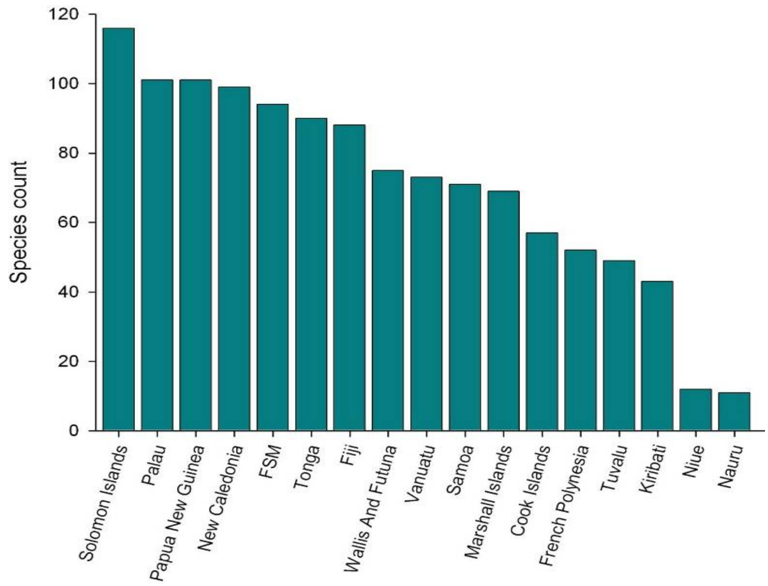


Figure 3.1: Total invertebrate species count for Pacific Island countries and territories (PICTs) as measured in the study.

Importantly, this count was seen to be largely similar among sites of a single country/territory. This gives us some comfort when making comparisons at higher levels of data amalgamation, as this suggests that results from the four-to-six sites sampled within an individual country are relatively representative of that country's complement of target species (Figure 3.2).

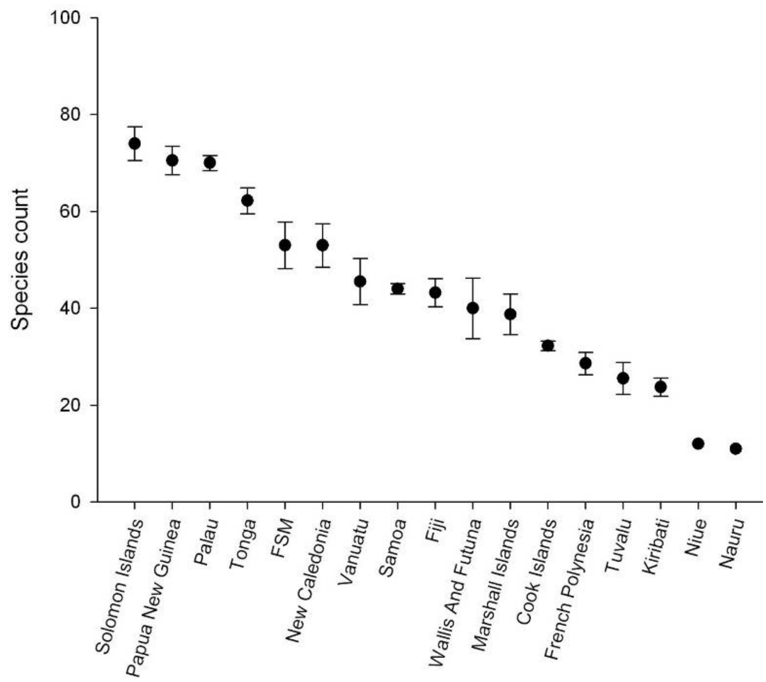


Figure 3.2: Average invertebrate species count (±SE) for PICTs as measured in the study.

Not unlike the results for finfish fisheries, biogeographic differences, such as latitude and longitude (Table 2.2), influence the rates of presence/absence of species groups. The fact that the relative position of each country within the Pacific region has an influence on the composition of the species found there is a characteristic common not just to invertebrates and fish, but to all life groupings (including terrestrial invertebrates and vertebrates). This biogeographic factor did not correlate very strongly with species richness as it was tempered by other factors such as island type and habitat variations (Figure 3.3).

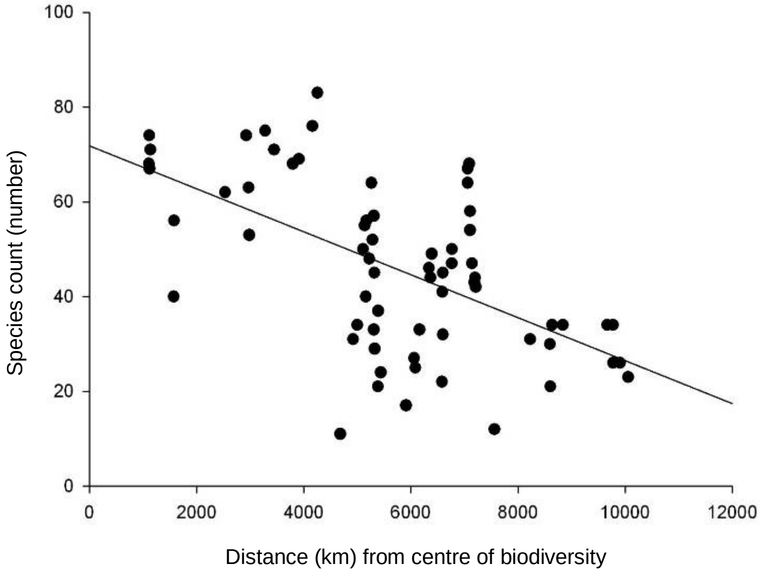
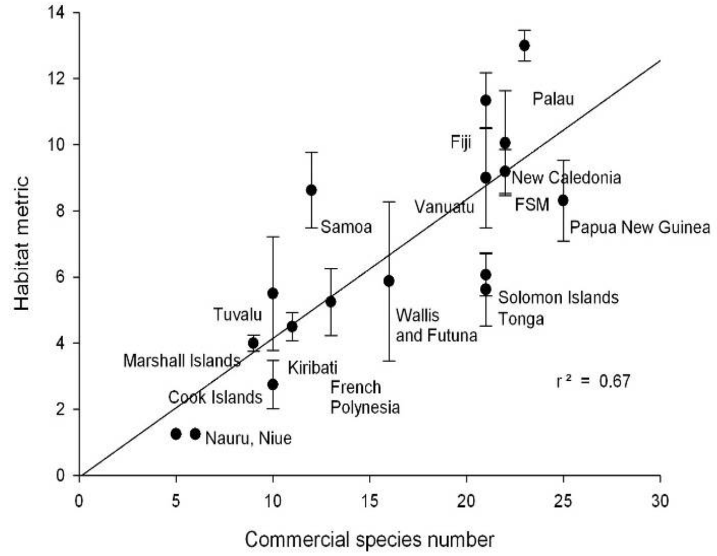


Figure 3.3: Invertebrate species count by sites, correlated with distance (km) from the centre of biodiversity (CoB).
Note the spread of data points along Y axis, which is caused by, among other things, variation in island type and variations in presence and quality of local habitats.

Similar to the results from finfish, the different island types (oceanic islands, atolls, complex islands; see Figure 2.1) were also seen to play a role in shaping the presence/absence and 'strength' of invertebrate resource stocks. Sea cucumbers of importance in commercial and subsistence contexts can be used as a subset of invertebrates to illustrate how the variation in species richness varies across countries/territories based on the type of island and the range and complexity of its habitats (Figure 3.4 a, b).

(a)



(b)

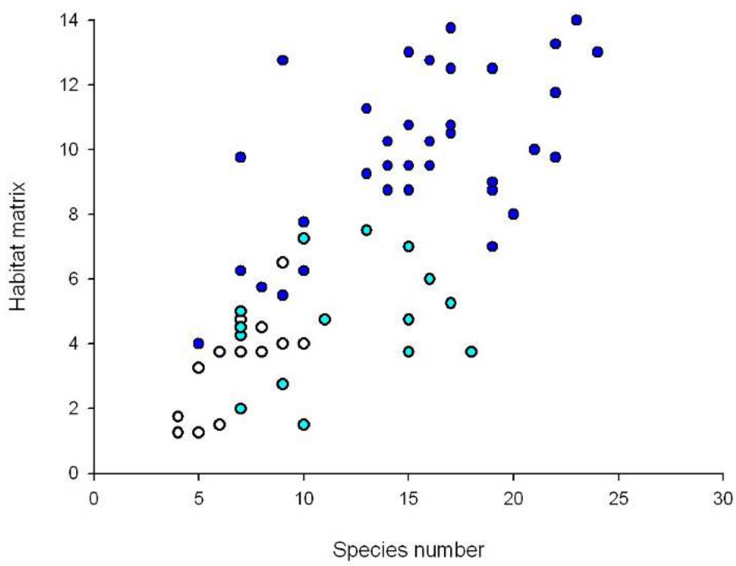


Figure 3.4: Species richness related to habitat complexity and island type.
Graph (a) shows sea cucumber species count by countries/territories and habitat complexity. Habitat complexity is calculated by giving a 1–5 score for presence and scale of tropical system components, such as landmass (or catchment area), reef (fringing-intermediate-outer), seagrass, and mangrove. Graph (b) shows individual sites depicted as being either low atoll island (white circle), high oceanic island or island with small lagoon (light blue circle) or high island with complex lagoon (dark blue circle).

As shown in the finfish section, variation in finer-scale environmental parameters is also critical, but reporting of this influence can be confounded by the differences within an individual site being larger in some cases than the differences between sites. This makes generalisation about an average substrate (e.g. coral cover) at a site level or country level difficult to show in a meaningful way (Variance can be too great.). However, variation in factors such as coral cover (Figure 3.5 a, b, c), level of coral predators (Figure 3.6), and algal-eating urchins (Figure 3.7) exists and can be clearly seen among countries in the study.

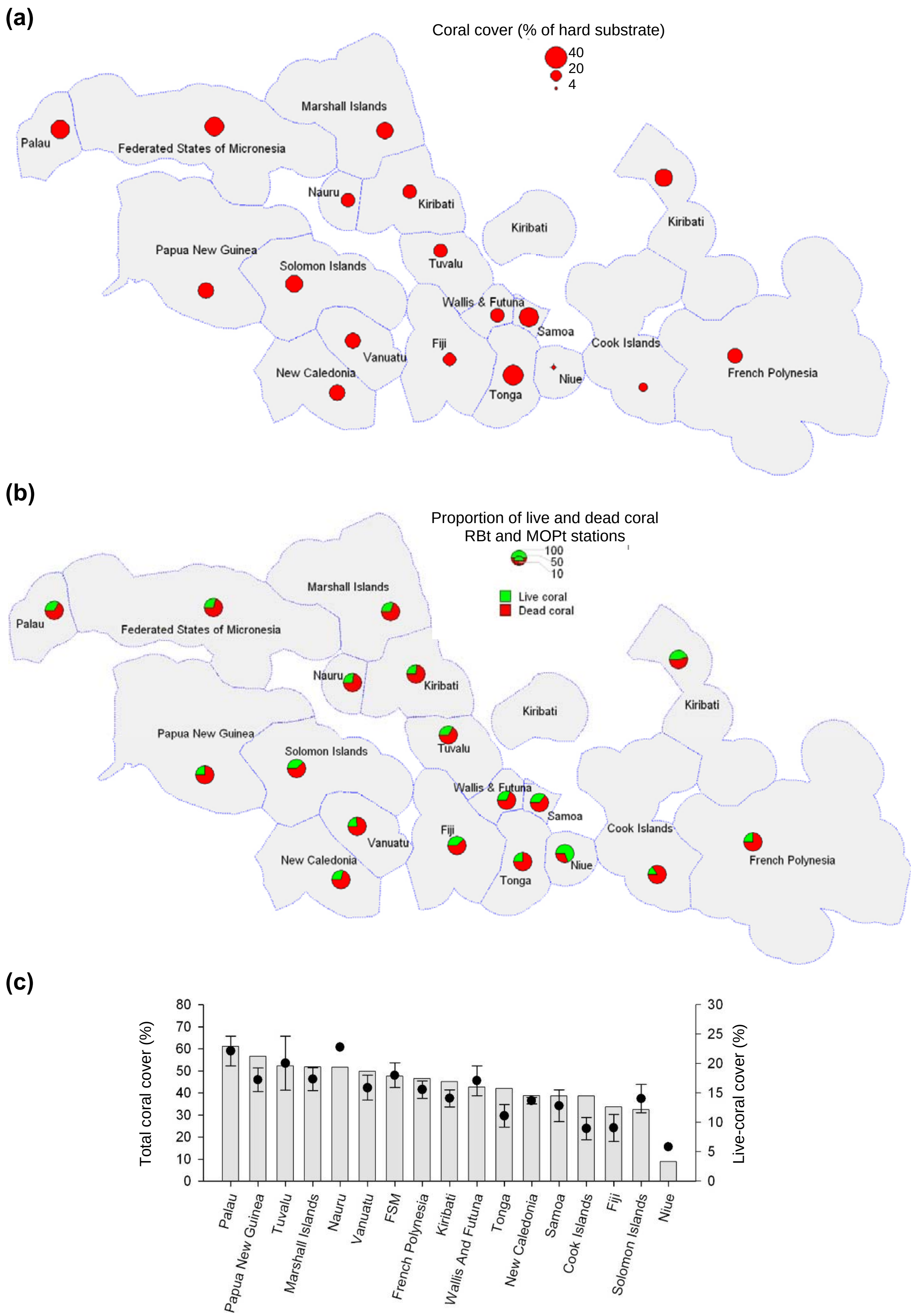


Figure 3.5: Variation in coral cover.
Map (a) shows live-coral cover from broad-scale survey, while the proportion of live versus dead coral cover as recorded on RBt and MOPt survey is shown in (b). Graph (c) shows total hard- and soft-coral cover (bars) and live-coral cover as points (with variation, ±SE). Niue experienced a large bioturbation, cyclone Heta, at the start of 2004.

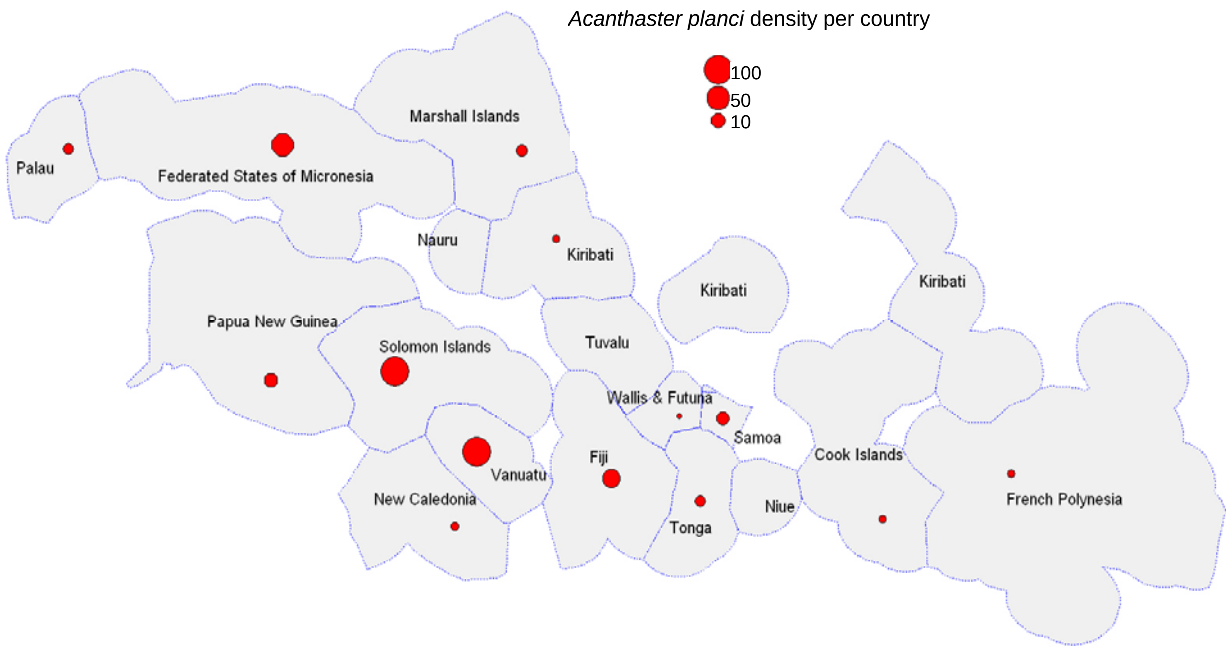


Figure 3.6: Density (numbers per ha) of the coral predator, the crown of thorn starfish (*Acanthaster planci*) from MOPt and RBt surveys (all records).
MOPt = mother-of-pearl transect; RBt = reef-benthos transect.

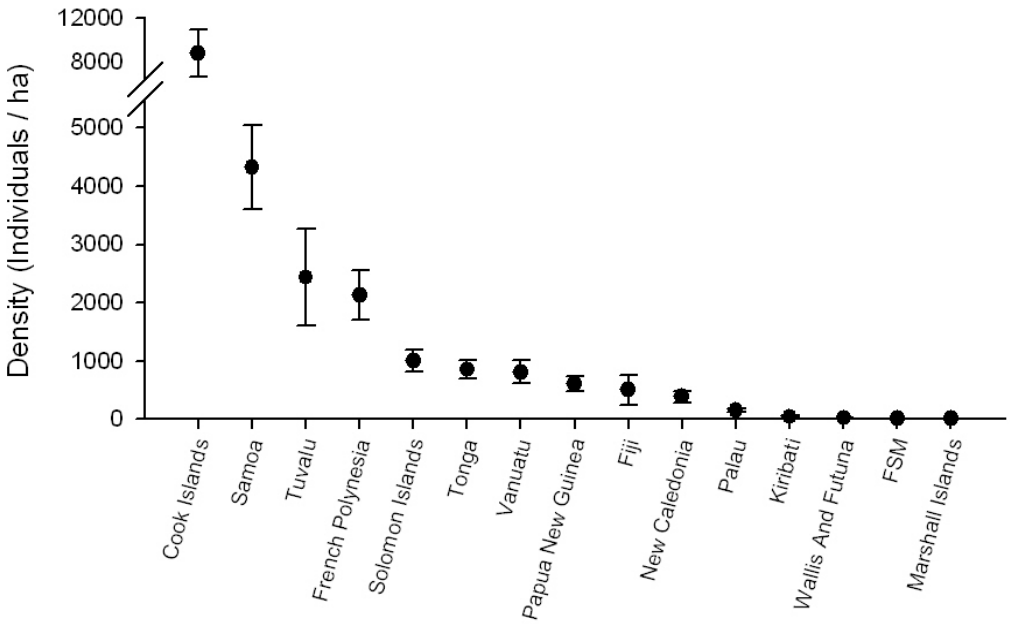


Figure 3.7: Density (numbers/ha) of the algal-eating urchins (*Echinometra mathaei* and *Parasalenia gratiosa*) as recorded in MOPt and RBt surveys.
MOPt = mother-of-pearl transect; RBt = reef-benthos transect.

When we look at the correlation between the number of species (total species counts) and land area found within 100 km radius of each site, we find that a significant proportion of the species number can be accounted for by the presence of land nearby. This result only starts to be significant ($P < 0.001$) when land area within a radius of 100 km is correlated to species richness (correlation not significant at 10 km and 50 km radius tests). Nevertheless, this significant correlation (relationship) only explains approximately 21% of the spread in the data (Figure 3.8).

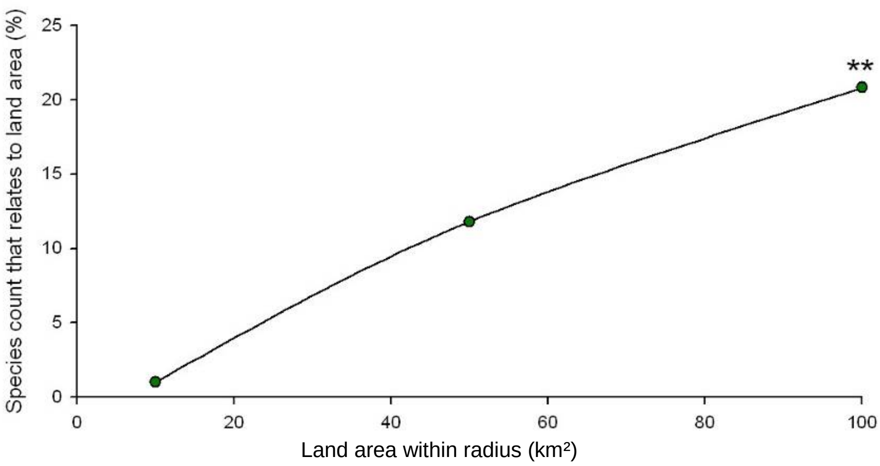


Figure 3.8: Correlation of species counts with presence of land in the vicinity of the sampling site.
** = correlation significant P<0.001

A similar assessment can be made against the presence of shallow-water reef area. In this case, reef area within a 100 km radius was also positively correlated with species number (P <0.001), so presence of reef is a factor to consider too; however, this correlation was slightly less strong than that of land proximity in that it explained 16% of the spread in the data (Figure 3.9).

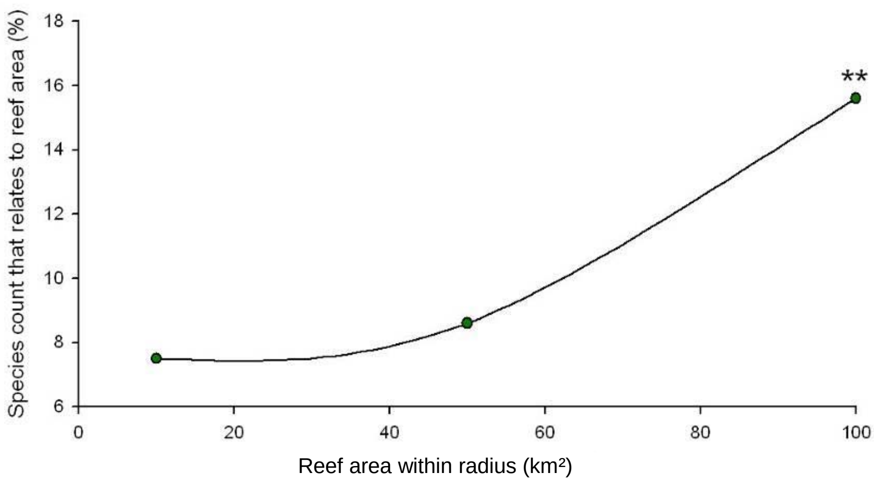


Figure 3.9: Correlation of species counts with presence of shallow-water coral reef in the vicinity of the sampling site.
** = correlation significant P<0.001

Examining the effect of land and reef together on species richness suggests that the combined relationship of these two factors helps explain approximately 50% of the species richness result (significance of multiple regression, P <0.05) or, putting it another way, the variance of species number can be partially accounted for by these large-scale environment factors.

Having ascertained that presence is affected by a number of large-scale factors, we next examined the availability of commercial and subsistence resource species and what their abundance and size can tell us about their stock status.

3.2 Status of commercial invertebrate species groups

Various commercially valuable invertebrates are associated with a range of mainly lagoonal (reef, sand and mud, mangroves and seagrass meadows) and reef-slope coral reef habitats in the Pacific. Typically, export fisheries common across the Pacific are either related to sea cucumber fisheries (selling dried sea cucumber: bêche-de-mer) or mother-of-pearl fisheries (pearl shell or nacre from topshells, pearl oysters and others: MOP).

3.2.1 Bêche-de-mer fishery stock status

Fisheries for sea cucumber species have long been widespread throughout the region (Wright and Hill 1993, Dalzell *et al.* 1996), and are one of the oldest forms of commerce in the region (Conand and Byrne 1993, Kinch *et al.* 2008a, b). The fishery is based largely on high demand from China for the boiled and dried body wall of these animals, known as 'bêche-de-mer', 'trepang' or 'hai shen'/'hai san'. Fisheries for sea cucumbers have brought considerable benefits to PICTs because harvesting, processing and storage are easily completed by local communities, requiring no specialised equipment or refrigeration (Preston 1993). For many PICTs, bêche-de-mer provides one of the few sources of income for remote coastal communities and about 35 species are currently harvested from the Pacific (SPC 2008b). From the study we recorded an average of around 13 species that could be harvested per PICT (Figure 3.10), with greater numbers noted in the west and fewer in the east, reflecting the natural biological diversity gradient away from the centre of biodiversity.

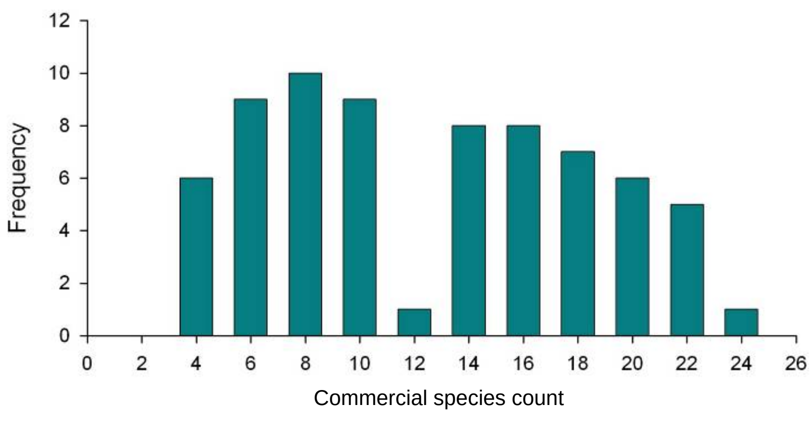


Figure 3.10: Number of commercial sea cucumber species noted at sites sampled in the study.

Not surprisingly, given the importance of land influence and reef systems, the major producers of bêche-de-mer have been Papua New Guinea (PNG), Solomon Islands, New Caledonia and Fiji Islands. These PICTs exported up to 1000 tonnes of bêche-de-mer per year during peak production in the late 1980s (Preston 1993). In recent years, catches from these PICTs have exceeded this amount (>1200 t, Kinch *et al.* 2008a), with PNG alone supplying up to 10% of global demand for the dried product, bêche-de-mer (Kinch *et al.* 2008b). To make a valid comparison of what is being removed in comparison to pelagic finfish, sea cucumber exports (as represented by wet weights, typically converted by adding 90% to the dry weight) from fisheries in Fiji Islands, Solomon Islands and New Caledonia equate to 19–32% of tuna catches by national tuna fleets from their Exclusive Economic Zones (SPC 2008b). In the case of New Caledonia, the export value of bêche-de-mer in 2007 (USD 5.3 million) was twice that of tuna (Purcell *et al.* 2009).

Sea cucumbers have traditionally been collected by gleaning and snorkelling from coral reef habitats, but also commonly from seagrass meadows and soft substrates near mangroves. However, in some PICTs, the high value of sea cucumbers has induced fishers to invest in larger boats, SCUBA or hookah diving gear and even, on occasion, drag nets. Use of this equipment exacerbates the current overfishing of these valuable resources (Friedman *et al.* 2008) This, in turn, is resulting in serious overfishing in a number of cases and timed closures of these fisheries by some island states (e.g. PNG, Solomon Islands and Vanuatu), which causes significant periods of hardship for fishing communities that rely on sea cucumbers for income.

Defining the status of the sea cucumber fishery in PICTs is complicated by the fact that it is a multi-species fishery. Although we can lump together abundance results across species groups for some very basic comparisons (Figure 3.11), the amalgamated species data disguise important differences in species complements among countries, as different species have different life characteristics and so cannot be meaningfully compared.

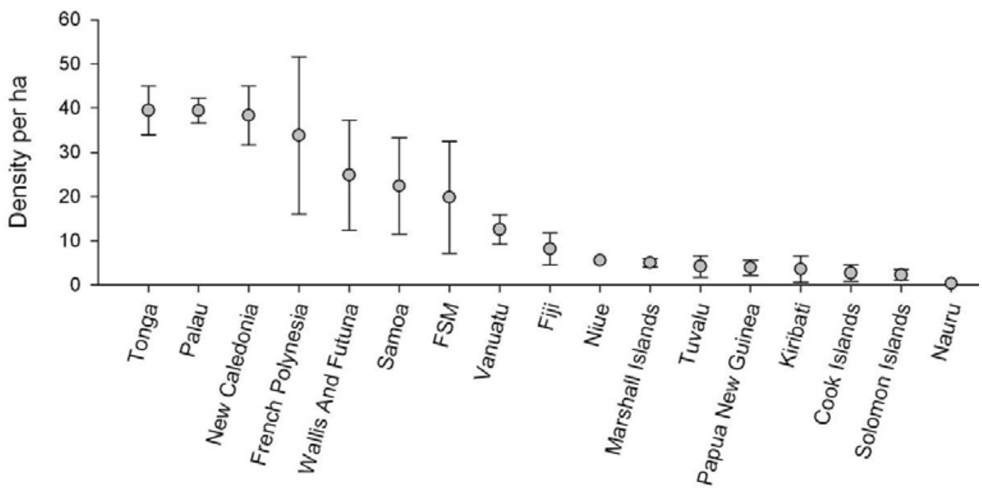


Figure 3.11: Density signal from amalgamated sea cucumber species groups.
This signal does not allow one to determine fishery status as information on low-density stocks that are of high value is lost within the higher-density information of lower-value species within the dataset.

Experience gained from the study suggests that managers will need to focus their attention (monitoring, evaluation and reporting) on a subset of relevant species groups and not the whole fishery in order to make the task of managing these resource stocks possible with the limited resources most have available. This does not mean the full set of baseline results cannot be used when needed to comprehensively define a fishery (the dataset is available for most commercial species). However, general management may need to be formulated around regular, simple surveys of abundance (and in some cases sizes) of a subset of species groups and setting management targets (thresholds) around these to simplify general understanding (See Figure 3.12 for suggested species groups that need to be surveyed and monitored.). Regulation and enforcement can be linked to export corridors and any prosecutions required for all species can be focussed at points of departure from the country.

Importantly, managers need to notice any shifts in fishing pressure among species groups, and access the full range of baseline surveys conducted when needed. This dataset also allows power-analysis calculations to be completed to ensure new and subsequent surveys (repeat surveys) are well targeted to achieve the outcomes required for driving the management programme.

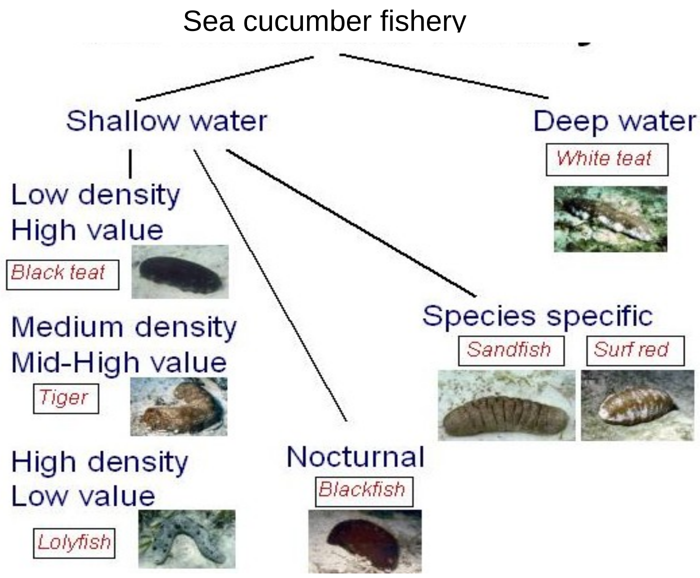


Figure 3.12: Suggested species groups and indicator species that should be monitored over time for establishing guidelines for and measuring effectiveness of general management.

Deciding what numbers (densities) need to be left in the water to retain breeding capacity is a research question that is beyond our current understanding of stock dynamics. Although examination of the dataset suggests a preliminary estimation, any initial understanding will need to be refined by countries sharing survey, catch and re-survey information over the following years to benefit from each others' precautionary trials and errors.

Although fishers have been able to respond to fishing pressures by expanding the species base that is sold (in the case of bêche-de-mer), or moving to new areas, there are now few new prospects available, and even fewer new areas to 'open up' for fishing. In the context of elevated levels of activity by fishery agents, evidence of overfishing, variable stock recovery, and limited potential for re-stocking (Bell *et al*. 2008), managers of sea cucumber fisheries will need to develop a better understanding of the spatial elements of the fishery (to limit serial depletion spatially, and prevent local extirpation) and, importantly, seek to maintain population metrics (e.g. coverage and density levels) at settings where effects related to overfishing do not result in negative population growth and eventual stagnation and disintegration of the fishery and its social benefits.

Because there is often a lengthy recovery period required when depleted fisheries are closed to fishing for a period of renewal, managers need to select and communicate conservative thresholds for stock abundances to limit fishery collapses and ecosystem shifts (Stephens *et al*. 1999, Petersen and Levitan 2001). Further understanding of what defines the acceptable and lower limit of a species' density (that which still allows timely recovery from fishing) can now be gathered from the range of information in the Pacific dataset. The dataset offers a window on the range of densities present across the Pacific and, therefore, some comparative information for managers to view when they are tasked with making decisions on sustainability targets (Figure 3.13).

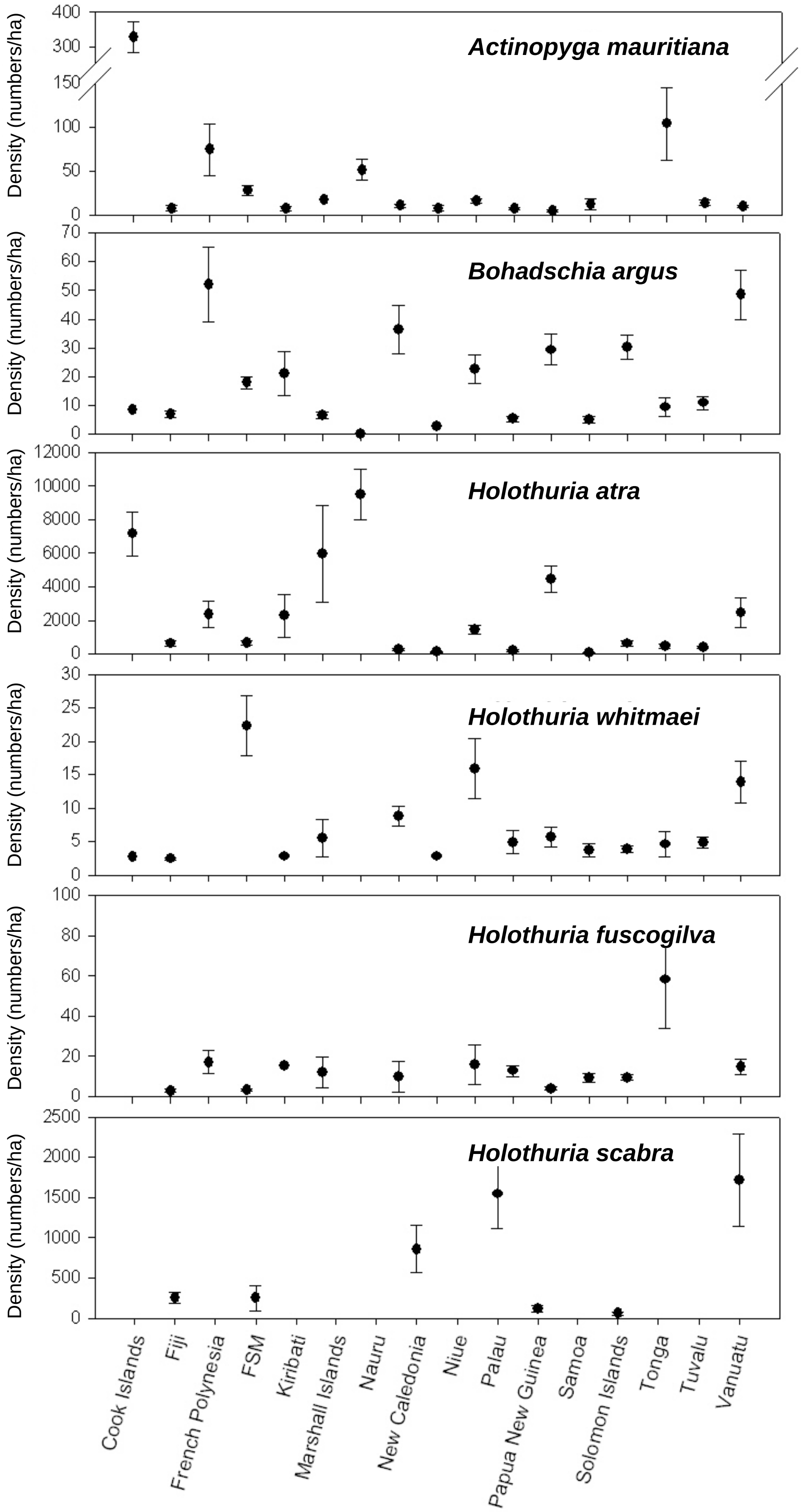


Figure 3.13: The density (numbers per ha) of six species of sea cucumbers recorded from survey.
The data listed are taken from the most representative survey method for that species (Dataset contains data for all commercial species for all methods from all sites and PICTs for reference (See Appendix 3.1.)).

There are almost no cases where these commercial stocks are still in their virgin or un-impacted condition in the Pacific. However, with knowledge that some of our sites were relatively protected from fishing and knowledge of stock metrics from reserves inside and outside the Pacific, we can advise managers what the density range a stock might be when in a healthy condition (green light of a 'traffic light' management system, see Friedman *et al.* Appendix 3.2). This allows managers to get a feeling for the level of pressure their current stocks are at, and what levels they should reasonably be able to aspire to before commercial harvests are to be considered (See Figure 3.14 for descriptions for three indicator species.).

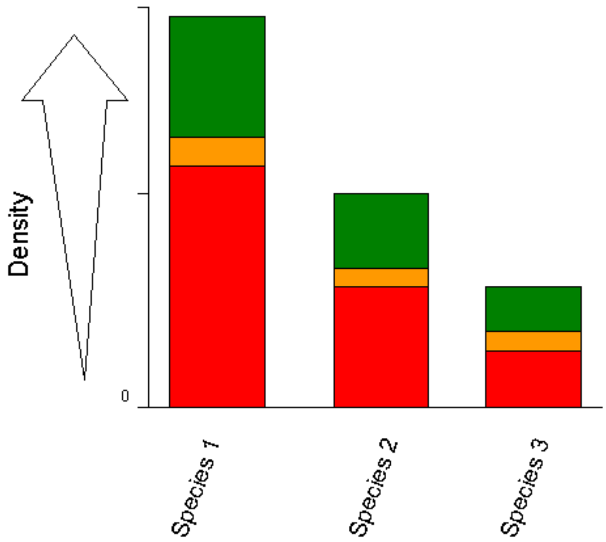


Figure 3.14: Each species or species group (group of a few similar species) will have a range of information collected across the Pacific relative to a stock metric (in this case stock density).
From the range of data collected across the Pacific, we will need to infer the density below which a stock is considered depleted and in need of protection from commercial fishing (limit reference point, red) and the threshold at which commercial/subsistence harvests can be considered (green). The demarcation of the lower end of the green target threshold and the upper end of the red limit threshold is presently not well defined (separated by an orange band). The final definition of these thresholds and bands can only be eliminated / refined through collaborative monitoring, evaluation and reporting (with sharing of management results around the region).

For an example using three of the key indicator species presented in Figure 3.12, see Figure 3.15.

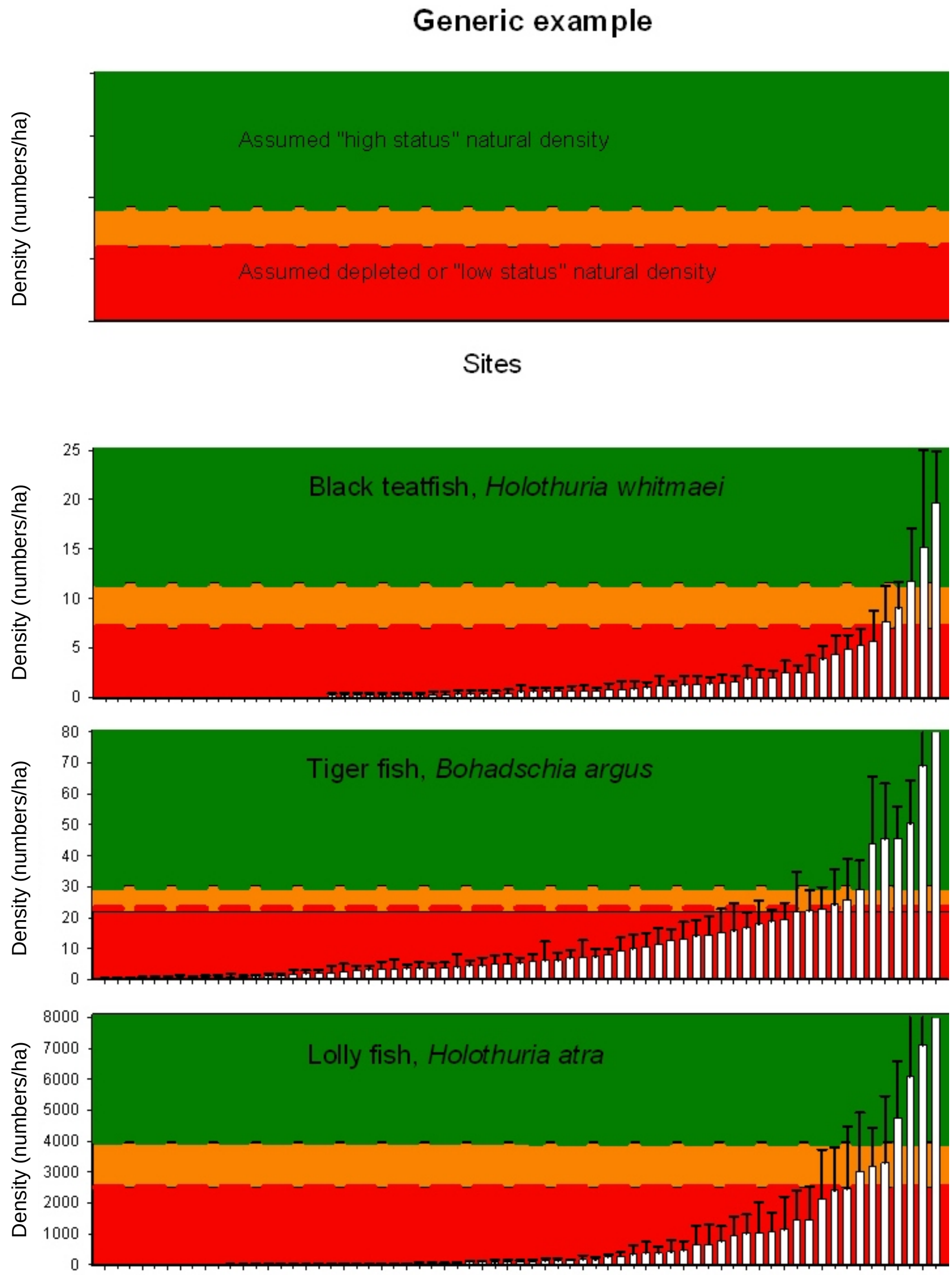


Figure 3.15: A generic example (top) followed by examples for three of the indicator species, with suggested threshold bandings, to depict 'high status' and 'depleted or low status' results. These average density records are from broad-scale surveys (all records).

Managers need to examine their site or country/territory records closely to see how local survey results compare to measures taken from across the Pacific (Figures 3.13, 3.15 and 3.16).

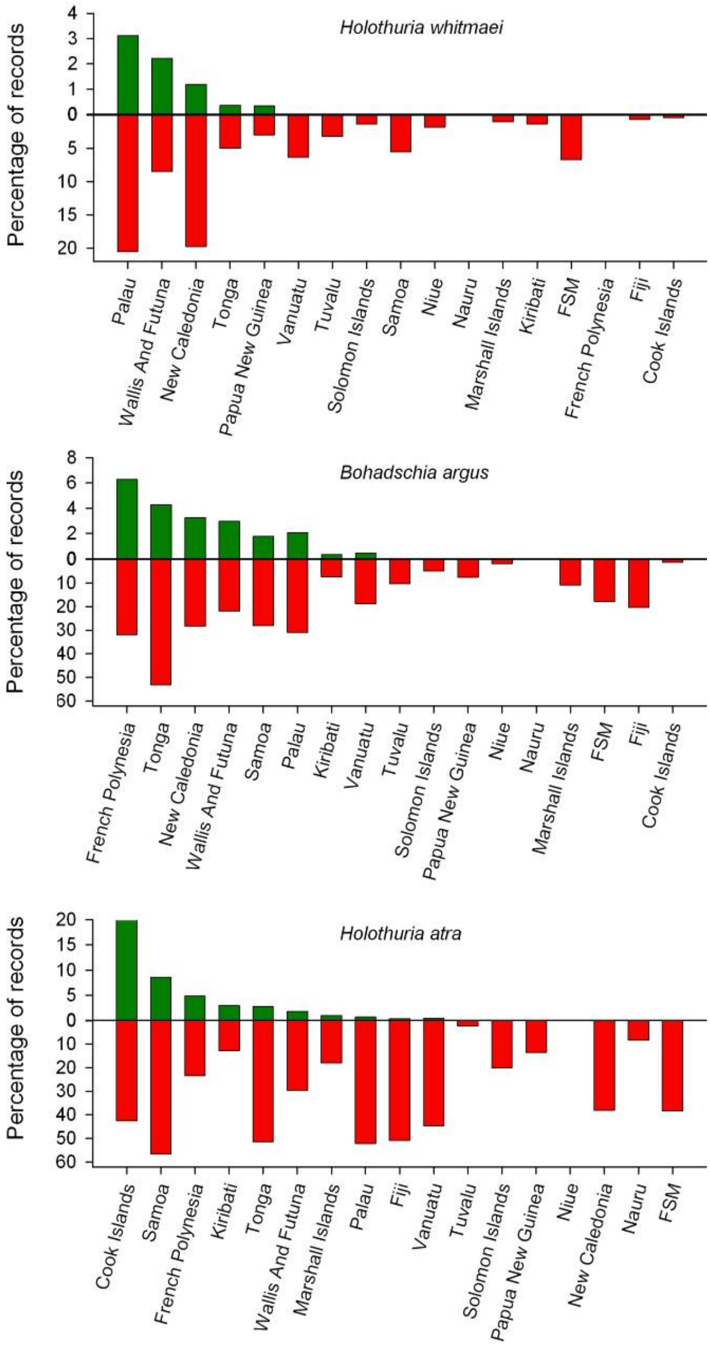


Figure 3.16: Abundance of three key species of sea cucumber as recorded through broad-scale survey in the study.
The sum of the percentages of the green and red portions of each bar gives the total percentage of samples where the species of interest was noted in survey. The green portion of each bar shows samples where the abundance of sea cucumbers was at or above a ‘high’ status threshold. The red portion reflects samples where the species was present but at a density below this threshold.

Results for sites can be viewed as a mean, or more informatively, can be viewed from the full range or distribution of individual station results noted for a site or country (Figure 3.16). In such a case, for example, we might examine local records against an average of the 25% highest abundance recordings from the complete Pacific dataset to see how local records compared (Figure 3.16). Although in this case we set the threshold at a mean of the highest 25% of Pacific records, we could change this cut-off point, if we wanted a more or less conservative threshold on which to compare local results.

The different styles of information presentation given above inform the manager on what is the likely spread in abundance between depleted versus high-status stocks by allowing comparisons of local datasets against a range of Pacific-wide measures (taken using the same methods). Managers can use the Pacific dataset and indicative thresholds provided above to make an estimation of local status of stocks.

A key need for managers is to know how quickly stocks respond to a moratorium on fishing and, with time, managers within the region can build up a better picture of how stocks respond, by continuing to monitor population metrics locally (coverage, density, and size of sea cucumbers) around fishing events and closures and by sharing information throughout the region (Friedman *et al.* in prep). This will help to refine local thresholds and active adaptive management of commercial harvesting regimes (See Figure 3.17; schematic from Managers' Toolbox (Friedman *et al.* 2008 in Appendix 3.2).).

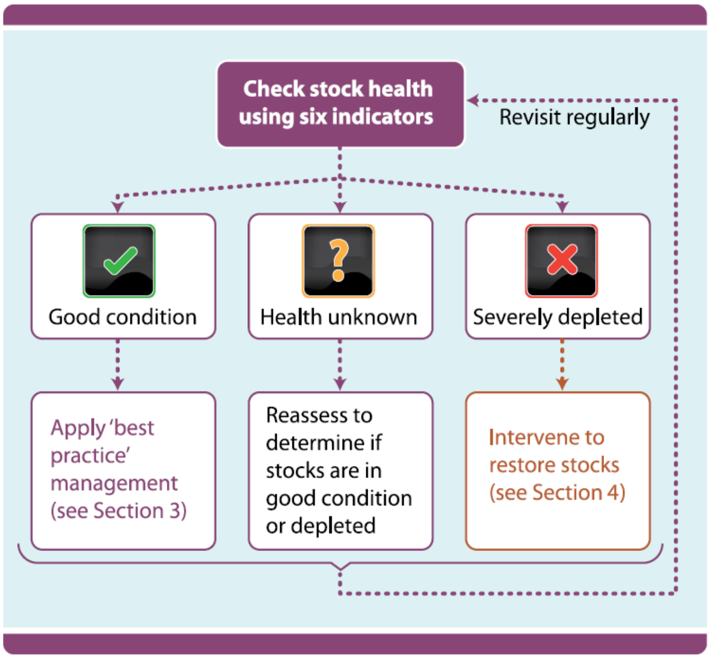


Figure 3.17: Schematic from sea cucumbers management toolbox where a number of stock metrics (general abundance, breeding group abundance and ratio of species, sea cucumber size, fishing gear used, and commercial structure of fishery) were listed (Friedman *et al.* 2008).

In this report, we have not presented much information on sea cucumber size (length or weight), but length records have particular value when examining the less 'plastic' or less 'variable' species such as *Holothuria scabra*, and weights can be used for species that display variable lengths when handled, for example, *Actinopyga miliaris*. Size and weight restrictions are useful in comparisons of species and for fisheries management controls (See Figure 3.18 for length-frequency graphs of *H. scabra* by site, and Appendix 3.3 for general size/weight table on species with suggested minimum size/weight limits for commercial harvest regulations.).

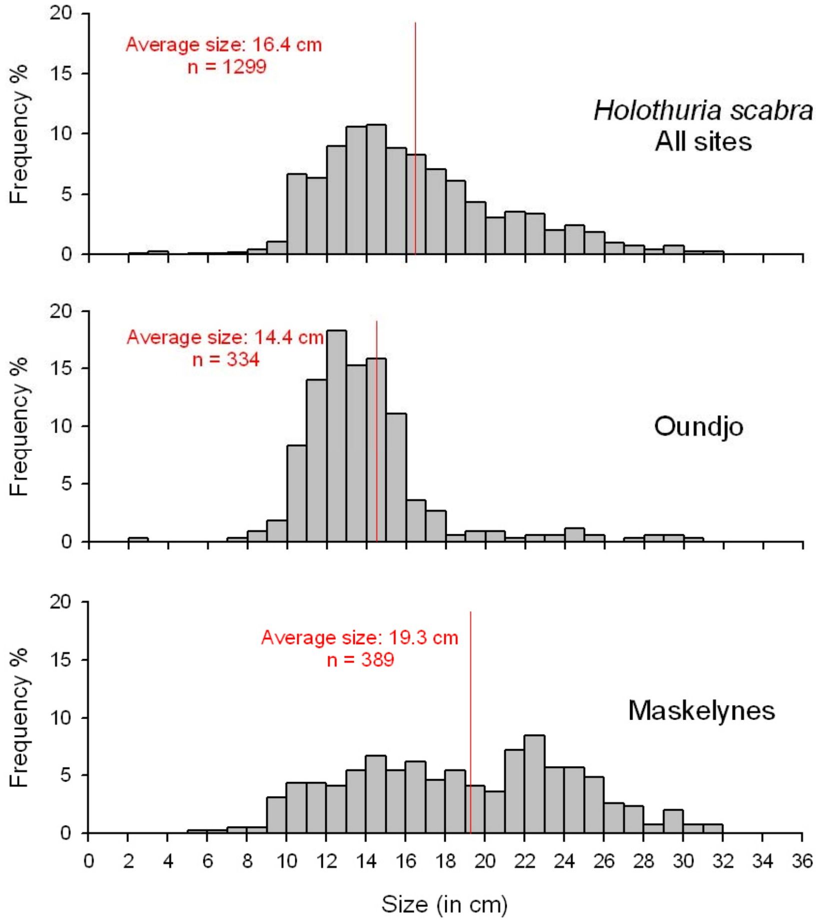


Figure 3.18: An example of *Holothuria scabra* length measures (cm) from in-water Reef Fisheries Observatory surveys.
The three graphs above show all body length measures (top), measures of sample with strong recruitment of small cucumber sizes from a site in New Caledonia (middle), and measures of a sample with both small sea cucumbers and mature individuals from Maskelynes in Vanuatu (bottom).

3.2.2 Mother-of-pearl fishery stock status

A few mollusc species also support commercial export fisheries in the Pacific. The most important of these is the commercial topshell (*Trochus niloticus*), also commonly known as trochus. This herbivorous gastropod is collected by diving or hand collection/gleaning of coral reefs, the nacre being exported predominantly for the production of buttons (especially since the early 1900s, see Nash 1993). Trochus is fished heavily throughout much of the Pacific and, once overfished, such resources lose much of the potential to naturally replenish themselves, which results in drastic decreases in the amount of cash reaching coastal communities (foreign income), with subsequent impacts on social advancement and cohesion.

Trochus has contributed greatly to fishery exports in Cook Islands, Fiji Islands, Federated States of Micronesia (FSM), New Caledonia, Papua New Guinea (PNG), Solomon Islands, Vanuatu, and Wallis and Futuna. Over the past century, the combined harvests of trochus shell from Fiji Islands, PNG and Solomon Islands alone totalled >50,000 t, with a current value of more than USD 200 million (SPC 2008b). Within the Pacific, there have been extensive introductions of trochus beyond its normal geographic range in order to expand economic benefits both within and among PICTs (Eldredge 1994, Dalzell *et al.* 1996).

Green snail (*Turbo marmoratus*) has also been harvested for its nacre and translocated across the Pacific, although the quantities involved are low compared to trochus (Richards *et al.* 1994). The results from assessments show greensnail presence across the Pacific is rare (only seven sites; Figure 3.19), with limited finds at sites in French Polynesia, Vanuatu and Tonga (Table 3.2).

Table 3.2: Density of greensnail (individuals per ha) when recorded at sites in the study

Country/Territory	Site	Survey Method		
		MOPt	RBt	RFs
French Polynesia	Maatea	104.2	250.0	25.8
	Mataiea	83.3	1041.7	
Tonga	Ha'apai			3.5
	Koulo			3.5
	Lofanga			3.5
	Manuka	20.8		
Vanuatu	Uri-Uripiv	72.9		

MOPt = mother-of-pearl transect; RBt = reef-benthos transect; RFs = reef-front search.

Prior to the development of large-scale pearl farming around 1980, ~450 t of blacklip pearl oysters (*Pinctada margaritifera*) were harvested for their nacre and exported per year from the Pacific. This fishery also has a history of overfishing and depletion with most fisheries exhausted of shell and failing to recover commercial densities after initial harvests and sales. For example, 250 t of pearl shell were removed from one lagoon in Kiritimati (Kiribati Line Islands) in the late 1800s and, despite no significant commercial fishing this century, there have been no subsequent sales or recovery of pearl shell to previous abundances. Despite the wholesale loss of commercial blacklip pearl oyster densities across the Pacific, French Polynesia and Cook Islands continue to export shell caught as spat and reared primarily for pearl aquaculture. The study shows that *P. margaritifera* is present in most Pacific lagoon systems and in most sites (Figure 3.19).

Today, shell buyers are diversifying their purchases to cut and sell nacre blanks from a range of species (including *Tectus pyramis, Turbo setosus*, and *Pteria* spp.). These exploratory markets are springing up in response to consumer demand for materials (possibly the art and crafts and home decoration industry) and because locally based shell processors are having trouble sourcing enough trochus to maintain profitability.

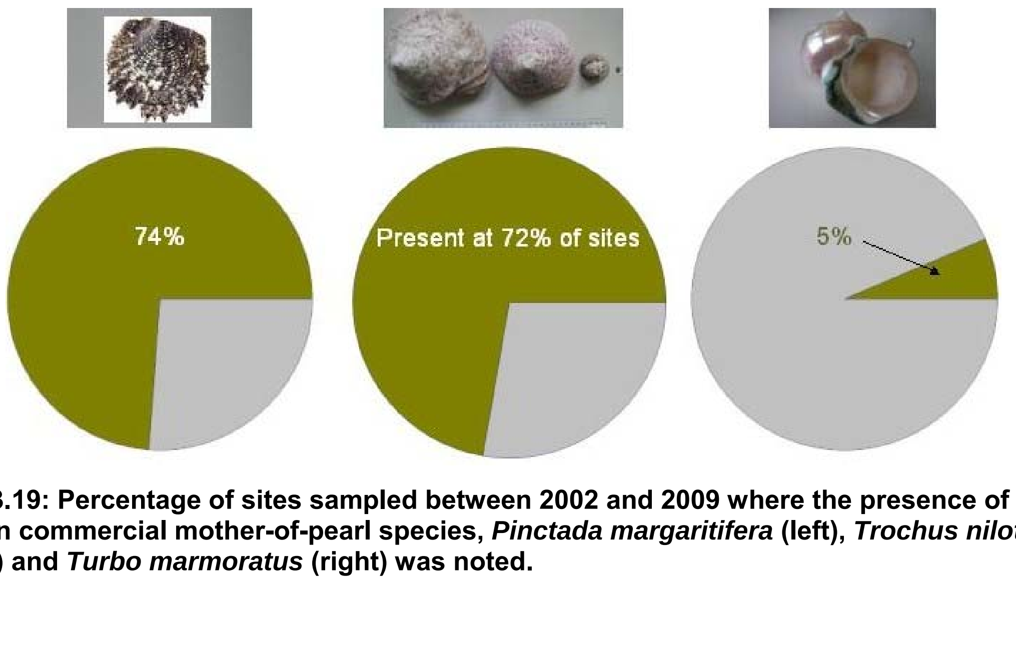


Figure 3.19: Percentage of sites sampled between 2002 and 2009 where the presence of common commercial mother-of-pearl species, *Pinctada margaritifera* (left), *Trochus niloticus* (middle) and *Turbo marmoratus* (right) was noted.

Concentrating on the topshell trochus, in this case we have a single species that is well dispersed throughout the Pacific (Figure 3.19). Trochus are found in well-defined habitats, with areas of major aggregation concentrated to shallow-water areas that are easily accessed by fishers. The shallow and aggregated life habit of trochus along with the simple requirement for post-harvest processing and storage makes this commercial resource very susceptible to overfishing.

Trochus are separate-sexed with a short larval cycle after broadcast spawning. This has negative implications for local recovery of stocks from spawn dispersing from distant reefs once local stocks are depleted. However, trochus are relatively fast growing (harvestable after three years of age) and can be prolific when given some protection from fishing; records of rapid stock increase have been documented when breeding stocks are protected from fishing. For example, after initial introductions of just 40 individual trochus (from Port Vila, in Vanuatu in 1957), stocks in Tahiti were given protection from commercial fishing for 14 years. No records of the first commercial harvest were found, but we do have records that state that approximately 4000 live shells were taken for translocation to other parts of French Polynesia between 1963 and 1972 and one of the subsequent commercial harvests (in 1973) yielded 261 t of commercial shell (an increase of approximately 800,000 individual shells). This type of outcome was also recorded in FSM, where introductions in 1927 resulted in a first commercial harvest of 230 t after 12 years of stock protection.

Introductions of trochus were commonly noted at the sites sampled. Almost 80 per cent of these sites had received introductions of adult shell rather than a release of seed trochus. Although the release location was sometimes not optimal and some stocks had not had sufficient time to fully extend across the full number of suitable reefs available at each site, 65% of introductions were noted as successful in the study (i.e. stocks had become self-sustaining), supporting the premise that introducing trochus is a highly viable proposition.

As in the case in most fisheries that have localised aggregations of stock (patchy distribution), trochus suffer from serial depletion when reefs are sequentially fished without regard for sustainability. In such cases, fishery catches remain high for long periods, followed by a sudden collapse of catch rates and exports, as unfished trochus grounds and ‘new’, more remote areas become scarce. This life trait of noted aggregations complicates the management of the fishery and limits potential for understanding and controlling the fishery by centrally monitoring export rates alone, without understanding the spatial context of where the product is originating.

The study conducted a series of fishery-independent surveys (direct in-water resource assessments) to better understand the presence/absence and density of trochus, *Trochus niloticus* (Table 3.3). These included mother-of-pearl transects and searches, reef-front searches, reef-benthos transects and manta-tow (broad-scale) transects. The results from these surveys are presented as a record of presence (presence/absence), abundance (numbers per ha) and shell basal width measures (mm). In the case of transect measures, the areas of the benthos assessed are well defined whereas, for searches, ‘indicative’ densities are given from calculations using approximate measures of distance covered taken from start and end waypoint measures.

Table 3.3: *Trochus niloticus* presence at the 74 study sites 2002–2008

Country/Territory	Name of sites	Sites surveyed	Sites with native trochus	Sites with introduced trochus	Percentage of sites with trochus
Cook Islands	Aitutaki, Mangaia, Palmerston, Rarotonga	4	0	4	100
Fiji Islands	Dromuna, Lakeba, Mali, Muaivuso, Nasaqalau, Nukunuku	6	6	0	100
French Polynesia	Fakarava, Maatea, Mataiea, Tikehau, Raivavae	5	0	4*	80
FSM	Kosrae, Piis-Panewu, Pohnpei, Riiken, Romanum, Yyin	8	0	8	100
Kiribati	Abaiang, Abemama, Kiritimati, Kuria	4	0	0*	0
Marshall Islands	Ailuk, Arno, Laura, Likiep	4	0	2*	50
Nauru	All Nauru	1	0	0	0
New Caledonia	Amede, Luengoni, Moindou, Ouasse, Oundjo, Thio	6	0	5*	83
Niue	All Niue	1	0	0*	0
Palau	Airai, Koror, Ngarchelong, Ngatpang	4	4	0	100
Papua New Guinea	Andra, Panapompom, Sideia, Tsoilaunung	4	4	0	100
Samoa	Manono-uta, Salelavalu, Vailoa, Vaisala	4	0	0*	0
Solomon Islands	Chubikopi, Marau, Nggela, Rarumana	4	4	0	100
Tonga	Ha'atafu, Koulo, Lofanga, Manuka	4	0	4	100
Tuvalu	Funafuti, Niutao, Nukufetau, Vaitupu	4	0	1	25
Vanuatu	Bonkovio-Brisbane, Burumba, Lamen Bay, Mapuna, Maskelynes, Mavelao-Valesdir, Moso, Paunangisu, Uri-Uripiv	9	9	0	100
Wallis and Futuna	Halalo, Leava, Vailala, Vele	4	4	0	100

* *Trochus niloticus* was introduced, but not recorded in survey at some sites.

Average trochus abundance as measured on reef slopes (using MOPt) and on reef flats (RBt method) showed great variance at sites across the Pacific (range 4–1423 per ha, Figure 3.20).

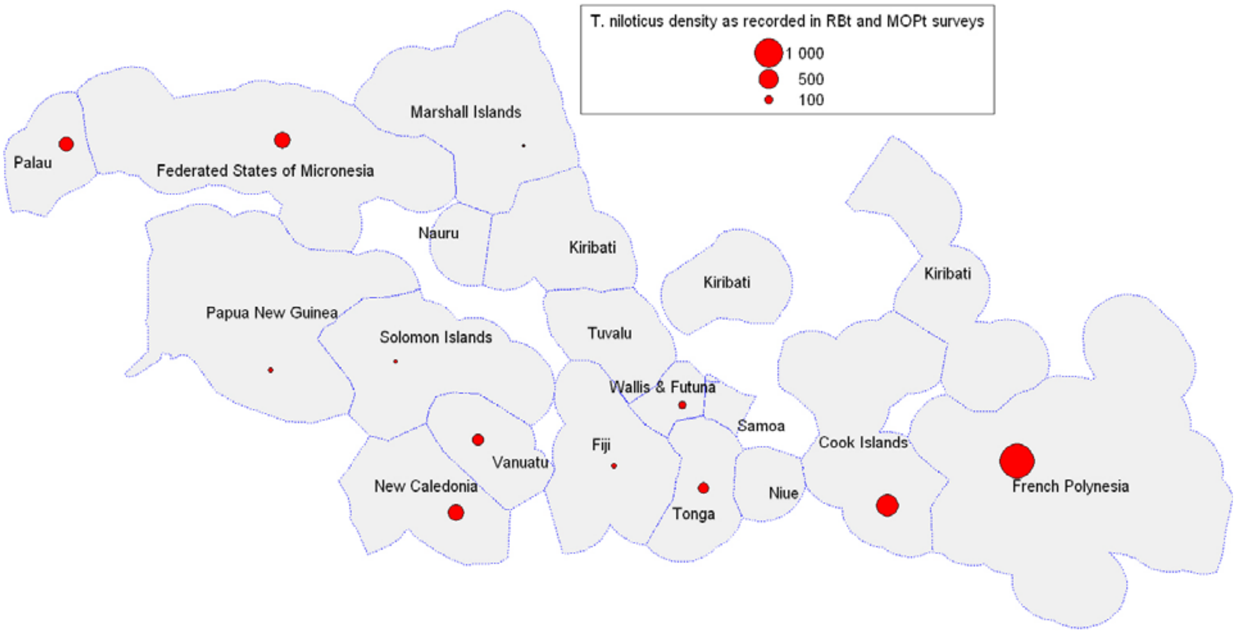


Figure 3.20: Densities (individuals per ha) of trochus, *Trochus niloticus*, aggregated from two survey methods.

As in the fishery for sea cucumbers, trochus stocks were found to be depleted at many of the sites surveyed, which can best be presented by examining the range of trochus densities recorded across the Pacific (Figures 3.21 and 3.22). This allows the results to be compared spatially among sites and countries where stocks are under differing fishing pressures and forms of fishery management.

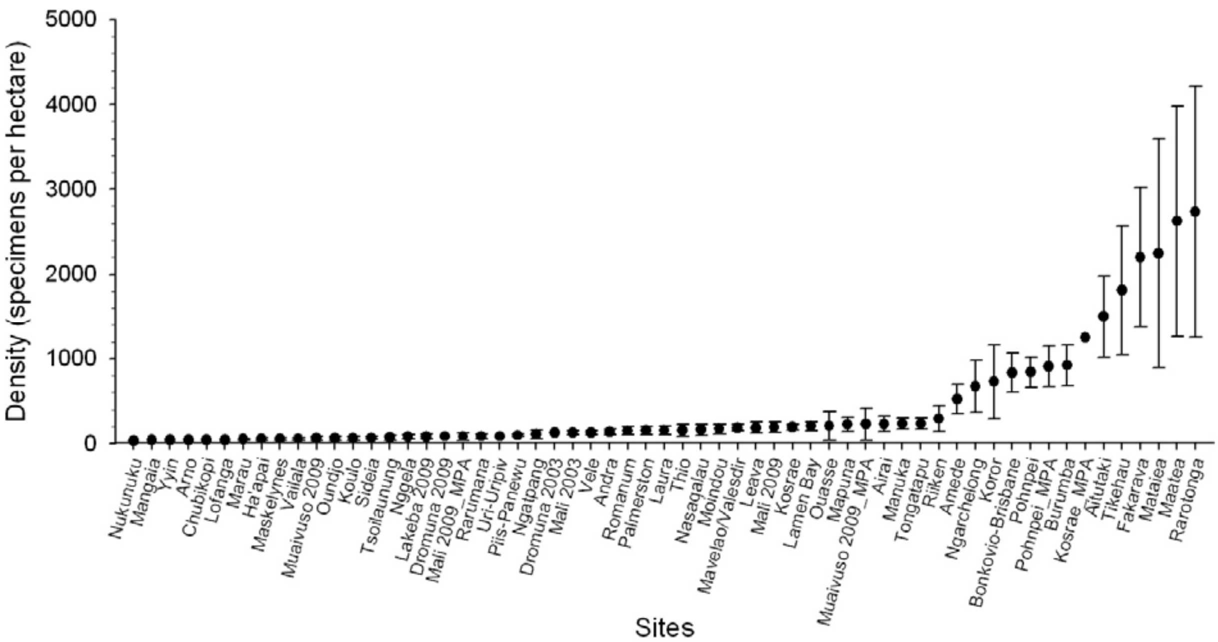


Figure 3.21: Trochus density as recorded by defined transect measures on snorkel (RBt) across sites where the commercial gastropod was found.
Additional sites to the sites surveyed under PROCFish are also included: Mavaleo/Valesdir, Lamen Bay, Nasaqalau, Bonkovio-Brisbane and Amede.

At approximately 500 individual trochus shells per ha, there would be an even spacing of one shell in every 20 m^2 patch (4 m x 5 m). As we know from the life habit of trochus, these gastropods do not spread themselves out randomly across the benthos but respond to habitat conditions and co-specifics to aggregate in groups (Figure 3.22). This is particularly important for the success of spawning as trochus are single-sexed and release eggs and sperm into the water column, which need to meet, fertilise, and settle out in suitable habitat to become future trochus harvests. The greater the distance between individual trochus, the less likely is successful reproduction to proceed.

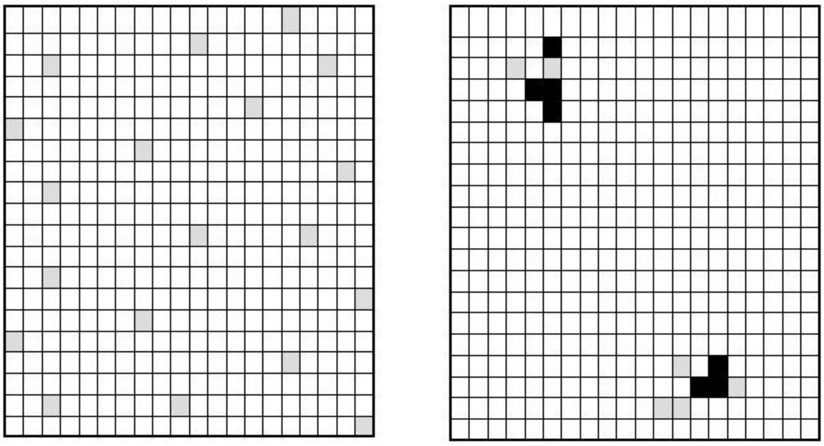


Figure 3.22: Conceptual diagram to show spacing of shells across a 20 m x 20 m depiction of the seabed at 500 shells per ha.
In the left representation, shells are spread out evenly, while in the right representation, trochus are aggregated into patches. Each of the boxes in this representation stands for 1 m^2 of space on the seabed; the grey squares are areas holding one trochus per m^2 and the black squares are areas holding >1 trochus per m^2.

As a manager, the main task at hand is to ensure trochus areas (aggregations) don't fall to a density where the number of adult stock is too low to support successful reproduction (seed supply for future generations of stock). Choosing a threshold of 500–600 per ha for these sites (Nash 1993) suggests there is a reasonable number of adult trochus in the areas of aggregation to allow successful reproduction to continue (and mass spawning of trochus can occur). The subtle life-history characteristics of trochus are not fully understood, but it is likely that trochus (like other molluscs) give each other hormonal cues when they are in close proximity to assist in synchronising spawning activity and therefore increase the chance of successful fertilisation and seed production. This not only maximises the chance of successful reproduction but also a fisher's chance of getting future catches.

As we have seen in other commercial invertebrate fisheries, most sites that have trochus, or have had trochus introduced, are severely overfished. In the surveys conducted on shallow reefs using snorkel (Figure 3.21), fewer than one-third of sites had average densities of >500 trochus per ha. Interestingly, from the two-thirds of sites that were generally overfished, 15% of sites had at least one station, and 80% of sites had at least one transect, where stocks were recorded at a density of above the 500 shells per ha. This threshold means that, spatially, some of the areas within the most overfished sites still remain at sufficient density to support recovery through spawning if stocks are allowed to recover under strong protection from fishing. A similar result was recorded for surveys of reef slopes on SCUBA (Figure 3.23).

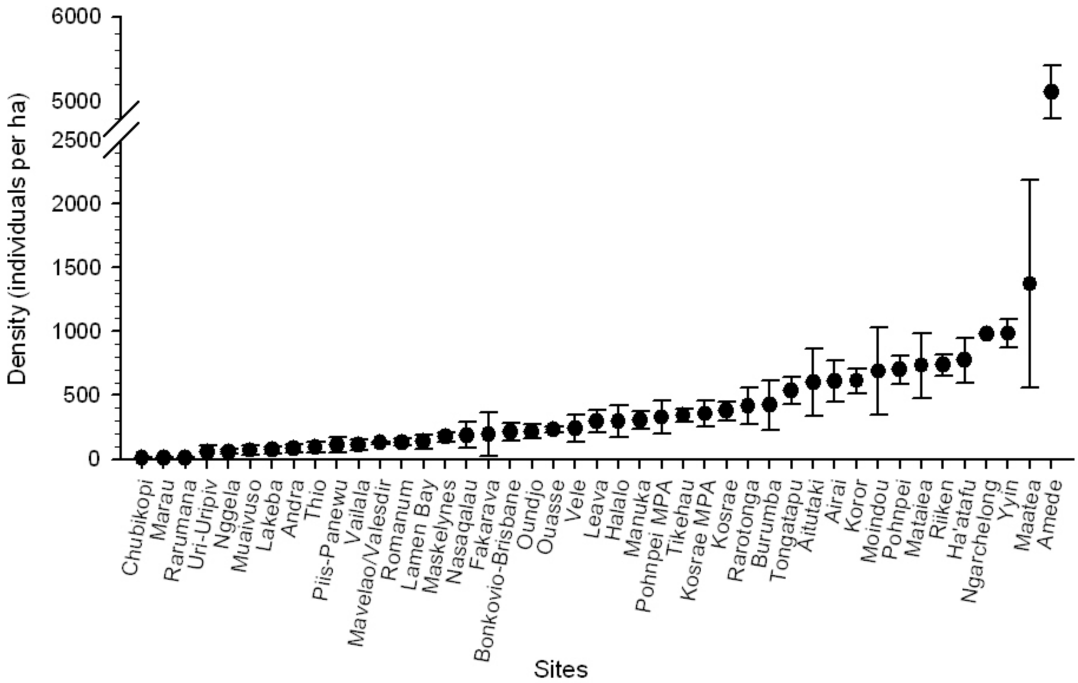


Figure 3.23: Trochus density as recorded by defined transect measures on SCUBA (MOPt) across sites where the commercial gastropod was found.
Additionnal sites to the sites surveyed under PROCFish are also included: Mavaleo/Valesdir, Lamen Bay, Nasaqalau, Bonkovio-Brisbane and Amede.

The deeper-water surveys completed on SCUBA revealed a similar pattern of low density related to fishing pressure. In this case only 13 sites recorded average densities above 500 trochus per ha. Despite the low densities recorded at most sites, at least 35% of the other sites had at least one survey station where trochus were recorded at above the 500 shells per hectare density threshold. This supports the assertion that, even at heavily fished sites, there is still scope for recovery if stocks are protected from fishing through strong management. Deeper-water remnant stocks and small patches of trochus in shallow water have the potential to re-seed reefs if management protects them for extended periods.

Active movement and manual aggregation of widely dispersed stock left over from previous fishing should only be considered when expert assistance is available, to ensure the last remaining stocks are not lost through inappropriate handling, or inappropriate site selection for relocation. This is often the case, as fishers generally prefer to shift remaining trochus to reefs close to their homes, where they can ensure there is compliance with fishery bans. This is often thought more desirable than placing trochus in areas of suitable habitat for growth and reproduction, which results in very slow recovery or further depletion of stocks.

When the position of *Trochus niloticus* was recorded across the Pacific there was a variation in the natural position of stocks across reef environments among PICTs (Figure 3.20). This has important implications for the translocation of trochus as the general understanding that trochus are most prevalent on the outer reef slopes cannot be used when considering all island types and reef configurations. In remote island locations and atolls, where sources of nutrients and resulting algae food can be scarce, trochus were found at relatively higher density within the lagoon system rather than outside (Figure 3.24).

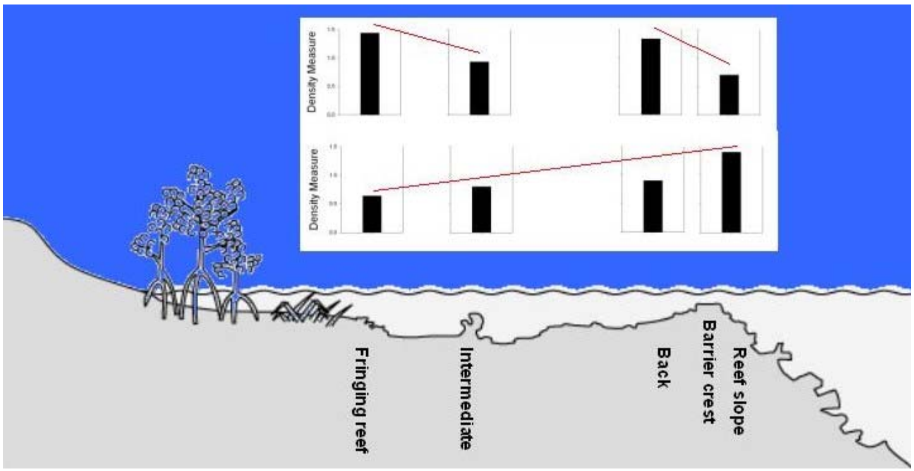


Figure 3.24: Distribution of *Trochus niloticus* across inshore fringing reef, intermediate reef, back-reef, barrier reef platform/crest and fore-reef slope.
The bottom set of density measure graphs shows the most characteristic distribution, with greater numbers of trochus being found on offshore-facing slopes than reefs inshore. This is not always the case in atoll and remote small island sites (upper series of graphs), where the main aggregations of shells are found closer to shore, associated with limestone reef where algal food sources are present.

Monitoring the change in the size of trochus offers a manager a valuable understanding of stock 'health' and an appreciation of potential catch values. Around the Pacific during the study, the local price of trochus ranged from USD 3 to 6 per kg. This equates to a 60 kg sack of trochus holding 150300 shells, at a local price of approximately USD 240 depending on size and quality (Figures 3.25 and 3.26).

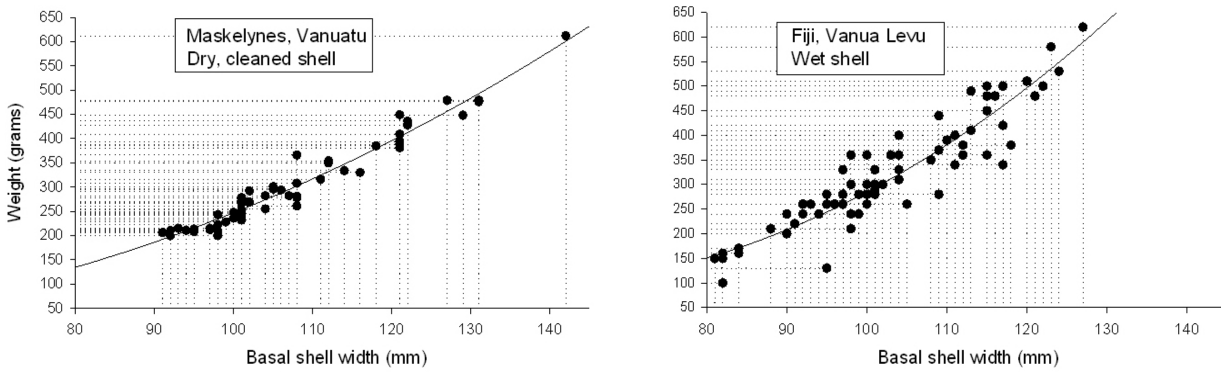


Figure 3.25: Trochus basal width and weight of shell measured and weighed during the study.

Figure 3.26: Indicative trochus basal width, age and weight of shell to enable the manager and fishers to make rough calculations for planning harvests.
The ages in grey are approximate as variation in growth would be found across the Pacific and there are very few tagging studies which record this information over long time scales.

Importantly, a manager needs to ensure commercial harvests are only being conducted when there are strong signs of recruitment (small shells entering the fishery). For each site this is likely to differ and spot checks for small shell or comparisons across the basal length frequency of shell sizes will show differences clearly (examples presented for six Pacific sites in Figure 3.27).

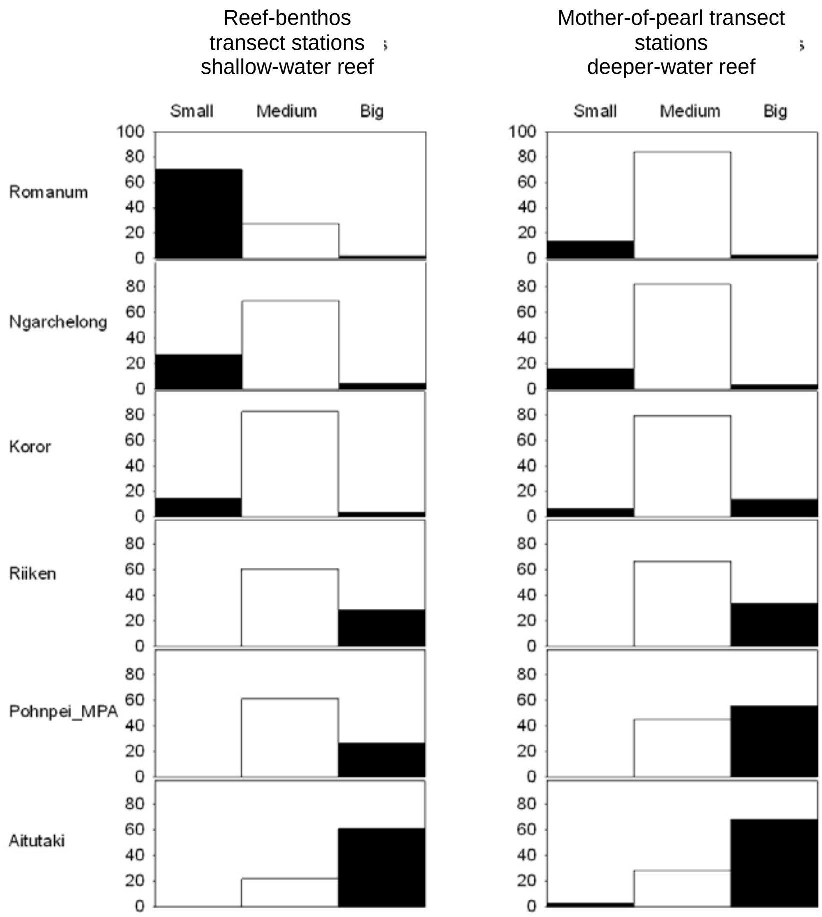


Figure 3.27: Presence of small (up to 8 cm basal width), medium, and big (>11 cm basal width) trochus at six sites across the Pacific (top three with strong recruitment and lower three somewhat dominated by older larger shells).
The graphs on the left are taken from shallow-water reefs surveyed on snorkel (<2 m depth) while the graphs on the right show fewer small trochus as the surveys were conducted in deeper water on SCUBA (2–6 m depth).

As shown in Figure 3.27, sites such as Romanum in FSM recorded strong recruitment. Cryptic (small and well camouflaged), young shell detected in surveys provides a useful indication of the new recruitment into the fishery, or the lack of a recruitment signal if they are missing, which could have implications for the numbers of trochus entering the capture size classes in the following two years. 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 life within the crevices of the reef structure to join the main stock. The number recorded, although not comprehensive, is usually sufficient to indicate whether a strong year class of juveniles is entering the fishery (First maturity of trochus is at 7–8 cm, at approximately three years of age.). When these small juveniles are missing, managers might consider delaying the opening of the fishery.

Some early researchers (Asano 1963) suggested that the large-sized portion of the stock must not become 'too' dominant, and it was better for the productivity of the fishery to fish the stock periodically, maintaining a reasonable number of large shells, but not letting them build up to become the dominant size class of the population. This is due to the fact that the relationship for most fish species between the level of egg production and the recruitment that this generates (termed the spawning stockrecruitment [SSR] relationship), follows a pattern whereby recruitment only increases with egg production levels until it reaches an asymptotic level (Figure 3.28). The spawning stock level/egg production level[5] where this asymptote is reached varies between 10 and 95% of unfished levels, depending upon the life history characteristics of the species in question. Once the stock size/egg production levels are within this asymptotic region (or 'egg saturation zone'), additional egg production will not always increase the average number of recruits surviving to add to the population the following year[6].

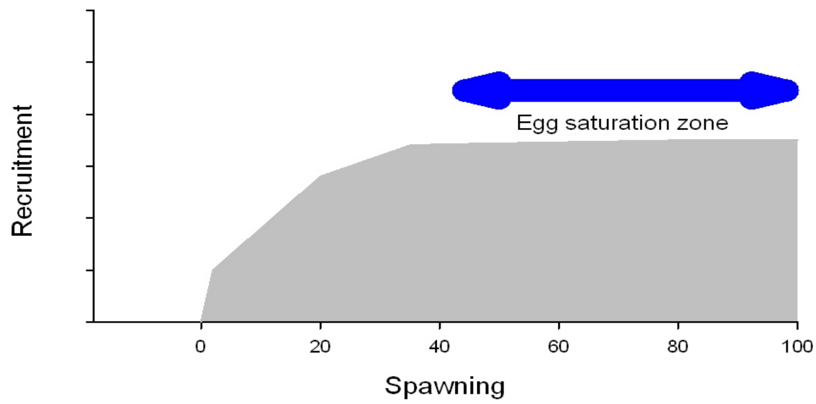


Figure 3.28: Theoretical understanding of how very large numbers of adults and spawning does not increase recruitment levels past a point of saturation (carrying capacity).
This Beverton & Holt type curve is applied for some finfish and invertebrates.

The appropriate breeding stock levels for some stocks, e.g. trochus (and abalone), may be further complicated; where the recruits inhabit the same space and compete for the same diet as the adults, a 'Ricker'-style spawning stockrecruitment relationship may occur (Figure 3.29). In such cases, larger, older shell can dominate some of the best trochus habitat, without

[5] Which includes the viability of eggs, not just raw production, and is not the same as total biomass – which will be substantially greater because this will also include the non-mature part of the population.
[6] The levels of recruitment in any one year are usually highly affected by environmental factors unrelated to egg production levels.

using the available food source for the production of new nacre (Much of the energy is taken up by maintenance and spawning.).

Figure 3.29: 'Ricker'-style curve, which gives a theoretical understanding of how very large numbers of adults can actually decrease recruitment levels as large adults dominate the population and main areas for habitation.
The high density of adults is thought to negatively affect the survival of recruits.

Because of the need to recognise recruitment and the potential effects of an aging stock, it would be wise as a manager to set targets for the three size groupings of your stock (small, medium, big) as a percentage of recordings in survey, in addition to thresholds based on abundance alone. These targets would help guide harvest plans to ensure that, firstly, recruitment was present before commercial fishing proceeded and, secondly, that large shells did not dominate the stock.

Long-term exports of trochus from Fiji Islands, PNG and Solomon Islands fisheries have produced >50,000 t, which has a value of USD 200 million at current market price. If we had better long-term production records from individual fisheries after multiple harvests, we would have some idea of the production capacity of individual sites and better understand their potential. In this regard, there are some records from the Japanese Pacific from the early 1900s, when catches of trochus per day were recorded. Asano (1963) wrote about fishers in 1903 collecting 4000 shells per fisher per day (15–20 sacks). Records also show us declines in individual fisheries in the Pacific and Australia through overfishing, even early on in the history of commercial trochus fishing. In 1912, fishing for trochus in Palau was closed by authorities for two years due to declines in catches; in 1920, fishing was limited to a two-month fishing season, and again reduced in 1937 to a one-month fishing season. Similarly, between 1912 and 1917 Australia's extensive reefs were depleted in a five-year period, from a starting point of about 4–6 sacks a day per fisher. This fishery waned and then recovered and, by 1949, approximately 200 trochus fishing boats were working out of Cairns, Townsville, and MacKay.

Using past records available for Cook Islands, Wallis and Palau, the productivity of these fisheries was calculated and the scale of locally fished reefs was determined by GIS. Determination of the scale of the fishery requires an understanding of the core fishing locations and not just a general measurement of all potentially suitable shallow-reef areas. From our assessments (16 site examples) an average of only 9% of shallow-water reef was considered as core habitat per site. Asano (1963) stated that sustainable harvests of 2.25 t of shell were possible from one nautical mile of core trochus fishery area.

Analysis of previous data from Cook Islands, Wallis, and Palau showed a surprisingly similar number was harvested:

- Cook Islands - 280,000 shells from 4.3 km^2 core fishery area, every three years;
- Wallis - 247,800 shells from 4.4 km^2 core fishery area, every three years;
- Palau - 524,200 shells from 8.9 km^2 core fishery area, every three years.

When we look at these harvests on a relative basis per annum, we find that Asano's (1963) estimate corresponds to a harvest of 180 shells per core fishery per hectare per year. For the data presented above this comes out as follows:

- Cook Islands' harvest was ~240 shells/ha/year;
- Wallis' harvest was ~187 shells/ha/year;
- Palau's harvest was ~140–195 shells/ha/year.

Based on a price of USD 4 per kg and a capture size of 10 cm shell (USD 1 per shell) with a three-year rotation, this equates to a yield of USD 42,000–66,000 /km every three years (Figure 3.26 shows conversions of shell weights to numbers.).

3.3 Status of semi-commercial, artisanal, and subsistence fisheries

3.3.1 Giant clam fishery stock status

Giant clams are an iconic group of bivalve molluscs found across the Pacific. This heterotrophic group of animals (that require both sunlight and food from filter feeding) is commonly found throughout reef systems in shallow-water reef and sedimentary areas, seagrass, and areas of rubble. Although generally recorded in shallow water (<5 m), the survey noted clams to depths of 35 m. Clams are a common food staple and a cash crop in some regions, occasionally being used for artisanal or commercial fishing (shell and meat products) but, in the majority of cases today, clams are taken for food.

Declines related to fishing have been widely noted for these species. The largest species, *Tridacna gigas*, is already reported to be extinct in the Commonwealth of the Northern Marianas (CNMI), FSM (Yap, Chuuk, Pohnpei and Kosrae), Fiji Islands (this is debated), Guam, New Caledonia, and Vanuatu. *T. derasa* is reported to be extinct at Vanuatu and *Hippopus hippopus* lost to American Samoa, CNMI, Fiji Islands, Guam, Samoa and Tonga. The Convention of International Trade in Endangered Species (CITES) currently lists giant clams under Appendix II, which covers species that may become threatened if their trade is not effectively regulated. This Appendix II listing of a species does not necessarily mean that it is currently threatened with extinction nor that trade in that species will be limited. However, any such trade must be determined not to be detrimental to the survival of the species in the wild, and should only involve specimens that were obtained in compliance with national laws for the protection of fauna and flora. The International Union for Nature Conservation's Red List of Threatened Species (IUCN 2010) is widely recognised as the most comprehensive list of species most in need of conservation attention if global extinction rates are to be reduced. The list provides a global index of the state of change of biodiversity. Currently, the true giant clam, *Tridacna gigas*, the 'smooth' clam *T. derasa*, and the devil clam, *T. tevoroa*, are listed as 'vulnerable'. A taxon is 'vulnerable' when the best available evidence indicates that a species is considered to be facing a high risk of extinction in the wild. The remaining species of giant clam: the horse-hoof or bear's paw clam *Hippopus*

hippopus, the china clam *H. porcellanus*, the elongate clam *Tridacna maxima*, and the fluted clam *T. squamosa*, are all listed as 'lower risk', but 'conservation dependent', with the exception of the boring clam *T. crocea*, which is listed as being of 'least concern'. A taxon is of 'least concern' when it has been evaluated against the criteria and does not qualify for incorporation under any of the other listings.

Using our survey techniques, six species of giant clam were commonly noted across the Pacific: *T. maxima*, *T. crocea*, *T. squamosa*, *T. derasa*, *T. gigas* and *H. hippopus* (Figures 3.30 to 3.36). Countries/territories with the greatest species diversity are found in the western Pacific, where at least six species of giant clam were commonly recorded. A seventh clam species, *H. porcellanus*, was noted in Palau and FSM (also said to be found from Philippines to western Irian Jaya), while an eighth, *T. tevoroa*, was only recorded in Tonga (also reportedly found in Fiji Islands and New Caledonia in small numbers).

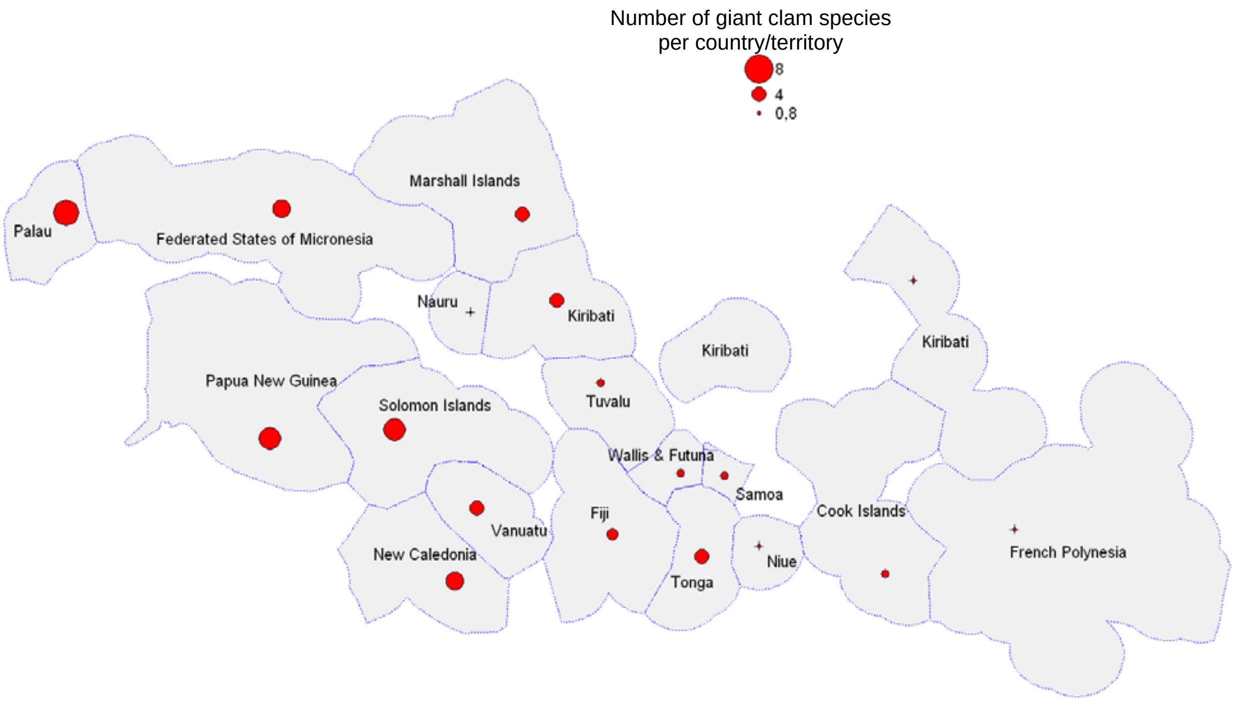


Figure 3.30: The number of clam species recorded per country/territory.

Giant clam presence in manta-tow and shallow-reef survey stations varied greatly per individual country/territory (Figure 3.31).

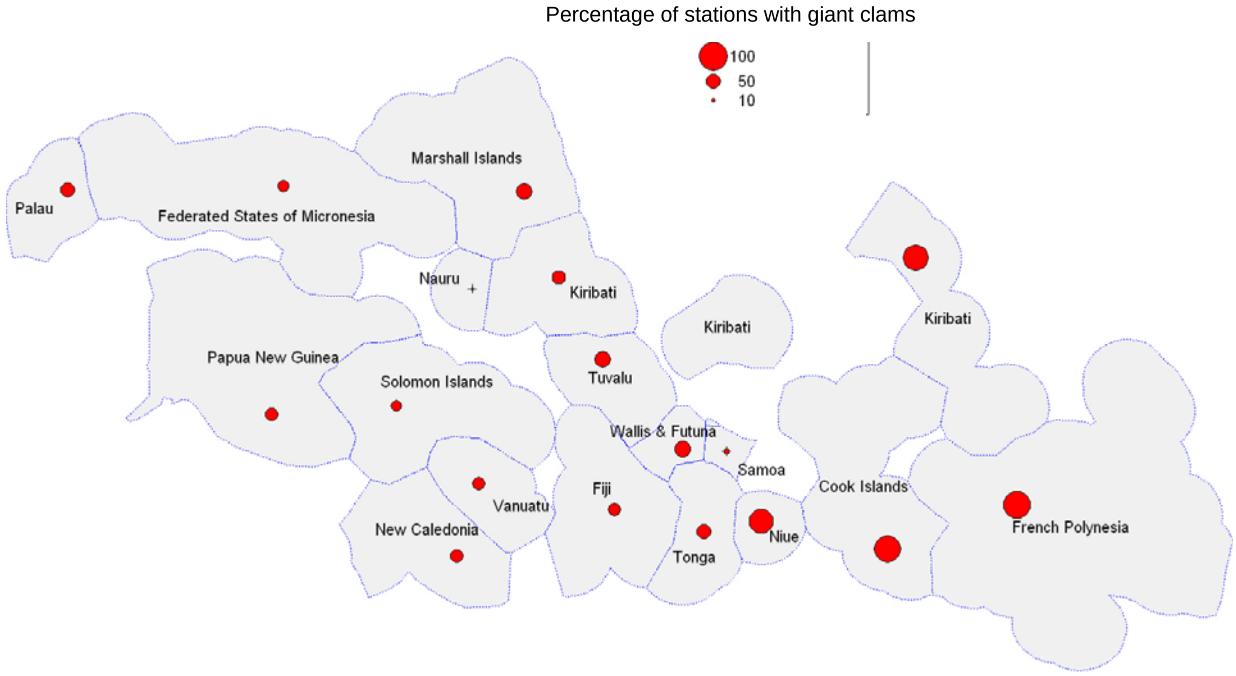


Figure 3.31: The percentage of survey stations (% of manta-tow and RBt stations combined) where giant clams were noted.
RBt = reef-benthos transect.

When considering the status of an invertebrate resource stock such as giant clams, the word 'status' is often linked with measures such as density and size, with 'higher' status sites being ones that support large numbers of the stocks in question and a range of individual sizes, including small juvenile clams and large mature individuals.

When one tries to define in a figure the concept of managing an inshore stock such as giant clams (Figure 3.32), the densities at a virgin abundance are likely to present the highest status a stock can reach. In today's terms this is an unrealistic goal for maintaining resource stocks that have been impacted by fishing pressure over generational time scales. What we can strive for across the Pacific is to hold stocks above a sustainable target reference point or threshold that we believe will ensure that the stock remains viable and resilient to natural pressures, but also able to provide an opportunity for periodic harvest. Although densities for high-status sites are higher than for low-status sites, and we need to formulate a 'target reference density' for harvested species groups, this must include some reference to a site's capacity to support the resource in question. There will be differences in this capacity, which means that in some cases a site which has a low capacity may never be able to reach the density of a site which has better habitat, incoming recruitment, and adequate food resources for the stock in question.

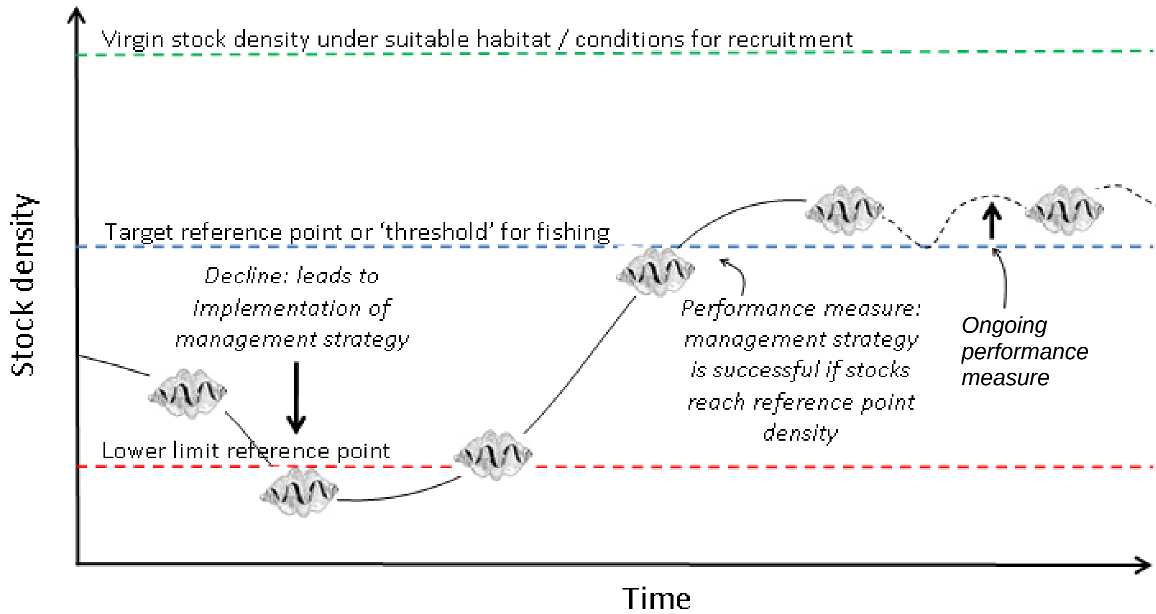


Figure 3.32: A conceptual understanding of how management can be implemented to stem a decline and increase the status of clam stocks.
Stocks returned to a abundance greater than the target or threshold where fishing can be considered are more resilient to natural and anthropogenic pressures that impact them, and can still provide an opportunity for periodic harvests (Figure adapted with permission from FAO, and from a recent sea cucumber technical manual by Purcell (2010).

Managers need to help local communities understand the local potential for sustainable harvest and assist communities to understand which stocks are likely to support active fisheries and which, due to insufficient natural habitat features, recruitment, or food availability, will not be robust enough to allow regular harvests even when they are actively managed. Finer tuning in the understanding of a site's capacity to support a stock that is regularly fished will only come through monitoring stock response to fishing pressure and recognising and respecting other pressures that are part of the natural cycle that impacts that resource (e.g. climate and weather factors, naturally variable recruitment, changes in associated species groups).

The key to working this out is to adopt a management strategy focused on target thresholds (Figure 3.33) for key resources and to react and put in place controls when communities notice a stock decline. Monitoring of stocks over time to check if there is recovery should ensure the community understands when stock levels are returned to the target reference point deemed necessary to ensure stock sustainability. If a reef is entirely depleted of giant clams, re-population will depend on larvae brought in by prevailing currents. If the reef is isolated or the current direction is unfavourable, re-establishment will take an extended period (decades, if at all), and, therefore, early management is preferable to trying to recover grossly depleted populations.

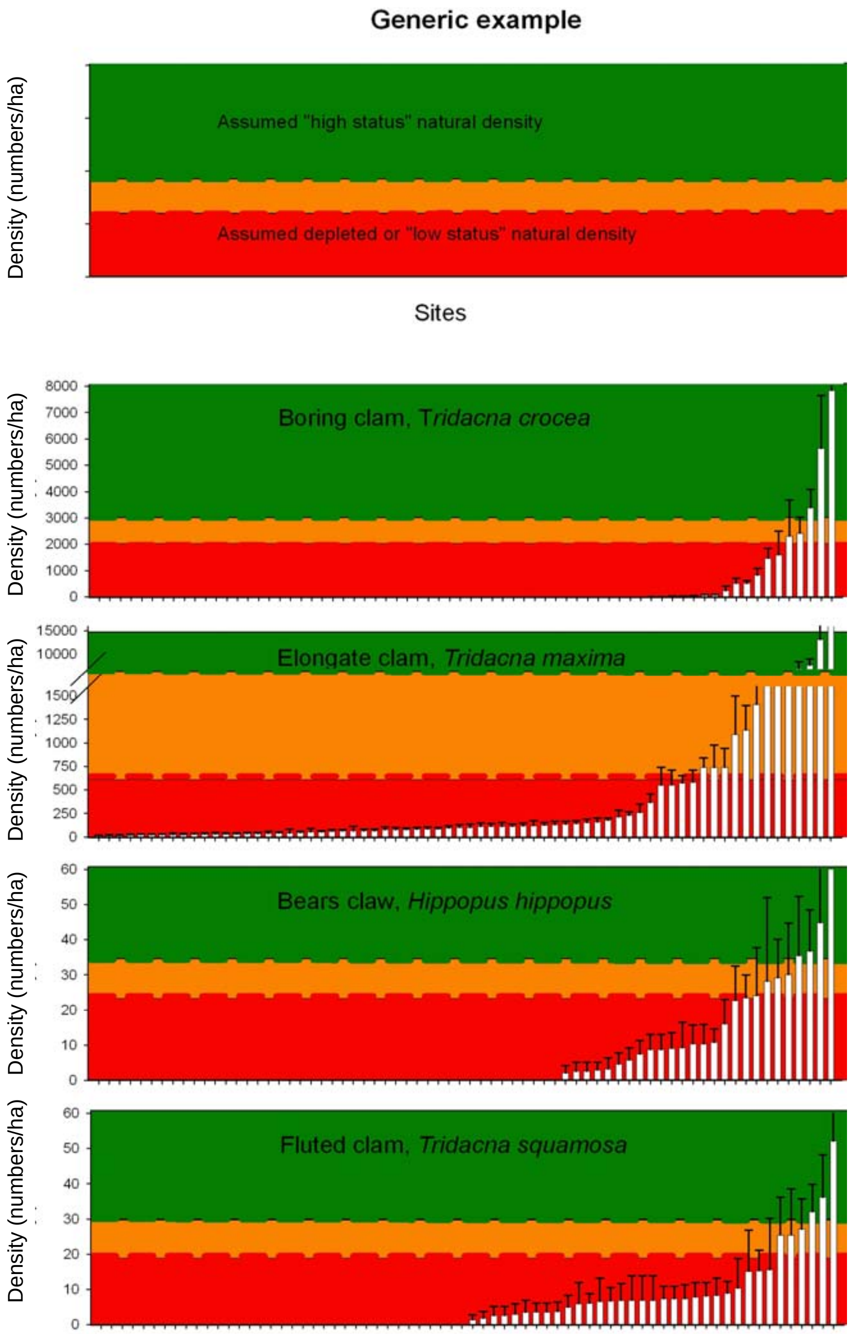
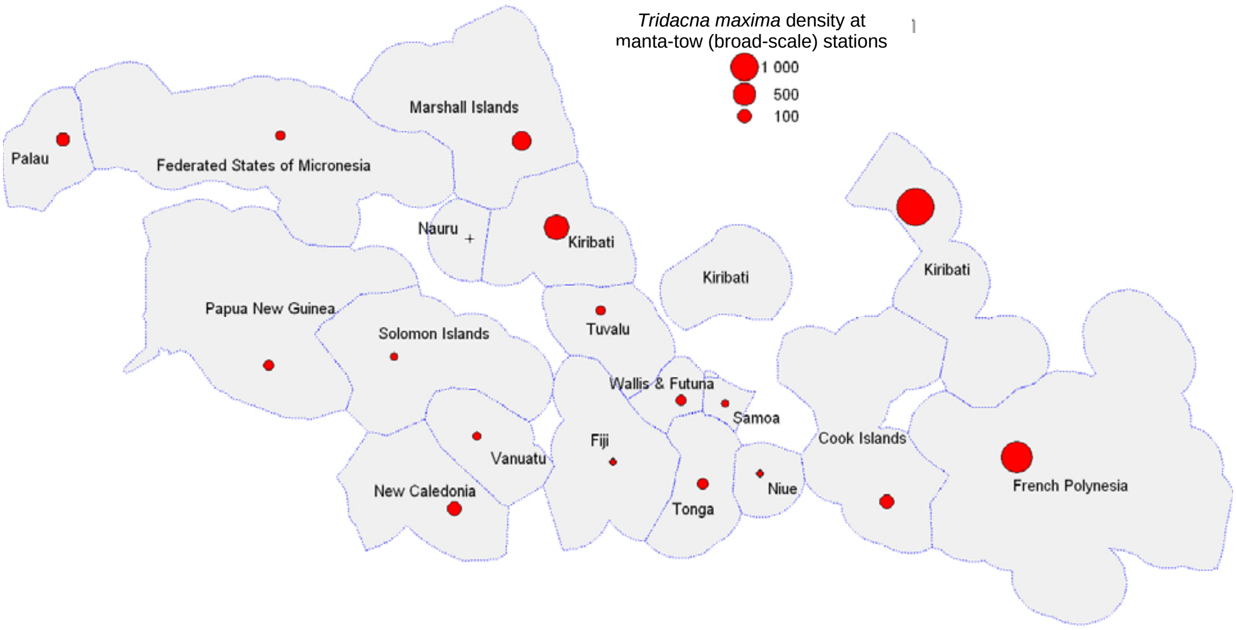


Figure 3.33: A generic example (top) followed by examples for four common clam species, with suggested threshold bandings, to depict 'high-status' and 'depleted or low-status' results. These average-density records are from reef-benthos transect (RBt) and mother-of-pearl transect (MOPt) surveys for all records, except *Hippopus hippopus*, where RBt and soft-benthos transect (SBt) survey records were amalgamated. Note the broad orange band for *Tridacna maxima*. This wide banding arises as the threshold for status is highly variable between closed atoll reefs where recruitment is elevated and open reefs of high islands where larvae of giant clams are not entrained (retained), and recorded densities are lower.

Abundance of giant clams

In general, records of clam presence from a site show a manager, among other things, how spatially common giant clams are and where the main aggregations of clams are located (indicating sites for future monitoring). The overall record of abundance from broad-scale and fine-scale sampling gives a signal of density. Densities of the small and most commonly recorded elongate clam *Tridacna maxima* and the inshore boring clam *T. crocea* from across the Pacific are presented in Figures 3.34 and 3.35.

(a)



(b)

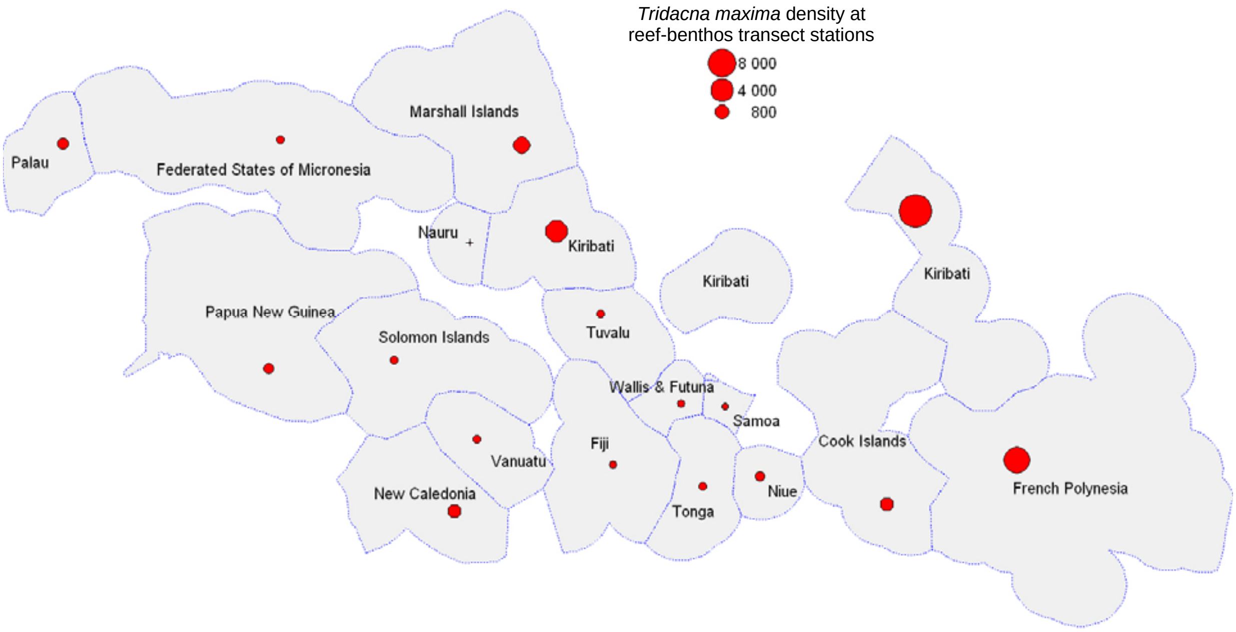


Figure 3.34: Average density of *Tridacna maxima* recorded on manta-tow (broad-scale) stations (a) and reef-benthos transect stations (b).
In both cases, we present average records of density from stations where *T. maxima* was noted.

For elongate clams (*T. maxima*) the average density in our surveys ranged from 2.7 to 4490.3 individuals per ha on broad-scale stations where the species was present; whereas smaller-scale targeted surveys of shallow reef yielded average densities ranging from 41.7 to 15,996.5 individuals per ha (RBt stations). Locally, the density of *T. maxima* reached 31,083.3 individuals per ha (at one RBt station in Kiritimati, Kiribati).

As can be seen from Figure 3.34, *T. maxima* is a common clam species whose abundance can be very high, especially within atoll lagoons of a suitable structure. This is thought to occur as their planktonic larvae become entrained within the semi-enclosed lagoon system, and cannot leave the shallow-water system, which facilitates large settlements and recruitment of clams. This is not the case in open lagoon systems and, therefore, setting management targets should acknowledge this natural difference in a site's capacity, and in historical understanding of giant clams presence and abundance.

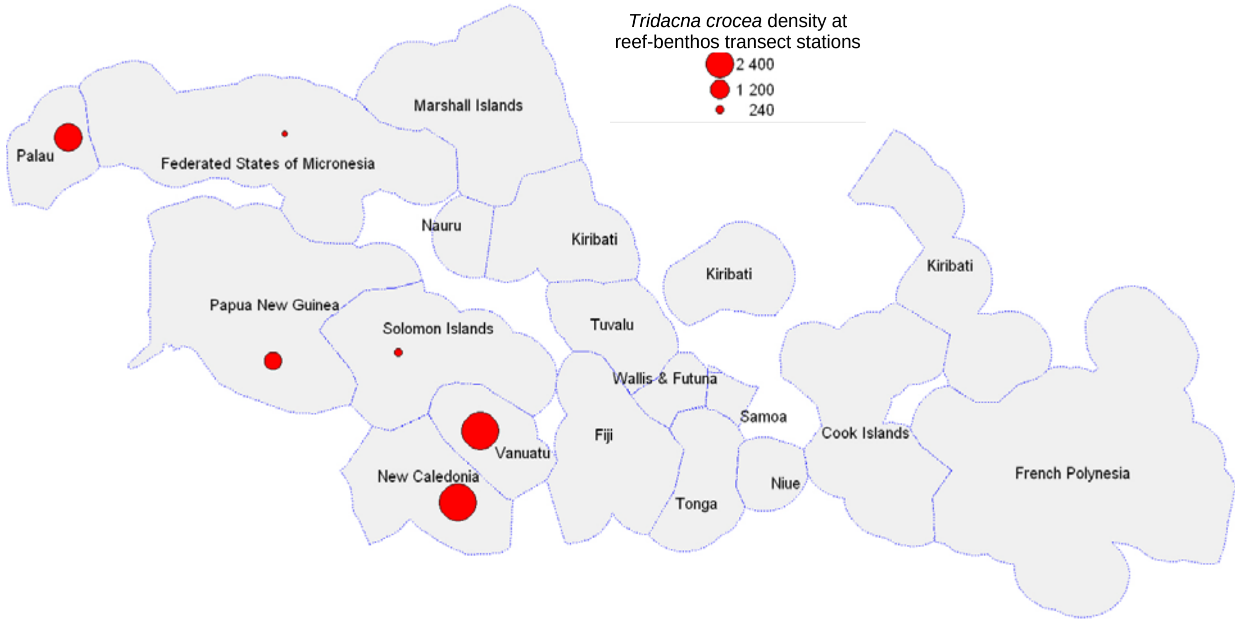


Figure 3.35: Average density of *Tridacna crocea* as recorded on shallow-water reef transect stations. Average records of density are taken from stations where *T. maxima* was noted.

The boring clam *T. crocea* is concentrated in certain more inshore areas in lagoon systems and can reach high densities. We recorded a range of densities in surveys from 41.7 to 7839.2 individuals per ha per site in targeted assessments of shallow-water reef (RBt stations). The numbers and density of the boring clam can also reach very high levels; in one shallow-reef snorkel station (RBt) in Moso Village in Vanuatu, clams reached a density of 28,458.3 individuals per ha.

The bear's paw clam *Hippopus hippopus* is larger than *Tridacna maxima* or *T. crocea* (commonly reaching a length of just over 30 cm) but it is also generally one of the smaller species compared to the larger clam species. This species was recorded at an average density ranging from 41.7 to 108.3 individuals per ha in targeted assessments of reef or soft-sediment areas. On one occasion 333.3 individuals per ha were noted at a remote atoll near Panapompom in PNG. This medium-sized clam has a subtle and cryptic colouration, which makes it difficult to detect and, therefore, survey results can be of mixed reliability depending on the experience of the survey team. Despite this, the Reef Fisheries Observatory dataset recorded the presence of the bear's paw clam at over 40% of sites across the Pacific (31 out of 77 sites) and presence and density estimates are available in the Pacific dataset for local comparisons by managers who have skilled staff to make comparable surveys.

The medium-sized fluted clam *T. squamosa* is found from 1 to 35 m depth across many countries and territories in the Pacific and this species also offers an option for monitoring the impacts of fishing, although in the mostly easterly parts of the Pacific representation is low (Figure 3.36).

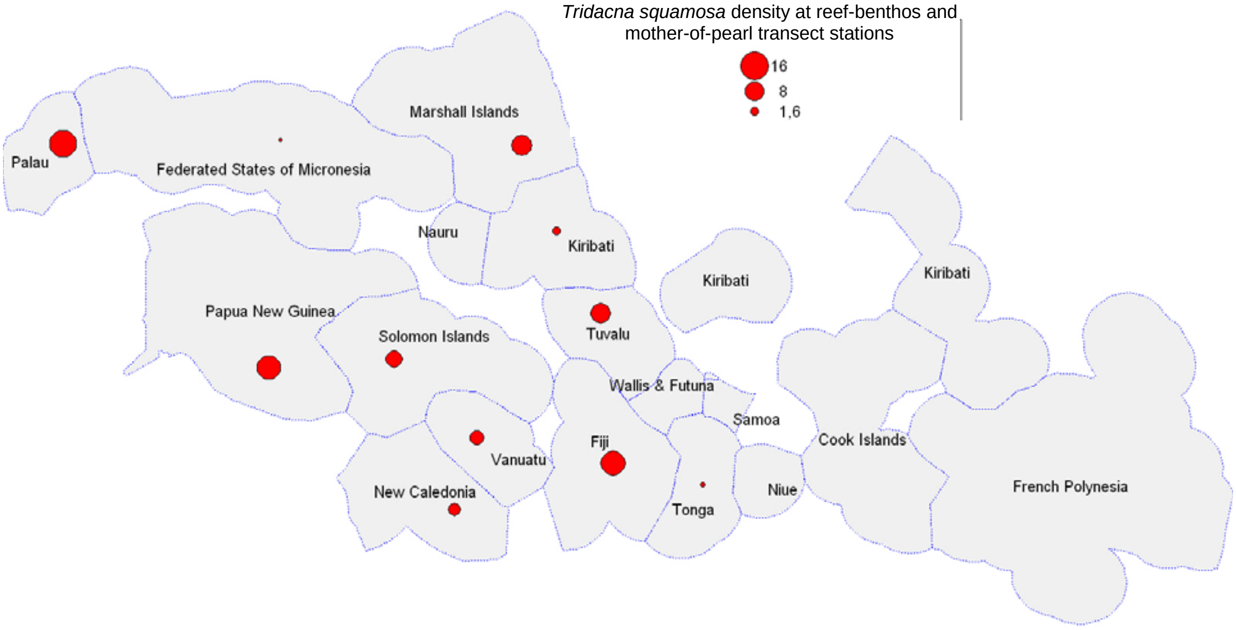


Figure 3.36: Average density of *Tridacna squamosa* as recorded on RBt and MOPt stations (aggregated records).
In both cases, we present average density from all stations.

Tridacna squamosa on broad-scale manta-tow surveys was also recorded, at a range of 2.8–30.6 individuals per ha. The greatest aggregation recorded for the fluted clam at small scale (RBt and SBt survey stations) was 291.7 individuals per ha at Maskelynes in Vanuatu.

The larger species of giant clam were rarely recorded in large numbers across the Pacific. From nine of the 17 countries where *Tridacna gigas* and *T. derasa* are listed as native, the largest species, *T. gigas* was only recorded at five countries within its extension range (Table 3.3) while *T. derasa* was recorded in all seven countries (Table 3.4). Occurrence at sites was rare and critically low when one examines the total number of individuals found. *T. gigas* was recorded in 30% of sites visited (11/37), while *T. derasa* occurrence was slightly less critical, being recorded at 51.6% of sites within its range extension (16/31). The numbers of clams from this group recorded across sites is shown in Tables 3.4 and 3.5. In many cases, the low number of records was not reflected by the lack of presence of shells onshore. In many sites, empty shell valves were being used as feed troughs for livestock, e.g. pigs, or as decorations at sites where they were missing from reefs.

Table 3.4: Records of wild *Tridacna gigas* across its range extension* from within the study

Country/Territory	Total noted in survey	Density (individuals per ha) All records	Density (individuals per ha) Stations where present
Fiji Islands (arguable if this species was ever native)	0	0	
FSM	0	0	
Kiribati	1	0.02	2.78
Marshall Islands	9	0.35	10.76
Palau	28	1.1	17.97
PNG	30	3.84	71.76
Solomon Islands	1	0.01	2.78
Tonga	0	0	
Tuvalu	0	0	

* includes places where species is introduced.

Table 3.5: Records of wild *Tridacna derasa* records across its range extension* from the study

Country/Territory	Total noted in survey	Density (individuals per ha) All records	Density (individuals per ha) Stations where present
Fiji Islands	1	0.01	2.08
FSM	2	0.01	2.78
New Caledonia	26	0.5	6.8
Palau	39	1.2	13.9
Papua New Guinea	14	0.54	13.38
Solomon Islands	6	0.36	14.16
Tonga	31	0.18	3.41

* includes places where species is introduced.

The size frequency of individual clams in survey and their size at harvest offer managers another view of the status of giant clam resources. In some cases, there is a legal harvest size stipulated for resource management (e.g. the legal size for *Tridacna maxima* is 180 mm in American Samoa, Guam, and Niue; 160 mm in Samoa; 155 mm in Tonga; and 120 mm in French Polynesia).

Analysis of *T. maxima* lengths shows that maximum clam sizes differed markedly across the Pacific, with a notably smaller maximum size recorded in the atoll reefs of the eastern Pacific (Figure 3.37).

Length frequency records for the species surveyed assist a manager to learn whether clams are actively recruiting to the resource population or not. As an example, we generally found that the samples we measured from sites with very few clams remaining held predominantly large adult clams at low density with few juveniles noted.

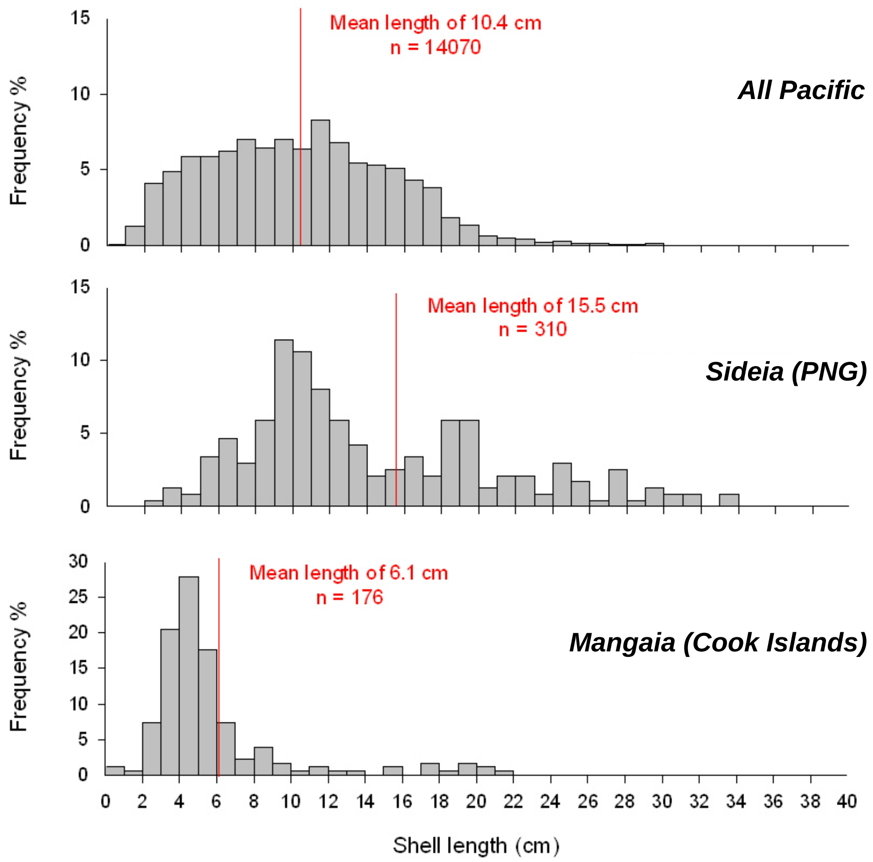


Figure 3.37: An example of *Tridacna maxima* length measures from in-water surveys.
The three graphs above show: frequency of all Pacific size measures (top graph), measures of a sample with both small clams and larger mature individuals from Sideia in Papua New Guinea (middle graph) and measures from a site in the eastern Pacific (Mangaia, Cook Islands) where maximum sizes are generally smaller (bottom).

3.3.2 Other invertebrate stocks noted in the study

Many other species groups support artisanal and semi-commercial fisheries, or are only accessed for food security. Among others these include: gleaning of spider conch, hand collecting turban shells, cutting sea hares, breaking sea urchins, ‘digging’ infaunal shells or hunting unsegmented worms.

The surveys detected and measured abundance and sizes of over 350 species of invertebrates (Table 3.6).

Table 3.6: Invertebrate group with species count per group noted within the surveys from the Pacific study

Group	Species count
Bivalves	60
Gastropods	170
Octopus	2
Sea cucumbers (Echinoderms)	40
Starfish (Echinoderms)	15
Urchins (Echinoderms)	21
Cnidarians (anemone and jellyfish)	9
Crustaceans (lobsters, crabs and prawns)	35

The surveys were not completed to maximise an understanding of biodiversity, but to gain a benchmark understanding of the presence and abundance of resource stocks. Most of the species recorded are used by village communities as resources for food security, and artisanal or semi-commercial use. For these records, the Pacific database holds information on their wide-scale distribution, their locations within sites, and on their abundance and size. This information can be used by managers wishing to get a regional understanding of resource status (for any of these species or species groups). For some species groupings, e.g. octopus, which supports an active fishery across reef environments of the Pacific, the dataset does not supply good benchmark data, as the species definition is not well understood from a genetic (taxonomic) viewpoint, and the cryptic nature of the resource made survey records an unreliable measure of abundance and availability (See socioeconomic dataset for some of these species.). However, there is a mass of information, from which a selection only is presented below.

Spider conchs

Spider conchs of the *Lambis* genus (Figure 3.38) are gastropods with finger-like protrusions (that extend from the outer lip of the whorl), which contain a sweet meat that can be extracted or cooked in the shell. Spider conchs are relatively fast growing omnivores, which gain most of their nutrition from scraping algal epiphytes from benthic surfaces. The edible spider conchs (mostly the common spider *L. lambis*, with some orange spider *L. crocata*) are taken from shallow-water reef and soft-sediment environments across the Pacific. The larger spider conch *L. truncata*, which is found at lower density, can be fished from more oceanic, deeper-water locations. Some other *Lambis* species (rugose spider *L. chiragra,* laciniate conch *Strombus sinuatus*) are also taken. In parts of the Pacific a smaller but equally appreciated member of the *Lambis* genus, the strawberry or red-lipped conch *Strombus luhuanus*, which is found in high-density patches, is similarly targeted as a food source.

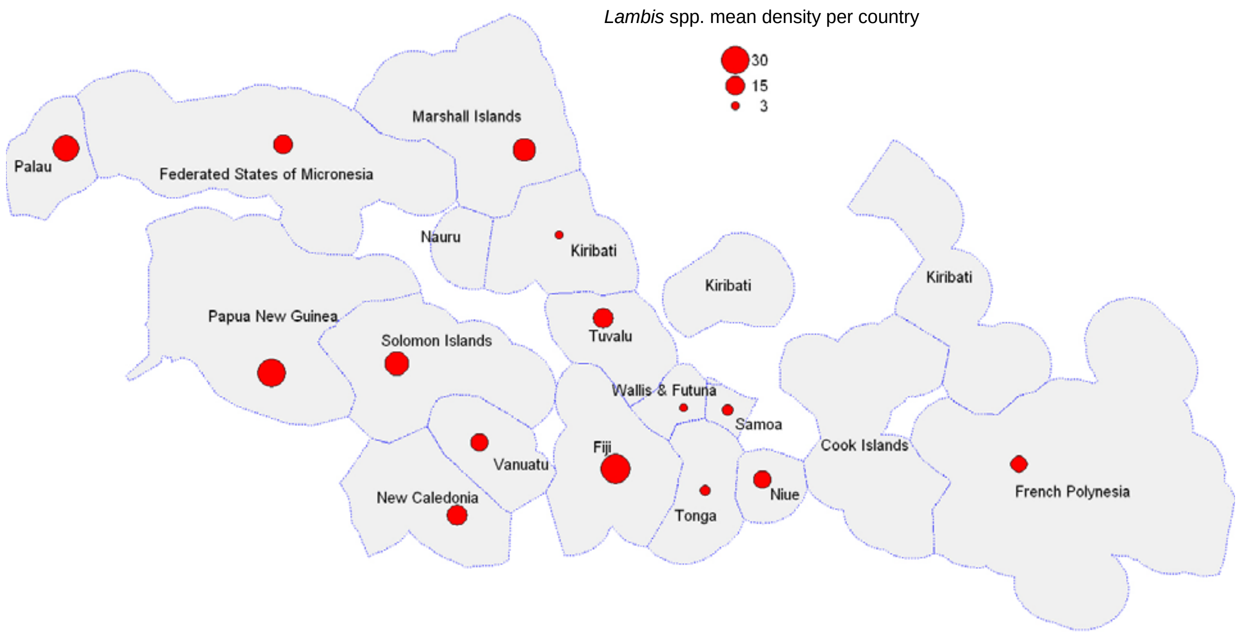


Figure 3.38: Density (individuals per ha) of *Lambis* spp. as recorded in RBt, SBt and MOPt surveys from the study (all records).
RBt = reef-benthos transect; SBt = soft-benthos transect; MOPt = mother-of-pearl transect.

Turban shell species

Unlike fishing for turban shell species that are targeted for the commercial nacre market (e.g. *Turbo marmoratus*), fishing for edible *Turbo* spp. in the Pacific generally targets aggregations of the rough turban *T. setosus* and the silver-mouth turban *T. argyrostomus*. Aggregations of *T. setosus* can result in rapid catches when conditions allow, but these sites are often difficult to access as they are found on complex benthos in the surf zone of reef fronts. Overall densities of *Turbo* spp. across the Pacific still show variation in the dataset despite the difficulties of access (Figure 3.39).

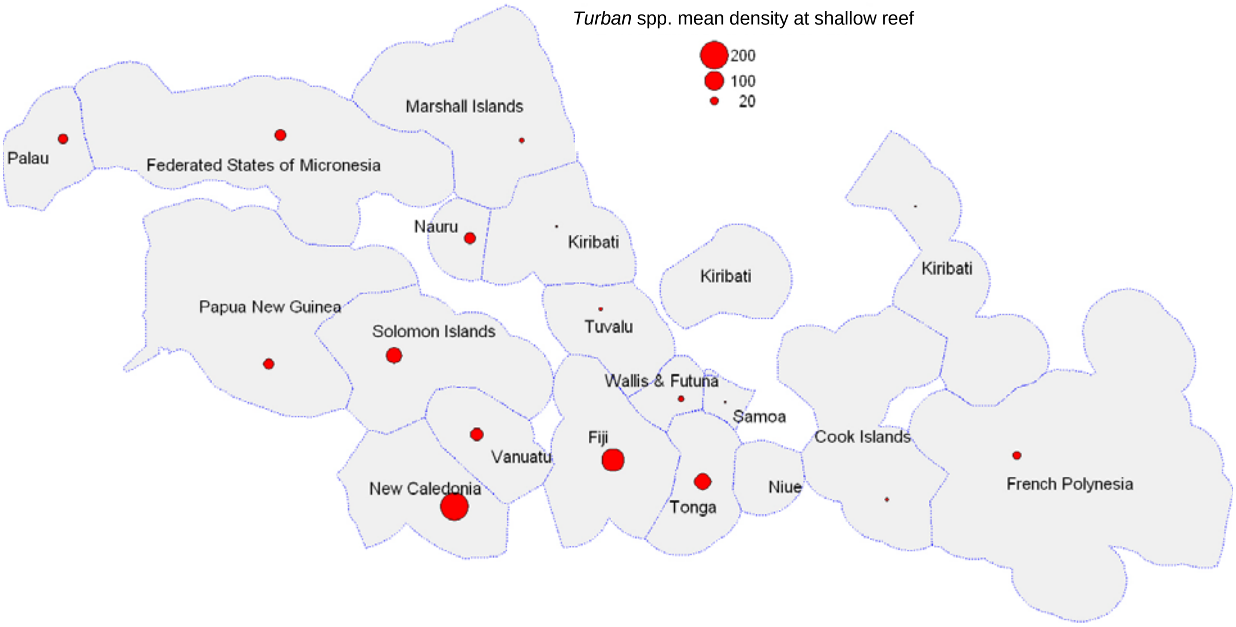


Figure 3.39: Density (individuals per ha) of *Turbo* spp. across the Pacific as recorded in RBt and MOPt surveys from the study (all records).
RBt = reef-benthos transect; MOPt = mother-of-pearl transect.

Green seahare or sea cat

In more sheltered locations, the green seahare (or sea cat) *Dolabella auricularia* is often fished as a food source by Polynesians. This soft-bodied, medium-sized sea slug (commonly up to 140 mm in length) is taken from cryptic locations in bays or lagoons (seagrass beds or on sand or mud). The mottled green and brown sea hare feeds on a variety of brown, green and red macroalgae and releases a tell-tale reddish purple 'ink' when disturbed[7]. In post-harvest processing, the liver, the red-coloured buccal mass and the upper sections of the body are taken for food while the bile sac (toxic gland), bottom part (foot) and parts of the intestine are mostly discarded. Average catch rates for this species in Tonga and Fiji Islands ranged between 10 and 16 pieces per hour in general gleaning, although dedicated fishing could yield 35 pieces per hour. As a point of comparison, Davis *et al.* (1998) recorded catch rates of approximately 24 pieces per hour for non-replicated observations in Fiji Islands. Detection rates of *D. auricularia* in survey transects were high at places where *Dolabella* were commonly fished (85% soft-benthos transect stations), despite their life habit of hiding during

[7] Note: *D. auricularia* is the source of Dolastatin 10 and 15, which are small peptides shown to be potent inhibitors of cell growth in human ovarian and colon carcinoma cell lines. Anti-cancer research using these molecules is ongoing

the day and only emerging at night to feed (average densities from Tongatapu, Tonga were recorded at 289.4 ±69.4 individuals per ha, with a maximum density at one site of 761.9 individuals per ha). All such estimates of abundance would not fully describe the stock present, due to the fact that fully buried individuals would be difficult to detect without thorough searches and disturbance of the substrate. The egg masses of this species are also considered a delicacy, resembling bundles of green noodles, of the size and consistency of well cooked 'vermicelli'. Such egg masses are left attached to seagrass or stones and provide a tasty snack for fishers.

Sea urchins

Sea urchins are targeted across most of the Pacific, mostly for their mature egg masses, which are eaten raw or cooked[8]. Although in Polynesia and Micronesia a wide range of species is taken, the collector urchin *Tripneustes gratilla* is targeted from Palau in the west to French Polynesia in the east. In back-reef surveys in Fiji Islands, where *T. gratilla* supported an artisanal fishery, its density reached a maximum of 33,750 individuals per ha, or 3.4 individuals per m^2 at urchin fishing locations (All stations' average was 14,263.9 individuals per ha ±9752.1). In the lagoons, the mean density of the collector urchin on soft benthos stations was lower (677.8 individuals per ha ±235.1) with a lower maximum recording at one area (2792 individuals per ha). This result was similar to that of records from PNG (2652 individuals per ha at some sites), although in PNG general densities across lagoon sites averaged 2000 individuals per ha. A creel survey of gleaners' catches in Fiji Islands revealed fishers could harvest 1–7 flour bags of urchins per fishing trip (approximately 150 sea urchins per 50 kg flour bag). The average size (test diameter) of these urchins was 7.5 cm ±0.1 (Figure 3.40).

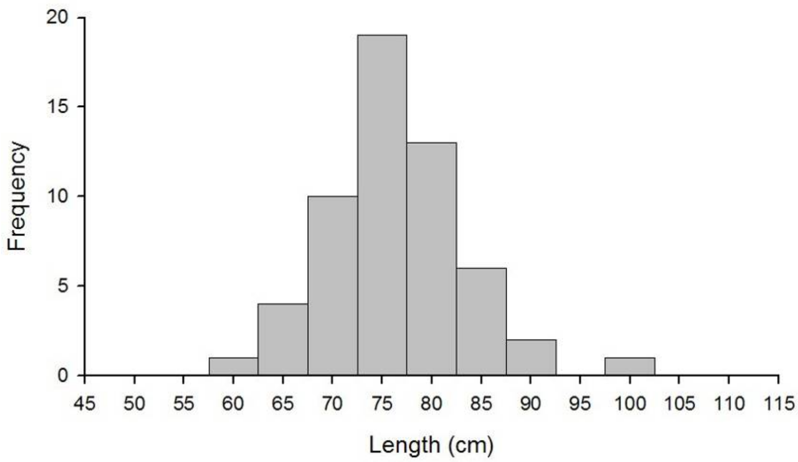


Figure 3.40: Length frequency (test diameter, cm) of collector urchin *Tripneustes gratilla* from artisanal catches in Fiji Islands.

Digging fisheries

Digging fisheries in the Pacific mostly target arc shells *Anadara* spp. (*A. antiquata*, *A. scapha* and *A. holoserica*, Figure 3.41) and Venus shells *Gafrarium* spp. (*G. tumidium*, *G. pectinatum*).

[8] A commercial market exists for export of this resource; however, processing and transportation constraints make accessing the market difficult for Pacific Island fishers.

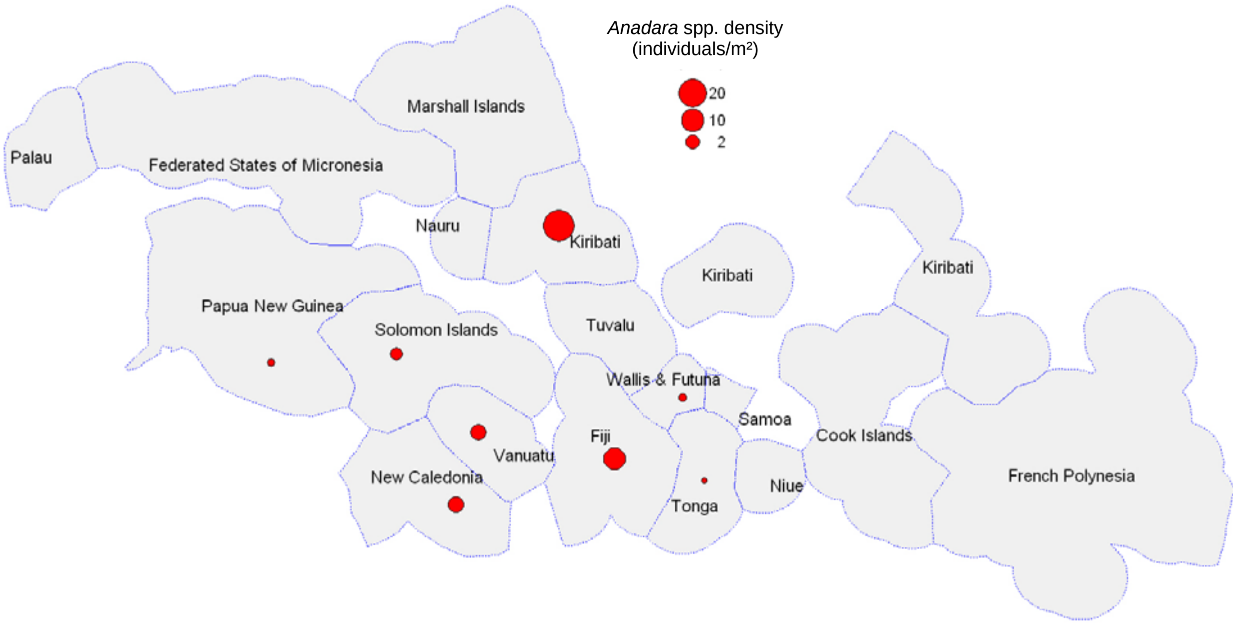


Figure 3.41: Density (individuals/m²) of arc shells *Anadara* spp. from infaunal surveys completed across the Pacific (all records).

Although infaunal species are not uncommon across the Pacific, the 'strength' of such fisheries often depended not only on the availability of extensive suitable habitat, but also on the suitability and presence of settlement substrates, current regimes and terrestrial influences. As sites supporting specific locations for the targeting of arc shells were not ubiquitous, another figure is presented below, to show densities of this common food bivalve by site (Figure 3.42).

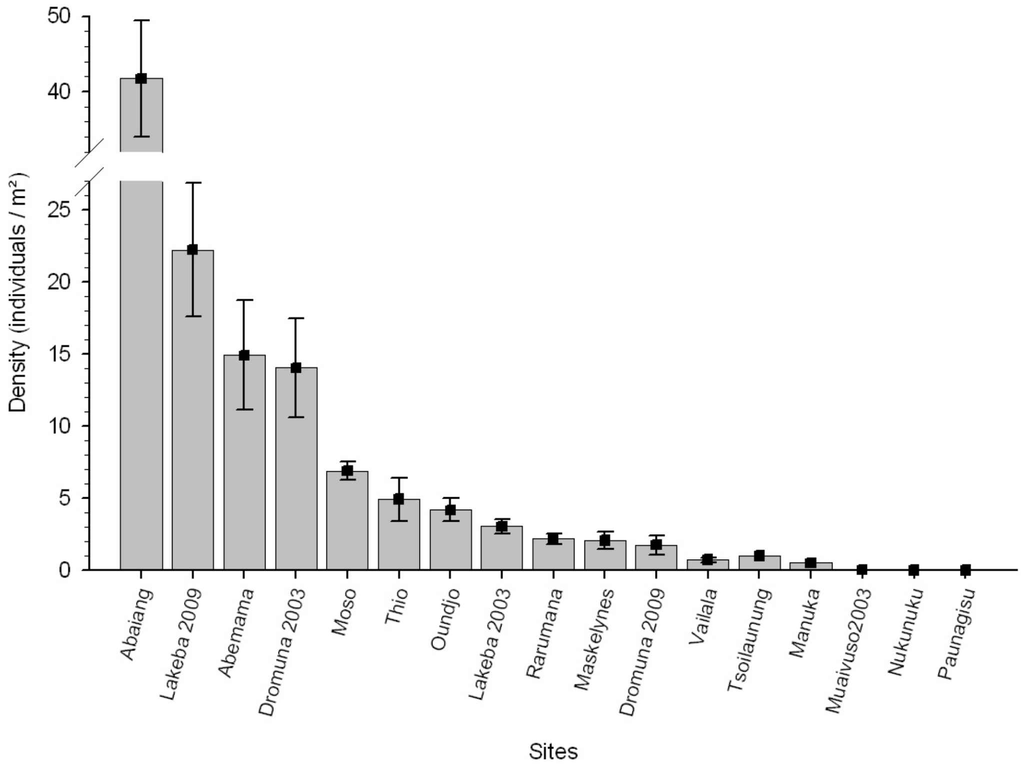


Figure 3.42: The density of arc shell *Anadara* spp. (individuals/m^2) from infaunal quadrat surveys at a subset of sites sampled during the study (only sites where present).

As for the management of other invertebrate fisheries, size records for arc shells from in-ground surveys and from catches illuminated the presence or absence of recruitment and large adults in the population (Figure 3.43), and the specificity of shell sizes targeted by fishers. In one example in Fiji Islands, fishers (generally women and children) collected between 378 and 621 shells per trip (well over 100 arc shells per hour). The shells that they collected had a mean length of greater than 6 cm, which only slightly exceeded that recorded in general survey (5.8 cm shell length). In addition to arc shells, fishers in this creel survey targeted other resource species: *Gafrarium* spp., *Cerithium aluco*, *Lingula* spp. *Periglypta puerpera* and *Vasticardium* spp. These species were all targeted in smaller numbers.

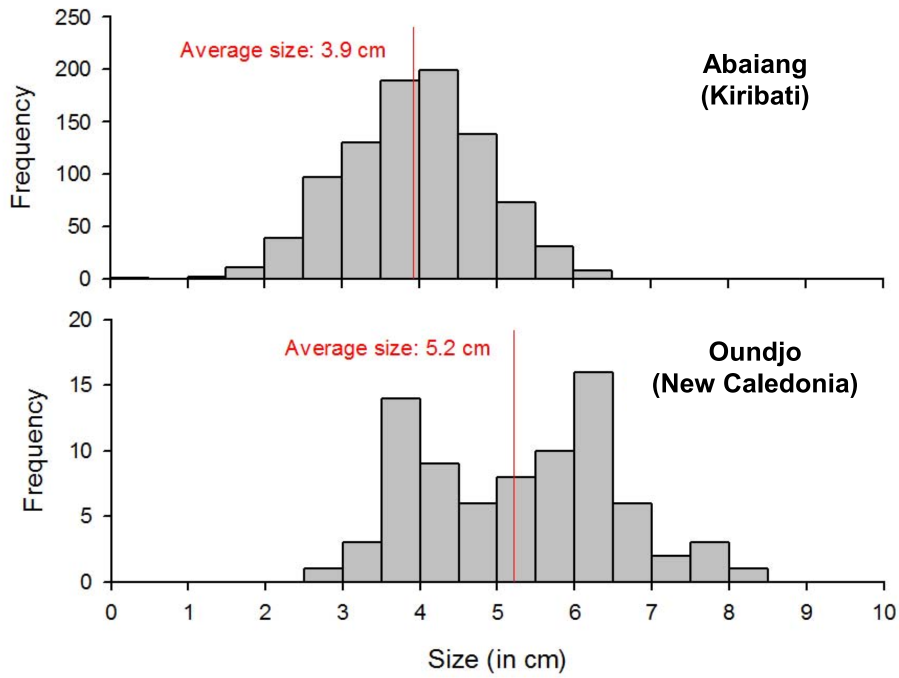


Figure 3.43: Length frequency of arc shells collected in digging surveys from two sites in the study.

Other infaunal species found at lower densities while collecting the main target species were commonly noted (*Periglypta puerpera*, *Fragum* spp., *Trachycardium* spp., *Pitar prora* and *Tellina palatum*). Although digging for arc and Venus shells is relatively common, there were also other locations and target species of infaunal shells noted in the Pacific-wide study. For example, collection of pipi clam species (e.g. *Lioconcha* spp. *Atactodea striata* and *Tapes literatus*) is centred at locations just below the lapping water on the shoreline of sandy beaches, while the lucinid clam *Anodontia philippiana* is collected from deep in the sediments of mangroves in some western Pacific countries. Lastly, the species *Asaphis violascens* is another infaunal species that is dug with tools from complex benthos (coarse sediments, gravels and boulders) in more exposed locations (e.g. reef-front sediments).

In general there is a range of resource species important for food security also collected from soft-sediment environments along with the infaunal species. For example, the sediment surfaces or seagrass beds are also searched for sea cucumbers (*Holothuria leucospilota*, *Stichopus horrens*), urchins (*Tripneustes gratilla*), gastropods (*Lambis* spp., *Strombus* spp. and *Conus* spp.) and other bivalves (*Modiolus* spp., *Atrina* spp. and *Pinna* spp.).

Lastly in this report, unsegmented marine 'worms' (*Sipunculus* sp.) were taken from white sand (Kiribati) while brachiopod lamp shells (*Lingula* sp.) are sourced from benthos near mangroves (Fiji Islands). To take the protostomate *Sipunculus* sp. Kiribati fishers locate the twin holes that indicate a sipunculid is present, and then stab in a sharpened piece of coconut frond midrib at a specific angle to the hole. *Sipunculus* sp., are eaten both raw and smoke-dried[9]. Brachiopod lamp shells (*Lingula* sp.) are filter feeders that, similarly to arc shells, are located by noting a slit on the surface of the benthos. They too can be found in dense aggregations, although *Lingula* sp. was rarely recorded in our surveys and no fishing for this species was witnessed during the study.

3.3.3 Other commercial fisheries not well covered by in-water surveys

Fisheries for spiny lobsters, mangrove crabs and coconut crabs for sale at local markets are also common in many PICTs. Spiny lobsters are traditionally caught by fishers walking reef platforms at night or by divers. Typically, the use of underwater torches and SCUBA or hookah are now needed in all but the most remote islands, as most sites had very low densities of lagoon and reef-front species of spiny lobster. Mangrove crabs are caught mainly by removing them from their burrows at low tide, often by women, and are commonly sold at central markets in Fiji Islands, FSM, New Caledonia, Palau, PNG, Solomon Islands and Vanuatu. Coconut crabs are renowned for their slow growth and declining availability across the Pacific. Surveys for all these species were not comprehensively targeted during the study although records do exist in the Pacific dataset. The reason for the omission was that dedicated surveys for these species were too difficult to complete within the time scale of the surveys, and snapshot views of such fisheries from in-water surveys were unlikely to yield a reliable signal of stocks.

Penaeid shrimps are the basis of a large commercial trawl fishery in PNG, but this fishery is not based on reefs and is also not covered in this report. In this case, most of the fleet operates in the Gulf of Papua, catching 1000–1300 tonnes of prawns per year, although smaller trawl fisheries have also been established at several other locations in PNG.

3.4 Discussion and conclusions

3.4.1 Bêche-de-mer

Managers who are able to control harvest periods for bêche-de-mer, by only opening a commercial fishery for small, pulse-fishing events, with regular monitoring (pre-fishing and post-fishing surveys) will be able to understand stock changes and refine management understanding of stock recovery. This 'closure – pulse fishing – closure' approach based on population metrics taken from these surveys can be adopted for many species or a subset of species as presented above. The metrics can become refined over time through sharing information and advice gleaned from the joint experiences of managers across the region. Continued research on the basic biology and ecology of sea cucumbers, which is slowly emerging for a few species (See aquaculture-related research in Agudo 2006.), will provide a valuable complementary dataset to inform community members about growth and reproduction, as will genetic studies that highlight isolation or connectivity between neighbouring populations.

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[9] Can cause allergic reactions in some people.

In the context of the Pacific it is important for the performance of these fisheries that government and civil society groups adopt a greater level of control and work toward regional diffusion of understanding that arises from local experience. Managers base their decision on both social as well as environmental constraints, and can decide along with local communities on how conservative a management framework is imposed. Alongside local initiatives, a regional framework for information sharing and governance of sea cucumber exports is needed, and small-scale as well as larger-scale regional cooperation could assist with this and a number of issues involving invertebrate export fisheries with similar characteristics (e.g. trochus fisheries) where ecosystem services and fishery benefits are important to Pacific Island communities.

3.4.2 Mother-of-pearl

Management considerations for mother-of-pearl resources may benefit from looking at the factors that were used to control fishing at sites that maintained average densities of stocks above the threshold of 500 per ha. Invariably these locations were managed through only allowing a limited number of active fishing periods, and ensuring these were short 'pulses' of commercial fishing, interspersed with longer periods when stocks were 'closed' to fishing. The mechanism for closing and opening the fishery was mostly controlled through centralised management, or a combination of centralised management and community input and instruction. In no case was community management alone used to maintain average density of stocks at or >500 per ha.

To allow stocks and, therefore, fishery productivity to rebuild at places where stocks are depleted, underperforming (and declining) fisheries need to be closed. In some cases live shells need to be aggregated within key fishery grounds to assist spawning success and to 'kick-start' a return to productivity. Regional cooperation by participating countries to coordinate harvests, in order to supply a continuous stream of product to market, could be of great benefit to all. It would provide overall industry security, by providing confidence to those investing in post-harvest processing machinery while decreasing price fluctuations driven by inconsistent supply.

To maintain stocks at reasonably high levels of abundance, community negotiations need to take place where local and Pacific-wide information is presented and discussed, and thresholds to determine what stock densities should be before any harvesting is considered should be agreed between centralised government and community leaders. Communities need to be involved in determining what information is needed on the status of stocks and interim surveys to inform fishers of the changing condition of stocks so they can see progress in their management. Centralised government control of fishing and exporters is needed to oversee any commercial harvest of this export species, and ensure data on catches and fishing time/area information are centrally collected and archived. Lastly, consideration of harmonising Pacific trochus policies would also be of benefit, as would sharing management outcomes and stock, when translocation was possible, to bring new areas that are suitable for trochus into the fishery.

3.4.3 Giant clams

Giant clams are a useful keystone species for encouraging community involvement in resource management. The colourful species are easy to locate and count, and changes in abundance and size are easily measured when setting and testing management targets. Giant clams are also useful species for teaching communities the complexity of life histories of invertebrate species, and how resource species are impacted by fishing and management decisions. In general, we found villagers were not generally aware of the life cycle and age of most resource species; giant clams, which are broadcast spawners with a short-lived planktonic larvae, are good examples for showing how spawning occurs and how small clams need to settle and grow to reach maturity (Note: *Tridacna maxima* develop as females from about 8 cm, *T. squamosa* from 15 cm and *T. gigas* from about 50 cm, or as old as ten years.). As they are protandrous hermaphrodites (begin as males and later become females), only the larger clams are female, and knowing this will help communities develop strategies for protecting some of the larger stock or for establishing protected areas and rules around allowable sizes for sustainable harvest in the interest of conserving populations.

3.5 Management recommendations

3.5.1 Bêche-de-mer

The following points are provided in support of the sustainable management of bêche-de-mer fisheries. Specific management advice for some countries is found in Appendix 3.4.

- ***Continue to define the fisheries:***
  - focus understanding on relevant species groups rather than the whole fishery;
  - map their distribution – determine how big and where are the fishery grounds;
  - examine the Pacific dataset and decide what numbers (densities/sizes) need to be left in the water to retain breeding capacity.

- ***Control the fisheries:***
  - set in place an agreed monitoring strategy;
  - simplify management – use an 'on/off' switch to manage harvests;
  - educate fishers in fishery understanding and post-harvest processing;
  - control access to the fishery by the marine product sector;
  - institute comprehensive export inspection and reporting.

- ***Grow the business:***
  - monitor and share understanding of productivity and responses in the fishery;
  - monitor and share market information;
  - focus on market development.

3.5.2 Mother-of-pearl

The following points are provided in support of the sustainable management of mother-of-pearl fisheries. Specific management advice for some countries is found in Appendix 3.4.

- ***Continue to define the fisheries:***
  - map their distribution – determine how big and where are the key fishery grounds;
  - examine the Pacific dataset and decide what numbers (densities/sizes) need to be left in the water to retain breeding capacity.

- ***Control the fisheries:***
  - set in place an agreed monitoring strategy;
  - simplify management – use an 'on/off' switch to manage harvests;
  - educate fishers in fishery understanding and post-harvest processing;
  - control access to the fishery by the marine product sector;
  - institute comprehensive export inspection and reporting.

- ***Grow the business:***
  - monitor and share understanding of productivity and responses in the fishery;
  - assist and facilitate translocation among areas with suitable habitat for trochus;
  - monitor and share market information;
  - focus on synchronising market access and on developing the markets.

3.5.3 Giant clams

The following points are provided in support of the sustainable management of giant clam fisheries. Specific management advice for some countries is found in Appendix 3.4.

- ***Continue to define the fisheries:***
  - map the distribution – determine how big and where are the key fishery grounds;
  - examine the Pacific dataset and decide what numbers and sizes need to be left in the water to retain breeding capacity.

- ***Control the fisheries:***
  - set in place an agreed monitoring strategy (Use the Pacific dataset and sampling strategy advice.);
  - educate fishers in fishery understanding;
  - decide on some 'no-take' areas, where fishing is banned to protect mature clams as a broodstock.

- ***Grow the understanding:***
  - monitor and share understanding of productivity and responses in the fishery among participating communities and countries who share the same resources.

4. PROFILE AND RESULTS FOR SOCIOECONOMIC ASSESSMENT

4.1 Introduction

In 2002–2009, 63 communities and their fishing grounds in 17 Pacific Island countries and territories (PICTs) were surveyed. In total, the socioeconomic survey covered 2310 households representing a total population of 85,117 people, or 17% of all 13,746 households registered in all 63 communities. In addition, associated finfish and invertebrate surveys were undertaken with 2660 finfish fishers (17% females, 83% males) and 2519 invertebrate fishers (49% females, 51% males).

The 17 PICTs included in the survey represent three main cultural groups.

- Melanesia is represented by 21 sites in five countries: Fiji Islands, New Caledonia, Papua New Guinea, Solomon Islands, and Vanuatu.
- Micronesia is represented by 17 communities distributed over five countries: Federated States of Micronesia, Marshall Islands, Nauru, and Palau.
- Polynesia is represented by 25 communities in six countries: French Polynesia, Niue, Samoa, Tonga, Tuvalu, and Wallis and Futuna (Figure 4.1).

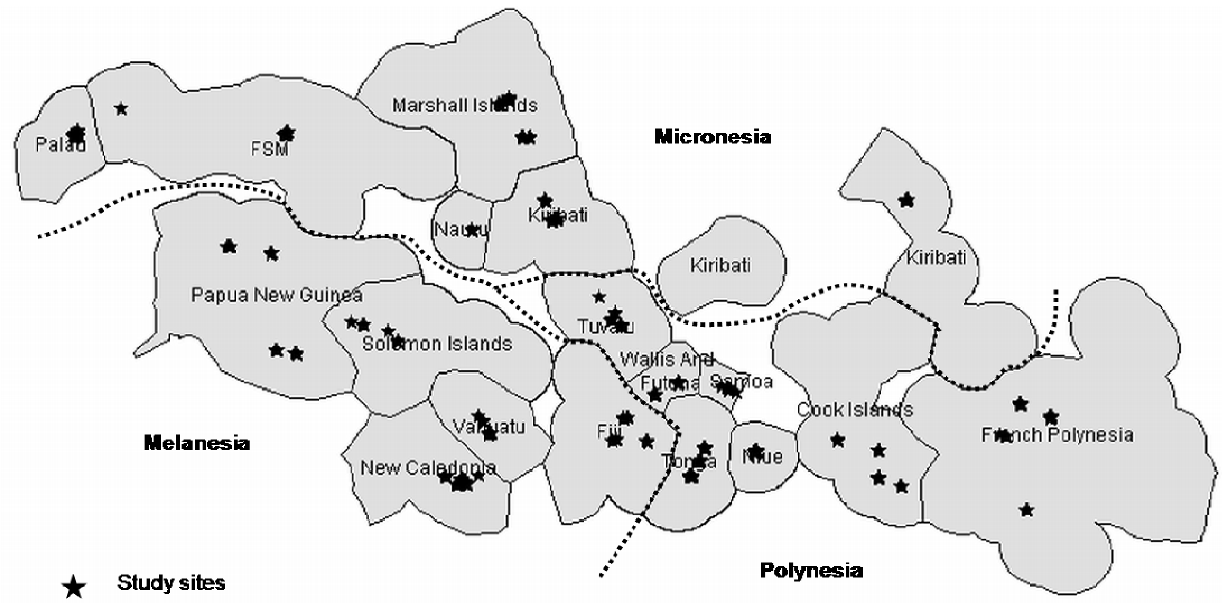

Figure 4.1: Location of communities surveyed in 17 PICTs and their distribution in three cultural groups: Melanesia, Micronesia, and Polynesia.

The survey design was closed and fully structured and based on a standardised questionnaire (Appendix 1.3). The information given by survey respondents was used to create individual site and country reports, the final regional report, and analytical papers published or intended for publication. Complementary data, particularly for national demographic, social and economic parameters, have been gathered from published statistical records.

This section provides a summary of the main achievements made during the implementation of the programme with a focus on the programme's socioeconomic component. Section 4.3 on fisheries management interventions – a joint analysis of socioeconomic, fishery and resource factors – has been compiled in cooperation between the Senior Reef Fisheries Scientist and the Community Fisheries Scientist.

4.2 Socioeconomic and fishery parameters – a regional comparison; summary of key parameters at the community and country level; and the economic, demographic, cultural and geographical context

The objectives of this section are:

- to demonstrate the range of major socioeconomic, demographic, and geographical framework parameters represented by 17 PICTs (no site or country-specific explanations are made here; for detailed interpretation and descriptive analysis, please refer to the individual PROCFish country reports);
- to show differences and commonalities among PICTs and communities, and to allow comparison of each particular community surveyed with other communities at the national and regional scales, and with the regional average;
- to introduce the concept that coastal small-scale fisheries cannot be disconnected from the overall national framework;
- to recommend that coastal fisheries management requires a widened approach to take into account development options and factors beyond the coastal fisheries sector.

One of the major objectives of the PROCFish/C CoFish programme was to assess the current status of reef and lagoon finfish and invertebrate resource use. Given the remote rather than urban rural coastal character of the communities selected for surveys, resource use is a consequence of the degree to which a rural coastal community is dependent upon the available marine resources. Resource dependency is determined by two major factors: consumption or subsistence needs (The latter includes non-monetary distribution of catch among family and community members as an investment and contribution to the traditional social security system, and future returns of services.), and income requirements.

Key parameters selected to summarise the region's dependency on coastal marine resources show:

- The per capita annual consumption of marine produce is high with an average across all sites studied of 67.8 kg of fresh fish, 7.5 kg of invertebrates (edible meat only), and 8.9 kg of canned fish (net weight) (Table 4.1).

Table 4.1: Country average figures for main per capita seafood consumption

Per capita consumption:	**Finfish**		**Invertebrate**		**Canned fish**		**n**
Country/Territory	**kg/person/year**	**SE**	**kg/person/year**	**SE**	**kg/person/year**	**SE**	
Cook Islands	75.2	7.1	3.7	1.3	11.6	4.3	138
Fiji Islands	74.0	2.6	9.6	1.8	2.4	0.3	66
French Polynesia	55.0	6.8	4.2	1.7	4.0	0.5	138
Federated States of Micronesia	65.5	9.3	15.9	5.6	21.7	9.7	83
Kiribati	107.3	6.5	4.6	1.6	6.0	0.8	98
Marshall Islands	105.0	11.2	6.5	1.0	5.1	0.8	78
Nauru	51.2	n/a	1.6	n/a	15.9	n/a	245
New Caledonia	25.4	3.3	8.9	2.2	6.5	2.3	148
Niue	31.0	n/a	2.5	n/a	17.2	n/a	218
Palau	57.5	3.0	12.0	5.0	6.1	0.3	128
Papua New Guinea	30.5	3.4	7.2	2.0	5.6	2.4	120
Samoa	63.6	5.5	10.2	2.5	24.8	2.6	207
Solomon Islands	104.3	2.2	10.8	2.3	3.8	0.3	182
Tonga	70.3	9.6	10.9	3.8	16.8	2.4	87
Tuvalu	138.7	10.3	3.7	1.0	2.3	0.3	113
Vanuatu	16.4	2.4	4.0	0.5	9.3	3.9	124
Wallis and Futuna	50.8	5.0	3.0	1.3	4.9	1.2	137
Regional average [(1)]	**67.8**	**4.4**	**7.5**	**0.8**	**8.9**	**1.1**	

n: number of households surveyed; SE: standard error; n/a: standard error not calculated or no information available; [(1)] Please note that 'regional average' refers to the average across all communities or sites (n = 63) studied and is thus limited to represent predominantly rural coastal communities in PICTs.

- Income dependency on fisheries as compared to salaries varies significantly, with an average across all sites studied of 29.5% and 20.2% of all households respectively earning primary and secondary income from fisheries, and 32.5% and 6.5% from salaries (Table 4.2).

Table 4.2: Country average figures on the percentage of households depending on primary and secondary income from fisheries and salaries

Households (%) with income from:	Fisheries				Salary				n
Country/ Territory	1st source	SE	2nd source	SE	1st source	SE	2nd source	SE	
Cook Islands	12.3	9.3	7.8	5.5	53.4	5.3	11.5	3.3	138
Fiji Islands	69.8	11.2	23.5	6.1	14.8	8.8	3.3	1.9	66
French Polynesia	15.4	6.0	11.3	3.2	44.8	12.7	9.3	4.3	138
Federated States of Micronesia	47.9	27.7	4.6	2.7	34.4	17.6	6.3	3.3	83
Kiribati	33.3	8.5	24.8	8.6	18.1	5.2	2.0	2.0	98
Marshall Islands	36.0	19.4	17.6	5.9	18.1	11.1	8.5	3.1	78
Nauru	4.9	n/a	17.1	n/a	85.7	n/a	2.9	n/a	245
New Caledonia	23.4	10.6	22.8	4.6	38.9	5.6	5.5	2.9	148
Niue	1.4	n/a	8.7	n/a	61.0	n/a	10.1	n/a	218
Palau	10.2	2.0	15.7	4.3	66.1	7.5	5.3	2.6	128
Papua New Guinea	53.3	5.8	32.5	6.4	13.3	3.6	3.3	1.4	120
Samoa	24.2	5.2	26.6	1.8	16.7	5.2	11.5	1.2	207
Solomon Islands	29.1	7.3	31.8	6.1	11.2	2.2	0.5		182
Tonga	41.5	12.3	4.7	0.3	20.9	6.5	10.7	4.5	87
Tuvalu	24.0	5.3	24.4	8.7	52.2	1.7	10.5	1.8	113
Vanuatu	21.4	7.6	39.8	11.7	10.9	5.6	2.8	1.9	124
Wallis and Futuna	14.8	11.7	21.0	6.8	54.2	9.4	5.5	1.2	137
Regional average (1)	**29.5**	**3.3**	**20.2**	**1.8**	**32.5**	**3.1**	**6.5**	**0.8**	

n: number of households surveyed; SE: standard error; n/a: standard error not calculated or no information available; (1) Please note that 'regional average' refers to the average across all communities or sites (n = 63) studied and is thus limited to represent predominantly rural coastal communities in PICTs.

- Finfish fisheries satisfy both subsistence and commercial needs. On average across all sites studied about 45% of the total annual finfish catch is consumed by the population of the communities surveyed, while 55% is sold outside the communities to earn cash income (Table 4.3).

Table 4.3: Country average figures for the proportion of finfish catch serving subsistence and income purposes

Country/Territory	Proportion of total annual finfish catch for:				n
	Subsistence	SE	Commercial sale	SE	
Cook Islands	61.8	22.3	38.2	22.3	94
Fiji Islands	36.2	4.0	63.8	4.0	114
French Polynesia	23.6	6.2	76.4	6.2	108
Federated States of Micronesia	39.9	5.6	60.1	5.6	73
Kiribati	31.3	10.7	68.7	10.7	93
Marshall Islands	76.8	13.1	23.2	13.1	114
Nauru	98.3		1.7		424
New Caledonia	39.5	9.2	60.5	9.2	159
Niue	89.6		10.4		139
Palau	33.0	5.3	67.0	5.3	119
Papua New Guinea	14.5	2.4	85.5	2.4	156
Samoa	66.9	8.3	33.1	8.3	307
Solomon Islands	62.7	7.5	37.3	7.5	265
Tonga	46.2	13.5	53.8	13.5	57
Tuvalu	54.0	4.5	46.0	4.5	196
Vanuatu	17.0	2.4	83.0	2.4	119
Wallis and Futuna	43.6	9.3	56.4	9.3	123
Regional average [(1)]	**44.4**	**3.3**	**55.6**	**3.3**	

n: number of households surveyed; SE: standard error; [(1)] Please note that 'regional average' refers to the average across all communities or sites (n = 63) studied and is thus limited to represent predominantly rural coastal communities in PICTs.

- Small-scale artisanal and subsistence finfish fisheries yield on average about 2.7 kg finfish per hour of fishing trip (time spent from start to landing point); however, the average of several communities per country studied includes a range from as low as 0.8 to as high as 5.0 kg/hour fished (Figure 4.2). Note that some of the highest average CPUE figures may be misleading as they are determined by coastal artisanal fisheries in islands with no lagoon area and thus represent a high proportion of large-sized species, for example tuna, rather than the predominantly smaller-sized reef fish species caught elsewhere.

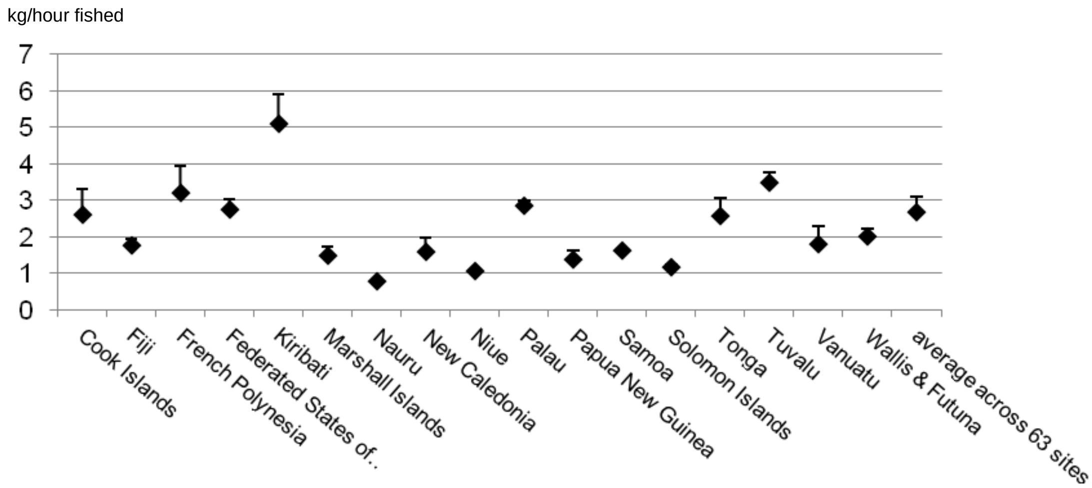

Figure 4.2: Country average figures for reported finfish fishing CPUEs.

- Current finfish fishing pressure is high. Finfish fishing pressure is here defined as annual total finfish catch per km^2 available total fishing ground (including lagoon surface areas) and total reef surface area (Small-scale artisanal and subsistence reef and lagoon fishery may contain some pelagic species; however, the catches included here are those not targeting pelagic species, nor using a pelagic fishing technique.). On average across all sites studied, current finfish fishing pressure amounts to 10.7 t/km^2 reef/year or, if diluted over the total fishing ground area, to 8.5 t/km^2/year. By comparison, the general threshold for sustainable finfish fishing is assumed to be 5 t/km^2 reef/year given the footprints (impacts from previous fishing) and other detrimental effects that have already contributed to ecosystem decline and thus a lowered natural productivity of the region's reef and lagoon systems. Again, the variation among sites and averages calculated per all sites studied by country is high (Table 4.4).

Table 4.4: Country average figures for finfish fishing catch rates per total fishing ground and reef surface areas

Country/Territory	Finfish catch rate (t/km^2/year)				n
	Total fishing ground	SE	Total reef surface area	SE	
Cook Islands	2.7	1.2	3.8	1.6	94
Fiji Islands	0.7	0.6	1.0	0.7	114
French Polynesia	12.9	8.9	21.7	13.8	108
Federated States of Micronesia	1.4	0.6	3.7	0.9	73
Kiribati	6.6	2.0	11.9	2.9	93
Marshall Islands	0.4	0.2	1.6	0.7	114
Nauru	78.2	n/a	78.2	n/a	424
New Caledonia	0.5	0.3	0.7	0.5	159
Niue	4.0	n/a	4.0	n/a	139
Palau	1.4	1.2	3.1	2.5	119
Papua New Guinea	3.0	0.9	4.8	1.7	156
Samoa	16.4	4.3	19.5	4.6	307
Solomon Islands	17.6	9.2	19.4	8.3	265
Tonga	0.2	0.1	1.1	0.7	57
Tuvalu	34.5	18.6	38.9	17.9	196
Vanuatu	6.0	1.1	6.0	1.1	119
Wallis and Futuna	6.4	5.7	6.9	5.6	123
Regional average (1)	**8.5**	**2.1**	**10.7**	**2.3**	

n: number of finfish fishery surveys conducted; SE: standard error; n/a: standard error not calculated or no information available; (1) Please note that 'regional average' refers to the average across all communities or sites studied (n = 63) and is thus limited to represent predominantly rural coastal communities in PICTs.

- Invertebrate fisheries are substantial in PICTs; however, they vary significantly among sites and countries studied. The importance of invertebrate fisheries for food security is supported by the average time spent fishing across all sites studied. The highest share of time spent invertebrate fishing is dedicated to gleaning (60%) rather than commercial diving activities (40%). However, it should be noted that commercial dive fisheries are subject to pulse fishing and closure, i.e. data for bêche-de-mer and trochus harvesting could only be included where the fisheries were opened during survey periods (Table 4.5).

Table 4.5: Country average of the total time spent invertebrate fishing, and the proportion of gleaning and free-diving activities

Country/Territory	Fishing time for invertebrates			n
	Total annual hours	Gleaning (%)	Diving (%) [(2)]	
Cook Islands	16,211	89.9	10.1	87
Fiji Islands	46,470	36.8	63.2	165
French Polynesia	23,507	18.7	81.3	85
Federated States of Micronesia	8435	88.4	11.6	55
Kiribati	49,785	81.1	18.9	72
Marshall Islands	10,308	58.1	41.9	147
Nauru	142,124	91.1	8.9	297
New Caledonia	15,371	74.9	25.1	198
Niue	25,906	99.2	0.8	140
Palau	13,470	99.6	0.4	86
Papua New Guinea	143,284	20.3	79.7	171
Samoa	17,414	64.0	36.0	195
Solomon Islands	63,287	89.4	10.6	388
Tonga	6538	87.2	12.8	66
Tuvalu	45,313	68.9	31.1	104
Vanuatu	50,055	90.5	9.5	168
Wallis and Futuna	60,903	66.3	33.7	95
Regional average [(1)]	**38,255**	**60.2**	**39.8**	

n: number of invertebrate fisher surveys conducted; [(1)] Please note that 'regional average' refers to the average across all communities or sites studied (n = 63) and is thus limited to represent predominantly rural coastal communities in PICTs; [(2)] including all free-diving activities, for trochus, bêche-de-mer, lobster.

- Additional key parameters are provided for each site in Appendix 4.1 and compared to the average across all sites studied.
  These include:
  - consumption of marine products,
  - sources of marine products consumed,
  - income sources,
  - household income diversity,
  - household assessments in terms of pigs and chickens,
  - educational level,
  - household expenditure level,
  - dependency on and quantity of remittances received,
  - proportion of fishers by fishery and gender,
  - availability of boats and boat types,
  - accessible habitats for fishing,
  - fishing ground and reef surfaces,
  - finfish production for subsistence and commercial reasons,

- o proportion of fishing techniques used,
- o CPUE,
- o major reported finfish catch composition,
- o fishing time spent in invertebrate collection,
- o proportion of subsistence and commercial interests,
- o diversity of reported invertebrate catch,
- o catch proportions of major invertebrate groups,
- o extrapolated annual invertebrate catches by major species groups,
- o population and fisher density,
- o catch rates per total fishing ground and reef surface areas, and
- o detailed tables on seafood consumption, income, finfish and invertebrate catch, and fishing grounds

- The selection of highly significant linear relationships (Figure 4.3) shows that traditional rural coastal lifestyle in PICTs is closely related to large average household sizes, and that these are more prominent in smaller island countries. The better the national economic conditions as indicated by the per capita GDP (nominal) and export–import balance, the higher the adult education (percentage of adults with tertiary education), the more households depend on salaries for primary income and, therefore, the less they depend on fisheries and agriculture. The larger the average household sizes are (suggesting a more traditional lifestyle influenced by factors at the national level, including higher national dependency rates (age groups 15–64 years) and higher national population densities (people/km^2 total land surface)), the higher are the per capita consumption rates of finfish and invertebrates, the lower are the average household expenditures, and the more dependent households are on remittances (i.e. external financial input).

- The dependency on external financial input (remittances) and the household's financial capacity (expressed in the average annual household expenditure level), again are closely related to socioeconomic and demographic parameters at the national and community levels. The higher the national dependency rate (age groups 15–64 years), the lower the per capita GDP (nominal) and the lower the per capita export–import balance, the more households depend on remittances. The lower the national population density (people/km^2 total land surface), the higher the per capita export–import balance, the higher the per capita GDP (nominal), the lower the percentage of adults in communities with only primary education, and the higher the proportion of households in communities earning primary income from salaries, then the higher are the average annual household expenditures.

- The higher the per capita GDP (nominal) and the greater the number of households earning primary income from salaries, than the higher is the proportion of tertiary adult education in communities surveyed. An increase in the proportion of secondary adult education in communities surveyed is closely linked to decreasing national gross migration and, at the community scale, to a decreasing number of boats per household and an increasing per capita canned fish consumption. The per capita canned fish consumption rate reduces as the proportion of adults in the community with only primary education increases.

- Similarly, subsistence finfish catch rates (kg/household/year) in communities surveyed are higher, when the per capita GDP (nominal) is low and the national consumer price index (CPI) is high. The higher the commercial finfish catch rates (kg/household/year), the higher is the productivity (CPUE – catch kg/hour fishing trip).

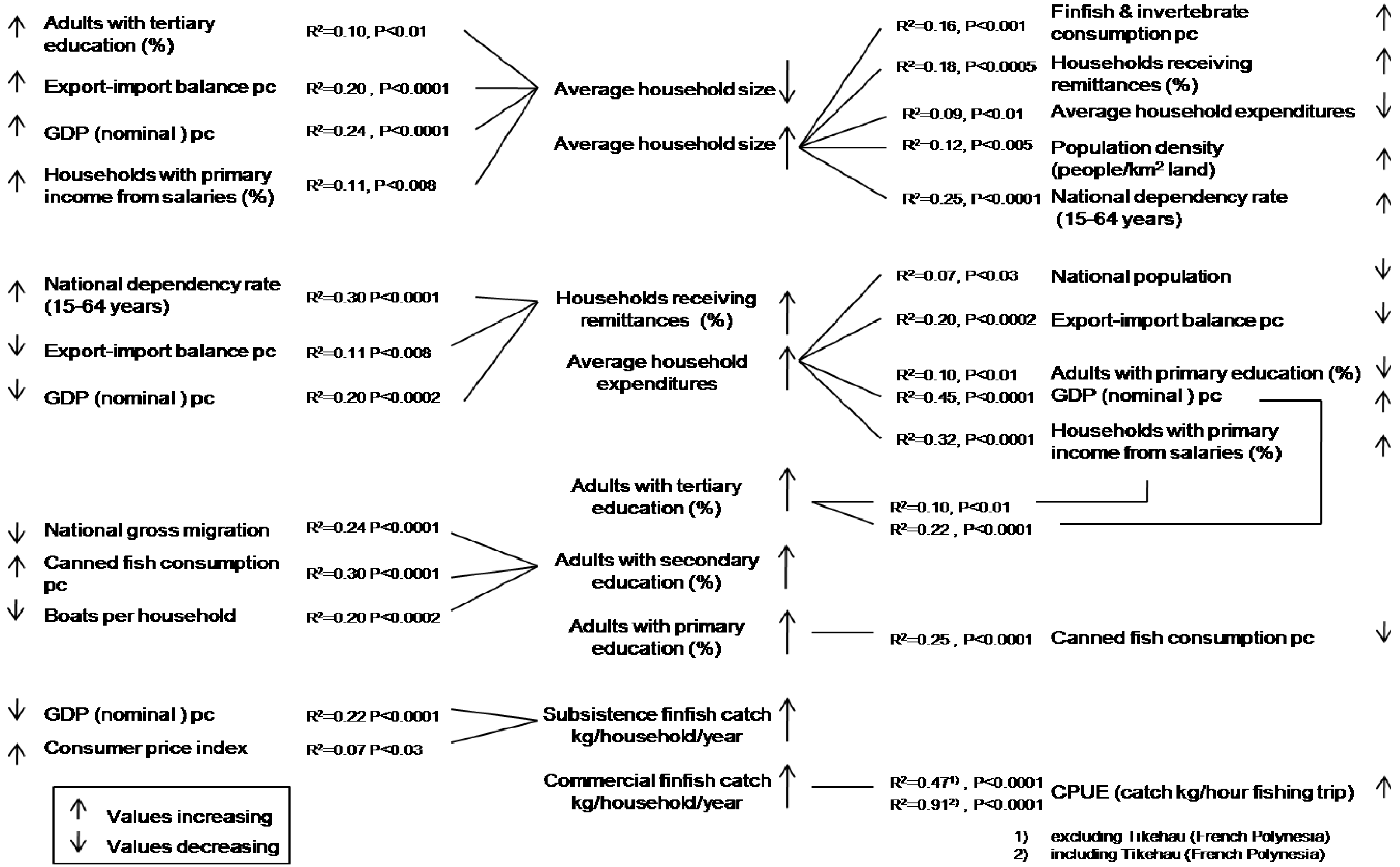

Figure 4.3: Statistically significant relationships between socioeconomic factors at the national and community scales using linear regression (R^2).

- Statistically significant linear regressions – although varying in their strength and distribution – confirm that the degree of dependency on marine resources for both subsistence and income determines the level of resource exploitation using the total population and the total annual catches (t) for finfish (Figure 4.4), and the total annual catch (numbers) for invertebrates, including giant clams (Figure 4.5), lobsters (Figure 4.6), and trochus (Figure 4.7). No such statistically significant relationships were found for bivalves, gastropods, octopus, bêche-de-mer, and others (*Dolabella* spp., Chitonidae, *Sipunculus* spp., sea urchins).

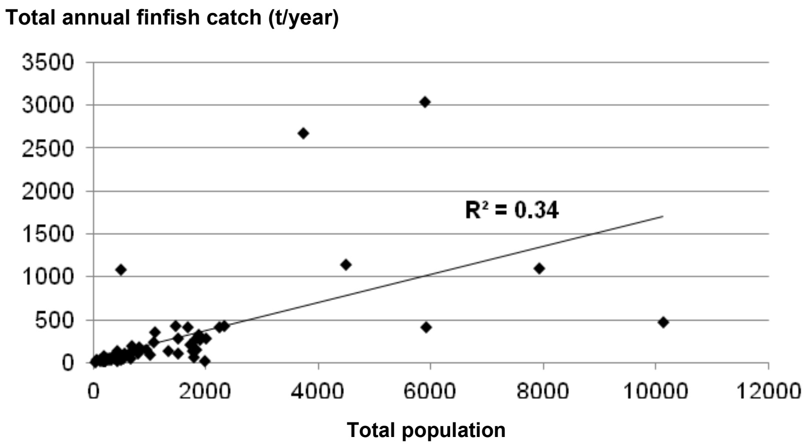

Figure 4.4: Linear regression between total population and total annual finfish catch of 63 communities surveyed.
Data are not log transformed (n = 63).

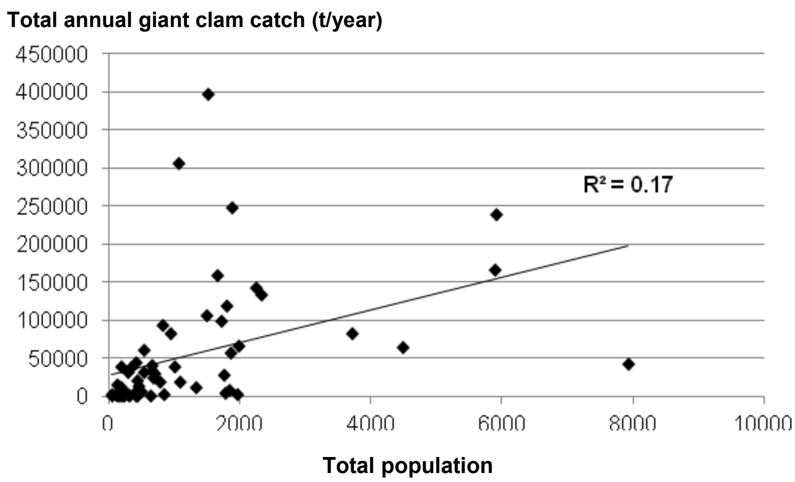

Figure 4.5: Linear regression between total population and total annual giant clam catch of 63 communities surveyed.
Data are not log transformed; only sites with giant clam catch records included (n = 60).

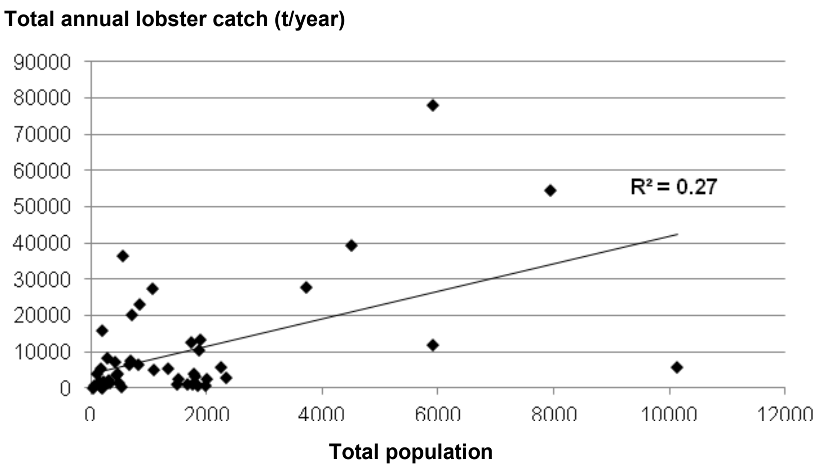

Figure 4.6: Linear regression between total population and total annual lobster catch of 63 communities surveyed.
Data are not log transformed; only sites with lobster catch records included (n = 48).

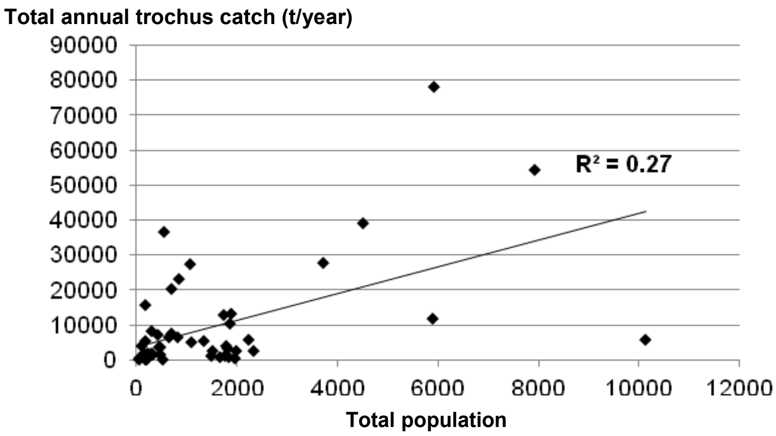

Figure 4.7: Linear regression between total population and total annual trochus catch of 63 communities surveyed.
Data are not log transformed; only sites with trochus catch records included (n = 29).

4.3 Socioeconomic drivers and indicators for artisanal coastal fisheries in Pacific Island countries and territories and their use for fisheries management strategies

The objectives of this section are:

- to disclose the socioeconomic context, major drivers, and indicators that determine the extent of current small-scale artisanal fisheries in PICTs;
- to identify which socioeconomic factors drive exploitation levels, particularly regarding income dependency;
- to assess how these factors vary among cultural groups, countries and sites;
- to improve the understanding of the dynamics between socioeconomic conditions and current exploitation levels, and to assess vulnerability as a function of dependency on coastal resources to develop more effective fisheries management strategies to ensure the livelihoods of coastal communities in PICTs are maintained.

For detailed explanations of input data, methodological approach, analysis, and scientific discussion, refer to Appendix 4.2.

The extent of current small-scale artisanal fisheries in PICTs is determined by catch for subsistence needs and catch for income generation.

The subsistence finfish catch rate (total annual finfish caught for subsistence needs of the community surveyed per km^2 of reef) and its impact as fishing pressure are a function of the community's total population size, the per capita consumption rate and the available reef area. Consequently, the variation in subsistence finfish catch rates is determined by the variation in any of the three determining factors:

- The larger the population and the higher the per capita finfish consumption, the higher is the total annual finfish catch for subsistence purposes;
- The smaller the available fishing ground and/or reef area appropriated by the community under survey, the higher is the fishing pressure imposed by subsistence finfish catches.

In contrast, the extent of the commercial finfish catch rate and consequently its contribution to fishing pressure is not a simple equation between population and fishing ground or reef area sizes. We found a combination of nine principal socioeconomic and physical parameters at the community and national level that explain most of the variation found within the 63 communities surveyed. In summary, communities with a high commercial finfish catch rate show the characteristics shown in Table 4.6, below.

Table 4.6: Socioeconomic and physical parameters associated with a high commercial finfish catch rate

Socioeconomic parameters	Explanation
Community level	
Large number of boats	Increases access to and choice of fishing grounds and targeted habitats
Easy marketability	Finfish is mostly sold fresh, has limited shelf life; therefore, need good access to cooling facilities or regular provision of ice
High proportion of adult population with primary education only	Limited access to income opportunities that demand higher qualifications and skills
High dependency on remittances	A response to lack of alternative income opportunities locally or nationally
National level	
Small land surface at the country level	Little or limited agricultural production potential
Low proportions of urban population at the national level	Limited development of secondary and tertiary sectors at national scale, hence limited employment in these sectors
High consumer price index (CPI)	Need for income generation to cope with high living costs
High per capita GDP (nominal)	
Low consumption of canned fish	Low purchasing power of households (Canned fish is the preferred substitute for fresh fish.)

A marketability index was developed to classify catch community into three categories describing ease of access to markets: 'easy', 'possible', or 'difficult'.

The above argument for subsistence-oriented finfish catch rates also applies to invertebrates. However, there is a great range of targeted invertebrate species found in PICTs, and most of these require different habitats, so they may be targeted separately, at different times, and for different purposes. Analysis was therefore done individually for the main invertebrate species groups distinguished that were not subject to pulse or restrictive fishing regulations (e.g. bêche-de-mer, trochus). A combination of various socioeconomic and physical parameters was found that explains most of the variation found for each of the different invertebrate species groups, i.e. bivalves (excluding giant clams), giant clams, crustaceans (excluding lobsters), gastropods (excluding trochus), lobsters, and octopus. Even so, results showed the general trend that communities with higher invertebrate catch rates have the characteristics shown in Table 4.7, below.

Table 4.7: Socioeconomic and geographical parameters associated with a high invertebrate catch rate

Socioeconomic parameters	Explanation
Community level	
Small proportion of adults with higher education	Limited access to alternative income opportunities that require higher qualification and skills
Low household expenditure level	Limited purchasing power of households
High dependency on remittances	Difficulty in meeting living costs from local income sources
National level	
High national population density	High demographic pressure, competition for all types of resources
High demographic growth rates, and/or high dependency rates (age group 15–64 years)	
Longitudinal and latitudinal gradients	Important factors determining distribution of species, thus influencing differences in the extent to which certain fisheries are performed, particularly bivalve, gastropod and octopus fisheries

The main drivers and indicators identified for the extent of commercial finfish exploitation and catch rates for the various invertebrate species groups are summarised in Figure 4.8.

The main drivers for finfish and invertebrate subsistence fisheries are:

- demographic pressure; and,
- food dependency on marine produce.

The main drivers determining a high commercial finfish and small-scale artisanal invertebrate catch are:

- limited alternative income opportunities;
- difficulty in meeting living costs;
- easy access to and good choice of fishing grounds;
- easy marketability.

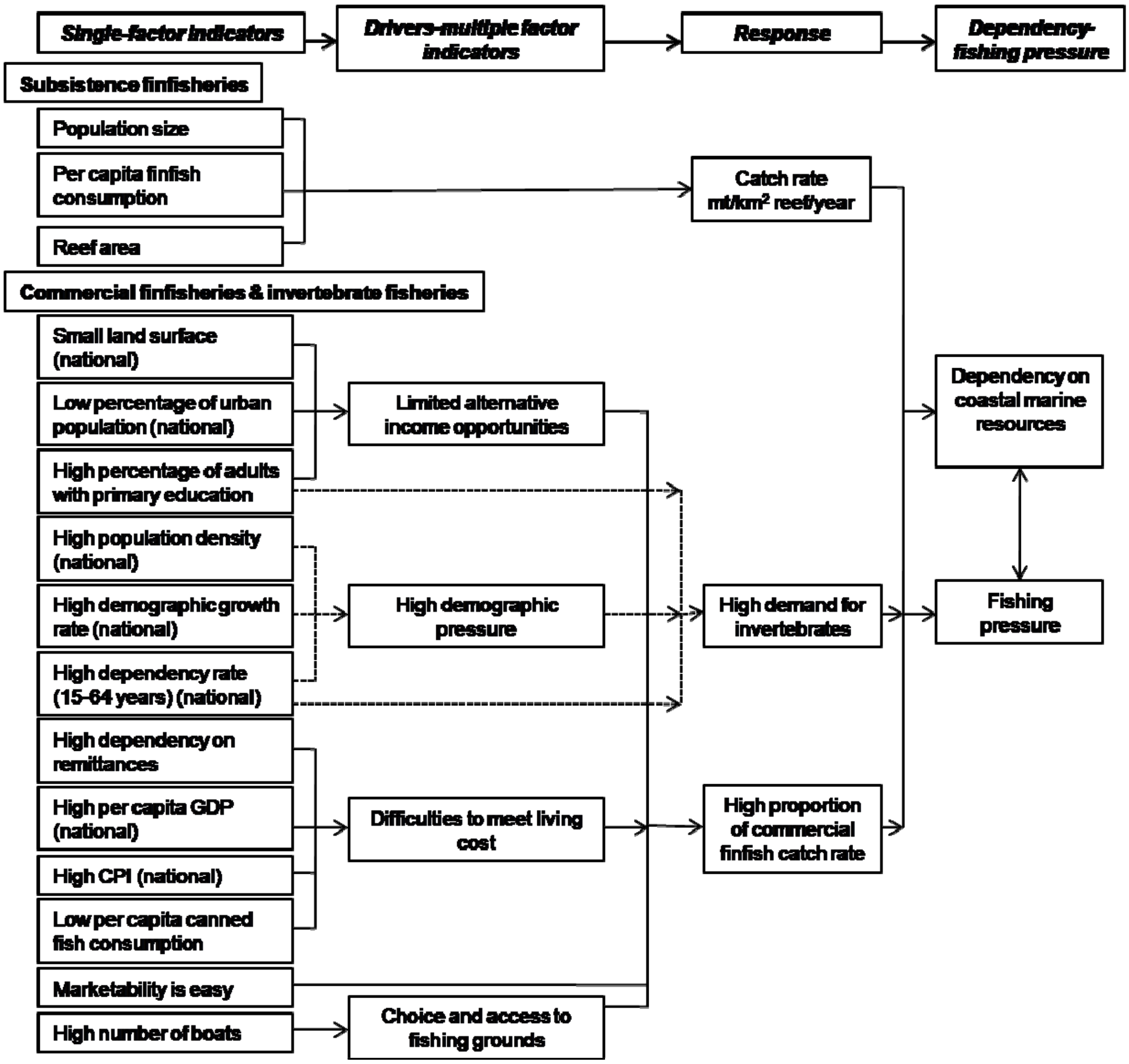

Figure 4.8: Indicators and major drivers determining responses of catch rates, dependency on coastal marine resources (subsistence and income) and fishing pressure.

In order to illustrate which drivers and indicators apply to which country and site surveyed, Figures 4.9 and 4.10 show the results of multivariate analysis with each community being identified. Both figures allow us to see the major drivers and indicators that determine the extent of the current exploitation levels of commercial finfish catch and of the major invertebrate species group in each community surveyed. The major drivers/indicators, whose combined effects explain exploitation levels per community, groups of communities, and cultural groups surveyed for finfish and invertebrate species group catches, are summarised and interpreted in Tables 4.8 and 4.9 respectively.

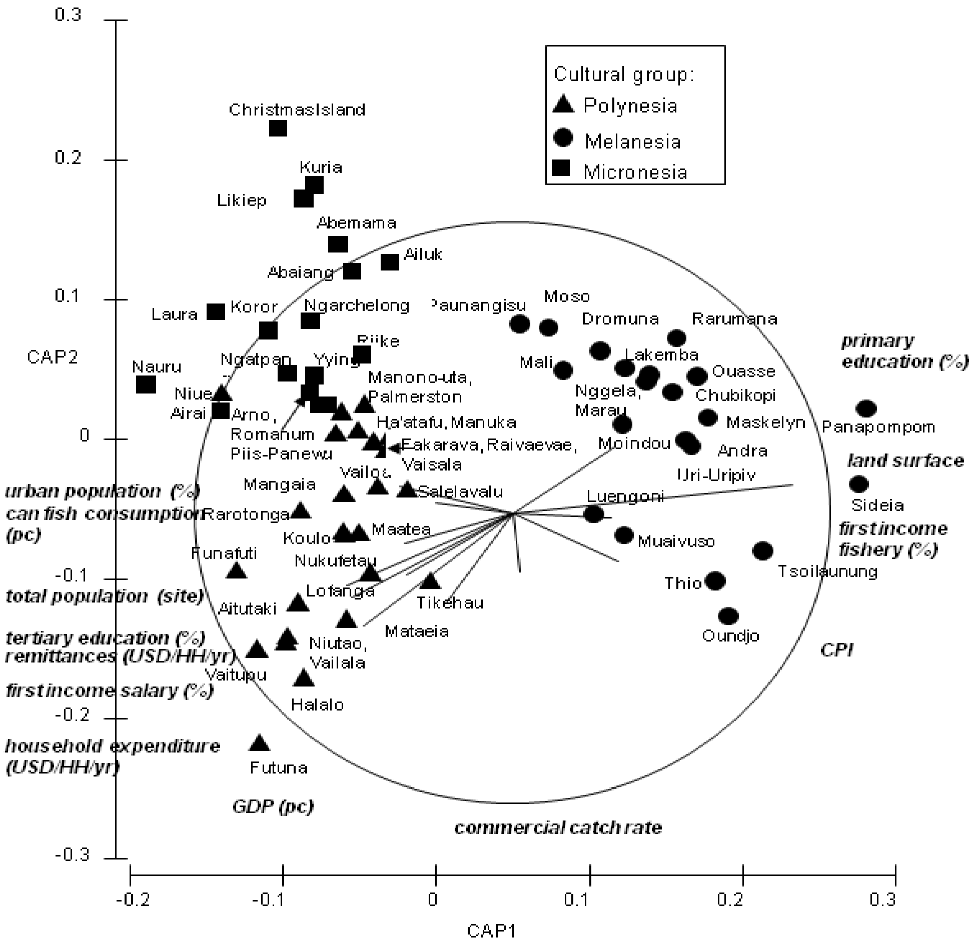

Figure 4.9: Socioeconomic drivers for finfish caught for sale, by culture and community (n=63) across PICTs and for each community surveyed (n = 63).
CAP = Canonical analysis of principal coordinates; Christmas Island = Kiritimati (Kiribati);
HH = household.

Table 4.8: Summary of major drivers and indicators per cultural group and community surveyed for explaining variation in the current extent of commercial finfish exploitation rates

Melanesia		
Indicator/driver	**Effect**	**Applying to:**
High proportion of adults with only primary education	Low educational level	All Melanesian communities; less so for Thio, Oundjo
Large land surface	Potential for agricultural production	All Melanesian communities; less so for: Dromuna, Lakeba, Mali, Marau, Moso, Nggela, Paunangisu
High proportion of households with primary income from fisheries	High dependency on fisheries for income	Particularly applying to Luengoni, Muaivuso, Tsoilaunung, Uri-Uripiv, Andra, Sideia
High CPI	Difficulties in meeting high living costs	Particularly applying to Luengoni, Muaivuso, Tsoilaunung, Uri-Uripiv, Andra, Sideia, Oundjo, Thio
Low household expenditure levels	Limited purchasing power of households	All Melanesian communities
Small community population size	Relatively low demographic pressure at community level	All Melanesian communities
Low proportion of urban population at national scale	Limited employment in secondary and tertiary sectors	All Melanesian communities; less so for: Thio, Tsoilaunung, Oundjo, Sideia, Luengoni
Low benefits from remittances	Need to cope with cash demand on their own	All Melanesian communities
Low proportion of households with primary income from salaries	Limited opportunities to earn cash income other than primary sector	All Melanesian communities
Low per capita canned fish consumption	Limited purchasing power of households	All Melanesian communities; less for Paunangisu, Moso, Dromuna, Mali, Rarumana, Lakeba, Nggela, Marau
Low GDP (nominal, pc)	Relatively unfavourable economic conditions at national scale	All Melanesian communities
Micronesia		
Low CPI	Less difficulties in meeting living costs	All Micronesian communities
High proportion of urban population at national scale	Access to employment in secondary and tertiary sector	All Micronesian communities; less for: Kiritimati, Abaiang, Abemama, Kuria, Ailuk, Likiep, Ngarchelong
High per capita canned fish consumption	Greater purchasing power of households	All Micronesian communities; less for Kiritimati, Abaiang, Abemama, Kuria, Ailuk, Likiep, Ngarchelong
Moderate community population size		All Micronesian communities
Mixture between low and high adult education levels		All Micronesian communities; more tendencies towards lower adult education for Kiritimati, Abaiang, Abemama, Kuria, Ailuk, Likiep, Ngarchelong
Moderate land surface sizes		All Micronesian communities; less for Kiritimati, Abaiang, Abemama, Kuria, Ailuk, Likiep, Ngarchelong
Mixture between households depending on fisheries and those depending on salaries for primary income		All Micronesian communities; more tendencies to depend on fisheries for primary income for Kiritimati, Abaiang, Abemama, Kuria, Ailuk, Likiep

These are results of multivariate and not linear relationships, i.e. use sets of indicators and drivers to interpret their combined effects.

Table 4.8: Summary of major drivers and indicators per cultural group and community surveyed for explaining variation in the current extent of commercial finfish exploitation rates (continued)

Polynesia		
Indicator/driver	**Effect**	**Applying to:**
High GDP (nominal, pc)	Relatively favourable economic conditions at national scale	All Polynesian communities; less for Manono-uta, Palmerston, Ha'atafu, Manuka
High household expenditure levels	Greater purchasing power of households	All Polynesian communities; less for Manono-uta, Palmerston, Ha'atafu, Manuka
High proportion of households with primary income from salaries	Greater access to alternative income sources	All Polynesian communities; less for Manono-uta, Palmerston, Ha'atafu, Manuka
High dependence on remittances	Difficulties in meeting living cost, external financial help	All Polynesian communities
High proportion of adults with tertiary education	High education level	All Polynesian communities; less for Manono-uta, Palmerston, Ha'atafu, Manuka
Large community population sizes	Relatively high demographic pressure at community level	All Polynesian communities
High per capita canned fish consumption	Greater purchasing power of households	All Polynesian communities
High proportion of urban population at national scale	Access to employment in secondary and tertiary sector	All Polynesian communities; less for: Niutao, Vailala, Vaisala, Halalo, Futuna, Vaitupu

These are results of multivariate and not linear relationships, i.e. use sets of indicators and drivers to interpret their combined effects.

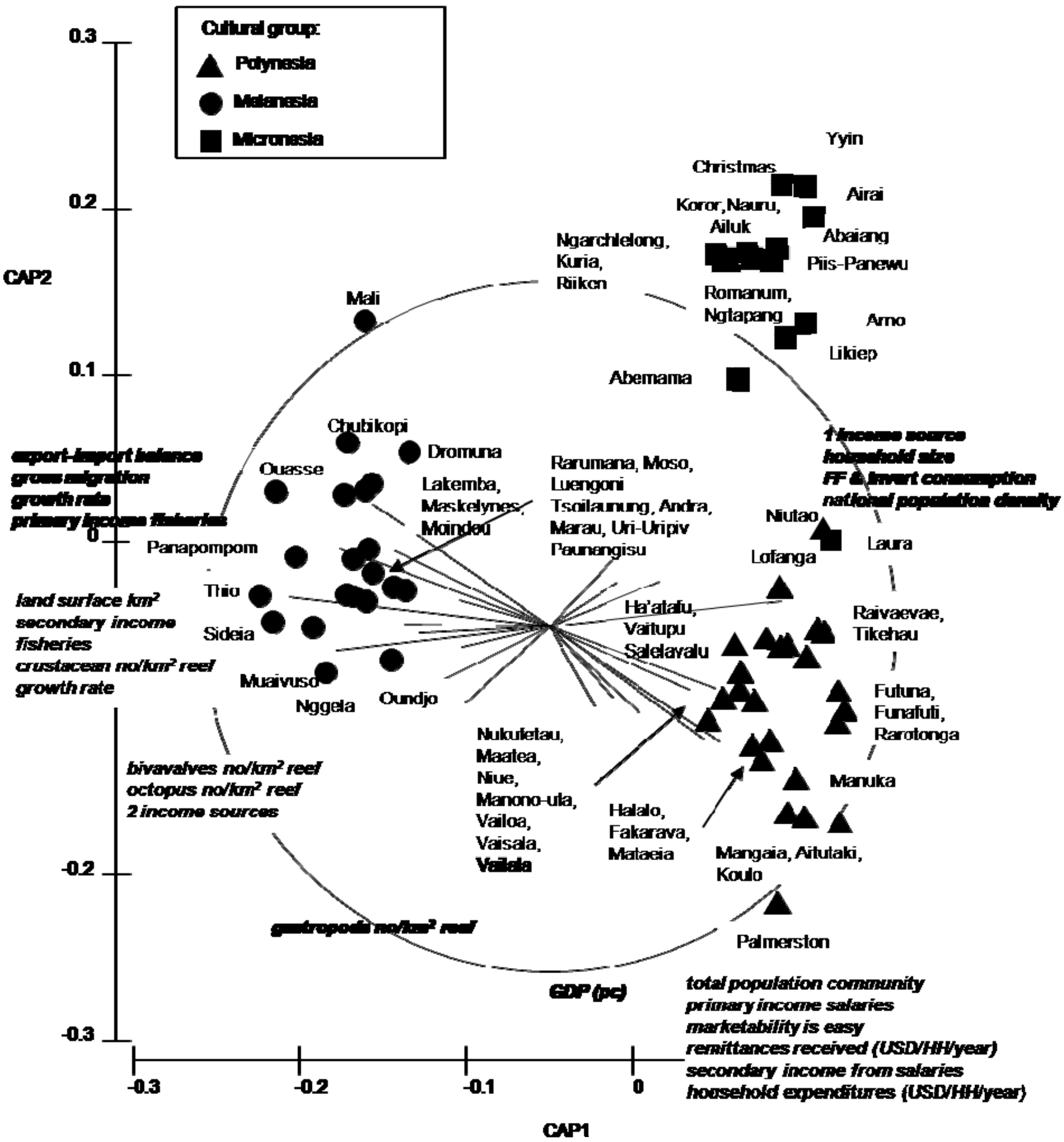

Figure 4.10: Socioeconomic drivers for invertebrate catch rates, by culture and community (n = 63) across PICTs.
CAP = Canonical analysis of principal coordinates.

Table 4.9: Summary of major drivers and indicators per cultural group and community surveyed for explaining variation in the current extent of invertebrate exploitation rates

Melanesia		
Indicator/driver	**Effect**	**Applying to:**
High (negative) per capita export–import balance	Relatively unfavourable economic conditions at national scale	All Melanesian communities
High gross migration	Relatively unfavourable economic conditions at national scale	All Melanesian communities
High growth rate	High demographic pressure on all resources	All Melanesian communities
High proportion of households with primary income from fisheries	High dependency on fisheries for income	All Melanesian communities
High proportion of households with secondary income from fisheries	High dependency on fisheries for income	All Melanesian communities
Large land surface	Potential for agricultural production	All Melanesian communities
High catch rates for crustaceans (number/km^2 reef)	High fishing pressure and/or good resource status	All Melanesian communities
High catch rates for bivalves (number/km^2 reef)	High fishing pressure and/or good resource status	All Melanesian communities; less for: Chubikopi, Mali, Dromuna
High catch rates for octopus (numbero/km^2 reef)	High fishing pressure and/or good resource status	All Melanesian communities; less for: Chubikopi, Mali, Dromuna, Lakeba, Maskelynes, Moindou, Ouassé
High catch rates for gastropods (number/km^2 reef)	High fishing pressure and/or good resource status	All Melanesian communities; less for: Chubikopi, Mali, Dromuna, Lakeba, Maskelynes, Moindou, Ouassé
Low community population size	Relatively low demographic pressure at community level	All Melanesian communities
Low proportions of households with primary and secondary income from salaries	Limited opportunities to earn cash income other than primary sector	All Melanesian communities
Marketability not easy	Limited marketing potential to earn cash income	All Melanesian communities
Low benefit from remittances	Need to cope with cash demand on their own	All Melanesian communities
Low household expenditure levels	Limited purchasing power of households	All Melanesian communities; less for: Thio, Sideia, Muaivuso, Nggela, Oundjo
Micronesia		
High proportion of households with one income source / low proportion with two income sources	Less diversification, higher risk, and/or higher security through salary-based income sources	All Micronesian communities; less for: Laura
Large household size	Relatively traditional lifestyle	All Micronesian communities; less for: Kiritimati, Abaiang, Abemama, Kuria, Ailuk, Likiep, Ngarchelong
High finfish and invertebrate per capita consumption	High dependency on seafood for protein and nutrition	All Micronesian communities; less for Kiritimati, Abaiang, Abemama, Kuria, Ailuk, Likiep, Ngarchelong
High national population density	High demographic pressure on all resources	All Micronesian communities; less for: Yyin, Kiritimati, Ngarchelong
Polynesia		
High national population density	High demographic pressure on all resources	All Polynesian communities; less for Palmerston
Large community population size	Relatively high demographic pressure at community level	All Polynesian communities; less for Palmerston
Easy marketability	Good marketing potential to earn cash income	All Polynesian communities; less for Palmerston
High benefit from remittances	Difficulties in meeting living cost, external financial help	All Polynesian communities
High proportion of households with secondary income from salaries	Opportunities to earn cash income other than primary sector	All Polynesian communities; less for Niutao, Lofanga
High household expenditure levels	Greater purchasing power of households	All Polynesian communities; less for Niutao, Lofanga

These are results of multivariate and not linear relationships, i.e. use sets of indicators and drivers to interpret their combined effects.

There is a close relationship between exploitation, hence fishing pressure, and economic factors, possibly poverty. Rates of commercial finfish catch and catch rates of invertebrate species groups (does not apply to lobsters) are closely correlated with the per capita expenditure, i.e. the lower the daily expenditure, the higher the catch rates. Overall, most of the communities surveyed fall into the lowest or very low household expenditure classes with USD <1 or 1–2 /person/day (Table 4.10). Region-wide comparison of average per capita daily household expenditures in each community and country depending on fishery or other sectors for primary income showed that, on average, a person whose income is not primarily from fishing spends USD 3.4 /day, and a person whose primary income is from fishing spends only USD 1.5 /day. Figure 4.11 further highlights that, in two-thirds of all the communities studied, people who depend on fishing for their primary income are financially disadvantaged, and spend less.

Table 4.10: Percentage of communities by average household expenditure (USD/person/day) classes

USD/person/day	<1	1–2	2–5	>5
% of communities studied (n = 63)	48	19	22	11

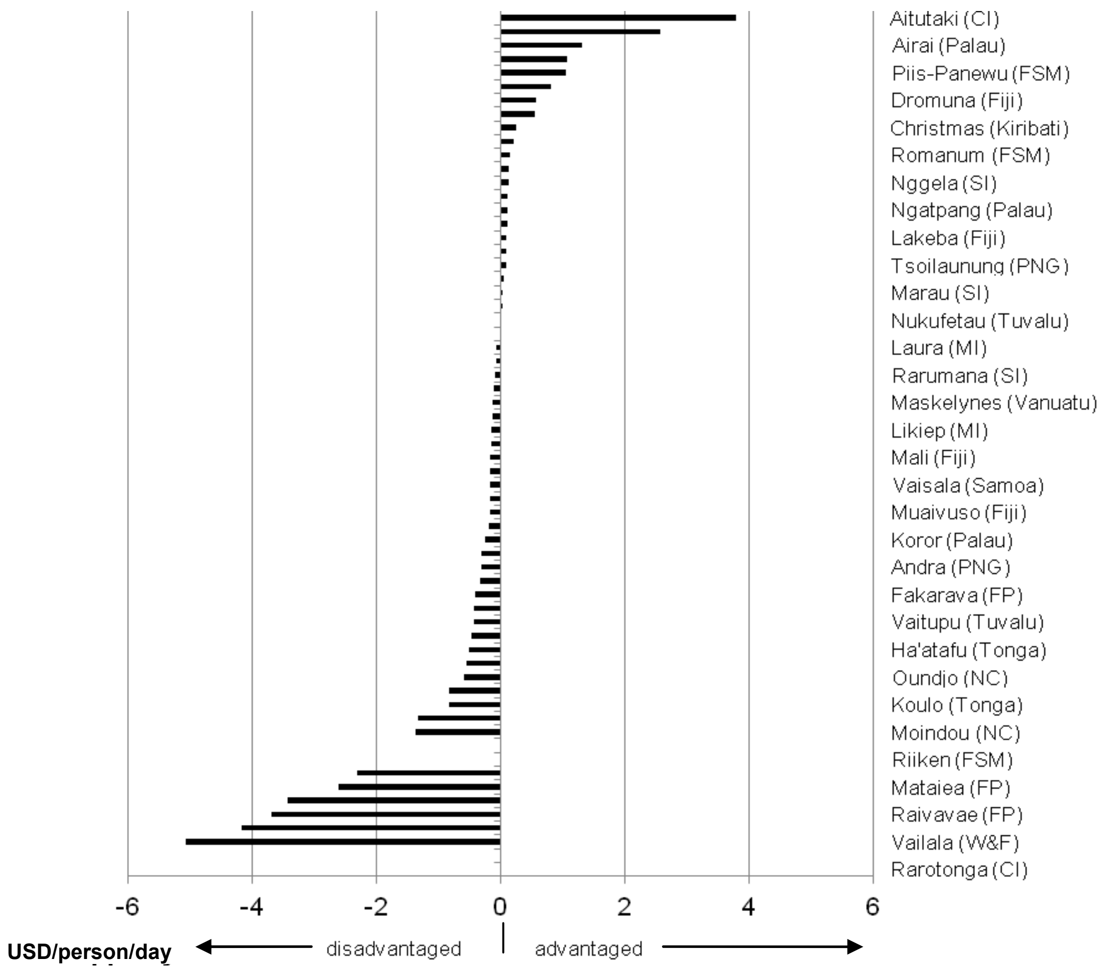

Figure 4.11: Difference in daily household expenditures (USD/person/day) based on a comparison of average household expenditure/person/household for households earning primary income from fisheries, against those households earning primary income from other sectors.
No income from fisheries reported for Rarotonga (Cook Islands), Ouassé (New Caledonia), and Riiken and Yiin (Yap, FSM).

Consequences for fisheries management

The overall objectives of sound fisheries management are to safeguard the livelihoods of coastal communities and ensure sustainable resource use. Based on the PROCFish analysis, there is proof that these objectives are associated with access to resources and the alternative income and employment opportunities provided by widened rural economic bases, as an integral part of the expanded national economy. There is also proof that communities explore and develop alternative economic opportunities if they exist. The availability of alternative sources for income, however, varies significantly among cultural groups, countries and even communities.

The strategic implications of the results of the survey are as follows:

- The future of the artisanal fishery sector and the livelihoods of coastal communities in PICTs will depend to a large extent on access to and potential of alternative subsistence and income sources. These are necessary in order to reduce fishing pressure to a sustainable level to maintain ecosystem services and food security.

As a word of caution, it should be borne in mind that, while economic development and provision of alternative income prospects are conducive to reducing fishing pressure, they are not guaranteed to achieve sustainable resource use!

- In order to harmonise objectives for resource use and development diversification needs to be promoted, including alternatives to coastal wild-caught fisheries, management strategies are required that make artisanal coastal fisheries an integral part of domestic rural development.

- Artisanal fisheries can no longer be managed independently of other resource uses and their environmental and socioeconomic impacts. The adoption of an approach that integrates development strategies in other sectors will be an effective means to reducing dependence on the resource, reducing fishing pressure, and making restrictive management easier or less controversial for the affected stakeholders.

Practical use of results should include applying the sets of particular drivers and indicators identified for each community, or groups of communities surveyed, to communities within the same countries (or country groups) that have comparative characteristics.
Such applications include:

- The major indicators and drivers identified at the regional, cultural and community levels (Figures 4.9–4.11) should be used to identify priorities, and to assess the overall advantages and limitations at the various levels and the vulnerability of the communities targeted. Coastal fisheries management strategies need to be tailored to suit:

    - socioeconomic and demographic characteristics (i.e. dependency on coastal marine resources, per capita consumption, percentage of population depending on primary and secondary income from fisheries; and national and local population densities, population growth, and migration rate);

    - the overall national economic situation, using indicators at the national scale (CPI, per capita GDP (nominal), percentage of urban population, per capita export–import balance) to assess the possible extent of subsistence catch rates, the demand for invertebrates, and the proportion of commercial finfish catch rates;

- the socioeconomic and economic conditions of the community, taking into account the combined sets of national and community-based factors including limitations of alternative income opportunities (sector development, diversification of household income sources, education level), demographic pressure (national and local population densities), difficulties in meeting living costs (average household expenditure level, percentage of households depending on remittances, average amount of remittances received), choice of and access to fishing grounds (availability of fishing ground and reef area, habitat diversification, and number of boats, particularly motorised boats);

- the relative economic situation of fishery-dependent households within coastal communities using indicators for dependency on fisheries for income and the available and accessible alternatives (adult education structure, average per capita household expenditure levels, benefits from remittances, and degree of diversification of household income sources for fishery-dependent and non-dependent households);

- the relative importance of major fisheries (finfish fisheries, invertebrates) and species groups contributing to both subsistence and complementary income, i.e. assessment of quantities and impact (total catch in t (finfish) or numbers (invertebrates) per km^2 reef per year), quality (catch composition), and value (monetary and non-monetary) at local and country levels.

4.4 Fishing pressure, indicators, and management

4.4.1 Reef finfish pressure risk model for Pacific Island countries and territories

The objectives of this section are to:

- provide a model to assess the risk of fishing pressure on reef finfish resources. This model allows managers to assess whether the current level of artisanal finfish fishing is sustainable or unsustainable for any given rural coastal community and its reef area;
- allow planners using a simple and relatively easy-to-obtain dataset, to confidently classify any coastal rural site within PICTs, as being exposed to low, low-to-medium, medium-to-high, or high finfish fishing pressure corresponding to a likelihood of increasingly unsustainable use from lowest to highest pressure groups.

This model was developed in response to limitations on data regarding the status of current resources and their use in PICTs. This lack of data makes it difficult to ascertain the level of fish supply needed to maintain the food security and livelihoods of coastal communities.

The model is based on the latest reef-productivity scenarios based on a global review (Newton *et al.* 2007) of: the currently known landing data; ecological footprints (historic impact of fishing); reported likelihood of reduced reef productivity in PICTS due to ecological and human factors; and the use of current finfish catch rates collected as a parameter for fishing pressure.

A detailed description and scientific discussion of the hypothesis and methodological approaches taken are provided in Appendix 4.3.1.

The process:

1. Defining four different finfish fishing pressure risk groups, referring to a finfish catch of:

   A <1 t/km^2 reef/year, indicating lowest risk;
   B 15 t/km^2 reef/year, indicating low-to-medium risk;
   C 510 t/km^2 reef/year, indicating medium-to-high risk;
   D >10 t/km^2 reef/year, indicating highest finfish fishing pressure.

2. Predicting current finfish catch rates expressed as finfish catch t/km^2 reef/year and the consequent classification into one of the four finfish fishing pressure risk groups based on data collected and analysed for 63 communities studied in 17 PICTs;

3. Making an underlying assumption that the lower the current finfish fishing pressure, the higher the likelihood of sustainable use; and that the higher the current finfish fishing pressure, the higher the likelihood of unsustainable use.

4. Validating our model with the average fish size by family of the target species collected from survey respondents as the best indicator of fishing impact.

5. Applying a statistical model to select the lowest number of variables that best predict the actual finfish catch rates and their classification into one of the four risk groups defined in step 1 above.

The model:

The best model developed has an error rate of 14.3%, i.e. in 85.7% of all predicted cases the classification of any site into any of the four finfish fishing pressure risk groups (low, low-to-medium, medium-to-high and high) is correct.

Modelling is done by using the formulae:

Log (total finfish catch):
~ country + percentage of households earning primary income from fisheries + total hours fished by male fishers + presence/absence of a back-reef + presence/absence of volcanic island geomorphology + latitude + longitude + total reef surface area (km^2)

Input variables are therefore:

(1) Country/Territory;
(2) Percentage of households earning primary income from fisheries;
(3) Total hours fished by male fishers;
(4) Presence/absence of a back-reef;
(5) Presence/absence of volcanic island geomorphology;
(6) Latitude;
(7) Longitude;
(8) Total reef surface area (km^2).

Input variables can be obtained by conducting a basic questionnaire survey. The questionnaire survey can be designed following the 'Socioeconomic Fisheries Surveys in Pacific Islands: a manual for the collection of a minimum dataset' (Kronen *et al.* 2007) including the necessary questions as indicated in the beginning of each chapter that applies and as referenced in the following. Data entry in the SEMCoS software system will prompt the requested results. How and from which sources the additional data can best be obtained is indicated in the following:

(1) Enter the name of the island country/territory concerned;

(2) From the total number of households in the community surveyed determine the percentage of households that earn primary income from fisheries;

(3) To obtain total hours fished by male fishers, sum the extrapolated total hours fished by male finfish fishers per habitat targeted from random survey to the extrapolated total number of male finfish fishers per habitat;

To obtain the total number of male fishers (and female fishers) for finfish fishing (and invertebrate fishing) use chapter 3.2.4 'number of fishers' (in Kronen *et al.* 2007).

To obtain the total hours fished by male finfish fishers (females are not a necessary input here) multiply the duration of a fishing trip in hours by the frequency of fishing trips per year per fisher and for each habitat targeted as obtained from survey data. Note that frequency data are corrected by a factor of 0.83 (Kronen *et al.* 2007);

(4) Determine whether the appropriated fishing grounds of each community have a combination of lagoon and outer reef, i.e. a back-reef;

(5) Determine, using the UNEP Islands website (http://islands.unep.ch/isldir.html) whether or not the island on which each community is located is of volcanic origin, or not;

(6) Take the latitudinal and longitudinal coordinates of each community by using GEONet Names Server (GNS) (http://earth-info.nga.mil/gns/html/index.html);

(7) Using satellite imagery, delineate the total appropriated fishing ground per each community, and determine the total reef surface area within this boundary.

If a larger error rate is acceptable, and in cases where the determination of the percentage of male fishers and total hours fished by male fishers poses serious problems, one can substitute the above model by the following formula, which employs total population. However, with this formula, the prediction error rate increases to 23.8%, i.e. in ~24% of all cases the predicted classification of a community and its appropriated reef areas into one of the four risk groups may not be correct.

Modelling using the simplified formula and accepting a larger error rate requires the following imput:

Log (total finfish catch):
~ country + percentage of households earning primary income from fisheries + total population + presence/absence of a back-reef + presence/absence of volcanic island geomorphology + latitude + longitude + total reef surface area (km^2).

- Substitute total hours fished by male fishers by the total population figure of the community concerned.

Consequences for fisheries management

The overall objective of this model is to help policy-makers and fisheries managers to identify:

- the priority area for fisheries management interventions;
- possible surplus and deficit fishing grounds for future food security and rural development planning.

The hypothesis that higher finfish catch rates are associated with a higher likelihood of unsustainable use was demonstrated by effects of growth-overfishing using decreasing average length of six important fish families in response to increasing catch rates. Catch rates have been used as parameters for assessing finfish fishing pressure. The use of the relationship found between average finfish size of certain fish families and increased catch rates as an indicator to assess and monitor the degree of current finfish fishing pressure will be discussed later in more detail.

The strategic and practical implications of the results are:

- To use the model (to be made available on the SPC website) to prioritise areas needing intervention, and to identify areas of surplus resources for the supply of reef and lagoon finfish;
- To use the areas and their current production deficit/surplus to verify to what extent finfish production from surplus areas can help to satisfy the increasing demand on areas subject to current unsustainable finfish resource use and in particular increasing market demands in semi-urban and urban areas;
- To give priority to areas with a currently high likelihood of unsustainable reef and lagoon finfish fisheries for fisheries and to rural development management interventions, focusing on the development of alternative income sources to maintain livelihoods in the communities concerned.

4.4.2 Socioeconomic and fishery indicators for identifying and monitoring finfish fishing pressure in rural coastal fishing grounds of Pacific Island countries and territories

The objectives of this section are:

- to demonstrate and assess the current status of finfish fishing pressure using risk models and scenarios across 63 sites in 17 PICTs;

- to identify major factors that determine current exploitation levels and resource status, including demographic and fishery drivers, main drivers to explain regional variability in total finfish catch, and drivers to explain regional variability in the trophic composition of finfish catch;
- to describe indicators to demonstrate fishing impact, including indicators associated with island type, and longitudinal and latitudinal differences;
- to assess the likelihood of sustainable or unsustainable use in coastal fisheries communities in PICTs;
- to demonstrate the impact of current finfish catch rates on the resource status and its indicators; and
- to demonstrate the impact of current finfish catch rates on the reported fish size and its indicators.

This chapter is structured by providing a summary of the major results and indicators in the beginning and, where possible, then followed by a section of more detailed analysis, results, and discussions for the interested readers. Results and interpretation of multivariate analysis are presented in Appendix 4.3.2.

Introduction

Finfish fishing pressure is determined by resource and user status. On a commonsense basis, we can assume that the better the resource status, the better is the buffer against overexploitation, and vice-versa. The more dependent people are on coastal finfish resources for food and for income, the higher the exploitation level, which is measurable in catch per available fishing ground or reef surface area. Catch rates, i.e. total annual finfish catch (t) over reef surface area (km^2), are used as a measure for finfish fishing pressure. Knowing which factors drive current finfish fishing pressure and which factors are attributable to current finfish fishing impact on the resource is essential to design strategies that manipulate or substitute for drivers where necessary to reduce finfish fishing pressure towards sustainable levels, and to identify indicators for monitoring future development in general, as well as the success of fisheries management regulations.

Drivers and indicators

Major drivers and indicators identified using statistical analysis focused on socioeconomic and fishery aspects, complemented by parameters from the finfish resource and physical database, are presented in the following (See also Appendix 4.2.).

<u>The current situation of coastal fisheries in PICTs (See Appendix 4.3.2.)</u>

- The risk and, presumably the existence of currently unsustainable coastal finfish fisheries in PICTs is high and widespread. Even under an optimistic reef production scenario (5 t/km^2/year) almost half (43%) of all coastal, fishery-dependent rural communities extract finfish beyond the annual sustainable production of their appropriated reef area (Figure 4.12). The likelihood of an even more severe situation is high, considering that this survey included rural rather than semi-urban or urban coastal communities and their fishing grounds, which, by comparison, can be expected to be much more effective in harvesting marine resources.

- The highest finfish fishing pressure in terms of the proportion of annual finfish catch (t/km^2 habitat surface area) is actually imposed on sheltered coastal reefs and outer-reef habitats, rather than lagoon areas. Although most finfish fishing hours are spent in lagoon habitats, differences in total surface areas among habitats targeted explain the resulting fishing pressure. If lagoon systems are present, they represent usually the largest proportion as compared to sheltered coastal reef and outer-reef surface areas and thus have a great buffer capacity to compensate for the effects of fishing effort and catch.

- Regarding possible future interventions, i.e. reducing actual catch rates of finfish to only supply rural communities with their minimum requirements for healthy nutrition (37 kg/person/year), still leaves 17% of all communities at high risk of unsustainable coastal fisheries. This argument underpins the necessity to reduce current finfish fishing pressure, including both subsistence and commercial catches. This may require a widened approach to develop alternative income sources, to increase the cash income of rural coastal communities, to reduce fishing activities, and to divert a share of the current consumption to alternative food items.

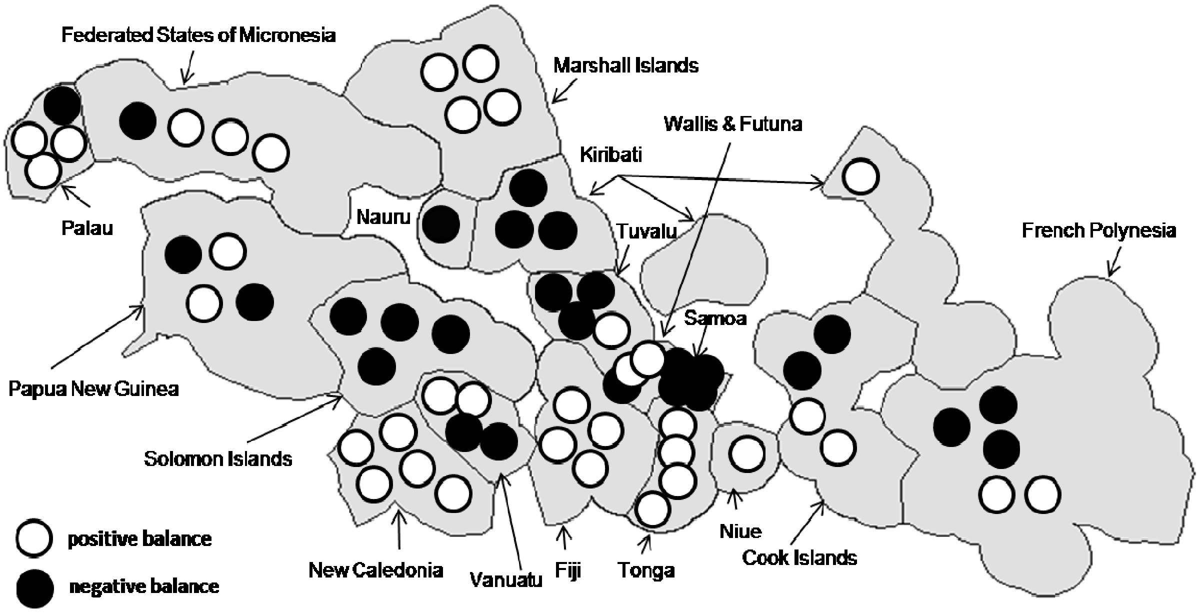

Figure 4.12: Positive or negative balance of reef productivity (5 t/km^2 reef/year) and current total annual finfish catch per each of the 63 communities studied in PICTs.

<u>Factors determining current exploitation levels and resource status</u>

- For fishery-dependent rural coastal communities in PICTs, population size matters. Fishing pressure is defined as the ratio of the available reef production surface to the total annual finfish catch. The latter is determined by population size and its associated proportions of fishers, boats and fishing hours. The larger the population, the larger is the proportion of fishers, boats and hours spent fishing, and the larger the total annual finfish catch. The smaller the appropriated reef surface area, the higher is the fishing pressure.

- The higher the annual finfish catch – in particular regarding the share of commercial finfish catches – the higher is the CPUE.

- Fishing impact is particularly related to the total time spent fishing by male fishers; the contribution by female fishers is almost negligible at the regional scale.

- Boat transport is correlated with fishing further offshore, and notably with commercial catches.

Demographic and fishery drivers

Positive linear relationships (Figure 4.13) confirm that the larger the population size of fisheries-dependent communities in PICTs, the higher the number of fishers, boats and total hours spent finfish fishing. The more fishers and boats there are, the higher the total annual finfish catch and the more boats there are the higher is the annual commercial finfish fishing catch. However, in terms of finfish fishing hours, a significant positive relationship exists for male fishers only. The higher the annual finfish catch is, the higher is the CPUE, and this positive relationship is particularly true for the commercial finfish catch. The size of the total finfish fishing ground also correlates positively with increased CPUE.

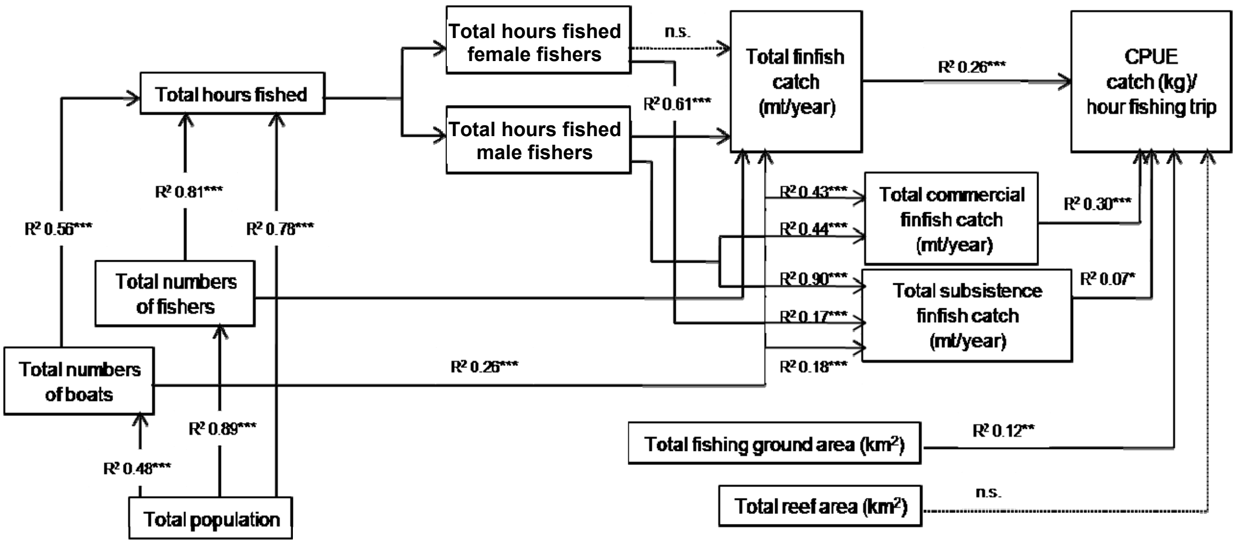

Figure 4.13: Linear relationships between socioeconomic parameters, total annual finfish catch, and productivity (CPUE).

As shown in Figure 4.14, analysis of the distribution of total annual finfish fishing hours by gender and habitat targeted reveals that male fishers account for most finfish fishing hours, and hence determine most of the impact. Overall, the highest pressure in terms of time fished is put on lagoon habitats. The use of boat transport and the objectives of fishing trips comparing habitats targeted suggest that the closest and most easily accessible habitats are mainly targeted by low-cost finfish fishing strategies that serve daily subsistence demand rather than commercial purposes. The closer to shore areas use the least boat transport, at least on a regular basis. The more regularly boat transport is used and the further offshore are the fishing grounds targeted, the more fishing trips are conducted for commercial purposes rather than subsistence needs. There was no differentiation found between habitats targeted concerning non-monetary distribution, sharing or gifting of catch among family and community members.

Habitat targeted	Sheltered coastal reef	Lagoon	Outer reef
Total hours spent finfish fishing per year			
Male fishers (% total hours)	26.7	34.4	20.4
Female fishers (% total hours)	9.9	7.9	0.7
Use of boat transport for finfish fishing (% of trips)			
	←	F 12.44***	
Never			
		F 6.84***	→
Regularly			
Objective of finfish fishing (% of trips)			
	←	F 7.36**	
Subsistence			
		F 2.59 (P<0.07)	→
Commercial			
	↔	n.s.	
Non-monetary sharing			

Figure 4.14: Relative influence of total annual fishing hours (by gender), on boat transport and objectives of fishing trips per habitat (average figures for 63 communities studied).

Main drivers of regional variability in total finfish catch

- While population size in fishery-dependent communities is a major factor in determining the amount of the catch, a large number of economic, social, and resource factors explain the variation found in the communities studied. The large number of parameters and their numerous inter-relationships necessitate a multivariate analysis.

Application of such statistical analysis by combining socioeconomic, fishery and resource datasets identified seven major drivers that explained 81% of the variation found in total annual finfish catches. Highest influence is due to four socioeconomic variables which together explain 48%, while the three resource variables together account for 24% of the total variation; the remaining 9% is due to the combined effects of all seven variables (Table 4.11).

- The socioeconomic indicators, i.e. easy marketability, the level of the national CPI and the current reported CPUE, must be regarded in combination with the total community size to fully understand why people in the respective community currently produce the amount of annual finfish catch.
- Furthermore, the resource indicators, i.e. the surface areas of back-reef and outer reef, and the fact that the community in question may or may not be located on a small-lagoon island type, are decisive parameters to describe the available resource and its productivity capacity, and must be taken into account.

Table 4.11: The seven major variables explaining 81% of the regional variation in total annual finfish catch, including four socioeconomic and three resource variables (RDA, CANOCO)

		Per cent explained
Socioeconomic drivers	Total population of the community surveyed	48%
	Easy marketability	
	Consumer Price Index (CPI)	
	CPUE (kg catch per hour of fishing trip)	
Resource drivers	Surface area of back-reef	24%
	Surface area of outer reef	
	Small-lagoon island type (or not)	
Combined effects		9%
Total variation explained:		**81%**

RDA = redundancy analysis using CANOCO 4.5 (canonical community ordination). See Appendix 4.2.

Main drivers to explain regional variability in the trophic composition of total finfish catch (Table 4.12)

- The ratio between herbivores and carnivores (H_s/C_s ratio) in finfish catches may indicate where current resource exploitation is likely to result in detrimental effects on trophic composition, particularly concerning the role of the fish belonging to higher trophic groups, i.e. carnivores. Information on the resource status is necessary to clarify whether the reported H_s/C_s ratio is a function of fishing strategies or a consequence of the present trophic resource structure. Again, a complex dataset is required that requires multivariate-analysis techniques.

- To understand why more (or less) herbivores or carnivores are currently caught, the proportion of line-fishing, and the difficulty (or ease) of marketing need to be combined with the population size of the community in question, as well as the overall degree of economic development of the country, using the percentage of urban population (at national scale) as a parameter. Also, the resource status, i.e. what is (still) available in the appropriated reef areas accessible to the community, notably the H_b/C_b biomass ratio and the lagoon reef surface area, is a decisive factor needed to explain the trophic composition of current finfish catches.

Table 4.12: Seven major variables explaining 62% of the regional variation in the H_s/C_s finfish catch ratio, including five socioeconomic and two resource variables (RDA, CANOCO)

		Per cent explained
Socioeconomic drivers	The percentage of hours spent line fishing	46.0%
	Difficult marketability	
	Total number of boats	
	The percentage of urban population at the national scale	
	Total population of the community surveyed	
Resource drivers	The average H_b/C_b biomass ratio	14.5%
	The lagoon reef surface area	
Combined effects		1.5%
Total variation explained:		**62.0%**

RDA = redundancy analysis using CANOCO 4.5 (canonical community ordination). See Appendix 4.2; H_s/C_s = catch ratio of herbivores to carnivores; H_b/C_b = biomass ratio of herbivores to carnivores.

<u>The relationship between island type and finfish fishing pressure risk, and socioeconomic, resource and fishery parameters</u>

- In a nutshell, fishers can only access and extract what is available in their fishing grounds. Biodiversity, quality and quantity of stocks, and their productivity are determined by physical conditions, and subject to effects of past and current anthropogenic factors.

In summary, the combined analysis of the major factors: island type and current finfish fishing pressure risk suggests the following.

- Atoll island sites are associated with high CPUE, lower population of communities, lower proportions of spearfishing hours (%), low H_s/C_s ratio, a higher average biomass of Serranidae, and a lower average biomass of Acanthuridae.
- Complex island sites have the tendency for a higher average biomass of Siganidae and Scaridae, and a lower average biomass of Serranidae. The proportion of spearfishing hours (%) is rather high.
- Oceanic island sites have high population of communities, rather low average biomass of Scaridae, Siganidae and Serranidae, but higher average biomass of Acanthuridae and Balistidae.
- Small-lagoon island sites have a high percentage of spearfishing hours (%), low CPUE, low average biomass of Serranidae, but relatively high average biomass of Scaridae and Acanthuridae.
- Sites with the highest catch rates (= highest finfish fishing pressure risk) are most associated with a large population size of communities, where marketing is easy, at close distance to capitals, and a rather low H_s/C_s ratio.
- Sites with the lowest catch rates (= lowest finfish fishing pressure risk) are highly associated with a smaller population size of communities, and a higher average biomass of Siganidae, Labridae, Mullidae and Scaridae. They have a higher proportion of line fishing hours and a lower proportion of spearfishing hours (%).

Indicators of fishing impact

<u>Ratio of herbivore/carnivore biomass H_b/C_b</u>

The H_b/C_b biomass ratio is used as an indicator for the resource status, i.e. the higher the ratio the worse the resource conditions as the percentage of herbivores increases on account of a decline in biomass of carnivores. Linear regression was done against individual socioeconomic and fishery parameters, the former at national and community scale, the latter at community scale. The highly statistically significant relationship between increasing H_b/C_b rate and decreasing CPUE supports the premise that historic fishing pressure – arguably in combination with other factors not considered in our analysis – has impacted the resource status.

As shown in Figure 4.15, a number of statistically highly significant relationships with socioeconomic parameters further suggest that:

- If an impacted resource status goes hand in hand with national and community-level development, a lower dependency on coastal finfish fisheries resources results, and a shift occurs to employment in other sectors.

This argument is supported by the relationships among increased H_b/C_b rate and decreased total finfish catch (for subsistence, and for commercial purposes, as well as the total annual subsistence and commercial finfish catch per household), and the per capita consumption rate of finfish alone, and finfish and invertebrates combined. Development at the national scale is represented by a slow-down in the national growth rate, a decrease in the average household size, an increase in the per capita GDP and an improvement in the per capita export–import balance. At the community level, development shows in the increased number of adults with secondary education, an increased consumption of canned fish, and an increase in the average household expenditure level.

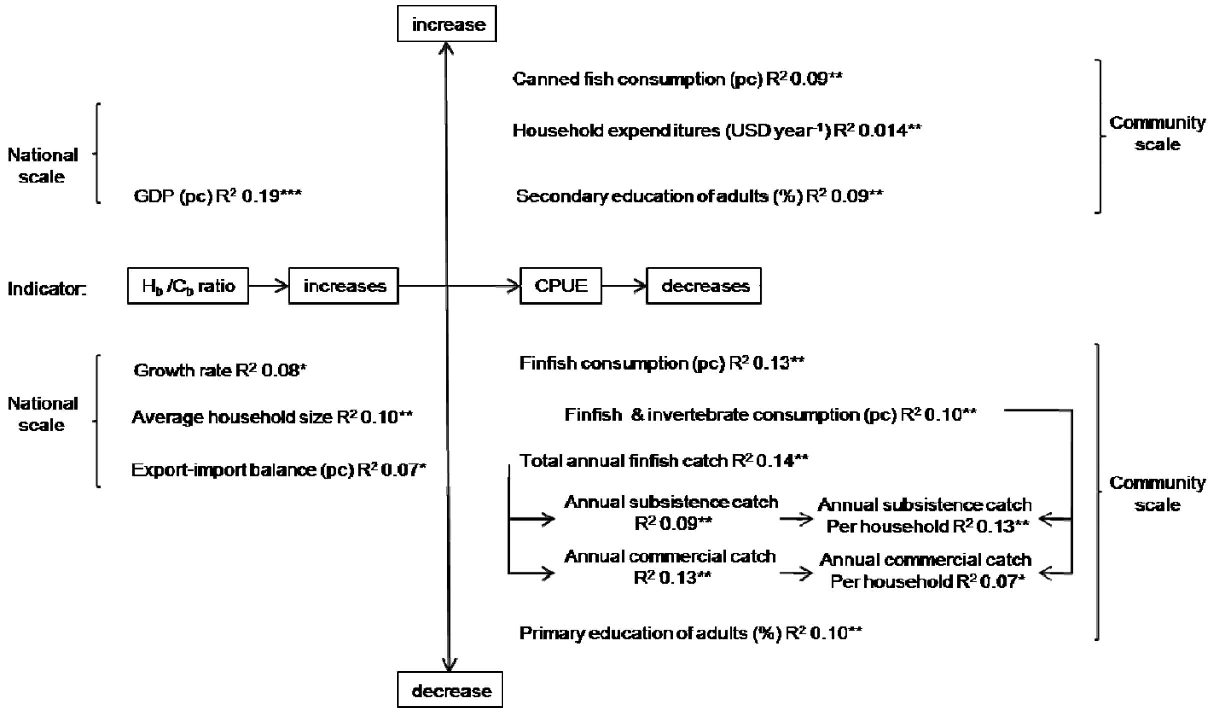

Figure 4.15: H_b/C_b ratio and CPUE indicator scheme showing linear relationships between H_b/C_b and socioeconomic drivers for impacted resource status and associated socioeconomic and fishery response.
H_b/C_b = biomass ratio of herbivores to carnivores.

Island type

Island type has already been identified as a strong factor to group the communities studied according to socioeconomic and resource drivers related to finfish fishing pressure. Linear regression done for each island type (Figures 4.16–4.19) shows that:

- Atoll and complex islands are currently associated with lower finfish fishing pressure, lower H_b/C_b ratio, and higher CPUE;
- Small-lagoon and oceanic islands are currently associated with higher finfish fishing pressure;
- A statistically significant relationship between island type, H_b/C_b ratio and CPUE was only found for the oceanic island type, associated with improved resource status and fishery productivity.
- The overall high correlation between finfish fishing pressure and island type (R^2 = 0.31; P <0.0001) must take into account that fishing pressure is a function of total annual finfish catch over fishing ground or reef area. Island-type definition includes habitats and,

hence, significant differences exist in the total available fishing ground, reef, and certain habitat surface areas.

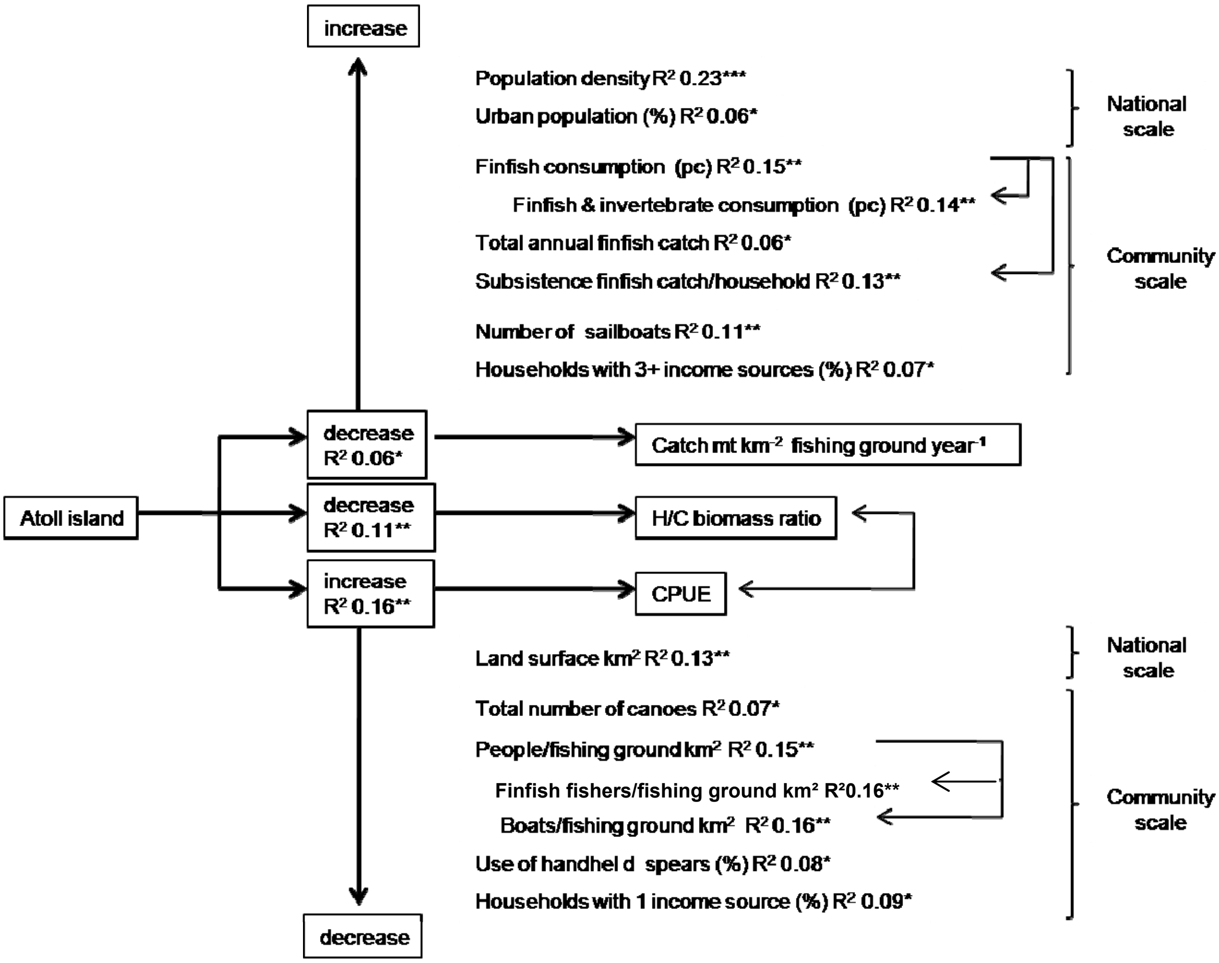

Figure 4.16: Indicators and drivers of current fishing pressure in atoll island types.

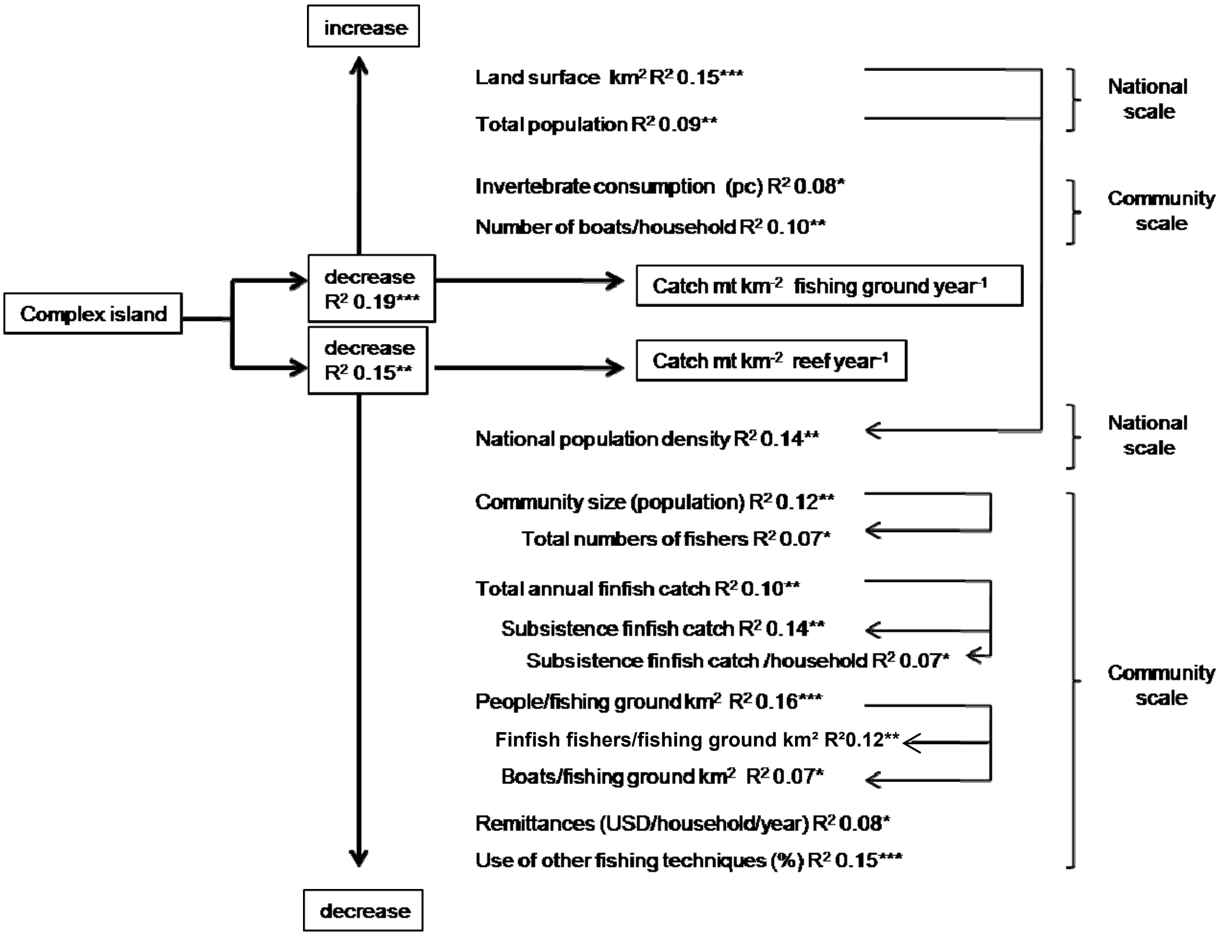

Figure 4.17: Indicators and drivers of current fishing pressure in complex island types.

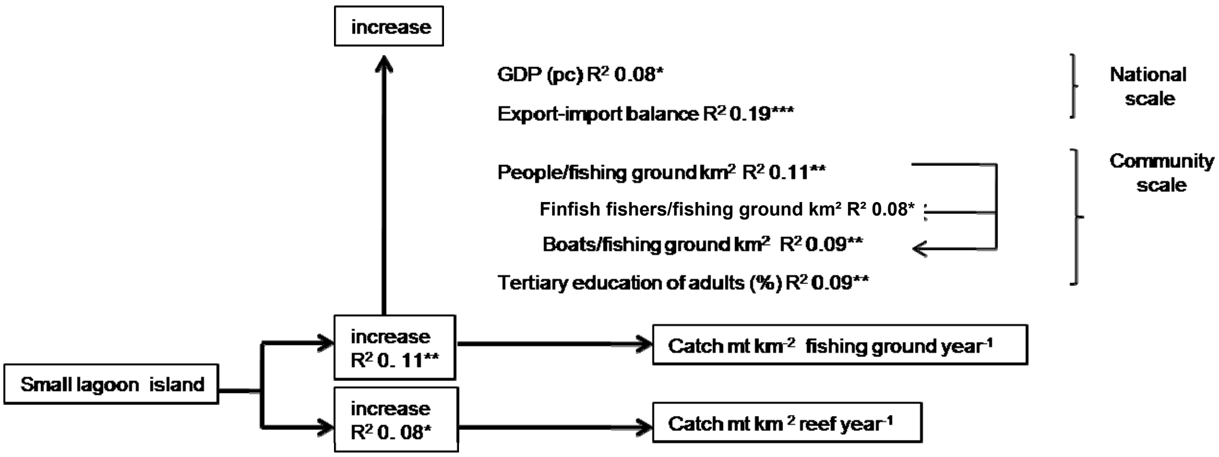

Figure 4.18: Indicators and drivers of current fishing pressure in small-lagoon island types.

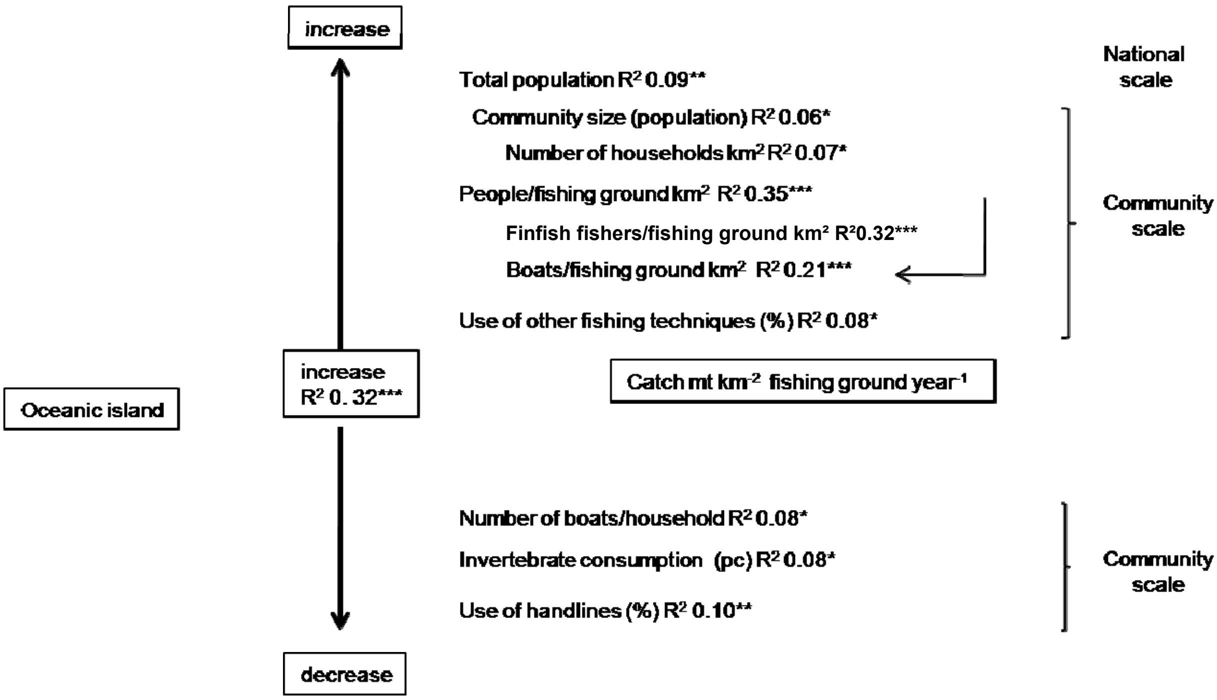

Figure 4.19: Indicators and drivers of current fishing pressure in oceanic island types.

ANOVA tests prove that significant differences exist between the naturally favoured complex and atoll islands, and the naturally disfavoured small-lagoon and oceanic island types if regarding coastal marine habitat characteristics. Complex and atoll islands have significantly larger fishing grounds, larger total reef areas and, within these units, larger sheltered coastal reef and lagoon areas.

Between the naturally higher complex and atoll islands, significant differences exist: atoll islands have larger surface areas of total fishing ground, included lagoon, and outer-reef.

There are no significant differences in any of the fishing ground or habitat surface areas of the naturally poor small-lagoon and oceanic island types.

Longitudinal and latitudinal differences

- Regional comparison among all 63 sites and 17 PICTs includes a wide range of longitudinal and latitudinal differences. These geographic differences have a major influence on physical and associated socioeconomic conditions. The three cultural groups represented by all PICTs studied are highly correlated with longitudinal and latitudinal effects. Therefore, to better understand which indicators apply to which cultural groups, countries and communities, the associated gradients in any of the main drivers identified need to be taken into account (Figure 4.20).

- Physical and resource gradients:

  - The H_b/C_b ratio decreases from furthest north to furthest south (latitude);
  - The occurrence of complex island types decreases, while the occurrence of small-lagoon island types increases eastwards (longitude).

- Socioeconomic gradients at the national scale:

  - Population density (total number of people per km^2 land surface), and the average household size increase from furthest south to highest north (latitude);
  - The national growth rate, gross migration and total land surface decrease eastwards (longitude);
  - The export–import balance (per capita) decreases eastwards (longitude), and also decreases from furthest north to furthest south (latitude);
  - GDP (per capita) increases eastwards (longitude) and decreases from furthest north to furthest south (latitude).

- Socioeconomic gradients at the community scale:

  - The average household size, the subsistence finfish catch per household per year, the per capita consumption rate of finfish, and of finfish and invertebrates combined increase from furthest south to furthest north (latitude); invertebrate consumption decreases eastwards (longitude);
  - The average household expenditure level, the proportion of households earning secondary income from salaries, and the total number of motor boats in a community increases eastwards (longitude); the number of boats/household in a community decreases eastwards (longitude);
  - The CPUE increases eastwards (longitude);
  - The use of deep bottom lines (in per cent of techniques used) increases from furthest south to furthest north (latitude), and decreases eastwards (longitude); the use of handheld spears (%) decreases from furthest north to furthest south (latitude).

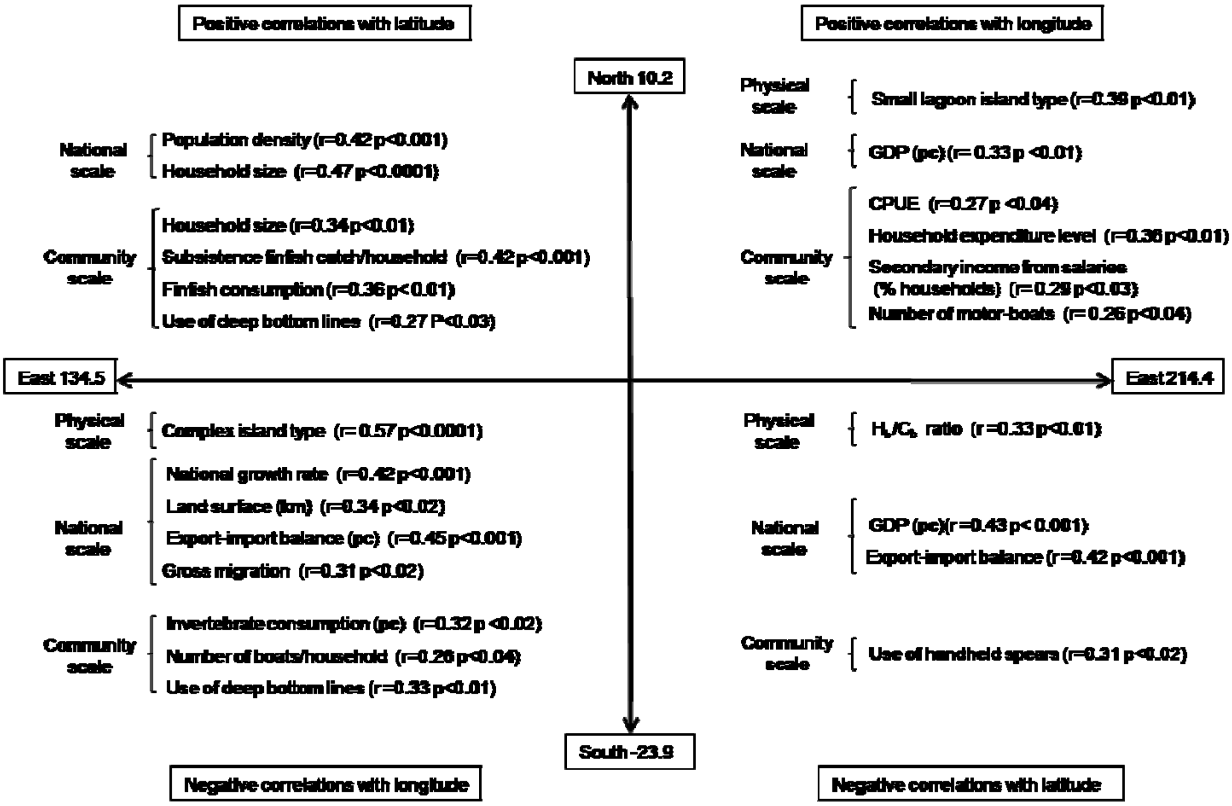

Figure 4.20: Latitudinal and longitudinal gradients of physical and socioeconomic factors at national and community scale.
Only parameters with statistically significant linear correlation (R^2) results are included.

<u>Likelihood of sustainable or unsustainable use in coastal fisheries communities in PICTs</u>

The island types and their naturally advantaged or disadvantaged conditions were classified into sustainable (<1–5 t finfish/km^2 reef/year) and unsustainable (>5 t finfish/km^2 reef/year) finfish fishing pressure groups. One would expect that the island types with naturally advantaged conditions for coastal fisheries, i.e. complex islands and atoll islands, to score the highest in terms of sustainable finfish fisheries. Similarly, we expect the highest proportions of unsustained current finfish fisheries to exist in naturally disadvantaged situations for coastal fisheries, i.e. small-lagoon and oceanic islands. This relationship is shown in Figure 4.21, which shows that 70% of all communities studied follow this expected pattern.

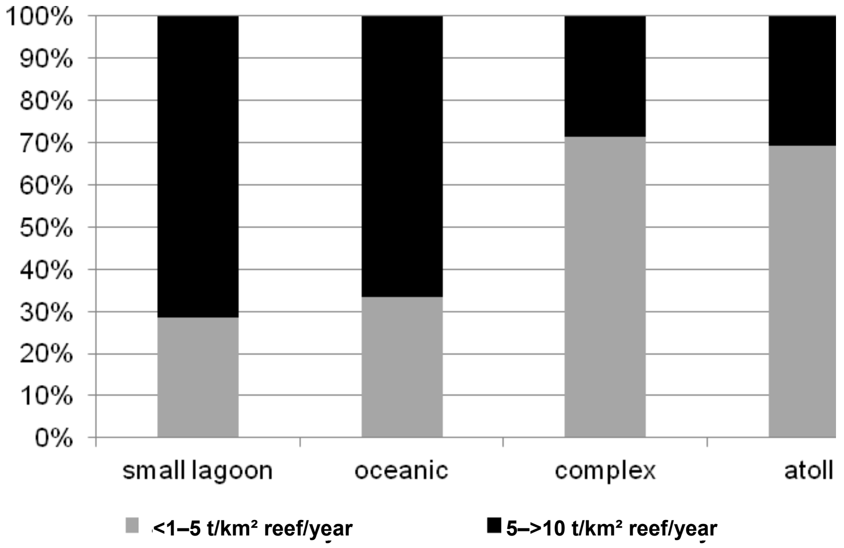

Figure 4.21: Percentage of sites classified in finfish fishing pressure risk groups <1–5 t/km^2 reef/year and 5–>10 t/km^2 reef/year for each island type.

Indicators versus current finfish fishing pressure risk groups

The major indicators identified for detection of historic and current finfish fishing impact (H_b/C_b ratio and CPUE) and the effects of and indicators for longitudinal and latitudinal variation were validated by comparing average data of these parameters of all communities classified in low (<5 t/km^2 reef/year) and high (>5 t/km^2 reef/year) finfish fishing pressure risk groups for each island type. Thus, we compared the naturally expected low or high productivity related to each island type with the current finfish fishing pressure risk expressed as total annual catch per km^2 reef per year.

Results show:

- Again population size matters! Regardless of favourable or unfavourable physical conditions, sustainability of coastal finfish fisheries is a function of population size (and its associated numbers of fishers, and total annual catch) and the available fishing ground area (particularly reef surface area) in fisheries-dependent communities.
- Finfish fishing pressure (t catch/km^2 reef/year) or its parameters (population/km^2 reef, fishers/km^2 reef) have already outrun even the best conditions (indicated by low H_b/C_b ratios, and high CPUE) in several locations studied. In contrast, finfish fishing pressure or its parameters may also be below the lowest production capacity given the most unfavourable physical or natural conditions.
- However, as a rule of thumb, the larger the appropriated fishing ground (and reef surface area) and the better the physical conditions, the greater is the capacity to withstand finfish fishing pressure.

Impact of current finfish catch rates on resource status

The H_s/C_s (catch) and H_b/C_b (biomass) ratios showed close associations with island types, finfish fishing pressure risk groups, and hence current finfish catch rates. The H_s/C_s ratio increases as the proportion of carnivores in the fish community decreases. This reduction in carnivores reflects fishing, which first targets larger specimens at the upper level of the food-chain. Thus, low H_s/C_s ratios can be used as an indicator for good conditions, while high H_s/C_s ratios suggest that fish from higher trophic levels have already been removed by fishing.

Indicators:

- Decreasing average biomass of Siganidae and Scaridae and, to a lesser extent, Labridae is an indicator of increasing finfish fishing pressure;
- Scaridae are particularly vulnerable and show strong negative correlation of decreasing average biomass under lowest finfish fishing pressure (<1 t/km^2 reef/year) (R^2 = 0.56, P <0.0003);
- Labridae seem to be vulnerable from lowest to highest finfish fishing pressure, showing negative correlation under lowest (<1 t/km^2 reef/year) (R^2 = 0.17, P <0.09) and highest (>10 t/km^2 reef/year) (R^2 = 0.18, P <0.10) pressure. Catch composition data confirmed that Labridae are significantly more represented as the catch rate increases.
- Positive correlations of average biomass of Holocentridae (R^2 = 0.30, P <0.01), Lethrinidae (R^2 = 0.21, P <0.05), Lutjanidae, Mullidae, Serranidae, and Kyphosidae (R^2 = 0.19, P <0.06) under lowest finfish fishing pressure (<1 t/km^2 reef/year), all turn into negative correlations under highest finfish fishing pressure (>10 t/km^2 reef/year). Lethrinidae are less represented in catch composition with increasing catch rates, while Holocentridae are increasingly more represented.
- Acanthuridae and Balistidae show positive correlation under all finfish fishing pressure situations, and are apparently the least vulnerable families studied. Significant positive correlation confirms the lower vulnerability of Acanthuridae, which are more represented in catch composition the higher the catch rates, i.e. with increasing fishing pressure.
- The proportion (weight) of Carangidae in reported catches increases with increasing finfish fishing pressure and may be a useful indicator to represent a fisher's adaptive strategies in increasingly targeting larger-bodied oceanic species in response to a decline in reef fisheries due to fishing pressure.

Impact of fishing techniques on trophic structure and fish family (average biomass)

- The proportional use of major fishing techniques does not significantly change among finfish fishing pressure risk groups.
- Line fishing is associated, as expected, with a higher proportion of piscivores (Lutjanidae, Serranidae) and carnivores (Lethrinidae) in catches.
- Gillnetting may generally be less oriented to specific target species than other techniques, but was found to be closely related to a catch decrease in piscivores, showing a negative impact on the average biomass of Holocentridae and Scaridae.
- As expected, speardiving increases the catch proportions of herbivores (Acanthuridae, Scaridae and Siganidae); and a negative impact was found on the average biomass of Scaridae, Serranidae and Siganidae.

Using the three major fish families identified as indicators of increasing finfish fishing pressure, i.e. Siganidae, Scaridae and Labridae (average biomass) and the results of selective impacts of fishing techniques, reducing the use of speardiving may have a positive impact on the recovery of Siganidae and Scaridae (and possibly Serranidae). Scaridae will also benefit from encouraging the use of line fishing. Holocentridae and Scaridae may benefit from the reduction of time spent gillnetting.

With increasing catch rates (5–10 t/km^2 reef/year) the negative impacts of speardiving also show in the decrease of the average biomass of Holocentridae and Kyphosidae. At the highest level (>10 t/km^2 reef/year), Mullidae and Lutjanidae are subject to the detrimental impacts of gillnetting.

Impact of current finfish catch rates on reported fish size and biomass

The decreases in average reported fish length (fork length) and in average biomass of certain fish families can be used as indicators of a measurable and detrimental impact caused by finfish fishing pressure.

These indicators include the following:

- Acanthuridae (although abundant in terms of biomass and catch composition) show a decrease in average fish sizes in response to increased fishing pressure;
- Lethrinidae are increasingly represented in catch composition and respond with decreased average biomass with increasing finfish fishing pressure; increased catches of Lethrinidae were also found with increasing time spent line-fishing;
- Mullidae decrease in average biomass with increased finfish fishing pressure;
- Siganidae also showed a decrease in average biomass and less proportional presentation in catch with increasing fishing pressure. Spearfishing catches showed an increase in the proportional catch of Siganidae, and a negative effect of speardiving on Siganidae was shown by a decrease in average biomass;
- Scaridae showed a general decline in average biomass with increasing finfish fishing pressure, even at the lowest level of pressure (<1 t catch/km^2 reef/year). Also, speardiving increases the proportional presentation of Scaridae in catches and average biomass decreases in response to more time spent speardiving.
- In the case of Lethrinidae, Mullidae, Siganidae and Scaridae, population density can be substituted for catch rate as an indicator of negative impact on average fish size caught.

4.4.3 Fisheries management interventions – a joint analysis of socioeconomic, fishery and resource factors

Coastal fisheries policy

- The future of the artisanal fishery sector and the livelihood of coastal communities in the Pacific Island region will depend to a large extent on access to and potential of alternative subsistence and income sources, which are necessary to reduce fishing pressure to a sustainable level to maintain ecosystem services and food security.

- The harmonisation of objectives for resource use and development requires the promotion of diversification, including alternatives to coastal wild-caught fisheries, and demands management strategies that make artisanal coastal fisheries an integral part of domestic rural development.

- Artisanal fisheries can no longer be managed independently of other resource uses and their environmental and socioeconomic impacts. The adoption of an approach that integrates development strategies in other sectors will be an effective means to reduce dependence on the fisheries resources, reducing fishing pressure, and making restrictive management easier or less controversial for the affected stakeholders.

- Access to improvements in quality of life and income must be available to both genders equally, including capital, equipment, technology, transport, credit, training, employment, and education. Gender equity in decision-making regarding resource use and use of household assets and income is also vital. The implications of livelihood diversification programmes on gender participation and responsibilities must be assessed in the early planning stage.

Strategic planning and setting of priorities (using the following drivers and indicators)

Country and community scales

For **identifying priority countries and communities** (or areas) for fisheries management and rural development interventions, it is recommended that the following processes are applied, focusing on their drivers and indicators at the national scale (to set regional priorities) and community scale (to set national priorities):

- **The higher the demographic pressure** *(indicators: large population, high population density per km^2 reef or fishing ground area at community scale, and/or per km^2 total land surface at national scale),* **and the higher the food dependency** *(indicator: per capita finfish and invertebrate consumption)* on marine produce, **then higher is the likelihood of unsustainable subsistence fisheries and detrimental impact on resources**;

- **The fewer the alternative income opportunities** to fisheries (*indicators: high proportion of adult population with primary education only; small land surface; low proportion of urban population at national scale, low per capita GDP, high demographic growth rate, high dependency ratio (age group 15–64 years))*, **and the greater the difficulty in meeting living costs** *(indicators: high CPI at national scale, low per capita consumption of canned fish, low household expenditure level, high dependency on remittances)*, **the easier the access and the greater the choice of fishing grounds** *(indicators: large choice of fishing habitats within close range of community, and/or large number of boats, particularly motorised boats),* **and the easier the marketability, then the higher is the likelihood of unsustainable commercial finfish and small-scale artisanal invertebrate fisheries**.

Within selected priority areas (countries and communities) further assess which fisheries and habitats should be targeted by fisheries management and rural development interventions based on the impact they account for. This can be done as follows.

- Determine the relative importance of major fisheries (finfish fisheries, invertebrates) and species groups contributing to both subsistence and complementary or main income, i.e. assess the quantities caught (total catch t finfish or numbers of invertebrates/km^2 reef/year), quality (catch composition) and value (monetary and non-monetary) at local and country levels.

- Take into account any cultural and gender differences. Impact on finfish resources is mainly accounted for by male fishers; however, Melanesian female fishers engage substantially in finfish fishing for food and income. While no major gender differences exist for most invertebrate fisheries, female fishers do not actively participate in invertebrate harvesting that requires free-diving and mostly targets commercial species for export.

Community and individual household scales

Use the following **drivers and indicators to assess the current situation at community and household scales** and to further characterise the status of priority areas (communities, households within communities) in comparison to non-priority situations.

- Assess the income available to the community; communities depending on fisheries for income have less daily per capita cash expenditure potential than do communities that depend on alternative income sources.

- Assess the income available to the individual households in a community; households that depend on fisheries for income generation have less per capita cash expenditure potential than do households that depend on alternative income sources.

- Estimate the current finfish catch rate expressed as finfish catch t/km^2 reef/year and classify each community into one of the four finfish fishing pressure risk groups defined above. Resulting priorities for fisheries management interventions and integrated development are shown in Table 4.13.

Table 4.13: Priorities for management interventions by finfish fishing pressure risk group

Finfish fishing pressure risk group (t/km^2 reef/year)	Priority for fisheries management intervention	Priority for integrated development
<1	-	-/+
1–5	+	+
5–10	++	++
>10	+++	+++

- Ensure that adequate attention is given to females' fisheries issues, which are often invisible. This also applies to community fisheries management programmes.

Fisheries management interventions

The summary results of the regional inter-disciplinary analysis of 63 communities and their fishing grounds studied give us a scale by which we can measure the current balance between the status of finfish resource and its use from overall best to overall worse conditions. Using this scale, we can assess the relative urgency with which we need to recommend fisheries management strategies. The classified 63 study sites (Table 4.17) are suggested as reference points to identify scope, urgency and feasibility of fisheries management strategies for other sites (communities and their fishing grounds).

Knowledge of the natural potential of a site is a required input to estimate its natural productivity potential, to assess the possible impact of current (and past) fishing, and to decide which fisheries management interventions are feasible – in particular, those that aim to restore the natural potential.

Whether a site is expected to be in 'naturally rich' or 'naturally poor' condition can be determined by using the following factors.

- Distance from the centre of biodiversity (CoB) determines the geographical range between higher and lower natural biodiversity richness;

- Reef complexity at meso-scale (~10 km radius of fishing ground assessed) using satellite images provides an insight of whether a location is naturally rich or poor;
- The number of reef types is another measure to characterise the natural complexity, and thus richer or poorer substrate conditions of locations;
- The percentage of the surface area of the outer reef as compared to the total reef surface available in a particular fishing ground is used as indicator to weight the naturally richer potential of the outer-reef habitat. This factor allows a location to be classified as being naturally equipped with a larger or smaller reef area of high productivity, and thus being naturally more or less rich.

Any of the four defined finfish fishing pressure risk groups (<1 to >10 t/km^2 reef/year) could be the result of any of the four possible combinations of natural potential and resource status, each being either low or high.

For example, sites that are classified as:

- Of naturally rich potential + actually good resource conditions + actually low finfish fishing pressure ⟶ represent the best possible scenario;
- Of naturally poor potential + actually low resource conditions + actually highest finfish fishing pressure ⟶ represent the worst possible scenario;
- Of naturally rich potential + actually low resource conditions + actually low to highest finfish fishing pressure ⟶ indicate a decline in resource conditions due to finfish fishing factors (and possibly other stress factors).

Monitoring

The evidence from the survey results calls for **immediately establishing and implementing monitoring programmes**.

- If current finfish fishing pressure is unknown, run the **finfish fishing pressure risk model** OR implement a **first baseline study** using a minimum dataset questionnaire survey to estimate total annual finfish catch by major habitats (sheltered coastal reef, lagoon, outer reef).

The scale of known current finfish fishing pressure on the community's appropriated reef resources determines the urgency of the monitoring programme (Table 4.14).

Table 4.14: Indicators used to monitor impact of finfish fisheries and success of fisheries management interventions

Family	Socioeconomic indicators		Finfish resource indicators			Monitoring approach						
	Catch proportion (%)	Average reported size	Biomass	Density	Size	Fishery catch composition survey [1]				Marketing survey [2]	Underwater resource survey	
Acanthuridae		↓	↑	↑	↓	+	++	+++	+++	+	++	++
Carangidae	↑			↓		+	+	++	+++	+		
Holocentridae	↑					+	++	++	+++	+		+
Labridae	↑		↓			++	++	++	+++	+		++
Lethrinidae	↓		↓		↓	+	++	++	+++	+	+	++
Scaridae [3]		↓	↓	↓	↓	+++	+++	+++	+++	+	++	++
Siganidae		↓	↓			++	++	+++	+++		+	++
Serranidae				↓							+	+
Piscivores (Lutjanidae & Serranidae)			↓								++	++
Frequency of monitoring						Once every 2–4 years	Once every 2 years	Once every 1–2 years	Once every 1 year	Continuous	Once every 1 year	Once every 6 months
Finfish fishing pressure (t/km^2 reef/year)						<1	1-5	5-10	>10		<1-5	>5

[1] Fisheries catch composition = average reported or measured size (or weight) per specimen caught; [2] marketing surveys = weight of individual specimens compared over time (applies for commercial catch only); [3] even under lowest finfish fishing pressure.

- Include all community groups, and male and female fishers as equal stakeholders in monitoring programmes (Table 4.15).

Table 4.15: Stakeholder engagement and frequency of monitoring activities under ideal and minimum conditions

		Proposed scenario to be achieved by 2020	Scenario to be implemented by current national capacities	Advantages	Disadvantages
Government and/or NGOs	Catch survey	Once a year	Once every 3–4 years	Concise, accurate database for long-term monitoring	NGO's engagement may be project-dependent, and may not be fully aligned with government-operated system
	Marketing surveys	Monthly	Every six months	Complementary information on commercial catch, could be integrated into already ongoing market surveys	Covers commercial catch only; NGOs may lack a comparative authority to government
	Underwater surveys	Twice a year, complete assessment	Once a year, major target groups	Database for references	
Local community (complementary)	Catch survey (log-book)	Continuous		Continuous database on catch composition and criteria, community engagement	Potentially poor quality and accuracy of data
	Marketing surveys				
	Underwater surveys	Twice a year, major target groups	Once a year, major target groups	Sense of ownership, pride	Lower quality of data

Reduction of finfish fishing pressure

The effects of fishing must be reduced where any likelihood exists that the current finfish fishing pressure exceeds sustainable productivity. Given the fact that pristine coral reef conditions no longer apply for PICTs, **exploitation rates at ≥5 t/km^2 reef/year are considered unsustainable**. However, applying a **precautionary approach, catch rates >1 t/km^2 reef/year** are already considered as indicating current or possible future detrimental effects given the large range of differences in natural conditions and fishery characteristics.

Taking into consideration the general current resource-user status of subsistence and small-scale fisheries, the following **general recommendations** apply (Table 4.16):

- Ban all speardiving at night time;
- Ban all speardiving using SCUBA equipment;
- Allow gillnetting for all users only if gillnets with a minimum mesh size (>6.4 cm) are used, and establish the following regulations:
  - maximum length (no longer than 150 m);
  - minimum distances between gillnets (>30 m apart);
  - may not be left for more than four hours in the water;

  - must be inspected within two hours after setting the net;
  - may not be used at night;
  - may not be used more than once every 24 hours;
  - corals must not be broken during removal of net;

It is important to aim regulations at avoiding target areas, in particular reef tops, that are known to be already highly impacted.

- Establish protected areas to recover natural potential and/or protect production.
- Re-establish traditional *tabu* zones, if applicable and still healthy.
- To enable production to return to pristine or semi-pristine levels and be a source of spillover to neighbouring areas, protected areas should be:
  - rightly placed at locations of high larval settlement;
  - areas of healthy substrate (i.e. high live-coral cover, high complexity of topography at different scales facilitating settlement and shelter for many species) or presenting a combination of ecosystems (i.e. mangroves as unique nurseries and habitat of specific fish, etc.);
  - permanent (re-opening areas has an overfishing effect, which defeats the positive effect of repopulation);
  - locally managed and enforced;
  - regularly monitored.
- Give specific protection to areas of spawning aggregation (SCRFA 2010): such areas, which are spatially and temporally discrete gatherings of often monospecific fish for the only purpose of reproduction, have a long history of commercial importance, and some are intensively fished. Unmanaged fishing on spawning aggregations can rapidly deplete fish populations with undesirable impacts on the livelihoods of communities who depend on them.

Conservation of coastal resources vulnerable to overfishing practices and environmental threats (climate change, invasive species, deforestation) for present and future generations is already being pursued in Micronesia through the Micronesia Challenge. This initiative aims to conserve at least 30% of the nearshore resources by the year 2020 (Micronesia Challenge 2010).

There are three major options available to reduce finfish fishing pressure:

(1) **Limit the catch rate determined by commercial finfish fishing**, i.e. the proportion of catch sold outside the community targeted for interventions.
Possible limitations are:
  a. Limit the number of authorised commercial finfish fishers;
  b. Limit the catch quota per commercial finfish fisher;
  c. Limit the number of fishing days permitted for each commercial fisher.

(2) **Divert current reef fisheries towards pelagic species** (which may require investment in establishing FADs where possible and feasible; and/or adequate fishing vessels; and change in fishing gear and strategies). Emphasise targeting passages and the outer reef for reef fisheries rather than the sheltered coastal reef or lagoon (including back-reef) as an intermediate measure towards this end.

(3) **Divert fishing pressure from the current target species towards other target species** by reducing or banning the use of speardiving. This will reduce fishing pressure and may

help Siganidae and Scaridae stocks to recover; also reduce the frequency and density of gillnetting and make a mesh size of >6.4 cm mandatory.

Table 4.16: Summary of major effects of fishing techniques on trophic composition and overall fishing impacts

Fishing technique	Effects on catch composition by trophic groups		
	Higher proportions	**Lower proportions**	**Overall fishing impact**
Line-fishing (handlines, rods, deep-bottom lines)	Piscivores (Lutjanidae, Serranidae)	Herbivores (Acanthuridae, Scaridae)	Less detrimental
	Carnivores (Lethrinidae)		
Gillnetting (castnetting)	Herbivores (Mullidae, Acanthuridae)	Piscivores	Potentially detrimental if mesh size smaller than 6.4 cm and if frequency and density of gillnets used are too high
		Carnivores (Labridae)	
Speardiving	Herbivores (Acanthuridae, Scaridae, Siganidae)	Carnivores (Lethrinidae)	Detrimental, particularly if done at night using torch light; also very size-selective, targeting larger specimens

Results of the regional analysis show that, generally, male fishers account for most of the time spent fishing, catch and impact. While finfish fisheries interventions should consequently mainly target male fishers, in Melanesian communities, however, female fishers need to be included as a major target group due to their significant involvement in finfish fisheries.

To successfully use any of the above recommendations or a combination thereof, the preconditions as shown in Figure 4.22 are considered essential.

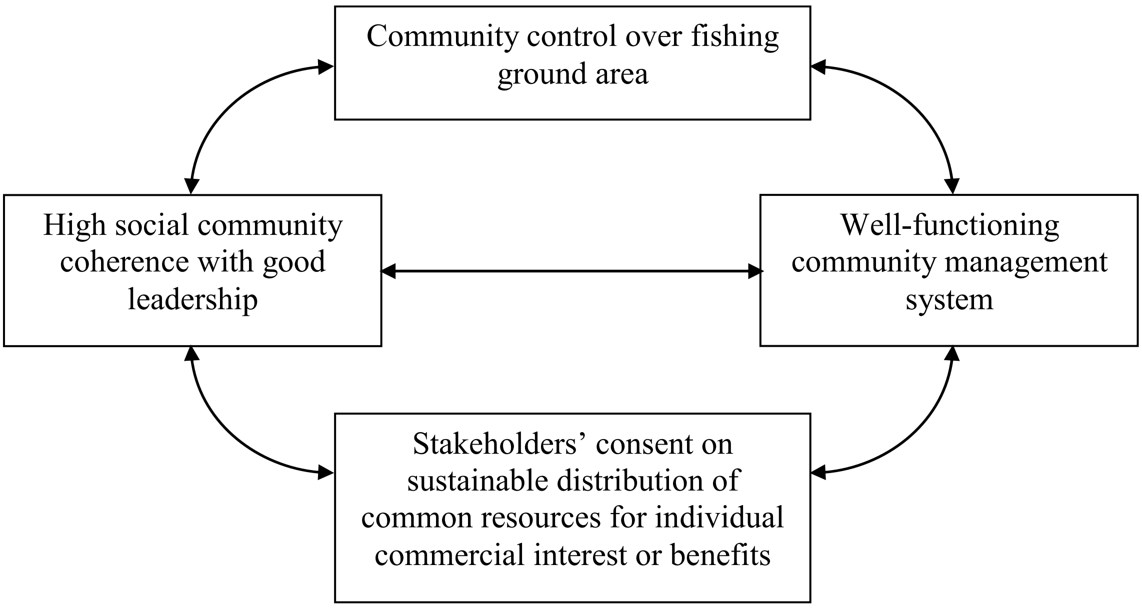

Figure 4.22: Preconditions to ensure the success of the fisheries management interventions proposed.

These preconditions are also required for successful compliance and enforcement of regulations set in place, and taking into consideration any possible conflicts that may rise from the rights described in any by-laws, or other community-based and governmental regulations.

Governmental and fisheries authorities can support any existing community management systems by:

- exploring and supporting the development of alternative income sources; and
- redirecting finfish fishing pressure from reef and lagoon to pelagic resources where appropriate, which may call for assistance in training fishers and access to new fishing techniques, vessels and gears, and possibly FADs.

Governmental and fisheries authorities can further support a reduction in commercial finfish fisheries by establishing – as far as possible – supply and demanddriven price mechanisms. Determining current production and marketing costs (including labour and time costs) and comparing them to current end-user prices for wild-caught finfish fisheries produce will help to determine the actual revenues needed by fishers and agents. Government may be able to ensure that the needed and justifiable revenues are obtainable by establishing a minimum pricing system that is economically viable and socially acceptable for fishers, agents, and end-users. An effective pricing and revenue distribution system may help to generate comparative financial income at lower catch rates.

Marine Protected Areas (MPAs)

For MPAs to be effective the following are required:

- A high compliance and enforcement rate;
- A long-term approach;
- Appropriate selection of the location considering ecological characteristics and resource potential, and socioeconomic needs and restrictions. It is important to ensure that the needs and limitations of all stakeholders, including female fishers, are taken into account when identifying appropriate locations for MPAs or other restricted fishing ground areas, in order not to jeopardise males' and females' contribution to supplying food and income for their families;
- Community control over the targeted fishing ground area; alternatively, governmental control;
- A high social community coherence with good leadership; alternatively, a well-defined governmental strategy and legal system for protected areas;
- A well functioning community-management system; alternatively a well functioning governmental enforcement system.

Table 4.17: Assessment of all 63 PROCFish sites according to their natural potential, actual resource and user status, and recommended fisheries management strategies

Classification system	Assessment of natural, current and use status			Reference points	Fisheries management strategies				
Class	Resource status	Finfish fishing pressure	Natural potential	PROCFish sites	Monitor	Reduce fishing pressure	Change fishery (habitat)	Change fishery (target species trophic)	Establish MPA for recovery
1	Good	<1	Good	Ailuk, Koror, Likiep, Ouassé, Rarotonga	+	-	-	-	+
2	Good	1–5	Good	Arno, Kiritimati, Fakarava, Laura, Nukufetau, Raivavae	+	-	+	+	+
3	Poor	<1	Good	Dromuna, Koulo, Lakeba, Mali, Moindou, Ngarchelong, Ngatpang, Oundjo, Panapompom, Thio, Vailala, Yiin	+	-	+	+	+
4	Good	5–10	Good	Rarumana, Uri-Uripiv	++	+	+	+	+
5	Poor	<1	Poor	Ha'atafu, Manuka	++	+	+	+	-
6a	Poor	1–5	Good	Halalo, Lofanga, Luengoni, Maskelyne, Moso, Muaivuso, Palmerston, Riiken, Romanum, Sideia	++	++	++	++	++
6b	Poor	5–10	Good	Andra, Chubikopi, Mangaia, Manono-uta, Paunangisu, Piis-Panewu	+++	++	+++	++	++
7a	Good	5–10	Poor	Kuria	+++	++	+++	++	-
7b	Poor	1–5	Poor	Niue	+++	++	+++	++	-
7b	Poor	5–10	Poor	Aitutaki, Tsoilaunung	+++	+++	+++	+++	-
8a	Good	>10	Good	Abaiang, Airai, Abemama, Funafuti, Nggela	++++	+++	+++	+++	+++
8b	Good	>10	Poor	Marau, Niutao, Vaitupu	++++	++++	++++	++++	-
9a	Poor	>10	Good	Maatea, Mataeia, Salelavalu, Tikehau, Vailoa	++++	++++	++++	++++	++++
9b	Poor	>10	Poor	Futuna, Nauru, Vaisala	++++	++++	++++	++++	-

Finfish fishing pressure (t per km² reef area per year).

4.4.4 Prediction model of giant clam catch rate in Pacific Island countries and territories

The objectives of this section are:

- to provide a model of giant clam catch rate that allows fisheries managers to predict giant clam catch rates in any rural coastal community where conditions are comparable to the character of the 63 communities and fishing grounds studied within an error margin of 24%;
- to equip fisheries managers and planners with a tool to compare rural, coastal fishery-dependent communities in terms of giant clam catch rates for identifying priority areas and communities for interventions.

This model was based on recognising regionwide:

- the importance of the giant clam fishery;
- the serious degree to which giant clam stocks are already impacted, including local extinction of certain species;
- the vulnerability of the remaining giant clam stocks due to naturally determined variation in distribution and recruitment potential, and their slow growth rate to reach sexual maturity and to significantly contribute to reproduction of stocks;
- the pressing need for giant clam fisheries management interventions to allow recovery of the natural potential for future use.

The process:

The model was developed using socioeconomic and fishery data collected in 63 communities in 17 PICTs using a 'forward selection – leave-one-out –' approach in R statistics. The leave-one-out error rate is 24%, i.e. in 76% of all predicted cases the prediction of any site's giant clam catch rate is correct. Please note that the giant clam catch rate includes all species, i.e. Tridacnidae and *Hippopus* spp. and, therefore, does not give any information or prediction on species composition of the catch rate. Also, the catch rate (kg) is based on assuming an average wet weight of 0.5 kg per specimen collected (Kronen *et al.* 2007). Catch rates can consequently be corrected if the average wet weight per specimen is locally known.

Modelling is done by using the formula:

Predicted catch per km^2 reef (kg per year):
~ country + percentage of households earning primary income from salary + percentage of adult population with secondary education + total number of fishers + average per capita finfish consumption (kg per year) + surface area in km^2 of lagoon including back-reef + longitude of site + presence/absence of a high island with a coastal reef + presence/absence of a coral island without lagoon

Input required:

(1) Country/Territory;
(2) The proportion of households in a community earning primary income from salaries;
(3) The proportion of adults in a community having acquired secondary education;
(4) The total number of fishers in a community;
(5) The average per capita finfish consumption in the community;

(6) Lagoon and back-reef surface areas;
(7) Longitude of the community;
(8) Absence or presence of a high island with a coastal reef;
(9) Absence or presence of a coral island without a lagoon.

Input variables can be obtained using a minimum questionnaire survey. The questionnaire survey can be designed following the manual for the collection of a minimum dataset (Kronen *et al.* 2007), including the necessary questions as indicated in the beginning of each chapter that applies and as referenced in the following. Data entry in the SEMCoS software system will prompt the requested results. How and from which sources to best obtain the additional data is indicated in the following:

(1) Enter the name of the island country or territory concerned;

(2) From the total number of households in the community surveyed determine the percentage of households that earn primary income from fisheries;

(3) From the total number of adults in the households surveyed determine the total number of adults (extrapolating the percentage of adults in the households surveyed to the total number of households in the community), and determine the percentage of adults that have acquired secondary education;

(4) To obtain the total number of male fishers (and female fishers) for finfish fishing (and invertebrate fishing) use Section 3.4.2 'number of fishers' in Kronen *et al.* 2007.

(5) To determine the average per capita finfish consumption in the community use Section 3.4.2 'consumption' in Kronen *et al.* 2007. Please note that our per capita consumption figures are corrected by an age-gender factor (Kronen *et al.* 2007);

(6) Using satellite imagery, delineate the total appropriated fishing ground per each community, identify the total lagoon surface (excluding sheltered coastal reef, mangroves, passages and outer reef) and determine within this boundary the total lagoon surface area including the back-reef;

(7) Take the longitudinal coordinates of each community by using GEONet Names Server (GNS) (NGA 2010) (http://earth-info.nga.mil/gns/html/index.html);

(8) Determine, using the UNEP Islands website (UNEP 2010) (http://islands.unep.ch/isldir.htm), whether or not the island on which each community is located is a high island with a coastal reef (for the latter, check using satellite imagery as described in (6) above);

(9) Determine whether or not the island on which each community is located is a coral island without lagoon (for the latter, check using satellite imagery as described in (6) above).

Consequences for fisheries management

The overall objective of this model is to help policy-makers and fisheries managers to identify:

- priority areas for giant clam fisheries management interventions;
- possible surplus and deficit fishing grounds for future food security and rural development planning, and for recovery and/or conservation of natural giant clam stocks.

The strategic and practical implications of the results are:

- To use the model (to be made available on the SPC webpage) to prioritise intervention areas, and to identify surplus areas for the supply of giant clams as a commodity (income generation);
- To use the areas and their current production deficit/surplus to verify how possible income can be generated at sustainable fishery levels from any surplus areas;
- To give priority to areas with a currently high likelihood of unsustainable giant clam fisheries and develop rural management interventions, focusing on the development of protection and conservation measures for the remaining giant clam stocks.
- To introduce regulations and monitor compliance with closing of the fishery and/or minimum shell length sizes, in order to conserve, recover and/or assess giant clam resources as a future option for fulfilling the subsistence and income needs of the communities concerned.

4.4.5 Socioeconomic drivers and their relation to physical variables explaining current fishing pressure on giant clams

Summary

- Physical or natural factors determine regional distribution;
- The hydro-geographic conditions in atoll islands favour recruitment and have a naturally higher potential than open systems (as represented by other island types);
- Footprints (impacts of historic exploitation) and current fishing pressure on giant clams are visible from the analysis of socioeconomic fishery survey data;
- The average reported shell length of harvested specimens indicates whether the fishery is sustainable or unsustainable;
- Most reported giant clam catch by shell length falls into the fishery group classified as unsustainable, i.e. a predominant collection of young and male specimens with no or little contribution to recruitment;
- Collection of small specimens in finfish fisheries is also highly associated with unsustainable resource use.

Indicators:

Indicators for high resource density (average density for *Tridacna maxima, T. squamosa*, *Hippopus hippopus*, manta-tow board survey data), suggesting lower vulnerability to overexploitation, and indicators for lower fishing pressure on giant clams, include the following.

Physical parameters:

- Atoll islands have the best natural densities and are less vulnerable to fishing pressure than the other island types;
- The larger the island area (land surface of countries studied) and the smaller the distance from CoB, the higher are the densities and the less vulnerable is the stock to fishing pressure.

Socioeconomic indicators at national scale:

- As the percentage of urban population and per capita GDP increase, the economic development potential improves and the more access people have to alternative income sources. With more options, people are more likely to change their lifestyle, becoming less dependent on traditional marine resources and, therefore, reducing fishing pressure.

Socioeconomic indicators at community scale:

- As the distance to markets increases, the proportion of commercial catch decreases, and fishing pressure is reduced;
- The higher the proportion of commercial finfish catch, the more alternative income is generated from finfish fisheries, resulting in less pressure on giant clams for commercial exploitation;
- The lower the average amount of remittances received by households in the community and the lower the population density over the appropriated reef surface area, the lower is the dependency of the community on fisheries resources for subsistence and income, and the lower is the fishing pressure on giant clams (and other wild-caught resources).

Indicators for high catch rates suggesting high risk of overexploitation:

Physical parameters:

- Atoll islands: best natural densities, prompting high exploitation rates;
- High islands, or high complexity of reef systems with good natural potential, prompting high exploitation;
- Longitudinal and latitudinal gradients influencing natural distribution and prompting exploitation accordingly.

Socioeconomic indicators at national scale:

- The lower the national population density (people per km^2 of total land surface), the lower the national economic development potential, and the higher the Consumer Price

Index (CPI), the higher is the demand for cash income to cope with the generally high living cost, and the higher are the catch rates (subsistence and commercial catch).

Socioeconomic indicators at community scale:

- The lower the education level of the adult population and the smaller the proportion of households earning income from salaries, the higher is the fishing pressure;
- The larger the average household size and the more traditional (rural) is the socioeconomic environment, the higher is the fishing pressure.

Analysis, results and discussions

Respondents in the 63 communities studied use vernacular names. Vernacular and scientific identification systems differ significantly and follow a different system making it difficult, and at times impossible, to clearly relate one system to the other. Consequently, some of the information collected from fishers can be related to single species, while other data cannot be separated by species. In the following, information explicit by species is indicated using scientific species names. The use of the term 'giant clams', however, generalises and includes data of all species of Tridacnidae and *Hippopus* spp.

Regional distribution of giant clam catch rates

The regional distribution of catch rates (defined as numbers of giant clams of reported annual catch per ha of available reef, Figure 4.23) shows lowest catch rates for Micronesian countries, and high catch rates for the most eastern countries, particularly French Polynesia, the Line Islands (Kiribati) and Cook Islands. These examples of high catch rates are represented by communities that are located on atoll islands and that have a dominance of *T. maxima* in their reported catch composition. High giant clam catch rates are also found in some of the Melanesian countries and communities studied.

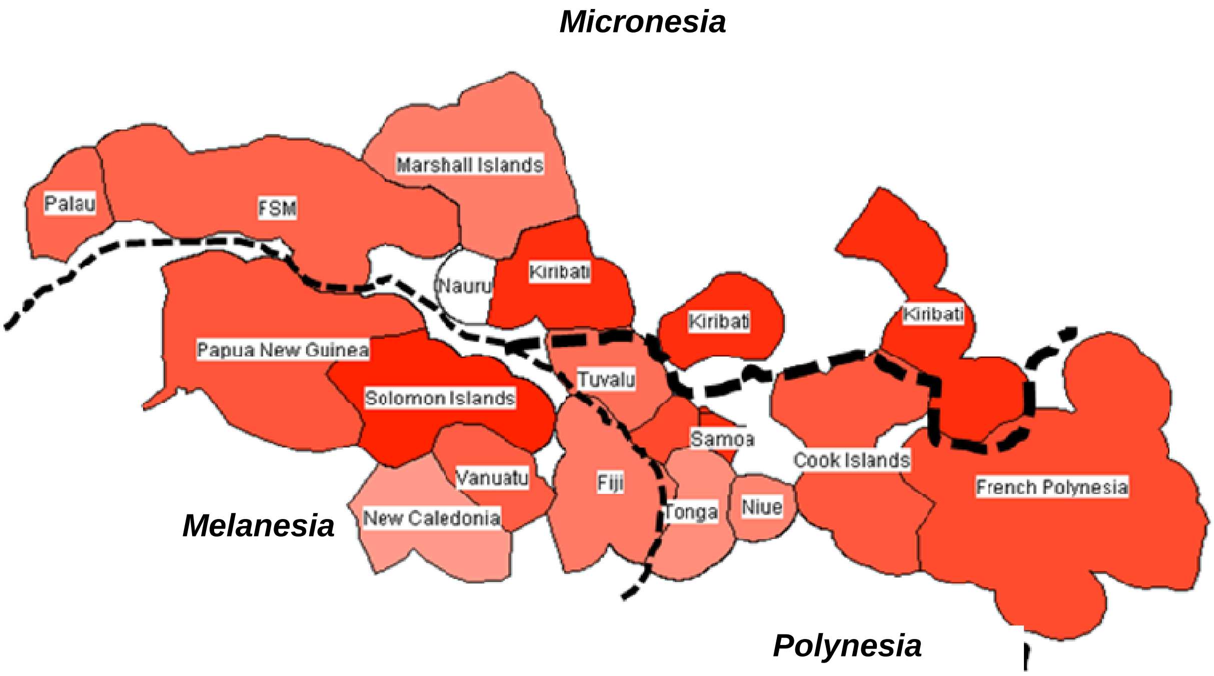

Figure 4.23: Regional distribution of catch rates of giant clams (log of numbers/ha reef/year)). Catch rates increase from lowest to highest red intensity; white indicates no giant clam catches.

While there is no doubt that physical factors determine natural distribution and densities of giant clam populations, the regional distribution of catch rates also suggests that such physical or natural factors are not the only drivers for exploitation levels.

This conclusion is further illuminated by using five selected socioeconomic variables and their statistically highly significant correlation with the reported annual giant clam catch. The five selected variables include four variables at the community level: population size, commercial finfish catch, proportion of households earning primary income from salaries, and average household expenditure. The single variable at the national scale is per capita GDP.

- Giant clam catch rates are a function of the population size of the community, particularly if comparing – as in our survey – fishery-dependent coastal Pacific Island communities (Figure 4.24). To put it simply, the more people there are, the higher is the catch rate.

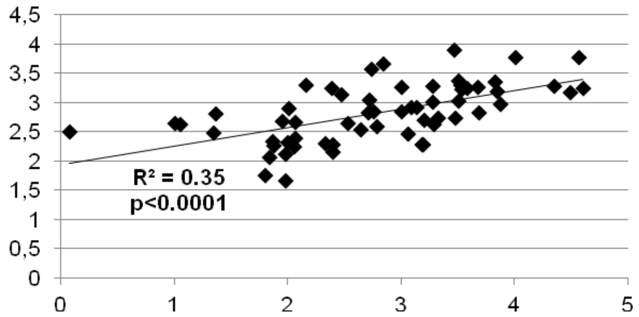

Figure 4.24: Reported giant clam catch rate and total population of the community studied.
Data are log transformed; only sites with giant clam records are considered, n = 60.

- Giant clam catch rates are highest where people have highest dependency on fishery produce for income generation. Giant clam catch rate increases as more finfish is caught for commercial (income) purposes (Figure 4.25), and decreases as more households in a community generate primary income from salaries (Figure 4.26), and more households can spend cash for their average household expenditures (Figure 4.27).

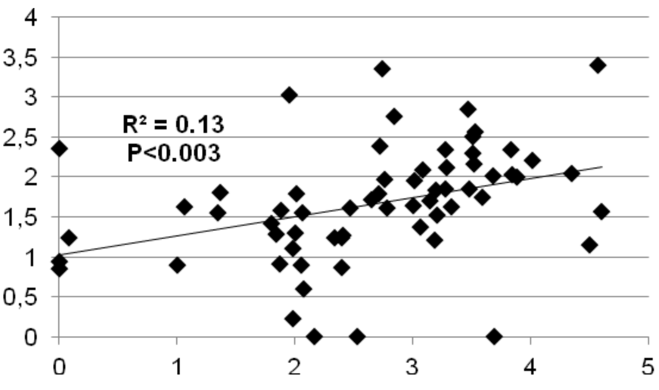

Figure 4.25: Reported giant clam catch rate and total commercial finfish catch in communities studied.
Data are log transformed; only sites with giant clam records and reported export finfish fishery are considered, n = 57.

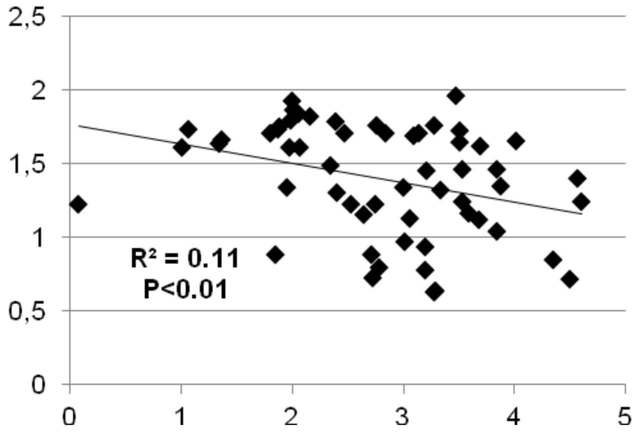

Figure 4.26: Reported giant clam catch rate and the proportion of households earning primary income from salaries in the community studied.
Data are log transformed; only sites with giant clam records and records on households with primary income from salaries are considered, n = 57.

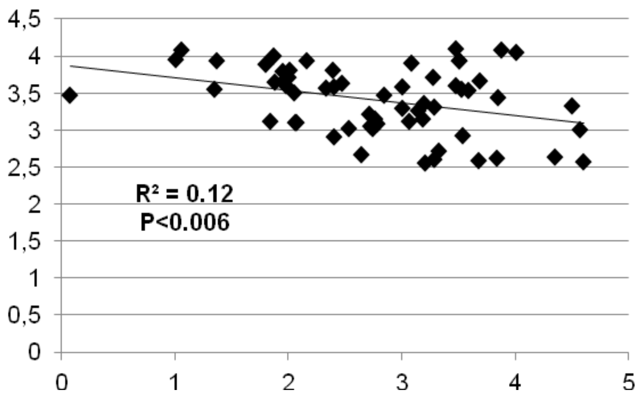

Figure 4.27: Reported giant clam catch rate and the average household expenditure level in communities studied.
Data are log transformed; only sites with giant clam records are considered, n = 60.

- Giant clam catch rates are also related to the overall economic potential of the country's economy. The higher the national per capita GDP, the lower the giant clam catch rate (Figure 4.28).

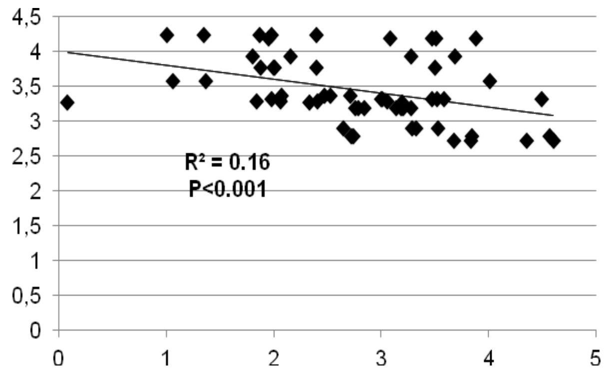

Figure 4.28: Reported giant clam catch rate and national per capita GDP.
Data are log transformed; only sites with giant clam records are considered, n = 60.

Reported catch sizes of giant clams as indicators of fishing pressure

Data on average catch sizes reported from respondents were grouped into four size classes applying a precautionary approach that takes into account published information on minimum shell length for giant clams (various species) required to reach spawning, and shell length to reach important spawning potential.

Accordingly, the four shell length classes harvested are considered as follows:

0–10 cm	these small specimens indicate a high likelihood that the fishery is unsustainable;
10–14 cm	these specimens are too young to have reached good spawning potential;
14–20 cm	these specimens have contributed substantially to reproduction, i.e. indicate a high likelihood of that fishery is sustainable; and
>20 cm	these large specimens are important for mass reproduction and should therefore preferably remain as important brood stock.

- Analysis of the data collected according to the shell-length groups defined above shows that most catches of giant clam species are unsustainable or detrimental to the stock (Figure 4.29), i.e. overfishing of either premature stock or collection of stock that has not yet significantly contributed to reproduction is occurring.

- This assessment of current giant clam fisheries is generally confirmed for *Tridacna maxima* (Figure 4.30), but appears slightly more favourable for the *Hippopus hippopus* (Figure 4.31) fishery. However, it should be noted that the sample size of *H. hippopus* data is small, which could possibly indicate that *H. hippopus* is exploited reasonably only at sites where stocks are still in good condition.

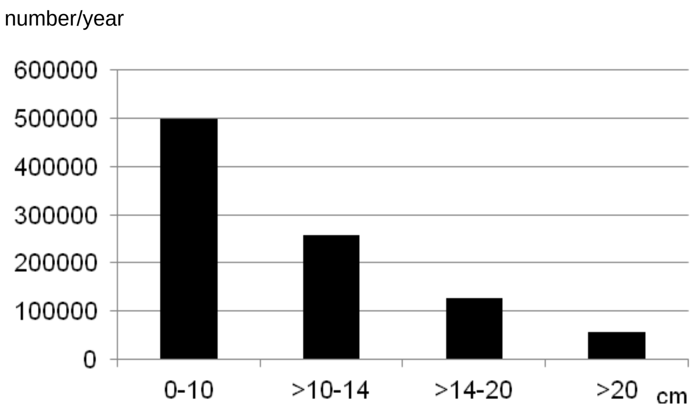

Figure 4.29: Proportions of reported shell length (cm) by length group for all giant clam catches in communities studied.

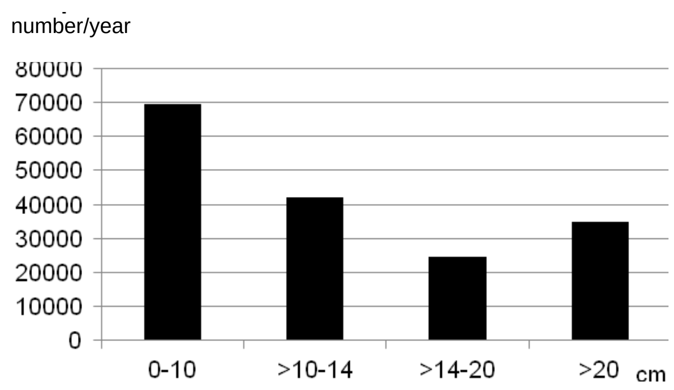

Figure 4.30: Proportions of reported shell length (cm) by length group for *Tridacna maxima* catches in communities studied.

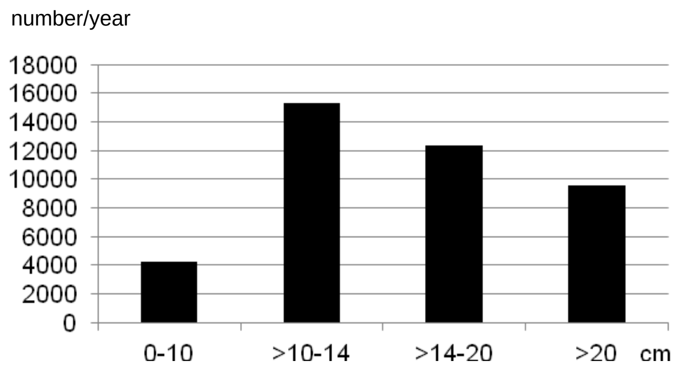

Figure 4.31: Proportions of reported shell length (cm) by length group for *Hippopus hippopus* catches in communities studied.

- The relationship between fishing pressure and impact is further underpinned by Figure 4.32: countries with the highest reported clam catches (total numbers/year) have the highest proportions of small shell lengths. Although shell sizes among different giant clam species may vary considerably, this conclusion is supported by the fact that most of the reported catch is represented by *Tridacna maxima*, i.e. 60% for Solomon Islands (*T. squamosa* 10.6%, *H. hippopus* 13.7%), 99.5% for Kiribati, 91.7% for Samoa, 100% for Wallis and Futuna, and 75.7% for Papua New Guinea (*T. squamosa* 10.6%, *H. hippopus* 13.7%).

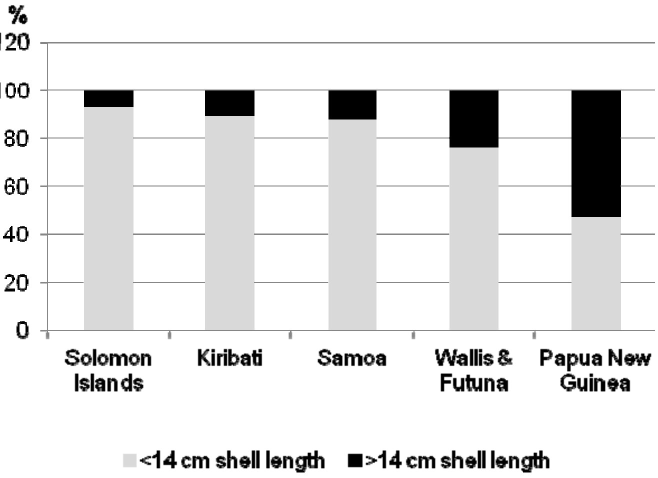

Figure 4.32: Proportion of unsustainable shell length representation in total annual reported catches for countries studied with overall highest giant clam catches (total annual numbers collected).

Application of finfish fishing pressure risk groups (Refer to Sections 3.4.1 and 3.4.2 in Kronen *et al.* 2007) confirms that finfish fishing and giant clam fishing pressure are related. The higher the current finfish fishing pressure, the higher was – or possibly still is - giant clam fishing as made visible in reduced reported shell length of giant clams (Figure 4.33).

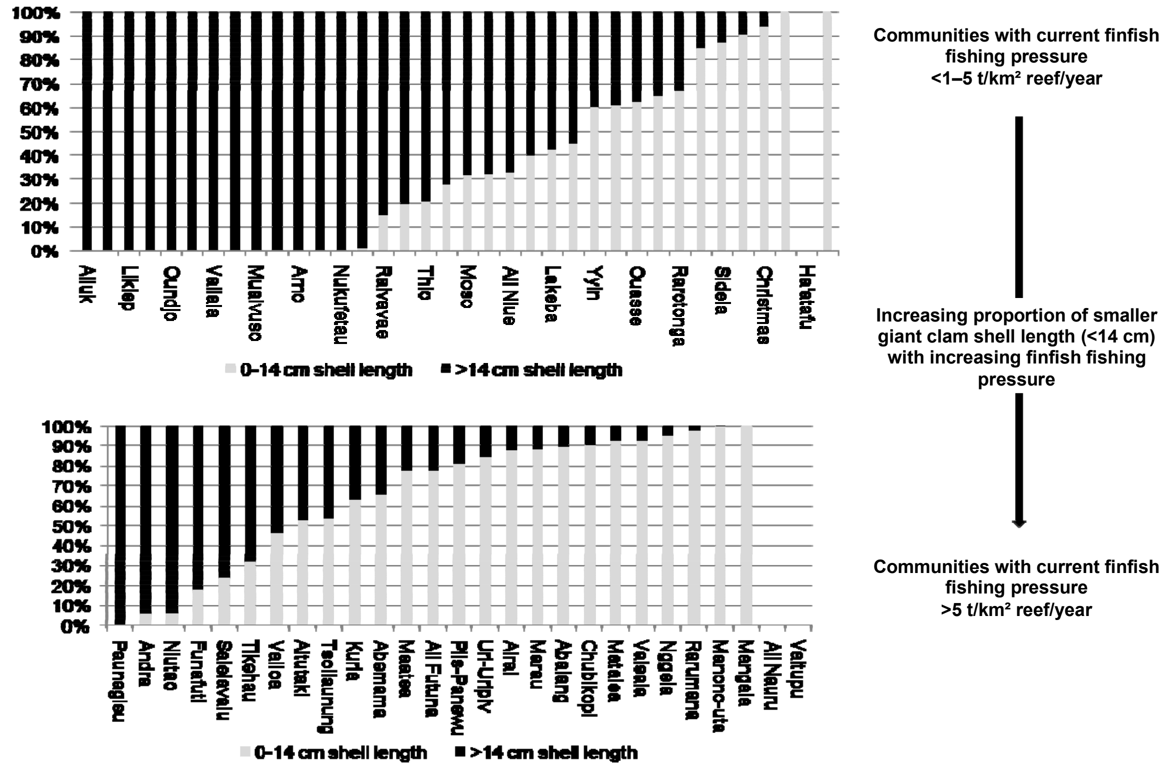

Figure 4.33: Comparison of sites classified with current low (<1-5 t/km^2 reef/year) and high (>5 t/km^2 reef/year) finfish fishing pressure and the increasing proportion of smaller-sized giant clams (shell length, cm) in reported annual catches.

Explaining regional variation in densities of Tridacna maxima, T. squamosa and Hippopus hippopus and total giant clam catches

Knowledge of the main drivers of the regional variation found in giant clam densities and current reported catches helps to identify entry points for fishery management interventions to reduce future fishing pressure, and indicators for future monitoring.

Multivariate statistic analysis (redundancy analysis [RDA], using the CANOCO software programme) selected nine drivers to explain >70% of the total variation in resource density data of three major giant clam species (*T. maxima*, *T. squamosa*, *H. hippopus*) as surveyed by manta-tow board counts across all communities studied (Figure 4.34).

Major results and conclusions are:

- Geographic or physical parameters are important as they determine resource distribution and natural density. Most importantly, atoll islands have a hydro-geographical condition that favours recruitment, and thus atolls have higher natural densities than other island types. Also, increasing distance from CoB (centre of biodiversity) is a parameter for decreasing natural distribution. The total land surface per country may characterise physically favoured sites for agricultural production and thus alternative income in the primary sector.

- However, while, unarguably, physical conditions determine natural distribution and densities, fishing impact (historic and current) shows in the fact that the highest proportion of the regional variation (if correcting for any other variables) found is determined by socioeconomic drivers:

  - The higher the per capita GDP and the higher the proportion of urban population and thus the better the general economic conditions for development at national scale, the better is the resource density (the less is the fishing pressure);
  - The more people are dependent on the fishery, i.e. the higher the commercial finfish catch, the larger the remittances received to cover living cost and the more people there are per reef surface unit, the lower is the natural resource density (the higher is the fishing pressure on giant clams).

- The most important result, however, is the fact that the interrelations between physical and socioeconomic parameters explain a high proportion of the regional variation (>22%), i.e. people’s behaviour is driven by economic and socioeconomic conditions. However, the fishery also adapts to naturally determined resource conditions. Also, on a regional scale, the influence of both favourable and unfavourable natural and socioeconomic conditions is visible.

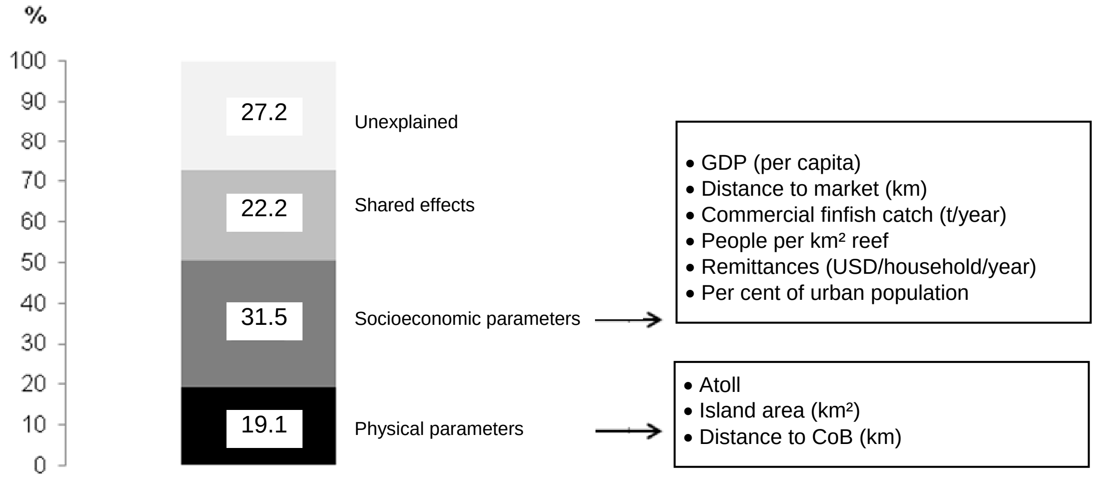

Figure 4.34: Variation in average densities (manta-tow board survey data) of three major giant clam species (*Tridacna maxima*, *T. squamosa*, *Hippopus hippopus*) explained using physical and socioeconomic variables (RDA, CANOCO software).
RDA = redundancy analysis using the CANOCO software programme.

- While the above results are based on multivariate analysis, i.e. the interrelationships between each single and all other parameters, the argument is also confirmed by linear relationships (correlations, with significance level denoted by number of *, with *** representing the highest significancy), i.e. correlations between individual parameters and average giant clam (three species) resource density.

The overall mean density of *Tridacna maxima*, *T. squamosa* and *Hippopus hippopus* increases with corresponding increases in:

- the proportion of urban population (indicator for development) **;
- the per capita GDP (indicator for development) **;
- the commercial finfish catch (indicator for alternative income from fisheries) *;
- the country land surface area (indicator for alternative income from agriculture) ***;

and also increases in atoll islands (indicator for natural favourable conditions) ***.

The overall mean density of *T. maxima*, *T. squamosa* and *H. hippopus* decreases with a corresponding decrease in:

- the remittances received (indicator for high dependency on fishery for subsistence and income);
- people density (over reef surface area) (parameter for general fishing pressure) ***.

The same multivariate statistic analysis approach (redundancy analysis [RDA], using the CANOCO software programme) was used to identify nine drivers that explain 70% of the total variation in total annual reported giant clam catch as recorded by socioeconomic fishery surveys across all communities studied (Figure 4.35).

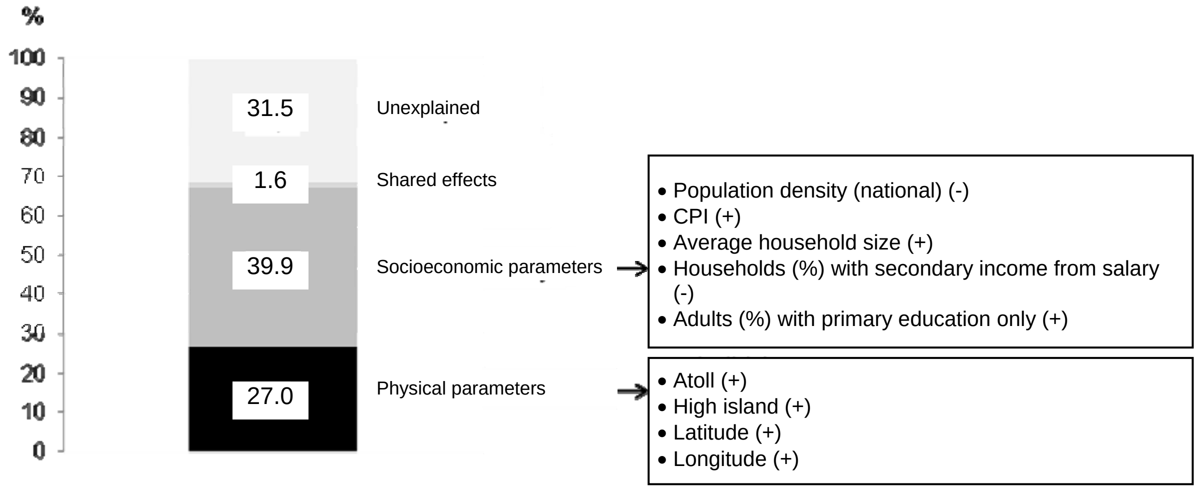

Figure 4.35: Variation in annual giant clam catches (socioeconomic fishery surveys) explained using physical and socioeconomic variables (RDA, CANOCO software).
RDA = redundancy analysis using the CANOCO software programme.

The major results and conclusions are:

- The importance of geographic or physical parameters determining resource distribution and natural density and thus fishery potential are confirmed. Again, the positive effect of naturally favoured atoll islands (recruitment) and high islands, and the dependency of natural distribution on longitudinal and latitudinal variations are visible.

- Again, socioeconomic factors (if correcting for any other variables) alone determine the greatest variation in annual catch:

  - The lower the national population density, the higher the consumer price index (CPI) (a parameter for development and increasing living standard), the larger the average household size (a parameter for more traditional lifestyle), the lower the proportion of households with secondary income from salary (a parameter for less alternative income options for the primary sector) and the higher the percentage of adult population with only primary education (a parameter for low development and few options for accessing alternative income sources from secondary and tertiary sectors in rural conditions), then the higher is the annual giant clam catch.

- In the case of explained variation in giant clam annual catches, however, the geographical and socioeconomic parameters have few shared effects (1.6%) indicating that physical parameters set the potential, and socioeconomic parameters determine the exploitation level, and both operate largely independently from each other.

4.4.6 Invertebrate fisheries management interventions – analysis of socioeconomic and fishery factors

Coastal Fisheries Policy

- The future of the artisanal and commercial invertebrate fishery sector and the livelihood of coastal communities in the Pacific Island region will depend to a large extent on access to and potential of alternative subsistence and income sources, which are necessary to reduce fishing pressure on the highly targeted and mostly over-exploited commercial species, and to provide alternatives where species decline has already resulted in reduction of income.

- The harmonisation of objectives for resource use and development in particular concerning commercial invertebrate species (bêche-de-mer, trochus, lobster, giant clams), requires the periodic (short to mid-term) and long-term closure of fisheries to enable declining resources to recover, together with the provision of alternatives to coastal wild-caught fisheries. Consequently it is necessary to aim at the management of artisanal coastal invertebrate fisheries as an integral part of domestic rural development.

- Invertebrate fisheries, in particular the fishing of commercial target species, can no longer be managed independently of other resource uses and their environmental and socioeconomic impacts. The adoption of an approach that integrates development strategies in other sectors will be the only effective means to allow for closure of fisheries subject to significant resource decline. This approach must be developed in cooperation with coastal communities in order to achieve the compliance of fishers.

- Access to improvement in quality of life and income must be available to both genders equally, including capital, equipment, technology, transport, credit, training, employment and education. Gender equity in decision-making regarding resource use and use of household assets and income is vital. The implications of livelihood diversification programmes on gender participation and responsibilities, particularly focusing on gender contribution through subsistence and small-scale invertebrate harvesting, must be assessed at the outset.

Strategic planning and setting of priorities (using the following drivers and indicators)

Country and community scales

Survey results and experience demonstrate that **priority should be given at all levels to invertebrate target species that are predominantly exploited for commercial export**, but that may also be exploited for subsistence and local commercialisation, and which are subject to significant decline in many – if not all – places.

These are:
- bêche-de-mer;
- trochus;
- lobsters; and
- giant clams.

For identifying priority countries and communities (or areas) for invertebrate fisheries management and rural development interventions – including commercial (export and local) and artisanal subsistence target species – apply the following processes, focusing on their drivers and indicators at the national scale (to set regional priorities) and community scale (to set national priorities):

- **The higher the demographic pressure** *(indicators: high population density; high demographic growth rate, high dependency rate (15–64 years) at national scale)*;

- **The fewer the alternative income opportunities to fisheries** (*indicators: high percentage of adults with only primary education at community scale, and high dependency rate (15–64 years) at national scale*);
- **The higher the demand for invertebrates**;
- **And the higher the fishing pressure**.

Within selected priority areas (countries and communities) further assess which fisheries and habitats should be targeted by fisheries management and rural development interventions based on the impact they account for, and based on their contribution to food security and small-scale occasional incomes versus predominantly income-generation (commercial) fisheries. This can be done as follows:

- Determine the relative importance of major fisheries and species groups in terms of subsistence (and occasional income) and income generation by assessing quantities by impact (total catch t or numbers of invertebrates/km^2 reef/year), quality (catch composition, species and size) and value (monetary and non-monetary) at local and country level.

- Take into account any cultural and gender differences. While no major gender differences exist for most invertebrate fisheries, female fishers do not often actively participate in invertebrate harvesting that requires free-diving and mostly targets commercial species for export.

Community and individual household scales

Use the following **drivers and indicators to assess the current situation at community and household scales** and to further characterise the status of priority areas (communities, households within communities) in comparison to non-priority situations.

- Communities depending on fisheries for income have less daily per capita cash expenditure potential than do communities that depend on alternative income sources.

- Households in a community that depend on fisheries for income generation have less per capita cash expenditure potential than do households that depend on alternative income sources.

- Commercial export invertebrate farm-gate prices, particularly for bêche-de-mer, are higher than any other possible income-generation activities from wild-caught fisheries, and in many cases are higher than any existing alternative-income opportunities in the rural context.

- The estimation of current giant clam catch rates (kg/km^2 reef/year) and the consequent classification of each community into low-to-high fishing pressure groups by applying a comparative approach will identify which areas have a current deficit (or surplus) and thus require fisheries management interventions (Table 4.18):

Table 4.18: Priorities for management interventions by giant clam pressure risk group

Giant clam pressure risk group (kg/km^2 reef/year)	Priority for fisheries management interventions	Priority for integrated development
Low	-	-/+
Low–medium	+	+
Medium–high	++	++
High	+++	+++

- Ensure that adequate attention is given to females' fisheries issues, which are often invisible. This also applies for community fisheries management programmes.

Invertebrate fisheries management interventions

Knowledge of the natural potential of a site is a required input to estimate its natural productivity potential, to assess the possible impact of current (and past) fishing, and to decide which fisheries management interventions are feasible – in particular, those that aim to restore the natural potential.

The exploitation rate of invertebrate species for subsistence and small-income generation is a function of demographic pressure, highlighting the importance of the fishery for food security and livelihood. While most bivalves, gastropods and others (sea urchins) have a high growth rate and annual reproduction capacity, giant clams and lobsters are much more vulnerable to increased fishing pressure.

Commercial export species, particularly bêche-de-mer and trochus but also, to some extent, giant clams (national markets) and lobsters are vulnerable to increased fishing pressure due to their slow growth rate and the long time period required to reach a level of maturity that sustains important spawning capacity.

The only successful means of restoring vulnerable invertebrate species (bêche-de-mer, trochus, lobsters, giant clams) is a relatively long-term closure of the fisheries (≥2–3 years) rather than a seasonal closure. Implementation of such fisheries management interventions is much easier to control for exclusively commercial export species. However, any such measure will continue to fail if no alternative income opportunities are offered to the coastal communities concerned, and as demonstrated for bêche-de-mer fisheries in Papua New Guinea, Solomon Islands and Fiji Islands. If competitive alternative-income opportunities are available, the fishing pressure on these commercial target species will either be self-regulating (e.g. the trochus fishery on Aitutaki, Cook Islands) or the closure of fishery will be accepted and complied with.

Monitoring

If current fishing pressure is unknown, use the giant clam catch prediction model in the case of giant clams OR implement a first baseline study using a minimum dataset questionnaire to estimate total annual catch by habitat concerned and by species group.

Table 4.19: Indicators used to monitor impact of invertebrate fisheries and success of fisheries management interventions

Species group	Socioeconomic indicators [1]			Monitoring approach [2]					
	Total catch	**Average reported size**	**Species composition**	**Fishery catch composition survey**			**Marketing/ Agent survey**	**Resource survey**	
Bivalves				+	+			+	
Gastropods		↓		+	+			+	
Octopus		↓		+	+	++		+	
Giant clams				+++	+++	+++	+	++	
Bêche-de-mer	↓	↓	↓	+++	+++	+++	+++	++	
Trochus	↓	↓		+++	+++	+++	+++	++	
Frequency of monitoring				Every 2–4 years	Every 2 years	Every 1–2 years	Continuous	Every 1–2 years	Every 1 year
Fishing pressure (kg/km^2 reef/year)				Low	Medium	High		Low-medium	Medium-high

[1] If more than one indicator: apply combination of all indicators; [2] complementary survey approaches.

Include all community groups, and male and female fishers as equal stakeholders in monitoring programmes (Tables 4.19 and 4.20).

Table 4.20: Stakeholder engagement and frequency of monitoring activities under ideal and minimum conditions

		Proposed scenario to be achieved by 2020	Scenario to be implemented by current national capacities	Advantages	Disadvantages
Government and/or NGOs	**Catch survey**				
	Open fisheries	Once a year	Once every 3–4 years	Concise, accurate database for long-term monitoring	Expensive, NGO's engagement may be project-dependent, and may not be fully aligned with government-operated system
	Closed fisheries				
	Marketing – agents surveys				
	Local markets	Monthly	Every 6 months	Complementary information on commercial catch, could be integrated into already ongoing market surveys, includes price information	Restricted to selected species, subject to seasonal fluctuations (natural, socioeconomic); may not be compatible with governmental-operated system
	Export markets	Monthly	Monthly	Easiest way to control catch by quantity, species composition and quality (size, etc.)	Needs cooperation with agents and exporters, standardised sheets for data collection; NGOs may lack a comparative authority to government
	Resource surveys	Twice a year complete assessment	Once a year, major target groups	Database for reference and fisheries management decisions concerning exploitation level and frequency	Expensive
Community	Catch survey (log-book)	Continuous, major target groups relevant to community fisheries		Continuous database on selected catch composition and criteria, community engagement	Potentially poor quality and accuracy of data, requires training and external support
	Marketing – agents surveys				
	Resource surveys	Twice a year, major target groups relevant to community fisheries	Once a year, major target groups relevant to community fisheries	Sense of ownership, pride	Lower quality of data, requires training and external support

Reduction of fishing pressure

There is no doubt that most – if not all – commercial invertebrate fisheries in PICTs are already heavily impacted if not depleted. This applies to bêche-de-mer, trochus and, to some extent, to lobster and giant clam fisheries. **The only effective means to restore at least part of the natural potential is to reduce fishing pressure to zero, i.e. close the fisheries**.

However, **implementing such a drastic measure is unrealistic if the households that depend on these fisheries for food, livelihood and main income source are not provided with competitive alternatives**. If such fisheries remain open, or are opened periodically without allowing adequate time for restoration or control of quantities and qualities fished then, at certain locations, coastal communities with a high dependency and need for income will fish the last resources available.

In the case of commercial and economically attractive target species, the following management options are suggested:

Government and fisheries authorities can support the restoration of **commercial export invertebrate fisheries** relevant to their country's natural resource potential by:

- **Closing fisheries** until resource surveys confirm that stocks have been re-established to provide an exploitable and economically viable resource; and at the same time;

- Providing support to coastal communities and fishers concerned through exploring and developing **alternative income sources**, including providing training, credits, investments and marketing; and at the same time;

- **Establishing a commercial network for each target species or fishery** by providing a commercial exploitation licensing system that defines each location to a controllable number of agents/exporters. This network needs to be carefully designed as to avoid competition among agents/exporters and to include the coastal communities concerned at every step from the beginning.

- The **licence system** is to be based on a government-controlled opening and closure system, including the control of agent/exporter-specific catch quantities and qualities. Applying the user-care principle as used elsewhere, the respective agent/exporter is responsible to maintain stocks in the dedicated harvesting areas, is obliged to provide stock assessments according to expert-specific survey methods and subject to government controls, to pay an annual user-fee to the community/ies concerned, and to recruit fishers from the communities concerned for harvesting and processing on-site at government-controlled unit prices.

Government and fisheries authorities can support the maintenance and restoration, if necessary, of **subsistence and small-income invertebrate fisheries** by:

- **Imposing minimum and maximum catch sizes for the most vulnerable species** that are relevant to their coastal communities and local fisheries, in particular giant clams, to ensure that a certain proportion of stocks remains in the fishing grounds for reseeding;

- **Reinforcing traditional catch limits and seasonal closure** where applicable, which may at least have positive effects on invertebrate species that have a high natural reseeding and growth potential;

- **Establishing marine protected areas in close cooperation with local communities** concerned (and taking into consideration gender-specific limitations and needs) to safeguard the most important fisheries and their associated habitats as buffer and re-growth zones.

4.5 Minimum data collection required for socioeconomic fishery surveys

The use of socioeconomic fishery surveys is widely acknowledged and confirmed as a valuable tool to substitute and complement resource surveys. Socioeconomic surveys are considered of advantage as they are less demanding in terms of cost, equipment and time. Also, they allow a wide range of survey scales to be covered, from national to community, household, and individual fisher levels. Furthermore, the skills and expertise required in designing, organising, implementing and analysing socioeconomic fishery surveys are likely to be available in any of the PICTs as each country maintains ongoing national surveys and census, and some of the departments have already been exposed to regular collection of fishery data.

However, as for all surveys, **it is imperative to decide the particular purpose, expected results, target group and accuracy required of any socioeconomic survey, and to reduce all required input and effort to the least possible.**

Firstly, experiences have shown that, generally, two major survey types need to be distinguished:

a) **a baseline survey** to establish a database against which future development can be monitored; and
b) **case or event-specific surveys** that serve to characterise a precise problem to be addressed.

Secondly, for each survey there is a need to distinguish whether the comparison envisaged is:

a) spatial,
b) temporal, or
c) both spatial and temporal.

Based on the experiences prior to and during the implementation of the PROCFish survey, the minimum dataset for socioeconomic baseline fisheries surveys in PICTs was defined, and a manual published, which included fully closed and structured questionnaire surveys, explaining methods, approach, steps in the survey, data collection, data entry, analysis and basic interpretation. This manual is complemented by a Software package SEMCoS developed by Franck Magron. Both documents are available in English and French and can be downloaded from the SPC website at the following address:

English:
http://www.spc.int/coastfish/en/publications/356.html (Kronen *et al.* 2007).
French:
http://www.spc.int/coastfish/fr/publications/356.html (Kronen *et al.* 2008).

SEMCoS Software:
http://www.spc.int/coastfish/en/features/coastal-fisheries-science-and-management/software.html (SPC 2010)

The manual and software package developed for minimum socioeconomic fishery data collection can be used to compare spatially – among communities, countries, cultural or other groups – and temporally, if the same survey is repeated, either irregularly or, regularly with defined intervals between surveys.

At least two staff members from each fishery service in 17 PICTs have been trained in using both the manual and the software package.

The **standardised design of the PROCFish socioeconomic and fishery survey** is, by comparison, much more comprehensive, because it aimed to develop and establish an integrated approach for combined data analysis covering socioeconomics, fisheries, resource status (finfish and invertebrates), and habitats. The results that have emerged from this regional analysis and combined data analysis and that follow the established PROCFish approach suggest – *inter alia* – the following:

- Fishing impact should be defined as:
  - total annual extrapolated catch per available reef, and available fishing ground area; and by larger habitat following the zones that are distinguished by fishers.
  - fishing ground areas – regardless of difference in the marine tenure – should be defined according to the fishing community targeted and the geographical limits that they exploit.

- Fishing communities should be defined as:
  - the coastal population (for extrapolation of catch and thus impact) that has access to the designated fishing ground area, and thus may include a number of communities if open access applies.

- Fishing ground surface areas should be established:
  - using available satellite and GIS facilities; for impact assessments there is no need to define habitats any more precisely than to establish the differences between reefs, mangroves and deeper lagoon areas.

- Definition of total catch varies between finfish and invertebrates.
  - In the case of invertebrates, no reliable length–weight relationships are available for species or families; therefore it is recommended to calculate fishing pressure for invertebrates as numbers per unit area caught, as compared to finfish, where weight can be calculated if average catch sizes are recorded.

Average catch sizes are reliable indicators.

  - Average catch sizes have proven to be reliable indicators to detect and to monitor fishing pressure. This conclusion is true for a number of finfish families, as well as for giant clams. Therefore, average reported fish size and average reported sizes for major invertebrate species should be recorded.

- Fishing responses can be detected at the family level.
  - Fishing and resource responses are detectable at the family level or, in the case of invertebrates, at the species group level. This conclusion bypasses the problem of incompatibility between scientific and vernacular nomenclatures.

- In the case that a particular species, identified by scientific name, is selected for monitoring or as an indicator, particular photographic charts need to be prepared to collect such data-specific information due to the above-mentioned bias between names used by researchers and fishers.
- Finfish fisheries in PICTs use multi-technique fishing methods. It has been demonstrated that total fishing hours by major technique group, distinguishing between line-fishing, net-fishing, and spearing, is a useful way to show differences in technique-related impact.

- Socioeconomic drivers at community and national scale are most important.

    - Results of the analysis highlight that socioeconomic drivers at community level are among the most important factors determining the extent of current and possibly future fishery intensity. Data on income sources, household expenditure, dependency on remittances, and education level are important indicators and need to be complemented by information on average household size.
    - Significant responses were obtained by linking the overall demographic and economic conditions at country level with socioeconomic data at the community level. Valuable parameters are per capita GDP, export–import balance, CPI, population density at national scale, national growth rate and the dependency rate (15–64 years).
    - The marketability index developed from data collected within PROCFish explains a significant proportion of current fisheries exploitation level and should therefore be applied where possible.

- Data on seafood consumption:

    - The use of per capita seafood consumption as a tool to assess the dependency of a given community on coastal marine resources and for future monitoring of food security involves several critical issues. First, coastal subsistence and artisanal fisheries are multi-species including a number of pelagic species, which opportunistically visit the lagoon and passages. Secondly, the proportion between reef and relatively pelagic (although opportunistic) fishes is determined by the available habitats, the objectives of the fisher (subsistence or commercial), availability of boat transport, weather and sea conditions, and other factors, and varies between fishing trips. Thirdly, consumption figures are usually calculated using a snapshot survey approach that requests fishers to give average figures. Thus, any information reported in the framework of this one-off type of snapshot survey does not provide an accurate estimate or allow changes in consumption between reef and pelagic fish to be monitored. However, this type of information does allow us to estimate and monitor total finfish consumption patterns.
    - Invertebrates are a fall-back position for rural coastal communities in times of need; in addition certain species may be collected as a local delicacy. However, invertebrate harvesting and consumption is often subject to opportunistic foraging strategies. Thus, the per capita consumption rate for invertebrates is likely to be often underestimated.
    - For future estimation of per capita seafood consumption it is strongly recommended that the gender–age and edible–non edible correction approach is applied. This is described in the PROCFish methodology and manual. It allows comparison of both consumption patterns in communities, regions and countries in terms of nutrition needs and calorific input, and total impact caused by subsistence needs as figures can be converted into total catch (wet weight).

The PROCFish programme has also highlighted that in the case of **event or species-specific surveys,** a specialised survey format is required rather than a general baseline approach. A good example is commercial export invertebrate fisheries, particularly those that are subject to pulse fishing, or temporary or long-term closure. Experience suggests that, if community- or fisher-based data is to be collected, survey formats need to be developed that take into account the target group, their regional distribution, and the seasons or time periods when fishing takes place. Such survey formats have been developed upon demand from fisheries services during implementation of PROCFish. One example, i.e. a baseline survey on sea cucumbers and trochus sustainable management in Shefa Province, Vanuatu, including consumption and fishery data, is attached as Appendix 4.4.

Furthermore, experience also suggests that data on quantity and quality of commercial export species may be much easier and more effectively collected from the given and known numbers of agents and exporters rather than targeting fishers in communities. A standardised survey format can be easily developed, and agents and exporters could be required by fisheries services to provide the requested information. Data obtained by standardised surveys provided by agents and exporters could be cross-checked with data from fisher surveys.

4.6 Gender roles and socioeconomic drivers for artisanal coastal fisheries in PICTs

The objectives of this section are:

- To address the lack of a regionwide, gender-disaggregated analysis of subsistence and small-scale artisanal fisheries at the community level to provide insight into contemporary differences and similarities between male fishers and female fishers in finfish fisheries and invertebrate harvesting across 17 Pacific Island countries and territories;
- To identify the major socioeconomic drivers that determine the extent to which males and females are dependent on wild-caught marine resources and to gain a better understanding of current gender roles in coastal subsistence and artisanal fisheries;
- To appraise gender-related vulnerabilities, comparing the three major cultural groups (Melanesia, Micronesia and Polynesia) in terms of their needs and limitations as entry-points for successful fisheries management strategies.

Successful planning and implementation of holistic small-scale artisanal fisheries and coastal resource management strategies depend on a sound understanding of the nature of the region's fishery production systems, including gender roles and shifts in access to resources and opportunities in the surrounding social, cultural and institutional context.

The major findings of a regional analysis have been explained and discussed in a manuscript entitled 'gender roles and socioeconomic drivers for artisanal coastal fisheries in Pacific Island countries and territories – a cross-cultural and regional analysis' submitted to the journal Human Ecology that is attached as Appendix 4.5.

Key results include:

- Finfish fishing was found to be the major food and income source and is principally accounted for by males (Figures 4.36 and 4.37). While females' finfish catch mostly contributes to home consumption, differences do occur, as Melanesian female fishers engage substantially in finfish fishing for food and income.

- Regionally and within cultural groups, total harvesting time and total annual catch of major invertebrate species groups are generally equally shared by males and females.
- Today, the major gender difference in invertebrate fisheries is the fact that females do not – or rarely participate in free-diving fishing activities, resulting in gender-biased access to, participation in, and benefit from commercial export fisheries.
- The main socioeconomic drivers found to determine fishers' productivity vary in their importance according to cultural group, but include a combination of demographic, economic and financial factors, and access to alternative income sources. Major differences emerge according to gender role.
- For **Melanesia**, **male fishers'** engagement in artisanal fisheries is determined by a high CPI, a high negative per capita export–income balance, a high dependency rate (15–59 years) and a tendency to a high gross migration rate characterising relatively poor economic conditions at the national scale, coupled with limited access to alternative income sources suggested by a high percentage of adults with primary education only at the community level. **Female fishers** are characterised by low educational and low household expenditure levels, suggesting a high dependency on marine resources because access to alternative and cash income is limited.
- **Males' fishing** in **Polynesia's fishing communities** is mainly driven by high population pressure on the available reef area and a high number of boats, while **Polynesian female fishers** are driven by high population pressure but also a high dependency on remittances, suggesting that the more difficulty female fishers have in covering living cost from local income, the more active they are in fishing.
- **Micronesian** fishing communities are the most diverse in terms of drivers determining male and female fishers' activities. Artisanal fishing, particularly done by **males,** is driven by a high urban population at the national scale, suggesting that urban populations have other income sources than fisheries, as well as a large average household size underpinning the persistence of a traditional lifestyle in the rural context. **Female fishers**' activities basically increase with larger average household size and higher per capita invertebrate consumption.
- Females are mostly affected by community-based or even household-based factors as their main contribution aims at subsistence needs, while males' commercial finfish and invertebrate production, matched with their subsistence contribution, is associated with an interaction of socioeconomic factors at the national and the community level.
- Results suggest that the substantial difference observed in Melanesian females' significant engagement in finfish fishing is a response to the combined effects of a rigorous economic environment and favourable cultural conditions.

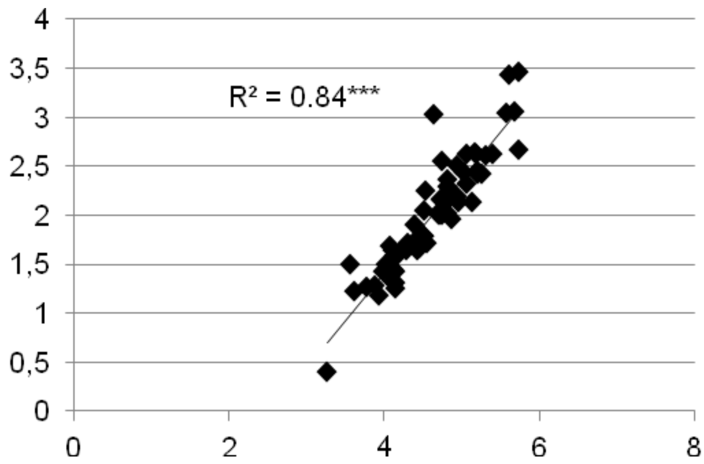

Figure 4.36: Regression between total hours spent finfish fishing by males and total annual finfish catch (Data are ($\log_{(X+1)}$) transformed.).

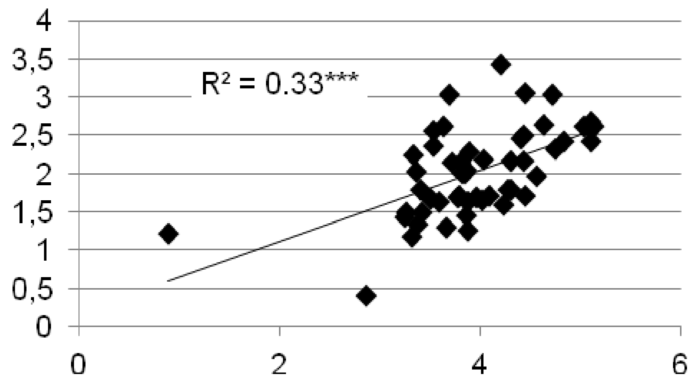

Figure 4.37: Regression between total hours spent finfish fishing by females and total annual finfish catch (Data are ($\log_{(X+1)}$) transformed.).

Implications for coastal fisheries management

The importance of taking gender into account to ensure effective resource management has been emphasised by the World Summit on Sustainable Development (United Nations 2002), and in more detail by the FAO's gender policies for responsible fisheries (FAO 2007), which call for gender-disaggregated data complemented by gender relations analysis to make possible effective formulation of fisheries management policies. Results suggest that effective planning should take into consideration the following:

- Combining coastal fisheries management with diversification of livelihoods of communities and households, to increase cash income and lessen dependency and pressure on wild-caught marine resources. This objective may require adaptive capacity assessments to tailor specific development programmes to the available resources and the communities' and households' capabilities, and to apply a gender lens beyond fisheries to tailor strategies to males' and females' contributions to the household's food and income security and their possibilities and limitations in exploring alternatives.
- Gender equity is required in access to improvements in quality of life and income, including capital, equipment, technology, transport, credit, training, employment and education, and equity in decision-making regarding resource use and use of household assets and income. Gender equity does not necessarily have to conflict with existing

social institutions and cultural traditions, as demonstrated by successful credit schemes and fisheries processing and marketing projects for females.

- The implications of livelihood diversification programmes on gender participation and responsibilities need to be considered. Female fishers are a vulnerable group in terms of the risk of becoming over-burdened as the responsibilities imposed by gender-defined roles may be maintained within traditional and cultural value systems. In response to economic stress, female fishers have already expanded their traditional roles to increasingly contribute to household cash income (particularly in Melanesia), while maintaining their traditional services for the well-being of their families and social institutions within communities.
- Female fishers need to be considered in training necessary to redirect fishing pressure from nearshore to offshore resources, including fishing at fish aggregating devices (FADs) and the outer reef.
- Female fishers need to be included as equal stakeholders in restocking and monitoring programmes for commercial or high-value invertebrate species, particularly bêche-de-mer and giant clams, to ensure their participation in the fisheries and their benefit from revenues.
- Although community fisheries management addresses the entire community, more attention should be given to females' fisheries issues that are often invisible. Habitats and fisheries important for females' gleaning and finfish fishing activities, particular fishing grounds that are close to shore and easy to access, should be included in protected management areas, or considered for pulse fishing, without jeopardising females' contribution to food supply of families and small household income.

4.7 Discussion and conclusions

The following points have been drawn from the socioeconomic component of the study, including some joint assessment covering both finfish and invertebrate data in some cases.

- The future of the artisanal fishery sector and the livelihood of coastal communities in the Pacific Islands region will depend to a large extent on access to and potential of alternative subsistence and income sources, which are necessary to reduce fishing pressure to a sustainable level to maintain ecosystem services and food security.

- The harmonisation of objectives for resource use and development requires the promotion of diversification, including alternatives to coastal wild-caught fisheries, and demands management strategies that make artisanal coastal fisheries an integral part of domestic rural development.

- Artisanal fisheries can no longer be managed independently of other resource uses and their environmental and socioeconomic impacts. The adoption of an approach that integrates development strategies in other sectors will be an effective means of reducing dependence on marine resources, reducing fishing pressure, and making restrictive management easier or less controversial for the affected stakeholders.

- The above objectives may require adaptive capacity assessments to tailor specific development programmes to the available resources and the communities' and households' capabilities. A gender lens also needs to be applied beyond fisheries to tailor strategies to male' and females' contributions to the household's food and income security and their possibilities and limitations in exploring alternatives.

- The implications of livelihood diversification programmes on gender participation and responsibilities must also be considered, taking into account that female fishers are a vulnerable group and may risk becoming over-burdened as the responsibilities imposed by gender-defined roles may be maintained within traditional and cultural value systems. In response to economic stress, female fishers have already expanded their traditional roles to increasingly contribute to household cash income (particularly in Melanesia).

- Current unsustainable small-scale artisanal and subsistence finfish fisheries ($\geq$5 t/km^2 reef /year) are widespread, affecting almost half of the 63 sites studied in 17 PICTs. While results confirm that coastal resources are subject to degradation and reduction of their natural productivity potential due to fishing and demographic pressure, the combined analysis of socioeconomic, fishery and resource data in a spatial comparative approach further revealed that: (1) increased fishery productivity is positively correlated with the proportion of commercial catch; (2) total finfish catch is also a result of the combined effects and interrelations of economic, social and resource factors; and (3) physical and ecological conditions and finfish fishing pressure are independent effects but must both be taken into account in order to achieve realistic and successful fisheries management.

- The main drivers determining high commercial finfish and small-scale artisanal invertebrate catches are factors that represent limited alternative-income opportunities, and difficulties in meeting living cost, combined with easy access to and good choice of fishing grounds, and easy marketability. As expected, demographic pressure and food dependency on marine produce are the main drivers for finfish and invertebrate subsistence fisheries.

- Finfish fishing was found to be the major source of food and income and is principally accounted for by males, while females' finfish catch mostly contributes to home consumption. Regionally and within cultural groups, total harvesting time and total annual catch of major invertebrate species groups are generally equally shared by males and females. Today, the major gender difference in invertebrate fisheries is the fact that women do not – or only rarely – participate in free-diving fishing activities, resulting in gender-biased access to, participation in, and benefit from commercial export fisheries.

- The region's per capita annual consumption of marine products is high with a regional average of 67.8 kg fresh fish, 7.5 kg of invertebrates (edible meat only) and 8.9 kg canned fish (net weight).

- Income dependency on fisheries as compared to salaries varies significantly, with a regional average of 29.5% and 20.2% of all households earning primary and secondary income from fisheries, and 32.5% and 6.5% from salaries respectively.

- Results confirm that dependency on marine resources for both subsistence and income determines the resource exploitation level for finfish and most invertebrates.

- A close relationship exists between exploitation, hence fishing pressure, and economic factors, possibly poverty. Households depending on fishing for primary income are financially disadvantaged as compared to those that have primary income sources other than fisheries.

- Analysis results also demonstrate, by comparing the expected natural productivity and current catch rates, that sustainability of coastal finfish fisheries in PICTs is a result of population size, its associated finfish fishing activities, and the available production area in fisheries-dependent communities.

- The herbivore/carnivore (H_b/C_b) biomass ratio was found to be the best indicator for finfish resource status, suggesting cascading top-down effects of fisheries. Spatial differences are a consequence of fishery, demographic and marketability factors. Island type emerged as the best surrogate for physical and ecological variation across study sites, while latitudinal and longitudinal variation had much less effect. Atoll and complex islands, corresponding to currently lower finfish pressure, higher H_b/C_b ratios, and higher reported CPUE, were found to contrast with small-lagoon and oceanic islands.

- Indicators for increasing catch rates and increasing likelihood of unsustainable finfish fisheries are the reported average catch size of Scaridae, Siganidae, Acanthuridae, Lethrinidae and, to a lesser extent, Mullidae. Removal of predators showed in a decrease of the proportion in catch of Lethrinidae. Impact of finfish fishing on trophic structure showed in a decreased proportion of catch of Siganidae, and increasing proportions of Labridae, Acanthuridae and Carangidae. Significant effects of different gear types on catch were made visible in catch composition and average biomass. The indicators found suggest that fishery data are a suitable means to detect overexploitation.

- Results confirm that even low finfish fishing intensity can cause cascading effects but also that these effects increase with increasing fishing pressure. Socioeconomic, fishery and resource data need to be combined to identify the cause-and-effect of fishing pressure. To achieve sustainable resource-use management of small-scale artisanal fisheries in PICTs, management should shift from the long-established goals to embrace a wider rural-development approach that fosters development of alternative-income opportunities and that restricts the use of fishing techniques with high impact, especially speardiving and gillnetting.

- Giant clam resources in PICTs are declining or depleted. Physical and natural factors were found to determine regional distribution, with atoll islands having naturally the highest potential as open systems, due to their favourable hydrogeographic conditions for recruitment. Impacts of past and current fishing pressure were made visible by socioeconomic survey data analysis. The average reported shell size was found to be the best indicator to detect overexploitation, and most shell sizes reported fall into the fishery classified as unsustainable.

- Survey results highlight the need to combine knowledge on the natural potential of a site and socioeconomic drivers to estimate its natural potential and thus feasible and achievable improvements, limitations, and potential determined by the economic, demographic and social environment.

- Results confirm that reducing finfish fishing pressure that has currently reached 5 t/km^2 reef/year is an urgent matter. Generally, speardiving at night, using SCUBA equipment, and commercial gillnetting should be banned; herbivores should be targeted rather than piscivores and carnivores. Areas to recover natural potential or to protect production and spawning aggregations at selected sites and/or during spawning seasons should be established. Impacts of commercial fishers should be reduced, reef fishers may be diverted to pelagic species, and fishing pressure on current target species may be diverted towards other target species.

- The successful use of any recommendation depends on a number of preconditions including strong governmental leadership, with a controlled network of commercial agents/exporters, strategies and implementation of rural coastal development projects offering alternatives to wild-caught fisheries, co-management to close fisheries temporarily or in the long-term where necessary. At the community level, the necessary preconditions are community control over fishing grounds, high social coherence with good leadership, well functioning community management systems, and stakeholders' consent on sustainable distribution of common resources for individual interests or benefit.

- Useful fisheries management tools to assess current finfish fishing pressure risk in any rural fishery-dependent coastal community in PICTs and to predict giant clam catch rates in PICTs have now been developed.

- A standardised method supported by a manual and software package (SEMCoS) has been developed to collect the minimum dataset for socioeconomic baseline fisheries surveys in PICTs. A set of parameters to be collected for similar surveys to the PROCFish programme is provided, including indicators, parameters for fishing response, and socioeconomic drivers at community and national scale.

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APPENDIX 1: SURVEY METHODS

1.1 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 A1.1.1). 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.

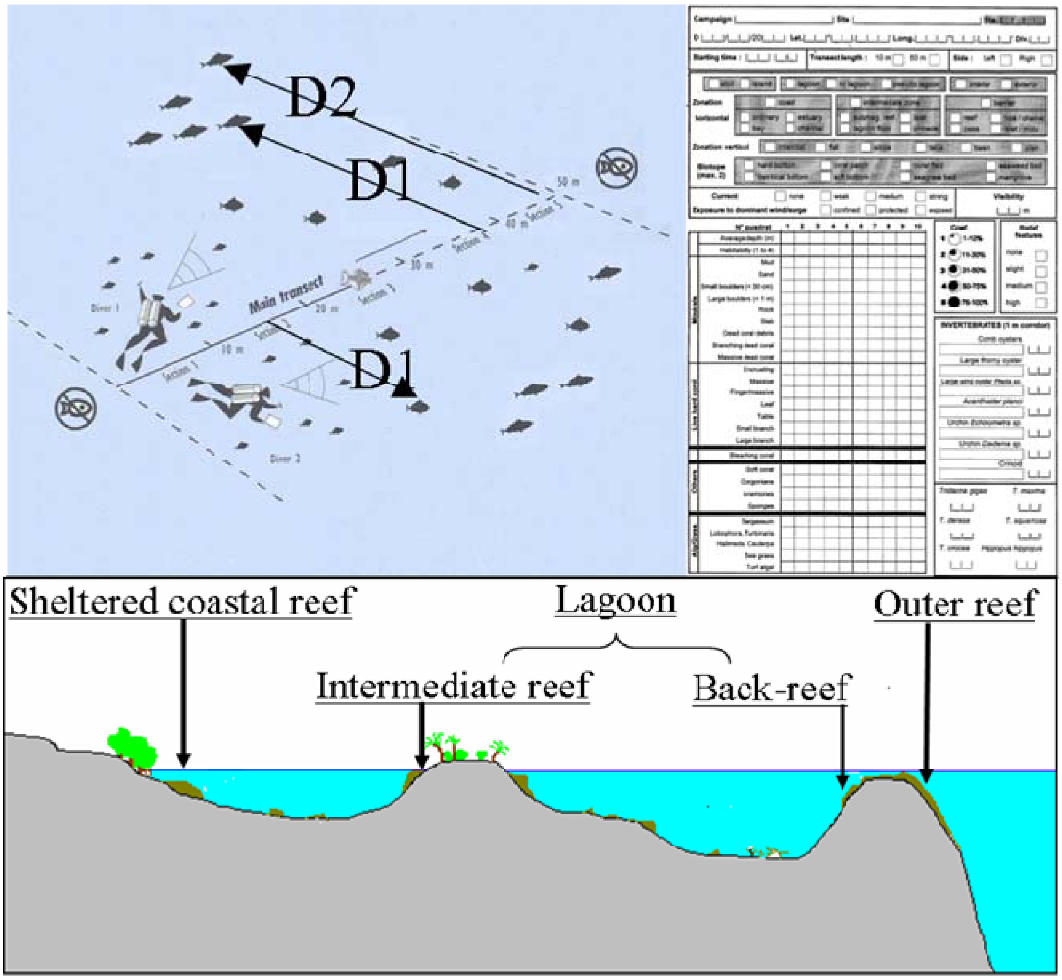


Figure A1.1.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys 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 A1.1.1). A full list od sprecies and abundance is given for each country in Appendix 3.2 of each PROCFish/C and CoFish country report.

Table A1.1.1: 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 A1.1.1). The transect's habitat characteristics are then calculated by averaging substrate records over the 20 quadrats.

Parameters of interest

In this report, the status of finfish resources has been characterised using the following seven parameters:

- **biodiversity –** the number of families, genera and species counted in D-UVC transects;
- **density** (fish/m^2) – estimated from fish abundance in D-UVC;
- **size** (cm fork length) – direct record of fish size by D-UVC;
- **size ratio** (%) – the ratio between fish size and maximum reported size of the species. This ratio can range from nearly zero when fish are very small to nearly 100 when a given fish has reached the greatest size reported for the species. Maximum reported size (and source of reference) for each species are stored in our database;

- **biomass** (g/m^2) – obtained by combining densities, size, and weight–size ratios (Weight–size ratio coefficients are stored in our database and were provided by Mr Michel Kulbicki, IRD Noumea, Coreus research unit);
- **community structure –** density, size and biomass compared among families; and
- **trophic structure –** density, size and biomass compared among trophic groups. Trophic groups are stored in our database and were provided by Mr Michel Kulbicki, IRD Noumea, Coreus research unit. Each species was classified into one of five broad trophic groups: 1) carnivore (feed predominantly on zoobenthos), 2) detritivore (feed predominantly on detritus), 3) herbivore (feed predominantly on plants), 4) piscivore (feed predominantly on nekton, other fish and cephalopods) and 5) plankton feeder (feed predominantly on zooplankton). More details on fish diet can be found online at: http://www.fishbase.org/manual/english/FishbaseThe_FOOD_ITEMS_Table.htm.

The relationship between environment quality and resource status has not been fully explored at this stage of the project, as this task requires complex statistical analyses on the regional dataset. Rather, the living resources assessed at all sites in each country are placed in an environmental context via the description of several crucial habitat parameters. These are obtained by grouping the original 23 substrate parameters recorded by divers into the following six parameters:

- **depth** (m)
- **soft bottom** (% cover) – sum of substrate components:
  (1) mud (sediment particles <0.1 mm), and
  (2) sand and gravel (0.1 mm <hard particles <30 mm)
- **rubble and boulders** (% cover) – sum of substrate components:
  (3) dead coral debris (carbonated structures of heterogeneous size, broken and removed from their original locations),
  (4) small boulders (diameter <30 cm), and
  (5) large boulders (diameter <1 m)
- **hard bottom** (% cover) – sum of substrate components:
  (6) slab and pavement (flat hard substratum with no relief), rock (massive minerals) and eroded dead coral (carbonated edifices that have lost their coral colony shape),
  (7) dead coral (dead carbonated edifices that are still in place and retain a general coral shape), and
  (8) bleaching coral
- **live coral** (% cover) – sum of substrate components:
  (9) encrusting live coral,
  (10) massive and sub-massive live corals,
  (11) digitate live coral,
  (12) branching live coral,
  (13) foliose live coral,
  (14) tabulate live coral, and
  (15) *Millepora* spp.
- **soft coral** (% cover) – substrate component:
  (16) soft coral.

Sampling design

Coral reef ecosystems are complex and diverse. The NASA Millennium Coral Reef Mapping Project (MCRMP) has identified and classified coral reefs of the world in about 1000 categories. These very detailed categories can be used directly to try to explain the status of living resources or be lumped into more general categories to fit a study's particular needs. For the needs of the finfish resource assessment, MCRMP reef types were grouped into the four main coralline geomorphologic structures found in the Pacific (Figure A1.1.2):

- **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.

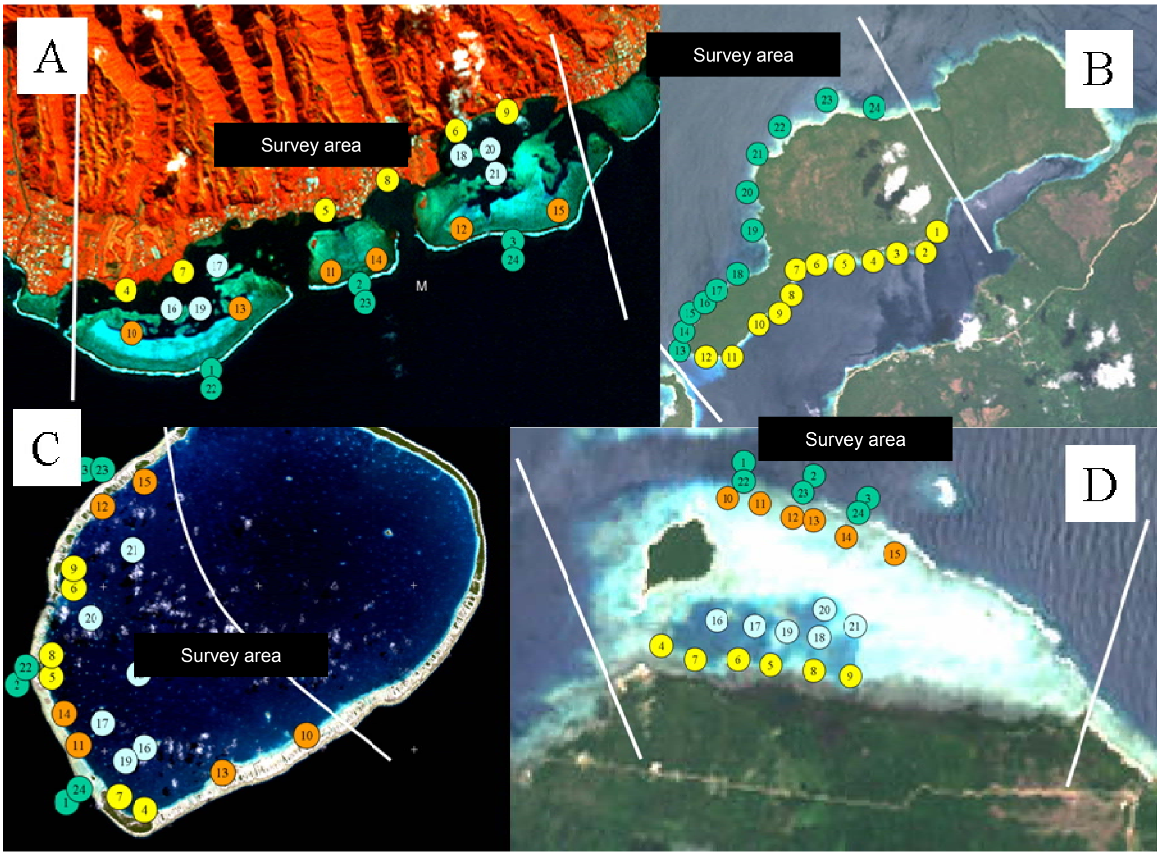


Figure A1.1.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, lagoon 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 each country are given in Appendix 3.2 in each PROCFish/C and CoFish country report. 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 ☐

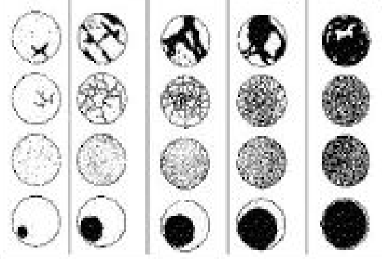
☐ coast		☐ intermediate zone		☐ barrier	
☐ linear	☐ cape	☐ submerg. reef	☐ pinnacle	☐ outer slope	☐ pass
☐ bay mouth	☐ back of bay	☐ near surf. reef	☐ islet lagoon	☐ reef crest	☐ hoa/channel
☐ estuary	☐ channel	☐ lagoon floor	☐ islet fringing reef	☐ back reef	☐ motu

☐ 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

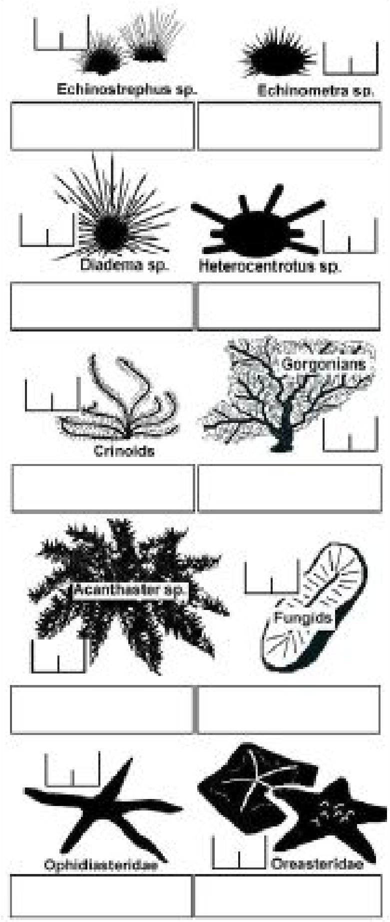
	current	relief features	exposure to dominant wind	oceanic influence	terrigenous influence
none	☐	☐	☐	☐	☐
medium	☐	☐	☐	☐	☐
strong	☐	☐	☐	☐	☐

1	2	3	4	5
1-10%	11-30%	31-50%	51-75%	76-100%



Quadrat limits 0 5 10 15 20 25 30 35 40 45 50

	Average depth (m)										
	Habitability (1 to 4)										
General coverage	Mud										
	Sand										
	Dead coral debris										
	Small boulders (< 30 cm)										
	Large boulders (< 1 m)										
	Eroded dead coral, rock										
	Old dead coral in place										
	Bleaching coral										
	(1) Live corals										
	(2) Soft invertebrates										
(1) Live corals	Encrusting										
	Massive										
	Digitate										
	Branch										
	Foliose										
	Tabulate										
	Millepora sp.										
(2)	Soft corals										
	Sponges										
Grass/alg	Cyanophyceae										
	Sea grass										
	Encrusting algae										
	Small macro-algae										
	Large macro-algae										
	Drifting algae										
	Micro-algae, Turf										
	Others :										



Appendix 1: Survey methods
Finfish

Campaign |___________________| Site |_____________________________| Diver |__|__| Transect |__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|’ Long.|__|__|__|°|__|__|,|__|__|__|’ Left ☐ Right ☐

ST	SCIENTIFIC NAME	NBER	LGT	D1	D2	COMMENTS

1.2 Invertebrate resource survey methods

1.2.1 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 was 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'[1] 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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[1] 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 A1.2.1).

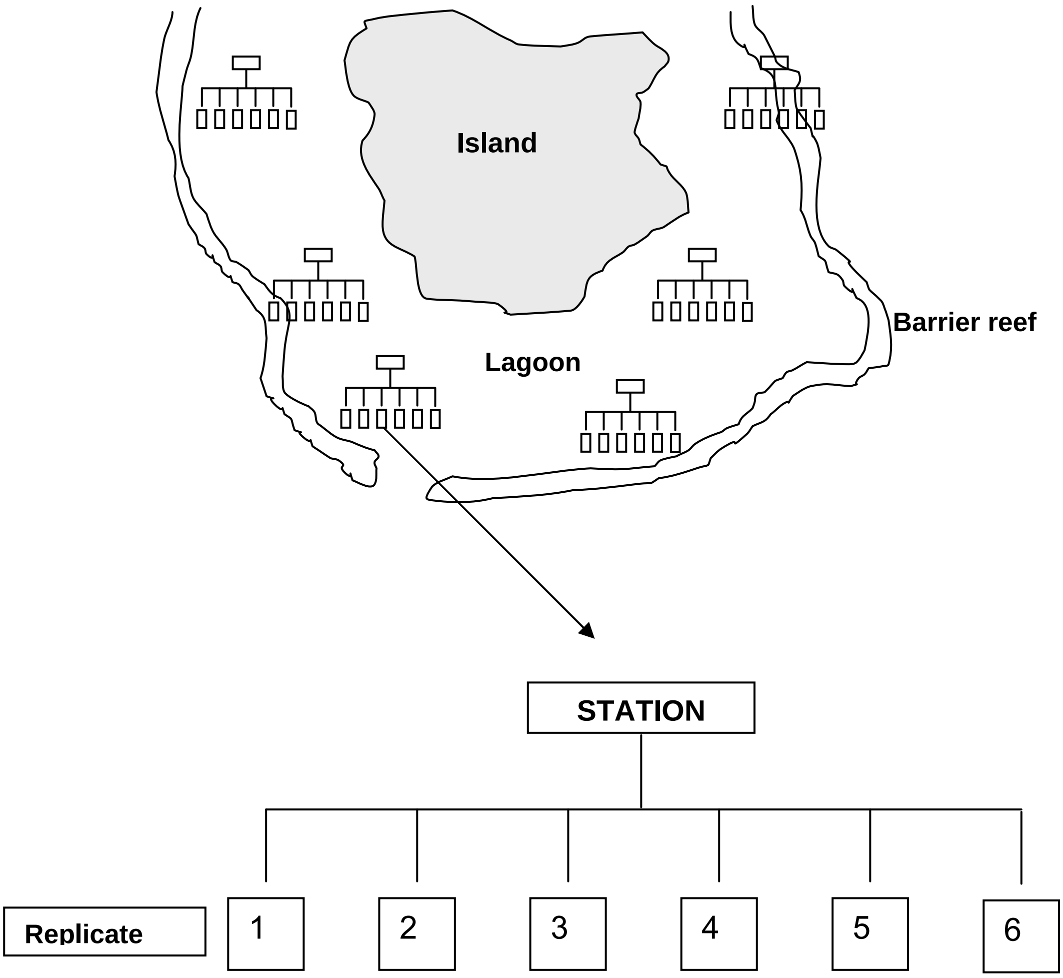

Figure A1.2.1: Stations and replicate measures at a given site.
Note: a replicate measure could be a transect, search period or quadrat group.

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 A1.2.2 and Appendix 1.2.2).

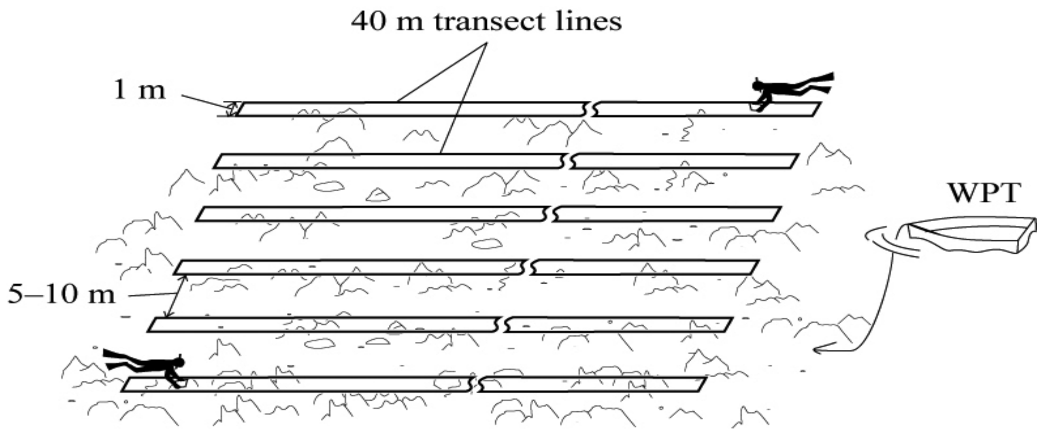

Figure A1.2.2: Example of a reef-benthos transect station (RBt).

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.

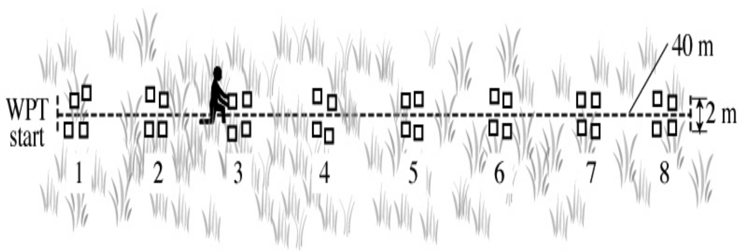

Figure A1.2.3: Soft-benthos (infaunal) quadrat station (SBq).
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

<u>Mother-of-pearl (MOP) or sea cucumber (BdM) fisheries</u>

To assess fisheries such as those for trochus or sea cucumbers, results from broad-scale, reef- and soft-benthos assessments were used. However, other specific surveys were incorporated into the work programme, to more closely target species or species groups not well represented in the primary assessments.

<u>Reef-front searches (RFs and RFs_w)</u>

If swell conditions allowed, three 5-min search periods (30 min total) were conducted along exposed reef edges (RFs) where trochus (*Trochus niloticus*) and surf redfish (*Actinopyga* *mauritiana*) generally aggregate (Figure A1.2.4). 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).

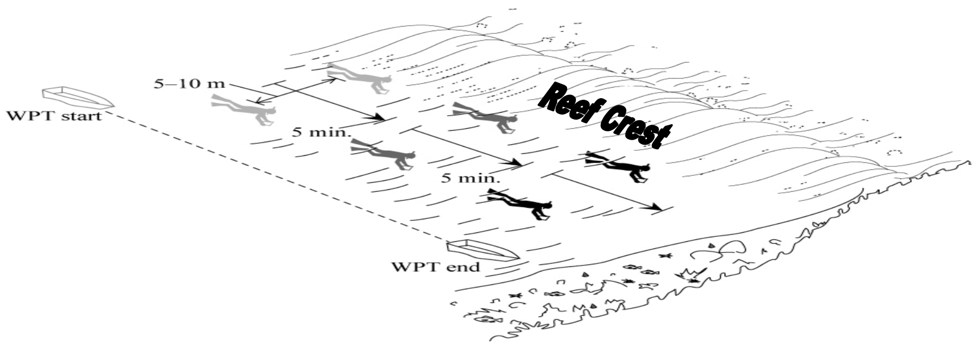

Figure A1.2.4: Reef-front search (RFs) station.

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 A1.2.5). 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.

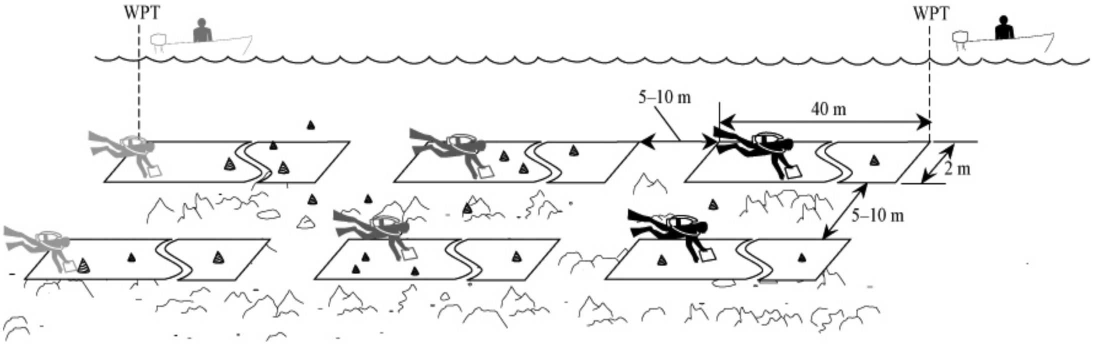

Figure A1.2.5: Mother-of-pearl transect station (MOPt).

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[2] (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.

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[2] 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.

1.2.2 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 A1.2.6: Sample of the invertebrate fauna survey sheet.

The sheet above (Figure A1.2.6) 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.

1.2.3 Habitat section of invertebrate recording sheet with instructions to users

Figure A1.2.7 depicts the habitat part of the form used during invertebrate surveys; it is split into seven broad categories.

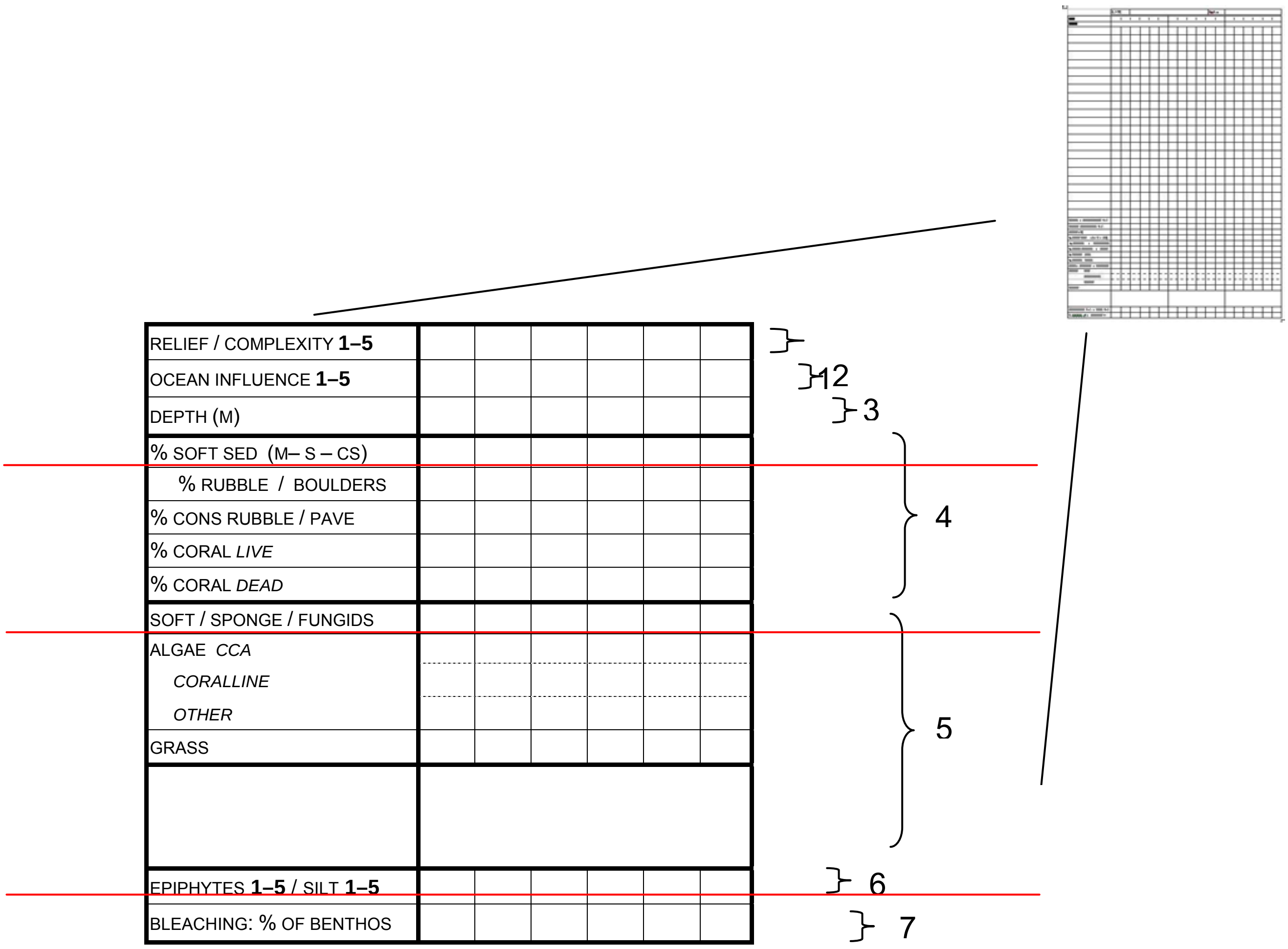

Figure A1.2.7: Sample of the invertebrate habitat part of survey form.

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

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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.

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Consolidated rubble is attached, cemented pieces of coral stone and limestone debris. We tend to use 'rubble' for pieces or piles loose in the sediment of seagrass, etc., and 'consolidated rubble' for areas that are not flat pavement but concreted rubble on reeftops and cemented talus slopes.
Pavement is solid, substantial, fixed, flat stone (generally limestone) benthos.

Coral live is any live hard coral.

Coral dead is coral that is recognisable as coral even if it is long dead. Note that long-dead and *eroded* coral that is found in flat pavements is called 'pavement' and when it is found in loose pieces or blocks it is termed 'rubble' or 'boulders' (depending on size).

Cover – what is on top of the substrate (section 5 of form)

This cannot exceed 100%, but can be anything from 0 to 100%. Surveyors give scores in blocks of 5%, so e.g. 5, 10, 15, 20 (%) etc. and not 2, 13, 17, 56.

Elements to consider:

Cover	Soft coral
Cover	Sponge
Cover	Fungids
Cover	Crustose-nongeniculate coralline algae
Cover	Coralline algae
Cover	Other (algae like sargassum, caulerpa and padina)
Cover	Seagrass

Soft coral is all soft corals but not Zoanthids or anemones.

Sponge includes half-buried sponges in seagrass beds – only sections seen on the surface are noted.

Fungids are fungids.

Crustose – nongeniculate coralline algae are pink rock. Crustose or nongeniculate coralline algae (NCA) are red algae that deposit calcium carbonate in their cell walls. Generally they are members of the division Rhodophyta.

Coralline algae – halimeda are red coralline algae (often seen in balls – *Galaxaura*). (Note: AIMS lists *halimeda* and other coralline algae as macro algae along with fleshy algae not having $CaCo_3$ deposits.)

Other algae include fleshy algae such as *Turbinaria*, *Padina* and *Dictyota*. Surveyors describe coverage by taking a bird's-eye view of what is covered, not by delineating the spatial area of the algae colony within the transect (i.e. differences in very low or high density are accounted for). The large space on the form is used to write species information if known.

Seagrass includes seagrass such as *Halodule*, *Thalassia*, *Halophila* and *Syringodium*. Surveyors note types by species if possible or by structure (i.e. flat versus reed grass), and describe coverage by taking a bird's-eye view of what benthos is covered, not by delineating the spatial area of the grass meadow within the transect (i.e. differences in very low or high density are accounted for).

Cover continued – epiphytes and silt (section 6 of form)

Epiphytes 1–5 grade are mainly turf algae – turf that grows on hard and soft substrates, but also on algae and grasses. The growth is usually fine-stranded filamentous algae that have few noticeable distinguishing features (more like fuzz).

1 = none
2 = small areas or light coverage
3 = patchy, medium coverage
4 = large areas or heavier coverage
5 = very strong coverage, long and thick almost choking epiphytes – normally including strands of blue-green algae as well

Silt 1–5 grade (or a similar fine-structured material sometimes termed 'marine snow') consists of fine particles that slowly settle out from the water but are easily re-suspended. When re-suspended, silt tends to make the water murky and does not settle quickly like sand does. Sand particles are not silt and should not be included here when seen on outer-reef platforms that are wave affected.

1 = clear surfaces
2 = little silt seen
3 = medium amount of silt-covered surfaces
4 = large areas covered in silt
5 = surfaces heavily covered in silt

Bleaching (section 7 of form)

The percentage of bleached live coral is recorded in numbers from 1 to 100% (Not 5% blocks). This is the percentage of benthos that is dying hard coral (just-bleached) or very recently dead hard coral showing obvious signs of recent bleaching.

1.3 Socioeconomic surveys, questionnaires and average invertebrate wet weights

1.3.1 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).

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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 1.3.2.

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).

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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 A1.3.1).

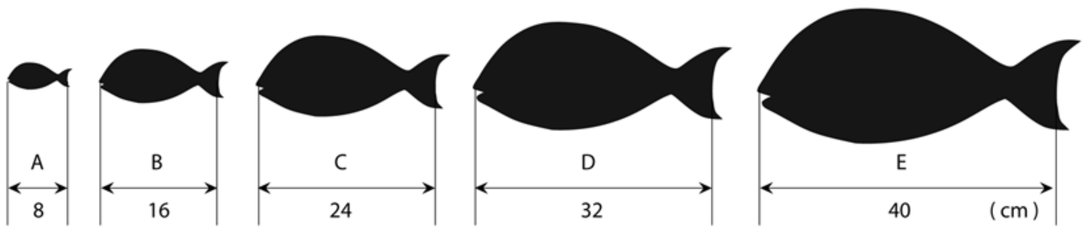

Figure A1.3.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).

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 1.3.3).[3] 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 1.3.3)
N_{ij} = number of invertebrates for species/species group$_i$ for household$_j$
n = number of species/species group consumed by household$_j$
W_{wi} = wet weight (kg) of unit (piece) for invertebrate species/species group$_i$
1000 = to convert g invertebrate weight into kg
F_{dj} = frequency of invertebrate consumption (days/week) for household$_j$
52 = total number of weeks/year
0.83 = correction factor for consumption frequency

[3] The index used here mainly consists of estimated average wet weights and ratios of edible and non-edible parts per species/species group. At present, SPC's Reef Fishery Observatory is making efforts to improve this index so as to allow further specification of wet weight and edible proportion as a function of size per species/species group. The software will be updated and users informed about changes once input data are available.

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Equation for canned fish:

Canned fish data are entered as total number of cans per can size consumed by the household at a daily meal, i.e.:

$$CF_{wj} = \sum_{i=1}^{n} (N_{cij} \bullet W_{ci}) \bullet F_{dcj} \bullet 52$$

CF_{wj} = canned fish net weight consumption (kg meat/household/year) of $household_j$

N_{cij} = number of cans of can $size_i$ for $household_j$

n = number and size of cans consumed by $household_j$

W_{ci} = average net weight (kg)/can $size_i$

F_{dcj} = frequency of canned fish consumption (days/week) for $household_j$

52 = total number of weeks/year

Age-gender correction factors are used because simply dividing total household consumption by the number of people in the household will result in underestimating per head consumption. For example, imagine the difference in consumption levels between a 40-year-old man as compared to a five-year-old child. We use simplified gender-age correction factors following the system established and used by the World Health Organization (WHO; Becker and Helsing 1991), i.e. (Kronen *et al.* 2006):

Age (years)	Gender	Factor
≤5	All	0.3
6–11	All	0.6
12–13	Male	0.8
≥12	Female	0.8
14–59	Male	1.0
≥60	Male	0.8

The per capita finfish, invertebrate and canned fish consumptions are then calculated by selecting the relevant formula from the three provided below:

Finfish per capita consumption:

$$F_{pcj} = \frac{F_{wj}}{\sum_{i=1}^{n} AC_{ij} \bullet C_i}$$

F_{pcj} = Finfish net weight consumption (kg/capita/year) for $household_j$

F_{wj} = Finfish net weight consumption (kg/household/year) for $household_j$

n = number of age-gender classes

AC_{ij} = number of people for age class i and household j

C_i = correction factor of age-gender $class_i$

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

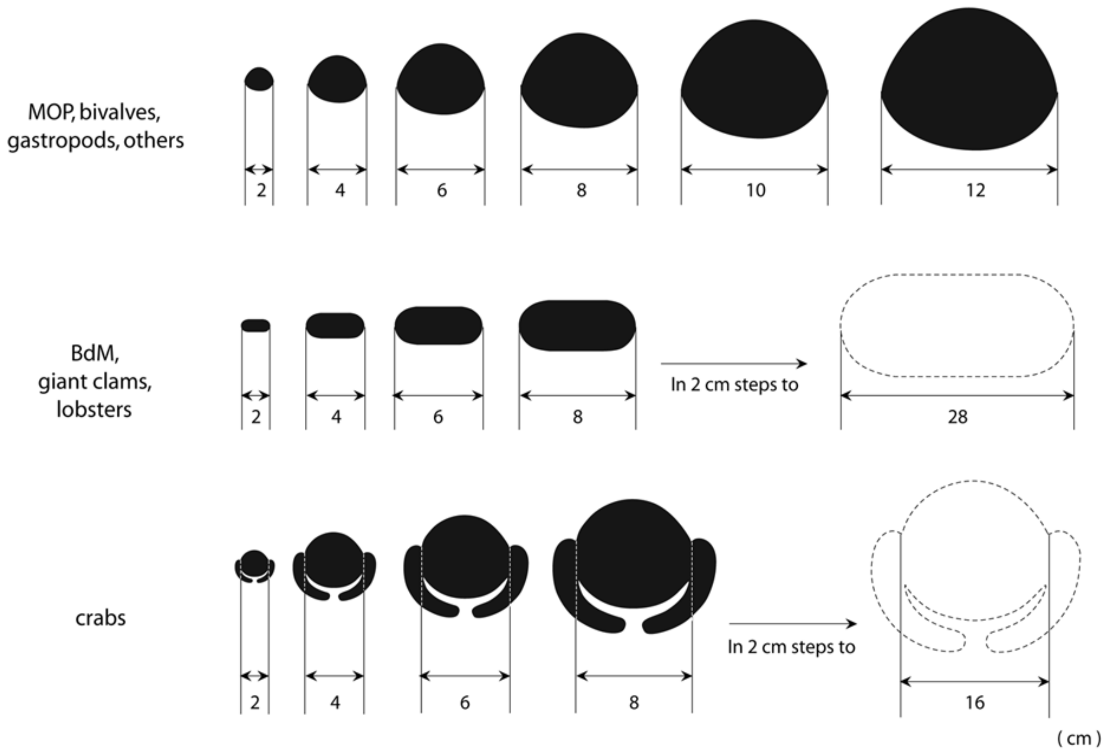

Figure A1.3.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).

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Finfish fisher survey

The finfish fisher survey primarily aims to collect the data needed to understand finfish fisheries strategies, patterns and dimensions, and thus possible impacts on the resource. Data collection faces the challenge of retrieving information from local people that needs to match resource survey parameters, in order to make joint data analysis possible. This challenge is highlighted by the following three major issues:

(i) Fishing grounds are classified by habitat, with the latter defined using geomorphologic characteristics. Local people's perceptions of and hence distinctions between fishing grounds often differ substantially from the classifications developed by the project. Also, fishers do not target particular areas according to their geomorphologic characteristics, but instead due to a combination of different factors including time and transport availability, testing of preferred fishing spots, and preferences of members of the fishing party. As a result, fishers may shift between various habitats during one fishing trip. Fishers also target lagoon and mangrove areas, as well as passages if these are available, all of which cannot be included in the resource surveys. It should be noted that a different terminology for reef and other areas fished is needed to communicate with fishers.

These problems are dealt with by asking fishers to indicate the areas they refer to as coastal reef, lagoon, outer-reef and pelagic fishing on hydrologic charts, maps or aerial photographs. In this way we can often further refine the commonly used terms of coastal or outer reef to better match the geomorphologic classification. The proportion of fishers targeting each habitat is provided as a percentage of all fishers surveyed; the socioeconomic analysis refers to habitats by the commonly used descriptive terms for these habitats, rather than the ecological or geomorphologic classifications.

Fishers may travel between various habitats during a single fishing trip, with differing amounts of time spent in each of the combined habitats; the catch that is retrieved from each combined habitat may potentially vary from one trip to the next. If targeting combined habitats is a common strategy practised by most fishers, the resource data for individual geomorphologic habitats need to be lumped to enable comparison of results.

(ii) People usually provide information on fish by vernacular or common names, which are far less specific than (and thus not compatible with) scientific nomenclature. Vernacular name systems are often very localised, changing with local languages, and thus may differ significantly between the sites surveyed in one country alone. As a result, one fish species may be associated with a number of vernacular names, but each vernacular name may also apply to more than one species.

This issue is addressed, as much as possible, through indexing the vernacular names recorded during a survey to the scientific names for those species. However, this is not always possible due to inconsistencies between informants. The use of photographic indices is helpful but can also trigger misleading information, due to the variety of photos presented and the limitations of species recognition using photos alone. In this respect, collaboration with local counterparts from fisheries departments is crucial.

(iii) The assessment of possible fishing impacts is based on the collection of average data. Accordingly, fishers are requested to provide information on a catch that is neither exceptionally good nor exceptionally bad. They are also requested to provide this information concerning the most commonly caught species. This average information suffers from two major shortcomings. Firstly, some fish species are seasonal and may be dominant during a short period of the year but do not necessarily appear frequently in the average catch. Depending on the time of survey implementation this may result in over- or under-representation of these species. Secondly, fishers usually employ more than one technique. Average catches may vary substantially by quantity and quality depending on which technique they use.

We address these problems by recording any fish that plays a seasonal role. This information may be added and helpful for joint interpretation of resource and socioeconomic data. Average catch records are complemented by information on the technique used, and fishers are encouraged to provide the average catch information for the technique that they employ most often.

The design of the finfish fisher survey allows the collection of details on fishing strategies, and quantitative and qualitative data on average catches for each habitat. Targeting men and women fishers allows differences between genders to be established.

Determination of fishing strategies includes:

- frequency of fishing trips
- mode and frequency of transport used for fishing
- size of fishing parties
- duration of the fishing trip
- time of fishing
- months fished
- techniques used
- ice used
- use of catch
- additional involvement in invertebrate fisheries.

The frequency of fishing trips is determined by the number of weekly (or monthly) trips that are regularly made. The average figure resulting from data for all fishers surveyed, per habitat targeted, provides a first impression of the community's engagement in finfish fisheries and shows whether or not different habitats are fished with the same frequency.

Information on the utilisation of non-motorised or motorised boat transport for fishing helps to assess accessibility, availability and choice of fishing grounds. Motorised boats may also represent a multiplication factor as they may accommodate larger fishing parties.

We ask about the size of the fishing party that the interviewee usually joins to learn whether there are particularly active or regular fisher groups, whether these are linked to fishing in certain habitats, and whether there is an association between the size of a fishing party and fishing for subsistence or sale. We also use this information to determine whether information regarding an average catch applies to one or to several fishers.

The duration of a fishing trip is defined as the time spent from any preparatory work through the landing of the catch. This definition takes into account the fact that fishing in a Pacific Island context does not follow a western economic approach of benefit maximisation, but is a more integral component of people's lifestyles. Preparatory time may include up to several hours spent reaching the targeted fishing ground. Fishing time may also include any time spent on the water, regardless of whether there was active fishing going on. The average trip duration is calculated for each habitat fished, and is usually compared to the average frequency of trips to these habitats (see discussion above).

Temporal fishing patterns – the times when most people go fishing – may reveal whether the timing of fishing activities depends primarily on individual time preferences or on the tides. There are often distinct differences between different fisher groups (e.g. those that fish mostly for food or mostly for sale, men and women, and fishers using different techniques). Results are provided in percentage of fishers interviewed for each habitat fished.

To calculate total annual fishing impact, we determine the total number of months that each interviewee fishes. As mentioned earlier, the seasonality of complementary activities (e.g. agriculture), seasonal closing of fishing areas, etc. may result in distinct fishing patterns. To take into account exceptional periods throughout the year when fishing is not possible or not pursued, we apply a correction factor of 0.83 to the total provided by people interviewed (this factor is determined on the basis that about two months of every year – specifically, 304/365 days – are not used for fishing due to festivals, funerals and bad weather conditions).

Knowing the range of techniques used and learning which technique(s) is/are predominantly used helps to identify the possible causes of detrimental impacts on the resource. For example, the predominant use of gillnets, combined with particular mesh sizes, may help to assess the impact on a certain number of possible target species, and on the size classes that would be caught. Similarly, spearfishing targets particular species, and the impacts of spearfishing on the abundance of these species in the habitats concerned may become evident. To reveal the degree to which fishers use a variety of different techniques, the percentage of techniques used refers to the proportion of all fishers who use that technique. Percentages show which techniques are used by most or even all fishers, and which are used by smaller groups. In addition, the data are presented by habitat (what percentage of fishers targeting a habitat use a particular technique, where n = the total number of fishers interviewed by habitat).

The use of ice (whether it is used at all, used infrequently or used regularly) hints at the degree of commercialisation, available infrastructure and investment level. Usually, communities targeted by our project are remote and rather isolated, and infrastructure is rudimentary. Thus, ice needs to be purchased and is often obtained from distant sources, with attendant costs in terms of transport and time. On the other hand, ice may be the decisive input that allows marketing at a regional or urban centre. The availability of ice may also be a decisive factor in determining the frequency of fishing trips.

Determining the use of the catch or shares thereof for various purposes (subsistence, non-monetary exchange and sale) is a necessary prerequisite to providing fishery management advice. Fishing pressure is relatively stable if determined predominantly by the community's subsistence demand. Fishing is limited by the quantity that the community can consume, and changes occur in response to population growth and/or changes in eating habits. In contrast, if fishing is performed mainly for external sale, fishing pressure varies according to outside market demand (which may be dynamic) and the cost-benefit (to fishers) of fishing. Fishing strategies may vary accordingly and significantly. The recorded purposes of fishing are presented as the percentage of all fishers interviewed per habitat fished. We distinguish these figures by habitat so as to allow for the fact that one fisher may fish several habitats but do so for different purposes.

Information on the additional involvement of interviewed fishers in invertebrate fisheries, for either subsistence or commercial purposes, helps us to understand the subsistence and/or commercial importance of various coastal resources. The percentage of finfish fishers who also harvest invertebrates is calculated, with the share of these who do so for subsistence and/or for commercial purposes presented in percentage (the sum of the latter percentages may exceed 100, because fishers may harvest invertebrates for both subsistence and sale).

The average catch per habitat (technique and transport used) is recorded, including:

- a list of species, usually by vernacular names; and
- the kg or number per size class for each species.

These data are used to calculate total weight per species and size class, using a weight–length conversion factor (FishBase 2000, refer to Letourneur *et al.* 1998; Kulbicki pers. com.). This requires using the vernacular/scientific name index to relate (as far as possible) local names to their scientific counterparts. Fish length is reported by using size charts that comprise five major size classes in 8 cm intervals, i.e. 8 cm, 16 cm, 24 cm, 32 cm and 40 cm. The length of any fish that exceeds the largest size class (40 cm) presented in the chart is individually estimated using a tape measure. The length–weight relationship is calculated for each site using a regression on catch records from finfish fishers' interviews weighted by the annual catch. Data used from the catch records consist of scientific names correlated to the vernacular names given by fishers, number of fish, size class (or measured size) and/or weight. In other words, we use the known length–weight relationship for the corresponding species to vernacular names recorded.

Once we have established the average and total weight per species and size class recorded, we provide an overview of the average size for each family. The resulting pattern allows analysis of the degree to which average and relative sizes of species within the various families present at a particular site are homogeneous. The same average distribution pattern is calculated for all families, per habitat, in order to reveal major differences due to the locations where the fish were caught. Finally, we combine all fish records caught, per habitat and site, to determine what proportion of the extrapolated total annual catch is composed of each of the various size classes. This comparison helps to establish the most dominant size class caught overall, and also reveals major differences between the habitats present at a site.

Catch data are further used to calculate the total weight for each family (includes all species reported) and habitat. We then convert these figures into the percentage distribution of the total annual catch, by family and habitat. Comparison of relative catch composition helps to identify commonalities and major differences, by habitat and between those fish families that are most frequently caught.

A number of parameters from the household and fisher surveys are used to calculate the total annual catch volume per site, habitat, gender, and use of the catch (for subsistence and/or commercial purposes).

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Data from the household survey regarding the number of fishers (by gender and type of fishery) in each household interviewed are extrapolated to determine the total number of men and women that target finfish, invertebrates, or both.

Data from the fisher survey are used to determine what proportion of men and women fishers target various habitats or combinations of habitats. These figures are assumed to be representative of the community as a whole, and hence are applied to the total number of fishers (as determined by the household survey). The total number of finfish fishers is the sum of all fishers who solely target finfish, and those who target both finfish and invertebrates; the same system is applied for invertebrate fishers (i.e. it includes those who collect only invertebrates and those who target both invertebrates and finfish. These numbers are also disaggregated by gender.

The total annual catch per fisher interviewed is calculated, and the average total annual catch reported for each type of fishing activity/fishery (including finfish and invertebrates) by gender is then multiplied by the total number of fishers (calculated as detailed above, for each type of fishing activity/fishery and both genders). More details on the calculation applied to invertebrate fisheries are provided below.

<u>Total annual catch (t/year):</u>

$$\text{TAC} = \sum_{h=1}^{N_h} \frac{Fif_h \bullet Acf_h + Fim_h \bullet Acm_h}{1000}$$

TAC = total annual catch t/year
Fif_h = total number of female fishers for habitat_h
Acf_h = average annual catch of female fishers (kg/year) for habitat_h
Fim_h = total number of male fishers for habitat_h
Acm_h = average annual catch of male fishers (kg/year) for habitat_h
N_h = number of habitats

Where:

$$\text{Acf}_h = \frac{\sum_{i=1}^{If_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12} \bullet Cfi}{If_h} \bullet \frac{\sum_{k=1}^{Rf_h} f_k \bullet 52 \bullet 0.83 \bullet \frac{Fm_k}{12}}{\sum_{i=1}^{If_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12}}$$

If_h = number of interviews of female fishers for habitat_h (total number of interviews where female fishers provided detailed information for habitat_h)
f_i = frequency of fishing trips (trips/week) as reported on interview_i
Fm_i = number of months fished (reported in interview_i)
Cf_i = average catch reported in interview_i (all species)
Rf_h = number of targeted habitats as reported by female fishers for habitat_h (total numbers of interviews where female fishers reported targeting habitat_h but did not necessarily provide detailed information)
f_k = frequency of fishing trips (trips/week) as reported for habitat_k
Fm_k = number of months fished for reported habitat_k (fishers = sum of finfish fishers and mixed fishers, i.e. people pursuing both finfish and invertebrate fishing)

Thus, we obtain the total annual catch by habitat and gender group. The sum of all catches from all habitats and both genders equals the total annual impact of the community on its fishing ground.

The accuracy of this calculation is determined by reliability of the data provided by interviewees, and the extrapolation procedure. The variability of the data obtained through fisher surveys is illuminated by providing standard errors for the calculated average total annual catches. The size of any error stemming from our extrapolation procedure will vary according to the total population at each site. As mentioned above, this approach is best suited to assess small and predominantly traditional coastal communities. Thus, the risk of over- or underestimating fishing impact increases in larger communities, and those with greater urban influences. We provide both the total annual catch by interviewees (as determined from fisher records) and the extrapolated total impact of the community, so as to allow comparison between recorded and extrapolated data.

The total annual finfish consumption of the surveyed community is used to determine the share of the total annual catch that is used for subsistence, with the remainder being the proportion of the catch that is exported (sold externally).

Total annual finfish export:

$$E = TAC - \left(\frac{F_{tot}}{1000} \bullet \frac{1}{0.8}\right)$$

Where:

E = total annual export (t)
TAC = total annual catch (t)
F_{tot} = total annual finfish consumption (net weight kg)
$\frac{1}{0.8}$ = to calculate total biomass/weight, i.e. compensate for the earlier deduction by 0.8 to determine edible weight parts only

In order to establish fishing pressure, we use the habitat areas as determined by satellite interpretation. However, as already mentioned, resource surveys and satellite interpretation do not include lagoon areas. Thus, we determine the missing areas by calculating the smallest possible polygon (Figure A1.3.3) 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.

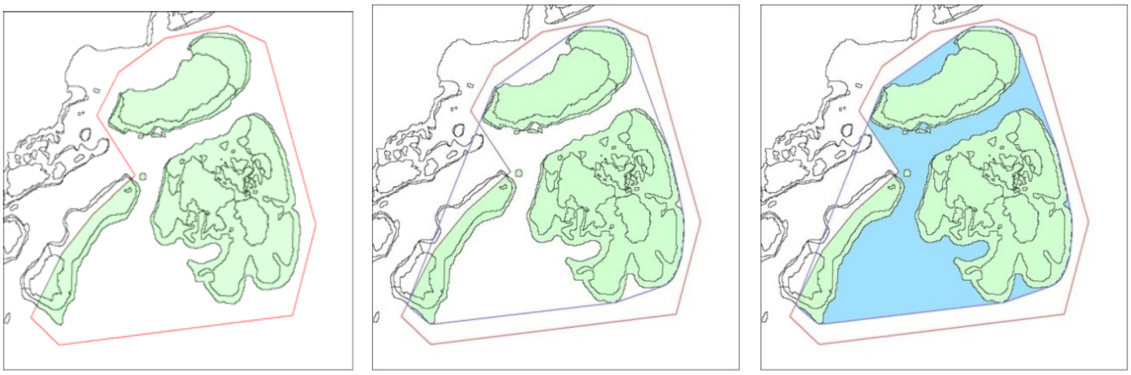

Figure A1.3.3: Determination of lagoon area.
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled as 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 shown. 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 1.3.3. We used this approach to estimate total biomass (wet weight) removed; we have also listed approximations of the ratio between edible and non-edible biomass for each species.

Information on invertebrate fishing strategies by fishery and gender includes:

- frequency of fishing trips
- duration of an average fishing trip
- time when fishing
- total number of months fished per year
- mode of transport used
- size of fishing parties
- fishing external to the community's fishing grounds
- purpose of the fisheries
- whether or not the fisher also targets finfish.

In addition, for each fishery (or combination of fisheries) the species composition of an average catch is listed, and the average catch for each fishery is specified by number, size and/or total weight. If local units such as bags (plastic bags, flour bags), cups, bottles or buckets are used, the approximate weight of each unit is estimated and/or weighed during the field survey and average weight applied accordingly. For size classes, size charts for different species groups are used (Figure A1.3.2).

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 1.3.3) results in a determination of total biomass (wet weight) removed, by fishery and by gender. The sum of all weights determines the total annual impact, in terms of biomass removed.

To calculate total annual impact, we determine the total numbers of months fished by each interviewee. As mentioned above, seasonality of complementary activities, seasonal closing of fishing areas, etc. may result in distinct fishing patterns. Based on data provided by interviewees, we apply – as for finfish – a correction factor of 0.83 to take into account exceptional periods throughout the year when fishing is not possible or not pursued (this is determined on the basis that about two months (304/365 days) of each year are not used for fishing due to festivals, funerals and bad weather conditions).

Total annual catch:

$$\text{TACj} = \sum_{h=1}^{N_h} \frac{F_{inv}f_h \bullet Ac_{inv}f_{hj} + F_{inv}m_h \bullet Ac_{inv}m_{hj}}{1000}$$

TACj = total annual catch t/year for species$_j$
$F_{inv}f_h$ = total number of female invertebrate fishers for habitat$_h$
$Ac_{inv}f_{hj}$ = average annual catch by female invertebrate fishers (kg/year) for habitat$_h$ and species$_j$
$F_{inv}m_h$ = total number of male invertebrate fishers for habitat$_h$
$Ac_{inv}m_{hj}$ = average annual catch by male invertebrate fishers (kg/year) for habitat$_h$ and species$_j$
N_h = number of habitats

Where:

$$Ac_{inv}f_{hj} = \frac{\sum_{i=1}^{I_{inv}f_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12} \bullet Cf_{ij}}{I_{inv}f_h} \bullet \frac{\sum_{k=1}^{R_{inv}f_h} f_k \bullet 52 \bullet 0.83 \bullet \frac{Fm_k}{12}}{\sum_{i=1}^{I_{inv}f_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12}}$$

$I_{inv}f_h$ = number of interviews of female invertebrate fishers for $habitat_h$ (total numbers of interviews where female invertebrate fishers provided detailed information for $habitat_h$)
f_i = frequency of fishing trips (trips/week) as reported in $interview_i$
Fm_i = number of months fished as reported in $interview_i$
Cf_{ij} = average catch reported for $species_j$ as reported in $interview_i$
$R_{inv}f_h$ = number of targeted habitats reported by female invertebrate fishers for $habitat_h$ (total numbers of interviews where female invertebrate fishers reported targeting $habitat_h$ but did not necessarily provide detailed information)
f_k = frequency of fishing trips (trips/week) as reported for $habitat_k$
Fm_k = number of months fished for reported $habitat_k$

The total annual biomass (t/year) removed is also calculated and presented by species after transferring vernacular names to scientific nomenclature. Size frequency distributions are provided for the most important species, by total annual weight removed, expressed in percentage of each size group of the total annual weight harvested. The size frequency distribution may reveal the impact of fishing pressure for species that are represented by a wide size range (from juvenile to adult state). It may also be a useful parameter to compare the status of a particular species or species group across various sites at the national or even regional level.

To further determine fishing strategies, we also inquire about the purpose of harvesting each species (as recorded by vernacular name). Results are shown 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.

1.3.2 Socioeconomic survey questionnaires

- Household census and consumption survey
- Finfish fishing and marketing survey (for fishers)
- Invertebrate fishing and marketing survey (for fishers)
- Fisheries (finfish and invertebrate and socioeconomics) general information survey

HOUSEHOLD CENSUS AND CONSUMPTION SURVEY

HH NO. ☐

Name of head of household: ________________ Village: _________________

Name of person asked: _____________________ Date: __________________

Surveyor's ID: __________________

1. Who is the head of your household? male ☐ female ☐
   (must be living there; tick box)

2. How old is the head of household? *(enter year of birth)* ☐

3. How many people ALWAYS live in your household? ☐
   (enter number)

4. How many are male and how many are female?
   (*tick box and enter age in years or year of birth)*

male	age	female	age
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐

5. Does this household have any agricultural land?

   yes ☐ no ☐

6. How much (*for this household only*)?

   for permanent/regular cultivation ☐ (unit)

   for permanent/regular livestock ☐ (unit)
   type of animals__________ no. ☐

7. How many fishers live in your household? ☐
(*enter number of people who go fishing/collecting regularly)*

invertebrate fishers		finfish fishers		invertebrate & finfish fishers	
M	F	M	F	M	F
☐	☐	☐	☐	☐	☐

8. Does this household own a boat? yes ☐ no ☐

9a. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP
9b. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP
9c. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP

10. Where does the CASH money in this household come from? (*rank options, 1 = most money, 2 = second important income source, 3 = 3rd important income source, 4 = 4th important income source*)

Fishing/seafood collection ☐

Agriculture (crops & livestock) ☐

Salary ☐

Others (handicrafts, etc.) ☐ specify: ____________________

11. Do you get remittances? yes ☐ no ☐

12. How often?	1 per month	1 per 3 months	1 per 6 months	other *(specify)*
	☐	☐	☐	☐

13. How much? *(enter amount)* Every time? (currency) ______

14. How much CASH money do you use on average for household expenditures (food, fuel for cooking, school bus, etc.)?

(currency) ______ per week/2-weekly/month (or? specify_______)

15. What is the educational level of your household members?

no. of people	having achieved:
	elementary/primary education
	secondary education
	tertiary education (college, university, special schools, etc.)

CONSUMPTION SURVEY

16. During an average/normal week, on how many days do you prepare fish, other seafood and canned fish for your family? *(tick box)*

	7 days	6 days	5 days	4 days	3 days	2 days	1 day	other, specify
Fresh fish								
Other seafood								
Canned fish								

17. Mainly at	breakfast	lunch	supper
Fresh fish			
Other seafood			
Canned fish			

18. How much do you cook on average per day for your household? *(tick box)*

	number	kg	size: A	B	C	D	E	>E (cm)
Fresh fish								

Other seafood

name:	no.	size	kg	plastic bag ¼	½	¾	1
______________	☐	☐	☐	☐	☐	☐	☐
______________	☐	☐	☐	☐	☐	☐	☐
______________	☐	☐	☐	☐	☐	☐	☐
______________	☐	☐	☐	☐	☐	☐	☐

19. Canned fish No. of cans: ☐ Size of can: ☐ small

☐ medium

☐ big

20. Where do you normally get your fish and seafood from?

Fish:

☐ caught by myself/member of this household

☐ get it from somebody in the family/village (no money paid)

☐ buy it at ______________

Which is the most important source? ☐ caught ☐ given ☐ bought

Invertebrates:

☐ caught by myself/member of this household

☐ get it from somebody in the family/village (no money paid)

☐ buy it at ______________

Which is the most important source? ☐ caught ☐ given ☐ bought

21. Which is the last day you had fish? ______________

22. Which is the last day you had other seafood? ______________

–THANK YOU–

FISHING (FINFISH) AND MARKETING SURVEY

Name: ____________________ F ☐ M ☐ **HH NO.** ☐

Name of head of household: _______________________ Village: ______________

Surveyor's name: _____________________ Date: ______________

1. Which areas do you fish?

coastal reef	lagoon	outer reef	mangrove	pelagic
☐	☐	☐	☐	☐

2. Do you go to only one habitat per trip?

Yes ☐ no ☐

3. If no, how many and which habitats do you visit during an average trip?

total no.	habitats:	coastal reef	lagoon	mangrove	outer reef
☐		☐	☐	☐	☐

4. How often (days/week) do you fish in each of the habitats visited?

coastal reef	lagoon	mangrove	outer reef	
☐	☐	☐	☐	__________/times per week/month
☐	☐	☐	☐	__________/times per week/month
☐	☐	☐	☐	__________/times per week/month

5. Do you use a boat for fishing?

	Always	sometimes	never
coastal reef	☐	☐	☐
lagoon	☐	☐	☐
mangrove	☐	☐	☐
outer reef	☐	☐	☐

6. If you use a boat, which one?

1 { canoe (paddle) ☐ sailing ☐
motorised ☐ HP outboard ☐ 4-stroke engine ☐ }

coastal reef ☐ lagoon ☐ outer reef ☐

2
- canoe (paddle) ☐ sailing ☐
- motorised ☐ HP outboard ☐ 4-stroke engine ☐

coastal reef ☐ lagoon ☐ outer reef ☐

3
- canoe (paddle) ☐ sailing ☐
- motorised ☐ HP outboard ☐ 4-stroke engine ☐

coastal reef ☐ lagoon ☐ outer reef ☐

7. How many fishers ALWAYS go fishing with you?

Names:____
____
____
____

Appendix 1: Survey methods
Socioeconomic

INFORMATION BY FISHERY **Name of fisher: ______________** **HH NO.** ☐

coastal reef ☐ lagoon ☐ mangrove ☐ outer reef ☐

1. HOW OFTEN do you normally go out FISHING for this habitat? *(tick box)*

Every Day	5 days/ week	4 days/ week	3 days/ week	2 days/ week	1 day/ week	other, specify:
☐	☐	☐	☐	☐	☐	____________________

2. What time do you spend fishing this habitat per average trip? ___________________
(if the fisher can't specify, tick a box)

<2 hrs	2–6 hrs	6–12 hrs	>12 hrs
☐	☐	☐	☐

3. WHEN do you go fishing? *(tick box)* day ☐ night ☐ day & night ☐

4. Do you go all year?

Yes ☐ no ☐

5. If no, which months <u>don't</u> you fish?

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6. Which fishing techniques do you use (*in the habitat referred to here*)?

☐ handline

☐ castnet ☐ gillnet

☐ spear (dive) ☐ longline

☐ trolling ☐ spear (handheld) walking ☐ canoe ☐

☐ deep-bottom line ☐ poison: which one? ______________

☐ other, specify: ____

7. Do you use more than one technique per trip for this habitat? If yes, which ones usually?

☐ one technique/trip ☐ more than one technique/trip:

____

8. Do you use ice on your fishing trips?

☐ always ☐ sometimes ☐ never

☐ is it homemade? ☐ or bought?

9. What is your average catch (kg) per trip? ☐ Kg <u>OR:</u>

size class:	A	B	C	D	E	>E (cm)
number:						

10. Do you sell fish? yes ☐ no ☐

11. Do you give fish as a gift (for no money)? yes ☐ no ☐

12. Do you use your catch for family consumption? yes ☐ no ☐

13. How much of your usual catch do you keep for family consumption?

kg ☐ <u>OR:</u>

size class	A	B	C	D	E	>E (cm)
no						

and the rest you gift? yes ☐

how much? kg ☐ <u>OR:</u>

size class	A	B	C	D	E	>E (cm)
no.						

and/or sell? yes ☐

how much? kg ☐ <u>OR</u>:

size class	A	B	C	D	E	>E (cm)
no.						

14. What sizes of fish do you use for your family consumption, what for sale and what do you give away without getting any money?

size classes:	all	A	B	C	D	E	and larger (no. and cm)
consumption	☐	☐	☐	☐	☐	☐	☐
sale	☐	☐	☐	☐	☐	☐	☐
give away	☐	☐	☐	☐	☐	☐	☐

15. You sell where?

☐ inside village ☐ outside village where? ___________________________

and to whom?

market ☐ agents/middlemen ☐ shop owners ☐ others ☐ ___________

16. In an average catch what fish do you catch, and how much of each species? *(write down the species in the table)*

technique usually used:____________________ boat type usually used:_______________
habitat usually fished: ____

Specify the number by size

Name of fish	kg	A	B	C	D	E	>E cm

20. Do you also fish invertebrates?

Yes ☐ no ☐ <u>if yes</u> for consumption? ☐ sale? ☐

–THANK YOU–

INVERTEBRATE FISHING AND MARKETING SURVEY
FISHERS

HH NO. ☐

Name: ____

Gender: ☐ female ☐ male Age: ☐

Village: ____

Date: ________________ Surveyor's name: ___________________

Invertebrates = everything that is not a fish with fins!

1. Which type of fisheries do you do?

☐ seagrass gleaning ☐ mangrove & mud gleaning

☐ sand & beach gleaning ☐ reeftop gleaning

☐ bêche-de mer diving ☐ mother-of-pearl diving trochus, pearl shell, etc.

☐ lobster diving ☐ other, such as clams, octopus

2. *(if more than one fishery in question 1):* Do you usually go fishing at only one of the fisheries or do you visit several during one fishing trip?

☐ one only ☐ several

If several fisheries at a time, which ones do you combine?

----

3. How often do you go gleaning/diving (*tick as from questions 1 and 2 above and watch for combinations*) and for how long, and do you also finfish at the same time?

		times/week		duration in hours (*if the fisher can't specify, tick the box*) <2	2–4	4–6	>6	glean/dive at D	N	D&N	fish no. of months/year
☐	seagrass gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐	mangrove & mud gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐	sand & beach gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐	reeftop gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐	bêche-de-mer diving	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐	lobster diving	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐	mother-of-pearl diving trochus, pearl shell, etc.	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐	other diving (clams, octopus)	☐	____	☐	☐	☐	☐	☐	☐	☐	________

D = day, N = night, D&N = day and night (no preference but fish with tide)

4. Do you sometimes go gleaning/fishing for invertebrates outside your village fishing grounds?

yes ☐ no ☐

If yes, where? ____

5. Do you finfish? yes ☐ no ☐

for: ☐ consumption? ☐ sale?

at the same time? yes ☐ no ☐

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

GLEANING: seagrass ☐ mangrove & mud ☐ sand & beach ☐ reeftop ☐

DIVING: bêche-de-mer ☐ lobster ☐ mother-of-pearl, trochus, pearl shell, etc. ☐ other (clams, octopus) ☐

SHEET 1: EACH FISHERY PER FISHER INTERVIEWED: ☐ **HH NO. __Name of fisher: _____________** **gender: F** ☐ **M** ☐

What transport do you mainly use? ☐ walk ☐ canoe (no engine) ☐ motorised boat (HP) ☐ sailboat

How many fishers are usually on a trip? (total no.) ☐ walk ☐ canoe (no engine) ☐ motorised boat (HP) ☐ sailboat

Species vernacular/common name and scientific code if possible	**Average quantity/trip**							**Used for** (specify how much from average for each category (cons., given or sold), and the main size for sale and cons. or given) gift = giving away for no money		
	total number/ trip	weight/trip					average size cm	cons.	gift	sale
		total kg	plastic bag unit							
			1	3/4	1/2	1/4				

Appendix 1: Survey methods
Socioeconomic

<table>
<tr><td>Species
vernacular/common name and scientific code if possible</td><td colspan="7">Average quantity/trip</td><td colspan="3">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</td></tr>
<tr><td rowspan="3"></td><td rowspan="3">total number/ trip</td><td colspan="5">weight/trip</td><td rowspan="3">average size cm</td><td rowspan="3">cons.</td><td rowspan="3">gift</td><td rowspan="3">sale</td></tr>
<tr><td rowspan="2">total kg</td><td colspan="4">plastic bag unit</td></tr>
<tr><td>1</td><td>3/4</td><td>1/2</td><td>1/4</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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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) finfish fishing

gillnets – most-used mesh sizes:

What is usually used for bait? And is it bought or caught?

b) invertebrate fishing → ***see end!***

5. Please give a quick inventory and characteristics of boats used in the community (length, material, motors, etc.).

Seasonality of species

What are the **FINFISH** species that you do not catch during the total year? Can you specify the particular months that they are **NOT** fished?

Vernacular name	Scientific name(s)	Months NOT fished

Seasonality of species

What are the **INVERTEBRATE** species that you do not catch during the total year? Can you specify the particular months that they are **NOT** fished?

Vernacular name	Scientific name(s)	Months NOT fished

How many people carry out the invertebrate fisheries below, from inside and from outside the community?

GLEANING	**no. from this village**	**no.**	**from village**	**no.**	**from village**
☐ seagrass gleaning	☐	☐	____	☐	____
☐ mangrove & mud gleaning	☐	☐	____	☐	____
☐ sand & beach gleaning	☐	☐	____	☐	____
☐ reeftop gleaning	☐	☐	____	☐	____
DIVING					
☐ bêche-de-mer diving	☐	☐	____	☐	____
☐ lobster diving	☐	☐	____	☐	____
☐ mother-of-pearl diving trochus, pearl shell, etc.	☐	☐	____	☐	____
☐ other (clams, octopus)	☐	☐	____	☐	____

What gear do invertebrate fishers use? *(tick box of technique per fishery)*

GLEANING (soft bottom = seagrass)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other ________		

GLEANING (soft bottom = mangrove & mud)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other ________		

GLEANING (soft bottom = sand & beach)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

GLEANING (hard bottom = reeftop)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

DIVING (bêche-de-mer)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

DIVING (lobster)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

Appendix 1: Survey methods
Socioeconomic

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?)

1.3.3 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)

1.3.3 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 cucculata	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

1.3.3 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.

APPENDIX 2: FINFISH ASSESSMENT DATA AND ANALYSIS METHODS

2.1 Methods

2.1.1 Fish and habitat assessment

Underwater visual census (Labrosse *et al.* 2002) was used to assess commercial finfish resources. This method consists in recording the species name, abundance, body length and distance to the 50 m transect line of each fish or group of fish observed. For the purpose of evaluating density and biomass, calculations were done from the counts considering a corridor area of 5 m distance each side of the tape, for a total volume of water assessed of 50 m x 10 m. Only reef fish of interest for consumption or sale and species that could potentially serve as indicators of coral reef health were surveyed. For size analysis, all data to the maximum distance were included in calculations. At the same time, a description of the substrate was done along the same surface determining, among many other variables, the area of coverage of the following substrate categories: live coral, dead coral, rubble (coral debris), bedrock and sand. More detailed information on substrate was collected at the transect (station) level, but only average values of some of such assessed categories were analysed to detect differences among reef types and sites.

Fish and associated habitat parameters were recorded along generally 24 transects per site, with a balanced design among the main geomorphologic structures or reef types present at a given site (at least six transects in each of the reef types present). For the specific needs of the finfish resource assessment, reef types were grouped into the four main coralline geomorphologic structures found in the Pacific: sheltered coastal reef, intermediate lagoon reef (patch reef that is located inside a lagoon or a pseudo-lagoon), back-reef (inner/lagoon side of outer reef), and outer reef (ocean side of fringing or barrier reefs). Maps from the NASA MCRMP (Andréfouët *et al.* 2006), satellite images and in situ observation at dive sites allowed identification of such habitats and calculation of reef areas in each studied site.

Composition and diversity of habitat at a larger scale (large-scale habitat complexity, at the scale of 10 km) were summarised by a computed variable, L4, equivalent to the average number of substrate pixels obtained by satellite photos describing substrate composition in a 10 km radius around each site.

Islands were grouped into four major morphological types, as a function of their geological development and distribution of reefs, based on a description compiled by South *et al.* (2004); such classification is defined in Table A2.1.1, with all habitat descriptors given in Table A2.1.2.

Table A2.1.1: Definition of four types of island based on geomorphology and composition of reefs

Island type and number of sites	Atoll (13)	Complex island (28)	Island with small lagoon (7)	Oceanic island (15)
Description of characteristic	Latest stage of a tropical island. No more native rocks; land is old reef or beach rock. Barrier reef with some *motu*, central lagoon	Includes barrier reef, back-reef, intermediate reef, deep lagoon, large-fringing reef , may include seagrass beds, mangroves	Intermediate-reef complexity with no full-size lagoon between a barrier reef and a fringing reef; may hold some parts of deep lagoon	Young fringing reef, almost exposed at low tide, sometimes with shallow and very limited pools; includes systems with lagoon in formation
Site examples	Likiep (MI), Piis-Panewu (FSM)	Chubikopi (SB)	Maatea (FP)	Niue, Mangaia (CK)
	Age of formation ◄────			

Table A2.1.2: List of selected large-scale habitat variables used in the analysis, including transformed variables to linearise some of them

Definition and number of transformed parameters	Abbreviation	Unit of measure
Latitude (2)	lat1, lat2	Described by two values each for linearisation of the variable
Longitude (2)	long1, long2	Described by two values each for linearisation of the variable
Island types (4)	as in Table A2.1.1	Described by binary values (presence/absence for each site)
Large-scale substrate diversity (1)	L4_10 km	Average number of categories describing substrate diversity of substrate pixels from satellite photos in a 10 km radius from site
Importance of coastal reef (1)	Coastal	Surface area in km^2 covered by coastal reefs
Importance of lagoon reef (1)	Lagoon	Surface area in km^2 covered by lagoon reefs
Importance of back-reef (1)	Back	Surface area in km^2 covered by back-reefs
Importance of outer reef (1)	Outer	Surface area in km^2 covered by outer reefs

2.1.2 Finfish data use

Data from the 63 sites and 1459 transects sampled from all the 17 countries were analysed. A total of 91 commercial genera and 392 species were counted, belonging to the 15 major commercial and indicator families: Acanthuridae, Balistidae, Chaetodontidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Nemipteridae, Pomacanthidae, Scaridae, Serranidae, Siganidae and Zanclidae. No Mugilidae were included in the underwater assessment due to their typical habitat (shallow turbid waters) not being suitable for diving and counting. Carangidae are too mobile a species and not strictly associated with coral reefs, therefore too difficult to properly sample with UVC (Kulbicki *et al.* 2007).

For analysis, fish were also assigned trophic guilds according to their most common diet, as recorded on FishBase (Froese and Pauly 1997) and from Kulbicki *et al.* (2005). Trophic categories were simplified as four major classes: herbivores, invertebrate-feeders, planktivores and piscivores. The total sample size for fish was 571,254, recorded in 162,436 observations. Only 11 families, 76 genera and 251 species were considered in this analysis due to the presence of too many missing values for Kyphosidae and Nemipteridae and to the low and rare commercial importance of Chaetodontidae and Pomacanthidae (counted for additional type of reef health assessment).

In order to study the conditions of resources and to measure the impact of fishing upon them, it is essential to analyse the geographical variation and the interrelation of fish communities with their habitat at different spatial scales. Both the association of species and the production of an ecosystem at a specific location change in relation to geography and habitat (Figure A2.1.1). Moreover, fishing practices are also highly related to the environment. Therefore studying the variation due to the natural conditions structuring the ecology of fish and humans is the first necessary step in the assessment of resources status and production.

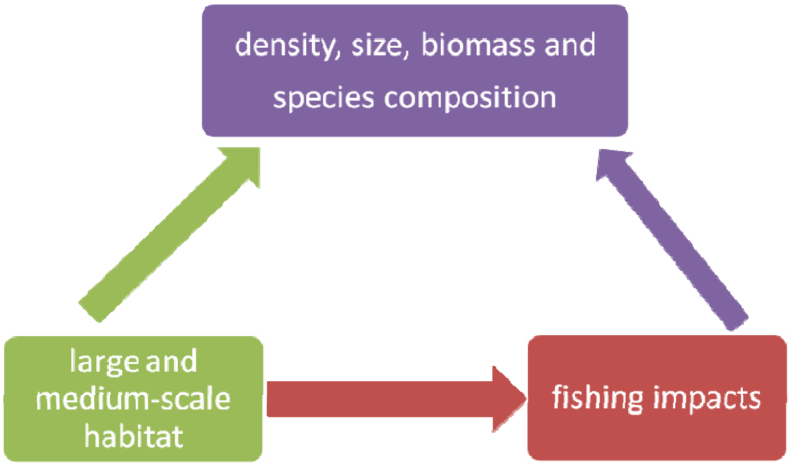

Figure A2.1.1: Relationship among the different components of this study: habitat diversity influences both fishing practices and community ecology (species composition, density and size of the components of the system).
Fishing practices have a direct influence on the ecological community.

(1) Regional variation in individual fish parameters and fish communities and their relation to habitat

- *Individual geographical variation of density, biomass and size of trophic guilds, families and species.* Relative density and biomass and average size of the four major trophic guilds, families, and most important species were analysed to look for possible preference of some fish groups for a specific reef habitat or island type (Figure A2.1.2).

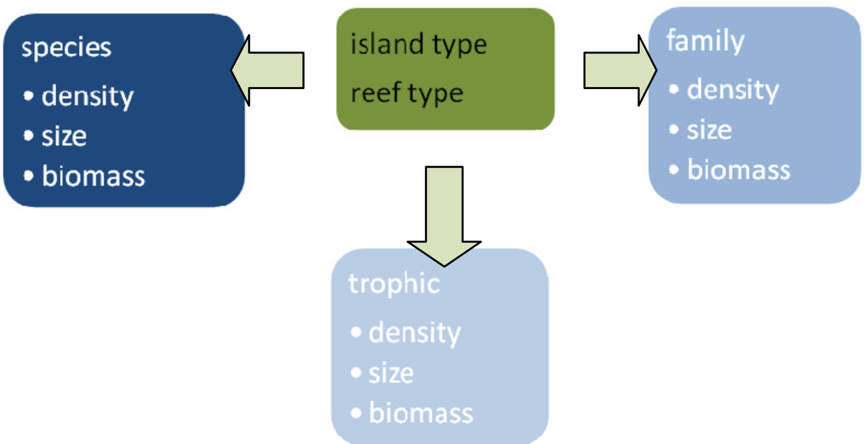

Figure A2.1.2: Individual analyses (ANOVA) were calculated for density, size and biomass of trophic groups, families and species to study preferences of fish for a specific reef habitat or island type.

- *Relations among trophic guilds, families, and species.* Principal component analysis (PCA) was conducted on matrices of relative density, biomass, and mean size of trophic group, family, or species to study relations among the different components of each data set to make an assessment of the fish community status (Figure A2.1.3).

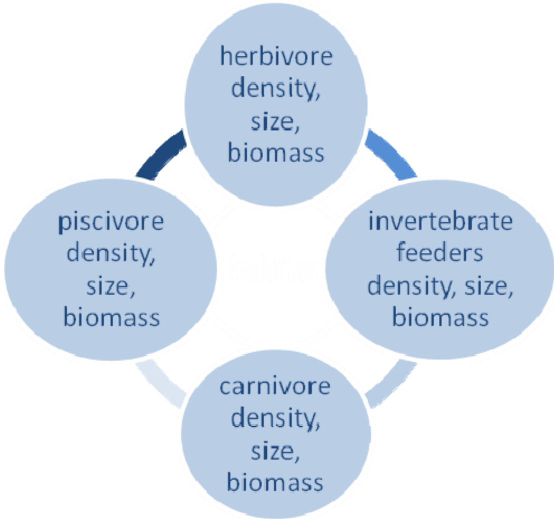

Figure A2.1.3: Individual principal component analyses (PCAs) were calculated for density, size, and biomass of trophic groups (herbivore, carnivore, piscivores, invertebrate feeder), families, and species to study relations among the different components of the fish community.

- *Relation of trophic guilds, families and species to habitat conditions* was studied by redundancy analysis (RDA) to identify the correlation of the faunal composition with the 13 selected habitat variables.

- *Selected species*: most frequent (present in >80% of transects) and abundant species distributions were analysed to evaluate their variation throughout the region using linear multi-regressions to the habitat matrix to gain a measure of the importance of habitat in controlling such species distribution and its relative importance in the community (Figure A2.1.4).

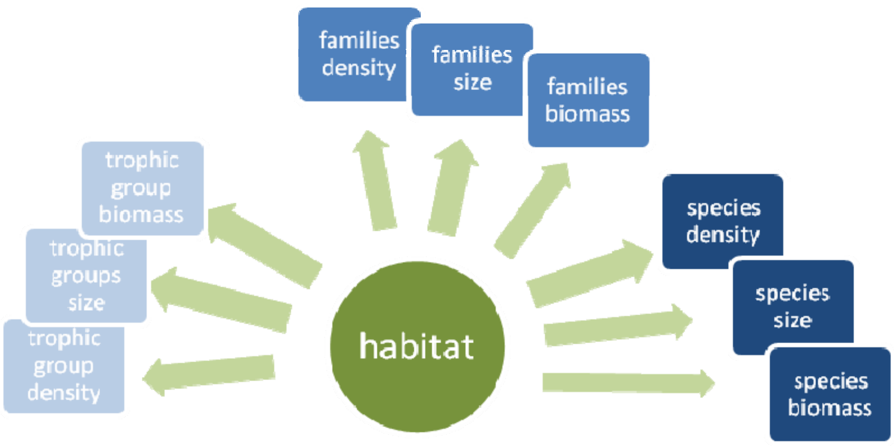

Figure A2.1.4: Individual RDAs were calculated for density, size, and biomass of trophic groups, families, and species to identify correlation of faunal composition with the habitat.

(2) Regional variations due to fishing pressure

- *Partition of variance of density, biomass, and size, of trophic guilds, families, and species among sites due to large-scale habitat, fishing pressure and other causes.* Partial ordinations (PCAs and RDAs, Borcard *et al.* 1992) were calculated to extract the percentage of the variance in the composition of trophic, family, or species groups among the sites that would be related to either habitat (Figure A2.1.5) or fishing pressure (Here simply defined by a three-variable matrix composed of: population density as people per km^2 area of reef, per capita consumption of fresh fish per year as kg/pc/year and catch devoted to sale as $t/km^2/year$.).

Figure A2.1.5: Individual PCAs and RDAs to partition variance of trophic, family, and species composition (density, size, and biomass) due to habitat, fishing pressure, and other causes.

(3) Community status indicators

- *Size-spectra.* One possible means to study this complex, multi-species, multi-gear fishery is through the study of the size composition of fish community through the use of size-frequency analysis. This is the analysis of the general distribution of all the individuals of a community in terms of their length, and it can help identify the status of health or stress of that community, based on the observations that increasing levels of stress on a community increase dominance of certain species (opportunistic species) over others. We consider fishing as a disturbance or stress in the fish community due to the fact that large fish are generally targeted before small fish (Pauly *et al.* 1998); an increase in the exploitation rate of the fish community leads to a reduction in the abundance of large predators and to an increase in the abundance of small preys (Daan 2005, Bianchi *et al.* 2000, Pope and Knights 1982). The more smaller-sized animals and less large-sized animals there are in the fish community, the steeper the slope of the size-frequency distribution (Pope and Knights 1982, Pope *et al.* 1987, Murawski and Idoine 1992, Gobert 1994, Bianchi *et al.* 2000, Zwanenburg 2000, Daan 2005).

  Different descriptors of such size-frequency distributions (slope, cumulative slope, intercept, ratio between the maximum frequency value in the distribution and its relative size [y_{max}/x_{max}], ratio between the 50% frequency value and its relative size [y_{50}/x_{50}], relative density of large species, relative biomass of small species, relative biomass of all major piscivores and relative biomass of herbivores over carnivores) were used to compare size spectra among groups of sites of different size composition (Figure A2.1.6).

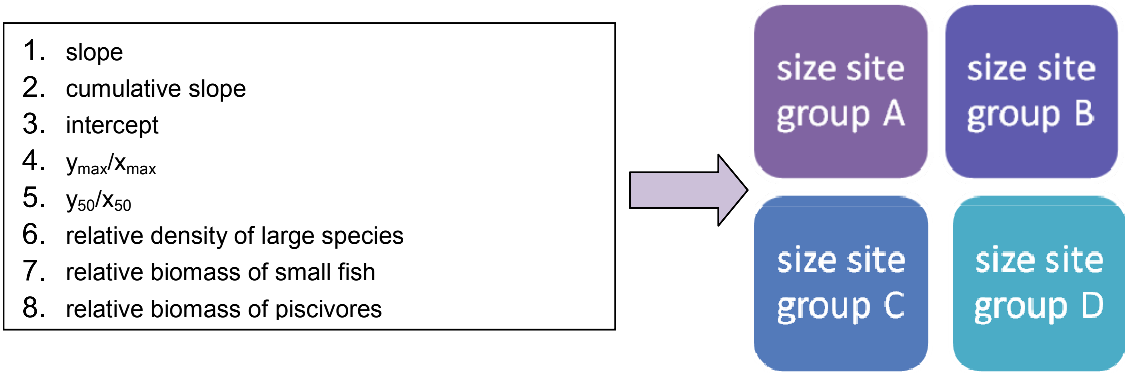

Figure A2.1.6: Grouping of sites based on the fish size composition and characterisation of each by different size and community ecology variables.

- *Biomass–density dominance curves.* Another approach to a community analysis based on size and number composition is the use of k-dominance curves (Lambshead *et al.* 1983), built by ranking species in decreasing order of abundance (or biomass). In natural or undisturbed conditions, the competitive dominant species in the community are large body-sized, long-life span species, rarely dominant in numbers but with a dominant biomass, with one or few large species represented by few individuals (Warwick 1986, Clarke and Warwick 1994); the opportunistic, short-lifespan species are, on the contrary, usually numerically dominant in natural conditions but do not represent a large proportion of the community biomass. In this equilibrium state, the biomass curve lies above the numerical curve. However, when a perturbation occurs, the long-lifespan species will be less favoured and opportunistic species become the biomass as well as the numerical dominants. When disturbance is represented by fishing, such a switch of the community distribution could be either a direct effect of targeted predation on selected large-sized species, as the one deriving most from fishing practice, or an indirect response of the preys (smaller-sized species) to a relaxation of predation (largest predators being mostly targeted by fishing), or both. Under moderate disturbance from fishing, the large dominant species are selectively reduced and the inequality between the numerical and biomass dominance is reduced so that the curves are closer to each other or may even cross. When the impact is severe, the community becomes increasingly dominated by one or few small opportunistic species and the abundance curve lies above the biomass curve.

  Communities at different levels of impact were compared by the standardised sum of all the single differences in values of biomass and density (B-D) at each rank. When the biomass curve is above the density curve (less stressed location), the (B-D) value will be positive. When the curves intertwine, the sum of these differences (W: sum of the differences standardised to a common scale for unequal number of species (Clarke 1990)), will tend to be near zero. When the density curve is above the biomass curve (highly stressed location), the sum of the difference (W) will be strongly negative.

- *L_{max} spectra.* The study of L_{max} spectra is a further help in the assessment of the conditions of exploitation of a community. This description measures the distribution of abundance among large-sized, mid-sized and small-sized species and not just individuals. Total abundance of species with low L_{max} increases with increasing exploitation and those with high L_{max} decreases. This trend supports the general idea that large-sized species are more sensitive to exploitation and that such small species seem to be advantaged by fishing exploitation owing to the removal of large predators (Bhonsack 1981, Daan *et al.* 2005).

(4) Statistical analysis for selection of best indicators of status and impact, and association of groups of sites of similar status with habitat conditions

Purpose: identification of descriptors of status and the association of groups of sites of different conditions of production and health with habitat and fishing. Studies of the different sites and their conditions were made by using indicators that were selected from all the previous approaches based on their individual strength in signalling conditions. Principle component analysis, partial principal component analysis, redundancy analysis and partial redundancy analysis were used to assess the relation of all such parameters to habitat and fishing pressure and to measure the relative importance of these two major sets of drivers in influencing the fish communities.

Such analyses were done on fish community descriptive matrices based on size composition as well as on other fish-community indicators:

- From indicator test analysis, we obtained a site matrix composed of the selected values of: a) the slope of the cumulative percentage frequency, b) the relative density of large species, c) the relative biomass of fish smaller than 20 cm, d) the relative biomass of piscivores, e) the relative ratio between herbivores and carnivores and f) the value of W (Figure A2.1.7).

- From other fish-community indicators we obtained several site matrices where parameters were respectively: a) biomass of four trophic groups, b) biomass of major families, c) biomass of selected species, d) density of trophic groups, e) density of major families, f) density of selected species, g) size of trophic groups, h) size of major families.

A separate analysis was done on the three sub-regions Melanesia, Micronesia and Polynesia.

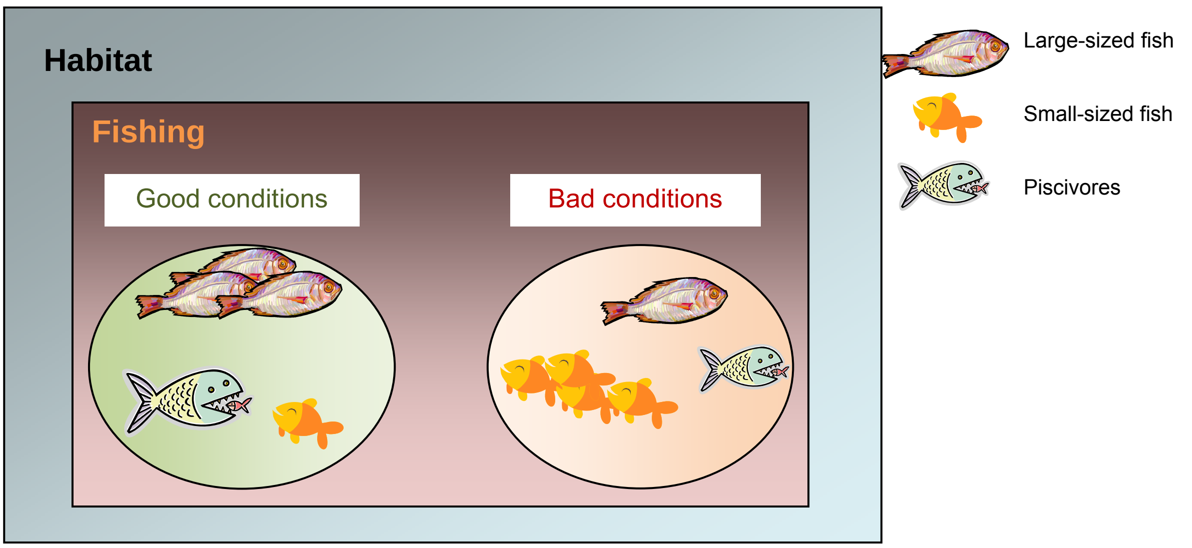

Figure A2.1.7: Simplification of one of the indicators' analysis processes, where the influences of habitat and fishing on the fish community are measured.
Fish community is represented by a) the slope of the cumulative percentage frequency, b) the relative density of large species, c) the relative biomass of fish smaller than 20 cm, d) the relative biomass of piscivores, e) the relative ratio between herbivores and carnivores and f) the value of W. The parameters b), c) and d) are represented in the diagram.

- *Refinement of indicators of status*. We conducted an ANOVA test on the four groups of sites based on the size analysis of parameters that resulted as important from all the previous analyses together with further *a priori* ones to test their significance and usefulness as indicators of status throughout the region. These parameters were, from previous analyses, the logarithmically transformed values of relative density of species of maximum size 52 cm (RD_{L52}), the relative biomass of fish of size <20 cm (RB_{20}), the relative biomass of all major piscivores (Lutjanidae and Serranidae, RB_{LS}), the relative biomass of herbivores over carnivores (H_b/C_b), the W statistics and, chosen *a priori*, the relative biomass of Acanthuridae, the relative biomass of Scaridae, the relative density of *Ctenochaetus striatus*, the relative density of *Chlorurus sordidus*, the relative biomass of *Naso lituratus*, the density of Carangidae, the presence of *Cheilinus undulatus*, the presence of *Bolbometopon muricatum*, the presence of sharks, and the average distance at which a fish keeps away from the divers.

2.2 Countries, sites, and corresponding abbreviations

Country/Territory	Abbreviation	Sites
Cook Islands	CK	Aitutaki, Mangaia, Palmerston, Rarotonga
Fiji Islands	FJ	Dromuna, Lakeba, Mali, Muaivuso
French Polynesia	FP	Fakarava, Maatea, Mataiea, Raivavae, Tikehau
Federated States of Micronesia	FM	Piis-Panewu, Riiken, Romanum, Yyin
Kiribati	KI	Abaiang, Abemama, Kiritimati, Kuria
Marshall Islands	MI	Ailuk, Arno, Laura, Likiep
Nauru	NR	Nauru
New Caledonia	NC	Luengoni, Moindou, Ouassé, Oundjo, Thio
Niue	NU	Niue
Palau	PW	Airai, Koror, Ngarchelong, Ngatpang
Papua New Guinea	PG	Andra, Panapompom, Sideia, Tsoilaunung
Samoa	WS	Manono-uta, Salelavalu, Vailoa, Vaisala
Solomon Islands	SB	Chubikopi, Marau, Nggela, Rarumana
Tonga	TO	Ha'atafu, Koulo, Lofanga, Manuka
Tuvalu	TV	Funafuti, Niutao, Nukufetau, Vaitupu
Vanuatu	VU	Maskelynes, Moso, Paunagisu, Uri-Uripiv
Wallis and Futuna	WF	Futuna, Halalo, Vailala

2.3 Island type classification for each site

Atoll sites		
1	Kiribati	Abaiang
2	Kiribati	Abemama
3	Marshall Islands	Ailuk
7	Marshall Islands	Arno
11	French Polynesia	Fakarava
12	Tuvalu	Funafuti
17	Tonga	Koulo
20	Marshall Islands	Laura
21	Marshall Islands	Likiep
22	Tonga	Lofanga
41	Tuvalu	Nukufetau
44	Cook Islands	Palmerston
56	French Polynesia	Tikehau
Oceanic island sites		
8	Kiribati	Kiritimati
13	Wallis and Futuna	Futuna
18	Kiribati	Kuria
23	New Caledonia	Luengoni
26	Cook Islands	Mangaia
33	Vanuatu	Moso
35	Nauru	Nauru
38	Solomon Islands	Nggela
39	Niue	Niue
40	Tuvalu	Niutao
46	Vanuatu	Paunagisu
49	Cook Islands	Rarotonga
58	Vanuatu	Uri-Uripiv
60	Samoa	Vailoa
62	Tuvalu	Vaitupu
Small lagoon sites		
24	French Polynesia	Maatea
27	Samoa	Manonouta
31	French Polynesia	Mataiea
34	Fiji Islands	Muaivuso
48	French Polynesia	Raivavae
53	Samoa	Salelavalu
61	Samoa	Vaisala

Complex island sites		
4	Palau	Airai
5	Cook Islands	Aitutaki
6	Papua New Guinea	Andra
9	Solomon Islands	Chubikopi
10	Fiji Islands	Dromuna
14	Tonga	Haatafu
15	Wallis and Futuna	Halalo
16	Palau	Koror
19	Fiji Islands	Lakeba
25	Fiji Islands	Mali
28	Tonga	Manuka
29	Solomon Islands	Marau
30	Vanuatu	Maskelynes
32	New Caledonia	Moindou
36	Palau	Ngarchelong
37	Palau	Ngatpang
42	New Caledonia	Ouassé
43	New Caledonia	Oundjo
45	Papua New Guinea	Panapompom
47	Federated States of Micronesia	Piis-Panewu
50	Solomon Islands	Rarumana
51	Federated States of Micronesia	Riiken
52	Federated States of Micronesia	Romanum
54	Papua New Guinea	Sideia
55	New Caledonia	Thio
57	Papua New Guinea	Tsoilaunung
59	Wallis and Futuna	Vailala
63	Federated States of Micronesia	Yyin

2.4 Percentage areas of the four studied reef types and their total area in km^2 for each site

Country/Territory	Site	Coastal (%)	Lagoon (%)	Back-reef (%)	Outer (%)	Total area (km^2)
Cook Islands	Aitutaki		51.6	29.2	19.2	39.3
	Mangaia				100.0	4.8
	Palmerston		1.1	75.7	23.3	25.3
	Rarotonga			40.2	59.8	16.5
Fiji Islands	Dromuna	20.6	44.2	32.5	2.7	84.4
	Lakeba	19.1	12.4	61.6	6.8	106.7
	Mali	11.6	9.7	72.2	6.4	82.8
	Muaivuso		0.1	88.1	11.8	11.6
French Polynesia	Fakarava		7.5	80.3	12.2	83.0
	Maatea	13.1	0.1	64.9	21.9	10.7
	Mataiea	6.0	4.7	73.8	15.5	14.6
	Raivavae	10.2		29.0	60.9	92.6
	Tikehau		3.2	85.2	11.7	78.8
Federated States of Micronesia	Piis-Panewu		0.6	75.4	24.0	20.0
	Riiken	15.5	0.1	62.7	21.7	11.3
	Romanum	13.6	7.9	68.4	10.1	25.8
	Yyin			83.0	17.0	3.9
Kiribati	Abaiang		2.8	71.5	25.7	114.9
	Abemama		1.1	66.6	32.2	66.3
	Kiritimati		30.7		69.3	53.1
	Kuria				100.0	37.9
Marshall Islands	Ailuk		4.0	46.2	49.8	18.2
	Arno		1.6	79.3	19.1	62.2
	Laura		5.2	80.9	13.9	36.2
	Likiep		3.0	53.8	43.3	68.8
Nauru	Nauru				100.0	2.5
New Caledonia	Luengoni			30.9	69.1	6.8
	Moindou	12.9	43.8	40.5	2.9	182.1
	Ouassé	25.7	22.4	32.8	19.1	24.7
	Oundjo	31.1	27.4	38.6	3.0	188.5
	Thio	25.3	23.5	29.3	21.9	34.7
Niue	Niue				100.0	10.1
Palau	Airai	55.2	1.9	27.3	15.5	40.2
	Koror	11.4	9.0	70.7	8.9	185.9
	Ngarchelong	17.5	21.6	32.0	28.9	103.3
	Ngatpang	9.3	14.5	69.0	7.2	40.2
Papua New Guinea	Andra	11.8	11.7	37.6	39.0	25.5
	Panapompom	17.1	14.8	34.6	33.5	88.7
	Sideia			5.8	94.2	4.6
	Tsoilaunung	49.8	6.0		44.3	49.1
Samoa	Manono-uta	7.3	47.3	12.8	32.7	37.2
	Salelavalu	35.6	35.9	14.0	14.6	11.3
	Vailoa	20.3		22.1	57.6	5.5
	Vaisala		6.6	48.7	44.7	3.5

2.4 Percentage areas of the four studied reef types and their total area in km² for each site (continued)

Country/Territory	Site	Coastal (%)	Lagoon (%)	Back-reef (%)	Outer (%)	Total area (km²)
Solomon Islands	Chubikopi	1.1	85.1	6.9	6.9	30.4
	Marau	1.7	16.6	58.5	23.2	20.7
	Nggela				100.0	6.3
	Rarumana	9.9	23.4	60.8	5.9	32.5
Tonga	Ha'atafu	67.0		22.9	10.1	35.7
	Koulo			81.3	18.7	49.6
	Lofanga			50.0	50.0	21.1
	Manuka	22.2		59.4	18.5	83.8
Tuvalu	Funafuti		2.1	68.7	29.2	87.9
	Niutao				100.0	1.1
	Nukufetau		0.1	76.7	23.2	42.0
	Vaitupu				100.0	3.1
Vanuatu	Maskelynes	20.0	0.4		79.6	20.3
	Moso	40.3			59.7	4.4
	Paunagisu	16.7	2.5	69.4	11.5	7.3
	Uri-Uripiv	32.9			67.1	4.1
Wallis and Futuna	Futuna				100.0	13.6
	Halalo	30.6	23.6	23.0	22.7	48.3
	Vailala	30.3	11.4	15.3	42.9	26.0

2.5 Results from multiple regressions on individual species' relative density (dark shade) and biomass (light shade) towards the habitat explanatory matrix

Species	P_D	P_B	L4		Longitude		Latitude		Atoll		Small lagoon		Oceanic islands	Lagoon		Coastal	Outer		Back	
Acanthurus blochii	NS	NS																		
*Acanthurus lineatus**	NS	<0.01				-	-	-												-
Acanthurus nigricauda	<0.01	0.02				+		-								+			-	
Acanthurus triostegus	<0.02	0.01			+	+								+						
Cephalopholis argus	<0.01	<0.01			+	+	+	+			-	-						+	+	
*Chaetodon auriga**	<0.01	<0.01			+	+						-								
Chaetodon citrinellus	<0.01	<0.01					-							-			-	-		
Cheilinus chlorourus	<0.01	<0.01			+	+			+	-					-				+	+
Chlorurus microrhinos	<0.01	<0.01						+	+	+										
Chlorurus sordidus	<0.01	<0.01										+						-	+	+
Ctenochaetus striatus	NS	<0.05						+												
Gnathodentex aureolineatus	NS	NS																		
Hipposcarus longiceps	NS	NS																		
*Lutjanus bohar**	<0.01	<0.01		-			+	+												
Lutjanus fulvus	NS	NS																		
Monotaxis grandoculis	<0.02	<0.05					+	-												
Mulloides flavolineatus	<0.02	NS	+				-				+		+							
*Naso lituratus**	<0.005	<0.05	-	-				+									-			
Parupeneus cyclostomus	NS	NS																	+	
Parupeneus multifasciatus	<0.05	<0.01																		+
Sargocentrum spiniferum	NS	NS																		
Scarus frenatus	<0.01	<0.01						-									+	+		
Scarus ghobban	<0.01	<0.01												+	+					
Scarus globiceps	NS	NS																		
*Scarus niger**	<0.01	<0.03				-		-	+	+		+							-	
Scarus psittacus	<0.01	<0.01				+					+	+			-		-			
Scarus schlegeli	<0.01	<0.01			-		-	-												

Values of P associated with the multiple regression test and relative variables resulting significant for each species. Underlined species are not common fishing targets, either due to their possibility of toxicity at least in some countries due to ciguatoxin, or for not being preferred food species. Species indicated by asterisks (*) are represented in the following charts. P_D = regression probability value for density test; P_B = regression probability value for biomass test; + = positive association; - = negative association.

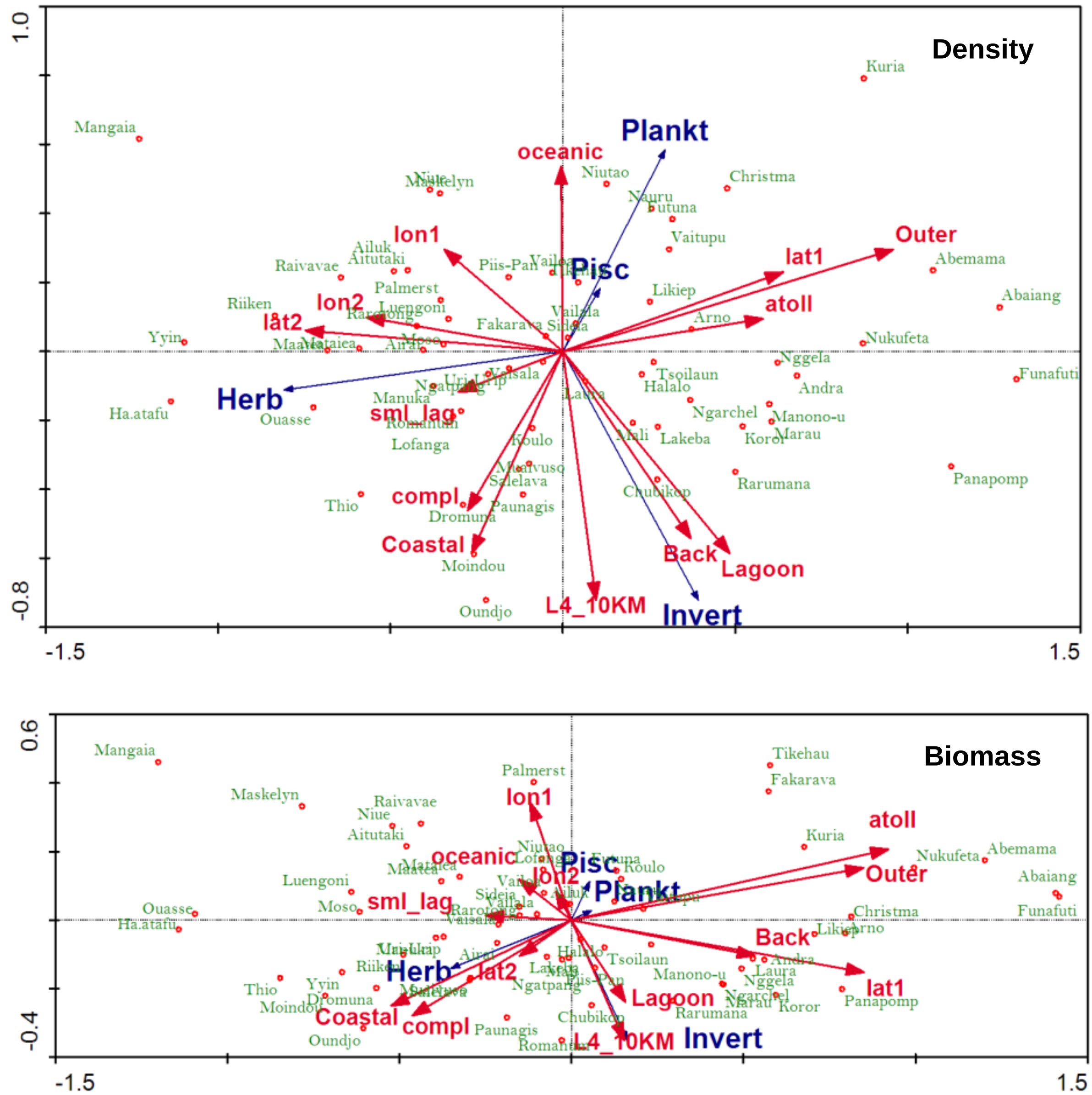

Figure A2.1.8: Redundancy analysis (RDA) of relative density and biomass by trophic group with relation to habitat.

Herb = herbivorous; Invert = invertebrate-feeding; Pisc = piscivores; Plankt = planktivores; lat = latitude; lon = longitude; sml_lag = small lagoon; compl = complex island type; L4_10km = computed variable equivalent to the average number of substrate pixels obtained by satellite photos describing substrate composition in a 10 km radius around each site; coastal = coastal habitat; outer = outer reef; back = back-reef.

2.6 Species with maximum length (L_{max}) between 25 and 29 cm (33 species)

Thirty-two per cent of the fish counted belonged to this group.

Family	Genus	Species
Acanthuridae	*Acanthurus*	*maculiceps*
Acanthuridae	*Acanthurus*	*nigroris*
Acanthuridae	*Acanthurus*	*pyroferus*
Acanthuridae	*Acanthurus*	*guttatus*
Acanthuridae	*Acanthurus*	*triostegus*
Acanthuridae	*Acanthurus*	*thompsoni*
Acanthuridae	*Ctenochaetus*	*hawaiiensis*
Acanthuridae	*Ctenochaetus*	*striatus*
Acanthuridae	*Ctenochaetus*	*marginatus*
Balistidae	*Rhinecanthus*	*aculeatus*
Balistidae	*Rhinecanthus*	*rectangulus*
Balistidae	*Rhinecanthus*	*lunula*
Caesionidae	*Caesio*	*cuning*
Caesionidae	*Pterocaesio*	*tile*
Chaetodontidae	*Heniochus*	*acuminatus*
Holocentridae	*Myripristis*	*murdjan*
Holocentridae	*Sargocentron*	*rubrum*
Labridae	*Halichoeres*	*hortulanus*
Labridae	*Novaculichthys*	*taeniourus*
Lethrinidae	*Lethrinus*	*genivittatus*
Mullidae	*Parupeneus*	*barberinoides*
Nemipteridae	*Scolopsis*	*trilineata*
Nemipteridae	*Scolopsis*	*margaritifera*
Pomacanthidae	*Apolemichthys*	*trimaculatus*
Pomacanthidae	*Apolemichthys*	*xanthopunctatus*
Pomacanthidae	*Pygoplites*	*diacanthus*
Scaridae	*Scarus*	*globiceps*
Serranidae	*Cephalopholis*	*urodeta*
Serranidae	*Epinephelus*	*merra*
Serranidae	*Epinephelus*	*sexfasciatus*
Siganidae	*Siganus*	*doliatus*
Siganidae	*Siganus*	*randalli*
Siganidae	*Siganus*	*corallinus*

2.7 Species with maximum length (L_{max}) between 35 and 39 cm (22 species)

Family	Genus	Species
Acanthuridae	*Acanthurus*	*auranticavus*
Acanthuridae	*Acanthurus*	*olivaceus*
Acanthuridae	*Acanthurus*	*lineatus*
Balistidae	*Melichthys*	*Niger*
Balistidae	*Melichthys*	*Vidua*
Balistidae	*Sufflamen*	*fraenatum*
Caesionidae	*Caesio*	*caerulaurea*
Carangidae	*Decapterus*	*Russelli*
Holocentridae	*Neoniphon*	*opercularis*
Labridae	*Cheilinus*	*chlorourus*
Labridae	*Cheilinus*	*fasciatus*
Labridae	*Choerodon*	*anchorago*
Labridae	*Coris*	spp.
Labridae	*Epibulus*	*insidiator*
Lutjanidae	*Lutjanus*	*fulviflamma*
Lutjanidae	*Lutjanus*	*kasmira*
Lutjanidae	*Lutjanus*	*semicinctus*
Lutjanidae	*Lutjanus*	*quinquelineatus*
Mullidae	*Mulloidichthys*	*vanicolensis*
Mullidae	*Parupeneus*	*Indicus*
Mullidae	*Parupeneus*	*trifasciatus*
Mullidae	*Parupeneus*	*heptacanthus*
Mullidae	*Parupeneus*	*ciliatus*
Nemipteridae	*Scolopsis*	*temporalis*
Pomacanthidae	*Pomacanthus*	*imperator*
Pomacanthidae	*Pomacanthus*	*semicirculatus*
Pomacanthidae	*Pomacanthus*	*xanthometopon*
Scaridae	*Leptoscarus*	*vaigiensis*
Scaridae	*Scarus*	*niger*
Scaridae	*Scarus*	*schlegeli*
Scombridae	*Rastrelliger*	*kanagurta*
Serranidae	*Cephalopholis*	*cyanostigma*
Serranidae	*Epinephelus*	*rivulatus*
Siganidae	*Siganus*	*argenteus*
Siganidae	*Siganus*	*puellus*

2.8 Values of W statistics for each site

Site	W	Site	W	Site	W
Kuria	-0.095	Mangaia	-0.032	Nauru	-0.012
Salelavalu	-0.082	Muaivuso	-0.031	Koulo	-0.012
Tikehau	-0.079	Vaitupu	-0.028	Airai	-0.011
Riiken	-0.070	Ngatpang	-0.028	Marau	-0.006
Palmerston	-0.064	Koror	-0.028	Manuka	-0.006
Vailoa	-0.063	Laura	-0.027	Raivavae	-0.003
Sideia	-0.058	Chubikopi	-0.027	Andra	-0.001
Vaisala	-0.057	Uri-Uripiv	-0.027	Arno	0.000
Aitutaki	-0.057	Romanum	-0.025	Yyin	0.000
Niue	-0.047	Lakeba	-0.022	Ailuk	0.002
Piis-Panewu	-0.047	Nggela	-0.022	Dromuna	0.003
Luengoni	-0.046	Ngarchelong	-0.019	Oundjo	0.004
Abemama	-0.044	Maatea	-0.018	Niutao	0.006
Paunagisu	-0.044	Rarumana	-0.018	Abaiang	0.008
Moindou	-0.043	Panapompom	-0.018	Tsoilaunung	0.016
Fakarava	-0.041	Futuna	-0.017	Lofanga	0.018
Likiep	-0.039	Thio	-0.017	Kiritimati	0.024
Ha'atafu	-0.036	Halalo	-0.017	Moso	0.033
Rarotonga	-0.034	Manono-uta	-0.017	Nukufetau	0.048
Vailala	-0.034	Funafuti	-0.016	Maskelynes	0.054
Mali	-0.033	Mataiea	-0.015	Ouassé	0.058

W is the standardised sum of all the single differences in values of biomass and density (B-D) at each rank

2.9 Species selected for partial analysis (PCAs and RDAs)

The species selected for partial analysis were:

- *Acanthurus lineatus*
- *Acanthurus nigricauda*
- *Acanthurus triostegus*
- *Cephalopholis argus*
- *Cheilinus chlorourus*
- *Chlorurus microrhinos*
- *Chlorurus sordidus*
- *Ctenochaetus striatus*
- *Monotaxis grandoculis*
- *Naso lituratus*
- *Parupeneus multifasciatus*
- *Scarus frenatus*
- *Scarus ghobban*
- *Scarus niger*
- *Scarus psittacus*
- *Scarus schlegeli*

2.10 Level of status groups and sites

Site	Group	Status level
Niue	I	Poor
Ha'atafu	I	Poor
Luengoni	I	Poor
Maatea	I	Poor
Manono-uta	I	Poor
Manuka	I	Poor
Moindou	I	Poor
Oundjo	I	Poor
Romanum	I	Poor
Salelavalu	I	Poor
Vailoa	I	Poor
Vaisala	I	Poor
Aitutaki	II	Average
Futuna	II	Average
Nauru	II	Average
Andra	II	Average
Chubikopi	II	Average
Dromuna	II	Average
Halalo	II	Average
Koulo	II	Average
Lakeba	II	Average
Lofanga	II	Average
Mali	II	Average
Mangaia	II	Average
Maskelynes	II	Average
Mataiea	II	Average
Moso	II	Average
Muaivuso	II	Average
Ngarchelong	II	Average
Ngatpang	II	Average
Palmerston	II	Average
Panapompom	II	Average
Paunagisu	II	Average
Piis-Panewu	II	Average
Riiken	II	Average
Sideia	II	Average
Thio	II	Average
Tikehau	II	Average
Tsoilaunung	II	Average
Vailala	II	Average
Abemama	III	Average–Good
Arno	III	Average–Good
Funafuti	III	Average–Good
Kuria	III	Average–Good
Laura	III	Average–Good
Nukufetau	III	Average–Good
Abaiang	IV	Good
Ailuk	IV	Good

2.10 Level of status groups and sites (continued)

Site	Group	Status level
Airai	IV	Good
Kiritimati	IV	Good
Fakarava	IV	Good
Koror	IV	Good
Likiep	IV	Good
Marau	IV	Good
Nggela	IV	Good
Niutao	IV	Good
Ouassé	IV	Good
Raivavae	IV	Good
Rarotonga	IV	Good
Rarumana	IV	Good
Uri-Uripiv	IV	Good
Vaitupu	IV	Good
Yyin	IV	Good

APPENDIX 3: INVERTEBRATE ASSESSMENT DATA AND ANALYSIS METHODS

3.1 Species presence per site

Table A3.1.1: Bêche-de-mer presence per site

Countries/Territories	Cook Islands				Fiji Islands						French Polynesia					FSM			
	Aitutaki	Mangaia	Palmerston	Rarotonga	Dromuna	Lakeba	Mali	Muaivuso	Nasaqalau	Nukunuku	Fakarava	Maatea	Mataiea	Raivavae	Tikehau	Piis-Panewu	Riiken	Romanum	Yiin
Number of species/site	**8**	**12**	**8**	**11**	**18**	**18**	**13**	**24**	**8**	**15**	**8**	**7**	**9**	**6**	**5**	**14**	**15**	**21**	**17**
Bêche-de-mer																			
Actinopyga caerulea																			
Actinopyga echinites					1			1	1	1									
Actinopyga lecanora					1	1													
Actinopyga mauritiana	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Actinopyga miliaris					1	1		1		1						1		1	1
Actinopyga palauensis																			
Actinopyga spp.																	1		1
Actinopyga spinea																			
Bohadschia argus	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bohadschia graeffei					1	1	1	1								1	1	1	
Bohadschia similis					1	1		1		1			1					1	
Bohadschia spp.																			
Bohadschia vitiensis					1	1	1	1			1	1			1	1	1	1	1
Euapta spp.								1											
Holothuria atra	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Holothuria cinerascens		1		1															
Holothuria coluber						1	1	1	1	1							1	1	1
Holothuria difficilis		1																	
Holothuria edulis					1	1	1	1		1						1	1	1	1
Holothuria flavomaculata																			1
Holothuria fuscogilva			1		1	1	1				1	1	1			1		1	
Holothuria fuscopunctata						1	1	1								1		1	1
Holothuria hilla		1		1				1		1									
Holothuria impatiens		1		1															
Holothuria leucospilota	1	1	1	1	1			1	1	1		1		1				1	
Holothuria nobilis		1	1	1	1		1	1	1	1	1		1	1			1	1	1
Holothuria pervicax		1		1				1											
Holothuria scabra					1	1		1		1							1		
Holothuria scabra versicolor																			
Holothuria spp.		1						1									1	1	
Stichopus chloronotus	1		1	1	1	1	1	1	1	1						1	1	1	1
Stichopus hermanni					1	1	1	1								1		1	
Stichopus hermanni-horrens										1									
Stichopus horrens	1		1		1	1		1					1					1	1
Stichopus monotuberculatus		1		1															
Stichopus pseudhorrens																			
Stichopus spp.																			1
Stichopus vastus																	1	1	1
Synapta maculata																			
Synapta spp.	1				1	1	1	1		1			1	1		1	1	1	1
Thelenota ananas	1	1		1	1	1		1			1	1	1		1	1	1	1	1
Thelenota anax								1			1					1		1	
Thelenota rubrolineata																			

Table A3.1.1: Bêche-de-mer presence per site (continued)

Countries/Territories	Kiribati				Marshall Islands				Nauru	New Caledonia					Niue	Palau			
	Abaiang	Abemama	Kiritimati	Kuria	Ailuk	Arno	Laura	Likiep	All Nauru	Luengoni	Moindou	Ouassé	Oundjo	Thio	All Niue	Airai	Koror	Ngarchelong	Ngatpang
Number of species/site	**9**	**10**	**7**	**9**	**9**	**10**	**8**	**6**	**5**	**9**	**18**	**18**	**16**	**16**	**6**	**27**	**24**	**25**	**27**
Bêche-de-mer																			
Actinopyga caerulea																			
Actinopyga echinites														1		1		1	1
Actinopyga lecanora												1	1	1		1	1	1	1
Actinopyga mauritiana	1	1	1	1		1	1		1	1	1	1	1	1	1	1	1	1	1
Actinopyga miliaris				1							1	1	1	1		1	1	1	1
Actinopyga palauensis												1	1	1	1				1
Actinopyga spp.																1	1	1	1
Actinopyga spinea											1								
Bohadschia argus	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Bohadschia graeffei	1	1							1			1		1		1	1	1	1
Bohadschia similis											1		1			1	1	1	1
Bohadschia spp.																			
Bohadschia vitiensis	1	1	1		1	1		1		1	1	1				1	1	1	1
Euapta spp.																			
Holothuria atra	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Holothuria cinerascens																			
Holothuria coluber												1	1	1		1	1	1	1
Holothuria difficilis																			
Holothuria edulis		1			1		1	1			1	1	1	1		1	1	1	1
Holothuria flavomaculata												1				1	1		1
Holothuria fuscogilva				1	1	1					1	1				1	1	1	1
Holothuria fuscopunctata				1						1	1	1	1	1		1	1	1	1
Holothuria hilla						1				1						1	1	1	1
Holothuria impatiens						1					1								
Holothuria leucospilota																			
Holothuria nobilis	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1
Holothuria pervicax																1			
Holothuria scabra											1		1			1		1	1
Holothuria scabra versicolor														1					
Holothuria spp.																		1	1
Stichopus chloronotus	1	1	1								1	1	1	1		1	1	1	1
Stichopus hermanni											1	1	1	1		1	1	1	1
Stichopus hermanni-horrens																			
Stichopus horrens													1			1	1	1	1
Stichopus monotuberculatus																			
Stichopus pseudhorrens																			
Stichopus spp.																			
Stichopus vastus																1	1	1	1
Synapta maculata																1	1		
Synapta spp.					1	1	1			1	1					1	1	1	1
Thelenota ananas	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Thelenota anax	1	1		1	1	1	1	1			1	1				1	1	1	1
Thelenota rubrolineata																			

Table A3.1.1: Bêche-de-mer presence per site (continued)

Countries/Territories	Papua New Guinea				Samoa				Solomon Islands				Tonga			
	Andra	Panapompom	Sideia	Tsoilaunung	Manono-uta	Salelavalu	Vailoa	Vaisala	Chubikopi	Marau	Nggela	Rarumana	Ha'atafu	Koulo	Lofanga	Manuka
Number of species/site	**22**	**16**	**16**	**24**	**11**	**11**	**10**	**12**	**17**	**16**	**18**	**14**	**20**	**16**	**18**	**20**
Bêche-de-mer																
Actinopyga caerulea		1														
Actinopyga echinites	1			1					1	1			1			1
Actinopyga lecanora	1	1		1					1	1	1	1	1	1		1
Actinopyga mauritiana	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Actinopyga miliaris	1			1								1	1	1	1	1
Actinopyga palauensis														1		
Actinopyga spp.														1		
Actinopyga spinea																
Bohadschia argus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bohadschia graeffei	1	1	1	1					1	1	1	1				
Bohadschia similis	1			1						1	1		1		1	1
Bohadschia spp.									1							
Bohadschia vitiensis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Euapta spp.																
Holothuria atra	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Holothuria cinerascens																
Holothuria coluber	1			1							1	1	1		1	1
Holothuria difficilis																
Holothuria edulis	1	1	1	1					1	1	1	1	1	1	1	1
Holothuria flavomaculata																
Holothuria fuscogilva	1	1	1	1	1	1	1	1	1	1	1	1				
Holothuria fuscopunctata	1	1	1	1	1			1	1	1	1	1	1	1	1	1
Holothuria hilla																
Holothuria impatiens																
Holothuria leucospilota	1		1	1	1	1							1	1	1	1
Holothuria nobilis	1	1	1	1	1	1	1	1		1	1		1	1	1	1
Holothuria pervicax				1												
Holothuria scabra	1			1							1					
Holothuria scabra versicolor													1		1	1
Holothuria spp.																
Stichopus chloronotus	1	1	1	1	1	1	1	1	1				1	1	1	1
Stichopus hermanni	1		1	1					1	1	1	1	1	1	1	1
Stichopus hermanni-horrens													1			
Stichopus horrens	1			1		1	1	1	1	1	1				1	1
Stichopus monotuberculatus																
Stichopus pseudhorrens		1														
Stichopus spp.																
Stichopus vastus				1					1			1				
Synapta maculata																
Synapta spp.	1	1	1	1	1	1	1	1		1	1		1		1	1
Thelenota ananas	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Thelenota anax	1	1	1	1				1	1		1	1	1	1	1	1
Thelenota rubrolineata			1													

Table A3.1.1: Bêche-de-mer presence per site (continued)

Countries/Territories	Tuvalu				Vanuatu				Wallis and Futuna			
	Funafuti	Niutao	Nukufetau	Vaitupu	Maskelynes	Moso	Paunagisu	Uri-Uripiv	Halalo	Leava	Vailala	Vele
Number of species/site	**10**	**4**	**9**	**4**	**20**	**16**	**17**	**17**	**14**	**7**	**17**	**10**
Bêche-de-mer												
Actinopyga caerulea												
Actinopyga echinites												
Actinopyga lecanora					1	1	1	1				
Actinopyga mauritiana	1	1	1	1	1		1	1	1	1	1	1
Actinopyga miliaris	1				1	1		1	1		1	
Actinopyga palauensis												
Actinopyga spp.												
Actinopyga spinea												
Bohadschia argus	1		1		1	1	1	1	1	1	1	1
Bohadschia graeffei					1	1	1	1	1		1	
Bohadschia similis					1	1	1					
Bohadschia spp.												
Bohadschia vitiensis	1		1		1	1	1	1	1		1	1
Euapta spp.												
Holothuria atra	1	1	1	1	1	1	1	1	1	1	1	1
Holothuria cinerascens												
Holothuria coluber					1		1	1				1
Holothuria difficilis												
Holothuria edulis					1	1	1	1				
Holothuria flavomaculata					1							
Holothuria fuscogilva	1		1						1		1	
Holothuria fuscopunctata	1	1	1		1	1	1	1	1	1	1	1
Holothuria hilla					1		1				1	
Holothuria impatiens												
Holothuria leucospilota												
Holothuria nobilis	1		1	1	1	1	1	1	1	1	1	1
Holothuria pervicax												
Holothuria scabra					1						1	
Holothuria scabra versicolor												
Holothuria spp.												
Stichopus chloronotus					1	1	1	1	1		1	
Stichopus hermanni					1	1	1	1	1		1	
Stichopus hermanni-horrens												
Stichopus horrens					1	1	1	1			1	1
Stichopus monotuberculatus												
Stichopus pseudhorrens												
Stichopus spp.												
Stichopus vastus								1				
Synapta maculata												
Synapta spp.					1	1	1	1	1		1	
Thelenota ananas	1	1	1	1	1	1	1	1	1	1	1	1
Thelenota anax	1		1			1			1	1	1	1
Thelenota rubrolineata												

Table A3.1.2: Bivalve presence per site

Countries/Territories	Cook Islands				Fiji Islands						French Polynesia					FSM			
	Aitutaki	Mangaia	Palmerston	Rarotonga	Dromuna	Lakeba	Mali	Muaivuso	Nasaqalau	Nukunuku	Fakarava	Maatea	Mataiea	Raivavae	Tikehau	Piis-Panewu	Riiken	Romanum	Yyin
Number of species/site	**4**	**4**	**6**	**5**	**16**	**12**	**8**	**10**	**3**	**13**	**4**	**4**	**4**	**4**	**5**	**8**	**8**	**9**	**7**
Bivalves																			
Acrosterigma spp.																			
Anadara antiquata					1	1		1									1		
Anadara holoserica																			
Anadara scapha																			
Anadara spp.						1													
Arca spp.															1				
Arca ventricosa																			
Asaphis violascens																			
Atactodea striata																			
Atrina spp.						1	1							1				1	
Atrina vexillum					1	1	1												
Barbatia spp.																			
Beguina semiorbiculata																			
Chama spp.	1	1	1	1			1	1		1	1	1	1	1	1	1	1	1	
Codakia interrupta																			
Codakia spp.																			
Dosinia spp.																			
Fragum fragum																			
Fragum unedo								1											
Gafrarium pectinatum																			
Gafrarium spp.																			
Gafrarium tumidum					1					1									
Hippopus hippopus																1	1	1	1
Hippopus porcellanus																			
Hyotissa spp.					1	1	1	1		1						1	1	1	
Isognomon spp.																			1
Lima spp.																			
Lopha cristagalli																			
Malleus spp.																			
Modiolus spp.			1		1	1				1									1
Modiolus auriculatus																			
Periglypta puerpera					1														
Periglypta spp.																			
Pinctada fucata																			
Pinctada margaritifera	1		1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	
Pinctada maxima																			
Pinctada spp.																			
Pinna bicolor					1			1	1	1									
Pinna spp.				1		1		1									1		
Pitar prora					1	1													
Pitar spp.					1														
Pteria penguin																			
Pteria spp.																		1	1
Saccostrea spp.																			
Spondylus spp.	1	1	1		1	1		1		1	1	1	1		1	1		1	1
Spondylus squamosus					1		1			1									
Tapes literatus																			
Tellina palatum					1					1									1
Tellina scobinata				1						1									
Trachycardium enode																			
Trachycardium spp.					1														
Tridacna crocea																1			
Tridacna derasa										1							1		
Tridacna gigas																			
Tridacna maxima	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tridacna spp.																			
Tridacna squamosa		1	1		1	1	1	1	1	1						1		1	

Table A3.1.2: Bivalve presence per site (continued)

Countries/Territories	Kiribati				Marshall Islands				Nauru	New Caledonia					Niue	Palau			
	Abaiang	Abemama	Kiritimati	Kuria	Ailuk	Arno	Laura	Likiep	All Nauru	Luengoni	Moindou	Ouassé	Oundjo	Thio	All Niue	Airai	Koror	Ngarchelong	Ngatpang
Number of species/site	**13**	**11**	**5**	**2**	**6**	**6**	**6**	**7**	**1**	**6**	**17**	**7**	**18**	**13**	**1**	**13**	**16**	**17**	**22**
Bivalves																			
Acrosterigma spp.																			
Anadara antiquata														1					
Anadara holoserica	1	1																	
Anadara scapha										1	1		1			1		1	1
Anadara spp.		1									1		1						1
Arca spp.						1											1	1	1
Arca ventricosa																			
Asaphis violascens																			
Atactodea striata	1																		
Atrina spp.			1								1	1		1				1	
Atrina vexillum			1										1			1	1		1
Barbatia spp.																			1
Beguina semiorbiculata							1									1	1	1	1
Chama spp.	1	1	1		1			1	1		1		1	1		1	1	1	1
Codakia interrupta																			
Codakia spp.																			
Dosinia spp.	1																		
Fragum fragum																			
Fragum unedo																			
Gafrarium pectinatum													1						
Gafrarium spp.	1	1																	1
Gafrarium tumidum											1		1						
Hippopus hippopus	1	1			1	1	1	1		1	1	1	1	1		1	1	1	1
Hippopus porcellanus																1	1	1	1
Hyotissa spp.																	1		1
Isognomon spp.																			
Lima spp.																			
Lopha cristagalli																	1	1	
Malleus spp.																	1		1
Modiolus spp.											1								
Modiolus auriculatus																			
Periglypta puerpera											1		1						
Periglypta spp.																			
Pinctada fucata											1								
Pinctada margaritifera	1	1	1		1	1	1	1		1	1	1	1	1		1	1	1	1
Pinctada maxima																			
Pinctada spp.																			
Pinna bicolor		1											1						
Pinna spp.	1									1	1		1					1	1
Pitar prora														1					
Pitar spp.																			
Pteria penguin																		1	1
Pteria spp.																			
Saccostrea spp.																			
Spondylus spp.	1	1		1	1	1	1	1			1	1	1	1		1	1	1	1
Spondylus squamosus		1																	
Tapes literatus											1			1					
Tellina palatum											1		1	1					
Tellina scobinata																			
Trachycardium enode													1						
Trachycardium spp.	1																		
Tridacna crocea												1	1	1		1	1	1	1
Tridacna derasa											1		1	1		1	1	1	1
Tridacna gigas	1							1								1	1	1	1
Tridacna maxima	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Tridacna spp.																			1
Tridacna squamosa	1	1			1	1	1	1		1	1	1	1	1		1	1	1	1

Table A3.1.2: Bivalve presence per site (continued)

Countries/Territories	Papua New Guinea				Samoa				Solomon Islands				Tonga			
	Andra	Panapompom	Sideia	Tsoilaunung	Manono-uta	Salelavalu	Vailoa	Vaisala	Chubikopi	Marau	Nggela	Rarumana	Ha'atafu	Koulo	Lofanga	Manuka
Number of species/site	**12**	**14**	**12**	**19**	**5**	**6**	**7**	**7**	**18**	**20**	**14**	**16**	**9**	**9**	**8**	**14**
Bivalves																
Acrosterigma spp.																
Anadara antiquata				1		1		1	1				1			1
Anadara holoserica																
Anadara scapha									1	1		1				
Anadara spp.				1			1	1		1		1				1
Arca spp.										1						
Arca ventricosa										1						
Asaphis violascens																
Atactodea striata				1												
Atrina spp.	1		1	1									1	1	1	1
Atrina vexillum		1		1					1	1	1	1		1	1	
Barbatia spp.																
Beguina semiorbiculata									1	1	1	1				
Chama spp.	1	1	1	1	1				1	1	1	1	1	1	1	
Codakia interrupta																
Codakia spp.				1						1						
Dosinia spp.																
Fragum fragum				1									1			1
Fragum unedo																
Gafrarium pectinatum																
Gafrarium spp.																
Gafrarium tumidum																
Hippopus hippopus	1	1	1	1					1	1	1	1				
Hippopus porcellanus																
Hyotissa spp.	1	1	1	1					1		1	1		1		1
Isognomon spp.																
Lima spp.																
Lopha cristagalli		1	1													
Malleus spp.										1						
Modiolus spp.				1												1
Modiolus auriculatus																
Periglypta puerpera								1	1			1				
Periglypta spp.									1	1						
Pinctada fucata																
Pinctada margaritifera	1	1	1	1					1	1	1	1	1	1	1	1
Pinctada maxima	1															
Pinctada spp.					1		1				1					
Pinna bicolor		1				1	1									1
Pinna spp.	1			1	1	1	1	1	1	1	1		1			1
Pitar prora																
Pitar spp.																1
Pteria penguin		1														
Pteria spp.				1					1		1	1				
Saccostrea spp.									1							
Spondylus spp.	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
Spondylus squamosus									1					1	1	
Tapes literatus																
Tellina palatum							1									
Tellina scobinata						1										1
Trachycardium enode																
Trachycardium spp.																
Tridacna crocea	1	1	1	1					1	1	1	1				
Tridacna derasa		1	1							1	1	1		1		
Tridacna gigas	1	1	1	1						1						
Tridacna maxima	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tridacna spp.										1		1				
Tridacna squamosa	1	1	1	1				1	1	1	1	1	1	1	1	1

Table A3.1.2: Bivalve presence per site (continued)

Countries/Territories	Tuvalu				Vanuatu				Wallis and Futuna			
	Funafuti	Niutao	Nukufetau	Vaitupu	Maskelynes	Moso	Paunagisu	Uri-Uripiv	Halalo	Leava	Vailala	Vele
Number of species/site	**4**	**3**	**5**	**2**	**15**	**14**	**13**	**9**	**5**	**2**	**14**	**3**
Bivalves												
Acrosterigma spp.							1					
Anadara antiquata					1	1						
Anadara holoserica												
Anadara scapha												
Anadara spp.					1				1		1	1
Arca spp.												
Arca ventricosa												
Asaphis violascens												1
Atactodea striata												
Atrina spp.					1			1				
Atrina vexillum						1	1					
Barbatia spp.											1	
Beguina semiorbiculata												
Chama spp.	1	1	1					1	1		1	
Codakia interrupta							1					
Codakia spp.											1	
Dosinia spp.												
Fragum fragum												
Fragum unedo						1					1	
Gafrarium pectinatum							1				1	
Gafrarium spp.							1				1	
Gafrarium tumidum						1	1				1	
Hippopus hippopus					1	1	1	1				
Hippopus porcellanus												
Hyotissa spp.						1		1	1			
Isognomon spp.												
Lima spp.											1	
Lopha cristagalli												
Malleus spp.												
Modiolus spp.					1						1	
Modiolus auriculatus						1						
Periglypta puerpera					1							
Periglypta spp.												
Pinctada fucata												
Pinctada margaritifera			1		1	1	1	1				
Pinctada maxima												
Pinctada spp.												
Pinna bicolor												
Pinna spp.					1						1	
Pitar prora					1	1						
Pitar spp.												
Pteria penguin												
Pteria spp.												
Saccostrea spp.												
Spondylus spp.	1	1	1	1	1	1		1	1		1	
Spondylus squamosus						1	1					
Tapes literatus					1							
Tellina palatum							1				1	
Tellina scobinata												
Trachycardium enode												
Trachycardium spp.					1	1						
Tridacna crocea					1	1	1	1				
Tridacna derasa												
Tridacna gigas												
Tridacna maxima	1	1	1	1	1	1	1	1	1	1	1	1
Tridacna spp.												
Tridacna squamosa	1		1		1		1	1		1		

Table A3.1.3: Cnidarians and crustaceans presence per site

Countries/Territories	Cook Islands				Fiji Islands						French Polynesia					FSM			
	Aitutaki	Mangaia	Palmerston	Rarotonga	Dromuna	Lakeba	Mali	Muaivuso	Nasaqalau	Nukunuku	Fakarava	Maatea	Mataiea	Raivavae	Tikehau	Piis-Panewu	Riiken	Romanum	Yyin
Number of species/site	**2**	**1**		**3**	**1**	**2**	**1**					**1**	**1**	**1**		**1**	**3**	**1**	**3**
Cnidarians																			
Actinodendron spp.																			
Cassiopea spp.						1	1										1		1
Cassiopea andromeda					1	1											1		1
Entacmaea quadricolor				1															
Heteractis aurora																			
Heteractis spp.	1			1															
Stichodactyla gigantea																			
Stichodactyla spp.	1	1		1								1	1	1		1	1	1	1
Number of species/site	**1**	**4**	**2**	**3**	**1**	**2**	**2**	**1**						**1**		**2**	**3**	**1**	**8**
Crustaceans																			
Atergatis floridus																			1
Calappa hepatica																			
Calappa spp.																			
Calcinus spp.																			
Carpilius maculatus				1												1			
Coenobita spp.																			
Dardanus spp.								1											
Eriphia sebana																	1		
Etisus spp.																			
Etisus splendidus																			1
Gonodactylus spp.		1															1		
Grapsus albolineatus																			
Grapsus grapsus		1																	
Lysiosquillina maculata																			1
Lysiosquillina spp.																			
Odontodactylus scyllarus																			
Panulirus femoristriga albiflagellum																			
Panulirus longipes																			
Panulirus penicillatus			1	1															
Panulirus spp.						1	1							1		1		1	
Panulirus versicolor					1	1	1												1
Parribacus caledonicus	1		1																
Penaeus spp.																			
Periclimenes brevicarpalis																			1
Periclimenes spp.																	1		
Pilumnus spp.																			
Portunus pelagicus																			
Portunus spp.																			1
Saron spp.		1																	
Scylla serrata																			
Stenopus hispidus				1															1
Thalamita spp.																			
Thalassina spp.																			
Thor amboinensis																			1
Zozymus aeneus		1																	

Table A3.1.3: Cnidarians and crustaceans presence per site (continued)

Countries/Territories	Kiribati				Marshall Islands				Nauru	New Caledonia					Niue	Palau			
	Abaiang	Abemama	Kiritimati	Kuria	Ailuk	Arno	Laura	Likiep	All Nauru	Luengoni	Moindou	Ouassé	Oundjo	Thio	All Niue	Airai	Koror	Ngarchelong	Ngatpang
Number of species/site	**1**	**1**		**1**	**1**	**2**	**2**	**1**	**2**	**2**	**2**	**1**	**1**	**1**		**2**	**4**	**3**	**4**
Cnidarians																			
Actinodendron spp.									1										
Cassiopea spp.																	1	1	1
Cassiopea andromeda											1					1	1	1	1
Entacmaea quadricolor						1	1										1		1
Heteractis aurora																			
Heteractis spp.										1									
Stichodactyla gigantea																			
Stichodactyla spp.	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Number of species/site	**2**	**1**	**2**	**1**	**3**	**5**	**6**		**10**	**4**	**6**	**2**	**2**	**2**		**6**	**6**	**6**	**6**
Crustaceans																			
Atergatis floridus						1													
Calappa hepatica																			
Calappa spp.									1	1									
Calcinus spp.									1										
Carpilius maculatus					1				1										
Coenobita spp.									1										
Dardanus spp.																			
Eriphia sebana									1										
Etisus spp.					1														
Etisus splendidus																	1		
Gonodactylus spp.							1												
Grapsus albolineatus									1										
Grapsus grapsus									1										
Lysiosquillina maculata						1											1	1	1
Lysiosquillina spp.	1		1						1							1			
Odontodactylus scyllarus																			
Panulirus femoristriga albiflagellum																			
Panulirus longipes										1									
Panulirus penicillatus							1										1		
Panulirus spp.	1	1	1	1	1				1		1	1	1	1		1	1	1	1
Panulirus versicolor							1				1	1		1		1	1	1	1
Parribacus caledonicus																			
Penaeus spp.																			
Periclimenes brevicarpalis																			
Periclimenes spp.																1			
Pilumnus spp.									1										
Portunus pelagicus											1								
Portunus spp.						1				1			1			1			
Saron spp.						1	1			1							1	1	1
Scylla serrata											1								
Stenopus hispidus							1											1	1
Thalamita spp.											1								
Thalassina spp.						1	1				1					1		1	1
Thor amboinensis																			
Zozymus aeneus																			

Table A3.1.3: Cnidarians and crustaceans presence per site (continued)

Countries/Territories	Papua New Guinea				Samoa				Solomon Islands				Tonga			
	Andra	Panapompom	Sideia	Tsoilaunung	Manono-uta	Salelavalu	Vailoa	Vaisala	Chubikopi	Marau	Nggela	Rarumana	Ha'atafu	Koulo	Lofanga	Manuka
Number of species/site	**1**	**1**	**1**	**2**	**1**	**2**	**1**	**2**	**4**	**1**	**5**	**3**	**1**	**2**	**2**	**1**
Cnidarians																
Actinodendron spp.																
Cassiopea spp.						1		1				1				
Cassiopea andromeda				1					1							
Entacmaea quadricolor									1		1	1				
Heteractis aurora											1					
Heteractis spp.											1					
Stichodactyla gigantea									1		1			1	1	
Stichodactyla spp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Number of species/site	**4**	**4**	**3**	**6**	**3**	**3**	**2**	**4**	**3**	**8**	**5**	**7**	**1**	**2**	**1**	
Crustaceans																
Atergatis floridus										1		1				
Calappa hepatica																
Calappa spp.				1	1						1					
Calcinus spp.																
Carpilius maculatus								1								
Coenobita spp.						1										
Dardanus spp.					1	1	1	1								
Eriphia sebana								1		1						
Etisus spp.																
Etisus splendidus							1					1				
Gonodactylus spp.																
Grapsus albolineatus																
Grapsus grapsus																
Lysiosquillina maculata		1	1	1						1	1	1				
Lysiosquillina spp.				1	1	1		1								
Odontodactylus scyllarus										1						
Panulirus femoristriga albiflagellum																
Panulirus longipes																
Panulirus penicillatus																
Panulirus spp.	1	1	1	1									1	1	1	
Panulirus versicolor	1	1	1	1					1	1	1	1		1		
Parribacus caledonicus	1	1														
Penaeus spp.																
Periclimenes brevicarpalis																
Periclimenes spp.																
Pilumnus spp.																
Portunus pelagicus										1						
Portunus spp.									1		1					
Saron spp.												1				
Scylla serrata	1			1												
Stenopus hispidus									1	1		1				
Thalamita spp.																
Thalassina spp.											1					
Thor amboinensis										1		1				
Zozymus aeneus																

Table A3.1.3: Cnidarians and crustaceans presence per site (continued)

Countries/Territories	Tuvalu				Vanuatu				Wallis and Futuna			
	Funafuti	Niutao	Nukufetau	Vaitupu	Maskelynes	Moso	Paunagisu	Uri-Uripiv	Halalo	Leava	Vailala	Vele
Number of species/site	**1**				**2**	**1**	**5**	**2**	**1**		**1**	**2**
Cnidarians												
Actinodendron spp.							1					1
Cassiopea spp.					1		1	1				
Cassiopea andromeda						1	1					
Entacmaea quadricolor												
Heteractis aurora												
Heteractis spp.												
Stichodactyla gigantea							1					
Stichodactyla spp.	1				1		1	1	1		1	1
Number of species/site	**2**		**1**	**2**	**2**	**1**	**1**	**1**	**4**	**6**	**3**	**6**
Crustaceans												
Atergatis floridus												
Calappa hepatica					1							
Calappa spp.												
Calcinus spp.												
Carpilius maculatus												
Coenobita spp.												
Dardanus spp.												
Eriphia sebana				1						1		1
Etisus spp.												
Etisus splendidus										1	1	1
Gonodactylus spp.												
Grapsus albolineatus												
Grapsus grapsus												
Lysiosquillina maculata									1		1	
Lysiosquillina spp.	1									1		
Odontodactylus scyllarus												
Panulirus femoristriga albiflagellum										1		
Panulirus longipes												
Panulirus penicillatus										1		1
Panulirus spp.			1	1	1		1	1	1			
Panulirus versicolor						1			1		1	1
Parribacus caledonicus										1		1
Penaeus spp.	1											1
Periclimenes brevicarpalis												
Periclimenes spp.												
Pilumnus spp.												
Portunus pelagicus												
Portunus spp.												
Saron spp.												
Scylla serrata												
Stenopus hispidus									1			
Thalamita spp.												
Thalassina spp.												
Thor amboinensis												
Zozymus aeneus												

Table A3.1.4: Gastropods presence per site

Countries/Territories	Cook Islands				Fiji Islands						French Polynesia					FSM			
	Aitutaki	Mangaia	Palmerston	Rarotonga	Dromuna	Lakeba	Mali	Muaivuso	Nasaqalau	Nukunuku	Fakarava	Maatea	Mataiea	Raivavae	Tikehau	Piis-Panewu	Riiken	Romanum	Yyin
Number of species/site	**17**	**32**	**17**	**26**	**16**	**16**	**25**	**28**	**20**	**26**	**12**	**16**	**21**	**11**	**11**	**30**	**47**	**33**	**36**
Gastropods																			
Acanthopleura gemmata																			
Astralium spp.	1	1	1	1						1		1	1	1	1	1	1		
Bulla ampulla								1											
Bulla spp.																			
Bursa bufonia				1															
Bursa cruentata																			
Bursa granularis				1															
Bursa rhodostoma																	1		
Cantharus fumosus																			
Cantharus spp.			1															1	1
Cassis cornuta												1						1	
Cerithium aluco						1		1									1		1
Cerithium nodulosum	1	1	1	1	1			1								1		1	
Cerithium spp.								1						1			1		1
Charonia spp.										1									
Charonia tritonis		1				1				1				1					1
Chicoreus brunneus																	1		
Chicoreus ramosus											1				1				
Chicoreus spp.																1			
Clanculus spp.																	1		
Conus arenatus																			
Conus bandanus																			
Conus capitaneus																			
Conus catus																			
Conus chaldeus		1																	
Conus consors																			
Conus coronatus				1															1
Conus distans																	1		1
Conus ebraeus	1	1					1									1	1	1	1
Conus eburneus																			
Conus emaciatus		1																	
Conus episcopatus																			
Conus flavidus		1		1		1	1	1						1		1	1		
Conus frigidus		1		1			1												1
Conus generalis																			
Conus geographus																			
Conus imperialis																			
Conus leopardus								1		1							1		1
Conus litteratus						1		1	1								1		1
Conus lividus		1		1													1		
Conus marmoreus										1							1		1
Conus miles							1	1	1	1		1						1	
Conus miliaris		1		1													1		
Conus nimbosus													1						
Conus pulicarius		1																	
Conus quercinus																			
Conus rattus		1		1													1		
Conus sanguinolentus		1		1															
Conus spp.	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Conus sponsalis		1		1															
Conus striatus																			
Conus textile								1											
Conus vexillum	1			1												1		1	
Conus virgo																	1		1
Coralliophila neritoidea																			
Coralliophila spp.																			
Cryptoplax spp.									1										
Cymatium lotorium																			
Cymatium muricinum																			
Cymatium rubeculum																			
Cymatium spp.			1											1					
Cymbiola spp.																			
Cypraea annulus	1		1		1			1	1	1		1	1	1	1	1	1	1	1
Cypraea arabica												1							
Cypraea argus																			

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Cook Islands				Fiji Islands						French Polynesia					FSM			
	Aitutaki	Mangaia	Palmerston	Rarotonga	Dromuna	Lakeba	Mali	Muaivuso	Nasaqalau	Nukunuku	Fakarava	Maatea	Mataiea	Raivavae	Tikehau	Piis-Panewu	Riiken	Romanum	Yyin
Number of species/site	**17**	**32**	**17**	**26**	**16**	**16**	**25**	**28**	**20**	**26**	**12**	**16**	**21**	**11**	**11**	**30**	**47**	**33**	**36**
Gastropods																			
Cypraea caputserpensis	1	1	1	1		1	1		1	1	1	1	1		1	1		1	
Cypraea carneola																	1		1
Cypraea eglantina																			
Cypraea erosa													1				1		
Cypraea helvola																			
Cypraea isabella													1				1	1	1
Cypraea lynx																	1	1	
Cypraea maculifera				1															
Cypraea mappa																			
Cypraea mappa mappa								1											
Cypraea moneta	1	1	1	1							1	1	1		1	1	1	1	1
Cypraea obvelata												1	1						
Cypraea schilderorum				1															
Cypraea scurra																			
Cypraea spp.					1		1	1			1		1		1	1	1		
Cypraea talpa																			
Cypraea tigris	1	1	1		1	1	1	1	1	1		1	1			1	1	1	1
Cypraea vitellus																			1
Dendropoma maximum		1								1									
Dendropoma spp.		1		1															
Distorsio anus		1																	
Dolabella auricularia					1			1											
Dolabella spp.		1																	
Drupa grossularia																			
Drupa morum																	1		1
Drupa ricinus																			
Drupa rubusidaeus		1																	
Drupa spp.		1		1			1	1		1	1		1	1			1	1	
Drupella cornus																	1		
Drupella spp.		1											1					1	
Haliotis asinina																	1		
Haliotis spp.																	1		
Harpa amouretta																			
Lambis chiragra		1	1	1												1	1	1	
Lambis crocata																1		1	
Lambis lambis					1	1	1	1	1	1	1					1	1	1	1
Lambis millepeda																			
Lambis scorpius																1			
Lambis spp.						1	1						1				1		
Lambis truncata	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1
Latirolagena smaragdula							1		1	1									
Latirus nodatus				1															
Mammilla melanostoma																			
Mitra mitra																			1
Mitra spp.																			
Mitra stictica																	1		
Morula spp.																	1		1
Nassarius spp.								1											
Nerita polita																			
Nerita spp.																			
Oliva spp.																			1
Onchidium spp.																			
Ovula ovum																1	1		
Peristernia spp.																			
Pleuroploca filamentosa			1						1								1		
Pleuroploca spp.																1		1	
Pleuroploca trapezium																			
Polinices mammilla																			
Polinices spp.					1														
Pyrene spp.																			1
Rhinoclavis aspera																			1
Rhinoclavis fasciata																			
Serpulorbis colubrinus																			
Siphonaria sirius																			
Strombus gibberulus gibbosus					1	1		1											1

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Cook Islands				Fiji Islands						French Polynesia					FSM			
	Aitutaki	Mangaia	Palmerston	Rarotonga	Dromuna	Lakeba	Mali	Muaivuso	Nasaqalau	Nukunuku	Fakarava	Maatea	Mataiea	Raivavae	Tikehau	Piis-Panewu	Riiken	Romanum	Yyin
Number of species/site	**17**	**32**	**17**	**26**	**16**	**16**	**25**	**28**	**20**	**26**	**12**	**16**	**21**	**11**	**11**	**30**	**47**	**33**	**36**
Gastropods																			
Strombus labiatus					1			1		1									
Strombus lentiginosus	1							1											
Strombus luhuanus					1			1								1	1	1	1
Strombus mutabilis																			
Strombus sinuatus																			
Strombus spp.												1				1			
Tectus conus																1		1	
Tectus fenestratus																			
Tectus pyramis					1	1	1	1	1	1						1	1	1	1
Tectus spp.										1								1	
Tectus triserialis																			
Telescopium telescopium																			
Terebra areolata																			
Terebra dimidiata																			1
Terebra maculata																			
Terebra spp.								1		1			1						
Thais aculeata	1	1	1	1			1						1			1		1	
Thais armigera		1		1					1										
Thais kieneri																			
Thais spp.	1		1				1		1		1	1			1	1		1	1
Thais tuberosa							1												
Trochus maculata							1			1						1	1	1	
Trochus niloticus	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
Trochus spp.	1				1		1	1	1	1						1	1	1	1
Turbo argyrostomus	1	1	1			1			1	1						1	1	1	1
Turbo chrysostomus					1		1	1	1	1							1		
Turbo crassus						1	1	1	1	1	1								
Turbo marmoratus												1	1						
Turbo petholatus																			
Turbo setosus	1	1	1	1					1		1	1	1	1	1				
Turbo spp.										1				1			1		1
Tutufa bubo						1													
Tutufa rubeta																		1	
Tutufa spp.																			
Vasum ceramicum							1						1			1	1	1	
Vasum spp.							1											1	
Vasum turbinellum							1		1	1									

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Kiribati				Marshall Islands				Nauru	New Caledonia					Niue	Palau			
	Abaiang	Abemama	Kiritimati	Kuria	Ailuk	Arno	Laura	Likiep	All Nauru	Luengoni	Moindou	Ouassé	Oundjo	Thio	All Niue	Airai	Koror	Ngarchelong	Ngatpang
Number of species/site	**12**	**8**	**5**	**13**	**18**	**34**	**34**	**16**	**24**	**35**	**38**	**12**	**29**	**21**	**6**	**52**	**38**	**48**	**39**
Gastropods																			
Acanthopleura gemmata																			
Astralium spp.					1	1	1			1	1		1	1		1	1	1	1
Bulla ampulla																			
Bulla spp.									1										
Bursa bufonia							1											1	
Bursa cruentata																			
Bursa granularis							1												
Bursa rhodostoma																			
Cantharus fumosus						1													
Cantharus spp.																			
Cassis cornuta	1			1		1		1									1		
Cerithium aluco											1		1	1					
Cerithium nodulosum		1		1	1	1	1			1	1		1	1		1	1	1	1
Cerithium spp.		1											1				1		
Charonia spp.																			
Charonia tritonis					1							1				1	1		1
Chicoreus brunneus							1									1		1	1
Chicoreus ramosus											1			1					
Chicoreus spp.					1									1		1			1
Clanculus spp.																			
Conus arenatus										1									
Conus bandanus							1									1			
Conus capitaneus										1									1
Conus catus																			
Conus chaldeus																			
Conus consors																1			
Conus coronatus										1									
Conus distans						1	1			1						1	1	1	1
Conus ebraeus																			
Conus eburneus											1		1					1	
Conus emaciatus										1							1	1	1
Conus episcopatus																			
Conus flavidus				1			1		1	1						1		1	
Conus frigidus																			
Conus generalis																			
Conus geographus																			
Conus imperialis										1						1		1	
Conus leopardus	1			1			1			1			1				1		
Conus litteratus										1			1			1		1	
Conus lividus						1	1			1						1	1	1	1
Conus marmoreus						1					1					1		1	1
Conus miles				1		1	1	1	1				1			1		1	
Conus miliaris							1			1						1	1	1	1
Conus nimbosus																			
Conus pulicarius							1			1						1			
Conus quercinus											1					1			1
Conus rattus										1								1	1
Conus sanguinolentus										1								1	
Conus spp.	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1	1	1
Conus sponsalis																			
Conus striatus																			1
Conus textile											1								
Conus vexillum																1	1	1	1
Conus virgo				1						1									
Coralliophila neritoidea																			
Coralliophila spp.							1									1			
Cryptoplax spp.																			
Cymatium lotorium																			
Cymatium muricinum						1							1						
Cymatium rubeculum																			
Cymatium spp.	1																		
Cymbiola spp.																			
Cypraea annulus					1			1								1	1		1
Cypraea arabica							1				1					1		1	
Cypraea argus																			

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Kiribati				Marshall Islands				Nauru	New Caledonia					Niue	Palau			
	Abaiang	Abemama	Kiritimati	Kuria	Ailuk	Arno	Laura	Likiep	All Nauru	Luengoni	Moindou	Ouassé	Oundjo	Thio	All Niue	Airai	Koror	Ngarchelong	Ngatpang
Number of species/site	**12**	**8**	**5**	**13**	**18**	**34**	**34**	**16**	**24**	**35**	**38**	**12**	**29**	**21**	**6**	**52**	**38**	**48**	**39**
Gastropods																			
Cypraea caputserpensis					1		1	1	1		1	1			1	1	1	1	1
Cypraea carneola																			
Cypraea eglantina						1													
Cypraea erosa																1	1	1	
Cypraea helvola																1			
Cypraea isabella						1		1								1			
Cypraea lynx																1	1		1
Cypraea maculifera						1													
Cypraea mappa						1													
Cypraea mappa mappa																			
Cypraea moneta						1	1	1	1	1	1					1	1	1	
Cypraea obvelata																			
Cypraea schilderorum																			
Cypraea scurra						1	1												
Cypraea spp.																	1		1
Cypraea talpa									1						1	1		1	
Cypraea tigris					1	1	1	1	1	1		1	1	1		1	1	1	1
Cypraea vitellus						1												1	
Dendropoma maximum																			
Dendropoma spp.																			
Distorsio anus																			
Dolabella auricularia											1		1	1					
Dolabella spp.																			
Drupa grossularia																		1	
Drupa morum				1					1										
Drupa ricinus																			
Drupa rubusidaeus						1										1	1		
Drupa spp.									1		1								
Drupella cornus																			
Drupella spp.						1			1										
Haliotis asinina													1					1	1
Haliotis spp.																			
Harpa amouretta							1												
Lambis chiragra				1	1	1	1	1			1						1	1	1
Lambis crocata											1								
Lambis lambis						1	1	1		1	1	1	1	1		1	1	1	1
Lambis millepeda																			
Lambis scorpius							1												
Lambis spp.						1													
Lambis truncata	1		1	1	1	1	1	1	1	1		1	1	1	1	1	1		1
Latirolagena smaragdula									1	1	1	1	1	1		1	1	1	1
Latirus nodatus																			
Mammilla melanostoma																			
Mitra mitra					1		1			1									
Mitra spp.										1									
Mitra stictica										1									
Morula spp.									1										
Nassarius spp.													1						
Nerita polita									1										
Nerita spp.									1										
Oliva spp.		1							1				1						
Onchidium spp.	1																		
Ovula ovum									1		1		1	1		1		1	1
Peristernia spp.																			
Pleuroploca filamentosa																	1	1	
Pleuroploca spp.					1						1					1			
Pleuroploca trapezium										1									
Polinices mammilla																			
Polinices spp.		1																	
Pyrene spp.																			
Rhinoclavis aspera							1												
Rhinoclavis fasciata											1								
Serpulorbis colubrinus															1				
Siphonaria sirius															1				
Strombus gibberulus gibbosus						1					1		1			1	1		

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Kiribati				Marshall Islands				Nauru	New Caledonia					Niue	Palau			
	Abaiang	Abemama	Kiritimati	Kuria	Ailuk	Arno	Laura	Likiep	All Nauru	Luengoni	Moindou	Ouassé	Oundjo	Thio	All Niue	Airai	Koror	Ngarchelong	Ngatpang
Number of species/site	**12**	**8**	**5**	**13**	**18**	**34**	**34**	**16**	**24**	**35**	**38**	**12**	**29**	**21**	**6**	**52**	**38**	**48**	**39**
Gastropods																			
Strombus labiatus																			
Strombus lentiginosus																1			1
Strombus luhuanus	1	1		1		1	1	1		1	1		1			1		1	1
Strombus mutabilis													1						
Strombus sinuatus																			
Strombus spp.																			
Tectus conus					1						1					1	1	1	1
Tectus fenestratus											1								
Tectus pyramis	1	1			1	1	1	1		1	1	1	1	1		1	1	1	1
Tectus spp.						1										1		1	
Tectus triserialis																1	1	1	1
Telescopium telescopium											1								
Terebra areolata										1									
Terebra dimidiata																			
Terebra maculata										1									
Terebra spp.																			
Thais aculeata							1				1					1		1	
Thais armigera						1			1					1	1				
Thais kieneri																			
Thais spp.	1		1	1				1	1	1	1							1	
Thais tuberosa																			
Trochus maculata					1	1	1			1	1	1	1	1		1	1	1	1
Trochus niloticus						1	1				1	1	1	1		1	1	1	1
Trochus spp.					1			1		1	1	1	1				1	1	
Turbo argyrostomus			1		1	1	1	1	1	1	1		1	1		1	1	1	1
Turbo chrysostomus											1	1	1	1		1	1	1	1
Turbo crassus											1			1					1
Turbo marmoratus																			
Turbo petholatus					1														
Turbo setosus	1								1		1							1	
Turbo spp.			1								1								
Tutufa bubo											1					1	1		
Tutufa rubeta																1			
Tutufa spp.																			
Vasum ceramicum	1					1			1					1		1	1	1	1
Vasum spp.	1						1		1								1	1	1
Vasum turbinellum		1		1		1	1						1	1		1	1	1	

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Papua New Guinea				Samoa				Solomon Islands				Tonga			
	Andra	Panapompom	Sideia	Tsoilaunung	Manono-uta	Salelavalu	Vailoa	Vaisala	Chubikopi	Marau	Nggela	Rarumana	Ha'atafu	Koulo	Lofanga	Manuka
Number of species/site	**33**	**39**	**40**	**37**	**20**	**19**	**17**	**26**	**40**	**60**	**50**	**44**	**34**	**23**	**19**	**38**
Gastropods																
Acanthopleura gemmata																
Astralium spp.	1	1	1	1			1		1	1	1	1	1		1	1
Bulla ampulla																
Bulla spp.																
Bursa bufonia																
Bursa cruentata										1						
Bursa granularis																
Bursa rhodostoma																
Cantharus fumosus																
Cantharus spp.																
Cassis cornuta		1								1	1					
Cerithium aluco						1	1				1	1				
Cerithium nodulosum	1	1	1	1	1	1	1		1	1	1	1		1		1
Cerithium spp.							1	1				1				
Charonia spp.																
Charonia tritonis								1		1			1			1
Chicoreus brunneus									1	1	1					
Chicoreus ramosus					1											1
Chicoreus spp.	1	1	1	1		1			1	1	1					
Clanculus spp.																
Conus arenatus																
Conus bandanus										1	1					
Conus capitaneus												1				
Conus catus																
Conus chaldeus										1						
Conus consors																
Conus coronatus										1						
Conus distans									1	1	1	1				
Conus ebraeus		1							1		1					
Conus eburneus												1				
Conus emaciatus																
Conus episcopatus										1						
Conus flavidus					1	1			1			1				
Conus frigidus							1									
Conus generalis											1					
Conus geographus																
Conus imperialis			1							1	1	1				
Conus leopardus			1		1			1	1		1	1				1
Conus litteratus	1		1	1	1		1	1	1	1	1	1				
Conus lividus									1		1	1				
Conus marmoreus		1	1	1				1	1	1	1	1				
Conus miles	1	1	1	1				1		1	1	1		1	1	
Conus miliaris																
Conus nimbosus																
Conus pulicarius											1					
Conus quercinus																
Conus rattus																
Conus sanguinolentus				1												
Conus spp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Conus sponsalis																
Conus striatus																
Conus textile			1							1	1	1				1
Conus vexillum	1	1	1	1					1	1			1			1
Conus virgo				1				1	1	1	1	1				
Coralliophila neritoidea																
Coralliophila spp.	1									1						
Cryptoplax spp.																
Cymatium lotorium											1					
Cymatium muricinum																
Cymatium rubeculum																
Cymatium spp.																1
Cymbiola spp.																
Cypraea annulus		1	1	1	1	1	1	1	1	1	1	1	1			
Cypraea arabica				1							1		1			
Cypraea argus													1			

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Papua New Guinea				Samoa				Solomon Islands				Tonga			
	Andra	Panapompom	Sideia	Tsoilaunung	Manono-uta	Salelavalu	Vailoa	Vaisala	Chubikopi	Marau	Nggela	Rarumana	Ha'atafu	Koulo	Lofanga	Manuka
Number of species/site	**33**	**39**	**40**	**37**	**20**	**19**	**17**	**26**	**40**	**60**	**50**	**44**	**34**	**23**	**19**	**38**
Gastropods																
Cypraea caputserpensis	1	1	1					1		1			1	1	1	1
Cypraea carneola										1		1				
Cypraea eglantina																
Cypraea erosa									1	1	1					
Cypraea helvola																
Cypraea isabella														1		
Cypraea lynx	1				1	1										
Cypraea maculifera																
Cypraea mappa																
Cypraea mappa mappa																
Cypraea moneta		1		1	1	1		1	1	1	1	1	1			
Cypraea obvelata																
Cypraea schilderorum																
Cypraea scurra																
Cypraea spp.	1				1	1	1	1	1	1	1	1				1
Cypraea talpa																
Cypraea tigris	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cypraea vitellus																
Dendropoma maximum																
Dendropoma spp.																
Distorsio anus																
Dolabella auricularia													1			1
Dolabella spp.	1			1		1										
Drupa grossularia																
Drupa morum													1			
Drupa ricinus																
Drupa rubusidaeus									1	1		1				
Drupa spp.		1				1		1				1			1	
Drupella cornus																
Drupella spp.	1						1				1					1
Haliotis asinina			1													
Haliotis spp.										1						
Harpa amouretta																
Lambis chiragra	1	1	1	1					1	1	1	1				
Lambis crocata		1	1	1							1		1			1
Lambis lambis	1	1	1	1	1				1	1	1	1	1	1	1	1
Lambis millepeda		1	1							1		1				
Lambis scorpius			1				1		1		1	1				
Lambis spp.		1			1					1	1	1				
Lambis truncata		1	1		1					1	1		1	1	1	1
Latirolagena smaragdula	1	1	1	1	1			1	1	1	1	1	1	1		1
Latirus nodatus																
Mammilla melanostoma													1			
Mitra mitra	1			1						1						1
Mitra spp.																
Mitra stictica																
Morula spp.																
Nassarius spp.								1	1	1			1			
Nerita polita																
Nerita spp.																
Oliva spp.											1					
Onchidium spp.																
Ovula ovum	1	1	1							1				1	1	1
Peristernia spp.																
Pleuroploca filamentosa	1	1	1	1			1	1	1	1	1		1			1
Pleuroploca spp.	1	1	1								1			1		
Pleuroploca trapezium										1	1					1
Polinices mammilla				1												
Polinices spp.																
Pyrene spp.																
Rhinoclavis aspera																
Rhinoclavis fasciata																
Serpulorbis colubrinus																
Siphonaria sirius																
Strombus gibberulus gibbosus				1		1			1	1		1	1			1

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Papua New Guinea				Samoa				Solomon Islands				Tonga			
	Andra	Panapompom	Sideia	Tsoilaunung	Manono-uta	Salelavalu	Vailoa	Vaisala	Chubikopi	Marau	Nggela	Rarumana	Ha'atafu	Koulo	Lofanga	Manuka
Number of species/site	**33**	**39**	**40**	**37**	**20**	**19**	**17**	**26**	**40**	**60**	**50**	**44**	**34**	**23**	**19**	**38**
Gastropods																
Strombus labiatus				1		1										
Strombus lentiginosus										1						
Strombus luhuanus		1	1	1	1	1	1	1	1	1	1	1				1
Strombus mutabilis													1			1
Strombus sinuatus			1													
Strombus spp.				1	1	1	1	1	1	1			1	1		1
Tectus conus		1		1					1							
Tectus fenestratus										1						
Tectus pyramis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tectus spp.		1	1			1										
Tectus triserialis																
Telescopium telescopium																
Terebra areolata																
Terebra dimidiata																
Terebra maculata																
Terebra spp.																
Thais aculeata										1			1			1
Thais armigera		1									1			1		
Thais kieneri																
Thais spp.	1	1	1	1		1		1	1	1	1	1		1	1	1
Thais tuberosa																
Trochus maculata		1	1						1	1	1	1	1	1	1	
Trochus niloticus	1	1	1	1					1	1	1	1	1	1	1	1
Trochus spp.	1	1	1	1	1		1	1	1	1			1	1		1
Turbo argyrostomus	1	1	1	1				1	1	1	1	1	1	1	1	1
Turbo chrysostomus	1	1	1	1					1	1	1	1	1	1		1
Turbo crassus	1							1		1			1		1	1
Turbo marmoratus														1	1	1
Turbo petholatus	1	1	1	1						1	1	1				
Turbo setosus	1							1	1			1	1	1	1	1
Turbo spp.					1				1	1	1	1		1	1	
Tutufa bubo															1	
Tutufa rubeta										1		1	1			1
Tutufa spp.			1													
Vasum ceramicum	1	1	1	1					1	1	1	1	1			1
Vasum spp.	1	1	1	1				1		1		1				
Vasum turbinellum	1	1	1	1									1			

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Tuvalu				Vanuatu				Wallis and Futuna			
	Funafuti	Niutao	Nukufetau	Vaitupu	Maskelynes	Moso	Paunagisu	Uri-Uripiv	Halalo	Leava	Vailala	Vele
Number of species/site	**20**	**13**	**11**	**14**	**30**	**10**	**15**	**22**	**44**	**25**	**48**	**32**
Gastropods												
Acanthopleura gemmata					1							
Astralium spp.		1							1	1	1	
Bulla ampulla												
Bulla spp.												
Bursa bufonia												
Bursa cruentata												
Bursa granularis											1	
Bursa rhodostoma												
Cantharus fumosus												
Cantharus spp.												
Cassis cornuta									1			
Cerithium aluco									1			
Cerithium nodulosum	1				1		1	1	1	1	1	
Cerithium spp.											1	
Charonia spp.												
Charonia tritonis		1										
Chicoreus brunneus									1		1	
Chicoreus ramosus	1		1					1	1		1	
Chicoreus spp.									1		1	
Clanculus spp.												
Conus arenatus												
Conus bandanus									1		1	
Conus capitaneus												
Conus catus									1		1	
Conus chaldeus												
Conus consors												
Conus coronatus									1		1	
Conus distans									1		1	
Conus ebraeus										1		1
Conus eburneus												
Conus emaciatus												
Conus episcopatus												
Conus flavidus							1	1	1		1	1
Conus frigidus									1			
Conus generalis												
Conus geographus								1				
Conus imperialis										1	1	1
Conus leopardus					1						1	
Conus litteratus					1	1	1					1
Conus lividus									1			
Conus marmoreus					1				1		1	1
Conus miles					1			1	1		1	
Conus miliaris												
Conus nimbosus												
Conus pulicarius											1	
Conus quercinus												
Conus rattus	1	1	1	1							1	
Conus sanguinolentus												
Conus spp.					1	1	1	1	1	1	1	1
Conus sponsalis												
Conus striatus											1	
Conus textile								1				
Conus vexillum									1	1	1	1
Conus virgo												
Coralliophila neritoidea							1					
Coralliophila spp.											1	
Cryptoplax spp.												
Cymatium lotorium												
Cymatium muricinum				1								
Cymatium rubeculum									1			
Cymatium spp.					1							
Cymbiola spp.					1							
Cypraea annulus					1	1	1		1	1	1	1
Cypraea arabica		1		1					1		1	

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Tuvalu				Vanuatu				Wallis and Futuna			
	Funafuti	Niutao	Nukufetau	Vaitupu	Maskelynes	Moso	Paunagisu	Uri-Uripiv	Halalo	Leava	Vailala	Vele
Number of species/site	**20**	**13**	**11**	**14**	**30**	**10**	**15**	**22**	**44**	**25**	**48**	**32**
Gastropods												
Cypraea argus												
Cypraea caputserpensis								1	1	1	1	1
Cypraea carneola												
Cypraea eglantina												
Cypraea erosa												
Cypraea helvola												
Cypraea isabella	1		1	1					1			
Cypraea lynx												
Cypraea maculifera					1	1			1	1	1	1
Cypraea mappa												
Cypraea mappa mappa	1											
Cypraea moneta	1			1								
Cypraea obvelata			1	1								
Cypraea schilderorum												
Cypraea scurra					1	1	1	1	1	1	1	1
Cypraea spp.												
Cypraea talpa												
Cypraea tigris												
Cypraea vitellus		1								1		
Dendropoma maximum					1							
Dendropoma spp.										1		
Distorsio anus		1										
Dolabella auricularia										1		1
Dolabella spp.	1								1			
Drupa grossularia												
Drupa morum									1			
Drupa ricinus									1			
Drupa rubusidaeus	1		1		1				1		1	
Drupa spp.												
Drupella cornus												
Drupella spp.												
Haliotis asinina												
Haliotis spp.												
Harpa amouretta	1	1	1	1	1	1	1	1				
Lambis chiragra												
Lambis crocata												
Lambis lambis					1							
Lambis millepeda					1	1			1	1		1
Lambis scorpius					1		1	1	1		1	1
Lambis spp.												
Lambis truncata												
Latirolagena smaragdula						1						
Latirus nodatus												
Mammilla melanostoma												1
Mitra mitra												1
Mitra spp.					1						1	
Mitra stictica												
Morula spp.												
Nassarius spp.												1
Nerita polita												
Nerita spp.												
Oliva spp.									1		1	
Onchidium spp.					1		1	1	1	1		
Ovula ovum									1		1	1
Peristernia spp.										1	1	1
Pleuroploca filamentosa												
Pleuroploca spp.						1					1	
Pleuroploca trapezium												
Polinices mammilla							1				1	
Polinices spp.												
Pyrene spp.												
Rhinoclavis aspera												
Rhinoclavis fasciata					1						1	
Serpulorbis colubrinus					1	1						

Table A3.1.4: Gastropods presence per site (continued)

Countries/Territories	Tuvalu				Vanuatu				Wallis and Futuna			
	Funafuti	Niutao	Nukufetau	Vaitupu	Maskelynes	Moso	Paunagisu	Uri-Uripiv	Halalo	Leava	Vailala	Vele
Number of species/site	**20**	**13**	**11**	**14**	**30**	**10**	**15**	**22**	**44**	**25**	**48**	**32**
Gastropods												
Siphonaria sirius											1	
Strombus gibberulus gibbosus	1	1	1	1	1		1		1		1	1
Strombus labiatus	1			1								
Strombus lentiginosus												
Strombus luhuanus											1	
Strombus mutabilis									1	1	1	
Strombus sinuatus												
Strombus spp.		1										
Tectus conus												
Tectus fenestratus	1	1		1								
Tectus pyramis												
Tectus spp.	1											
Tectus triserialis	1									1		1
Telescopium telescopium	1	1		1						1		
Terebra areolata	1	1		1				1				
Terebra dimidiata								1	1	1	1	1
Terebra maculata												
Terebra spp.					1		1	1	1			1
Thais aculeata					1		1	1	1	1	1	1
Thais armigera	1			1								
Thais kieneri	1		1		1			1	1		1	1
Thais spp.					1			1				1
Thais tuberosa										1		1
Trochus maculata			1					1				
Trochus niloticus		1		1								
Trochus spp.									1	1	1	1
Turbo argyrostomus									1		1	1
Turbo chrysostomus												
Turbo crassus												
Turbo marmoratus												
Turbo petholatus					1			1		1		1
Turbo setosus								1	1		1	1
Turbo spp.					1							
Tutufa bubo												
Tutufa rubeta												
Tutufa spp.												
Vasum ceramicum												
Vasum spp.												
Vasum turbinellum												

Table A3.1.5: Other species presence per site

Countries/Territories	Cook Islands				Fiji Islands						French Polynesia					FSM			
	Aitutaki	Mangaia	Palmerston	Rarotonga	Dromuna	Lakeba	Mali	Muaivuso	Nasaqalau	Nukunuku	Fakarava	Maatea	Mataiea	Raivavae	Tikehau	Piis-Panewu	Riiken	Romanum	Yyin
Number of species/site																	**1**		
Nudibranchs																			
Phyllidia spp.																	1		
Number of species/site		**1**	**1**	**1**		**1**	**1**				**1**	**1**	**1**		**1**	**1**		**1**	
Octopus																			
Octopus cyanea						1	1				1		1		1				
Octopus spp.		1	1	1								1				1		1	
Number of species/site	**2**	**3**	**2**	**4**	**4**	**4**	**4**	**4**	**2**	**3**	**1**	**3**	**2**	**1**	**1**	**3**	**4**	**4**	**5**
Starfish																			
Acanthaster planci	1	1	1	1	1	1	1	1	1	1		1	1			1	1	1	1
Archaster spp.																			
Archaster typicus					1														
Choriaster granulatus						1	1	1										1	
Choriaster spp.																			
Culcita novaeguineae				1	1	1	1	1		1	1	1	1		1	1	1	1	1
Fromia spp.																	1		
Leiaster speciosus																			1
Linckia guildingi		1		1															
Linckia laevigata	1	1	1	1	1	1	1	1	1	1		1		1		1	1	1	1
Nardoa novaecaledoniae																			
Nardoa spp.																			
Protoreaster nodosus																			1
Number of species/site	**7**	**8**	**3**	**6**	**5**	**2**	**3**	**7**	**3**	**4**	**4**	**6**	**5**	**4**	**3**	**4**	**7**	**4**	**4**
Urchins																			
Diadema savignyi	1	1																	
Diadema setosum																			
Diadema spp.	1	1	1	1		1	1		1	1	1	1	1		1		1		
Echinodiscus bisperforatus																			
Echinometra mathaei	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Echinometra oblonga																			
Echinometra spp.										1									
Echinostrephus spp.																			
Echinothrix calamaris	1	1			1			1				1	1				1	1	
Echinothrix diadema	1	1	1	1	1		1	1			1	1	1	1		1	1	1	1
Echinothrix spp.												1		1			1		1
Eucidaris spp.								1											
Heterocentrotus mammillatus	1	1		1					1	1	1					1			
Heterocentrotus spp.																			
Heterocentrotus trigonarius		1		1															
Laganum depressum																			
Mespilia globulus					1			1									1		1
Toxopneustes pileolus								1											
Tripneustes gratilla	1	1		1	1			1				1	1	1	1	1	1	1	
Total all invertebrate species per site	**41**	**65**	**39**	**59**	**61**	**57**	**57**	**74**	**36**	**61**	**30**	**38**	**43**	**28**	**26**	**63**	**88**	**74**	**80**

Table A3.1.5: Other species presence per site (continued)

Countries/Territories	Kiribati				Marshall Islands				Nauru	New Caledonia					Niue	Palau			
	Abaiang	Abemama	Kiritimati	Kuria	Ailuk	Arno	Laura	Likiep	All Nauru	Luengoni	Moindou	Ouassé	Oundjo	Thio	All Niue	Airai	Koror	Ngarchelong	Ngatpang
Number of species/site						**1**	**1**												
Nudibranchs																			
Phyllidia spp.						1	1												
Number of species/site	**1**	**1**	**1**		**1**	**1**	**1**	**1**		**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	
Octopus																			
Octopus cyanea		1	1							1		1	1	1				1	
Octopus spp.	1				1	1	1	1							1	1	1		
Number of species/site	**3**	**2**	**1**		**5**	**3**	**4**	**2**	**4**		**5**	**3**	**4**	**3**		**5**	**6**	**6**	**6**
Starfish																			
Acanthaster planci	1	1			1	1	1	1	1		1			1		1	1	1	1
Archaster spp.							1												
Archaster typicus											1								
Choriaster granulatus					1											1	1	1	1
Choriaster spp.					1														
Culcita novaeguineae	1	1	1		1	1	1	1	1		1	1	1			1	1	1	1
Fromia spp.									1										
Leiaster speciosus																			
Linckia guildingi																	1	1	
Linckia laevigata	1				1	1	1		1		1	1	1	1		1	1	1	1
Nardoa novaecaledoniae																			
Nardoa spp.												1	1	1					1
Protoreaster nodosus											1		1			1	1	1	1
Number of species/site	**3**		**4**	**3**	**3**	**4**	**4**	**4**	**5**	**4**	**10**	**6**	**4**	**6**	**6**	**6**	**5**	**6**	**6**
Urchins																			
Diadema savignyi																			1
Diadema setosum																	1		
Diadema spp.			1						1		1	1	1	1			1		1
Echinodiscus bisperforatus											1								
Echinometra mathaei	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Echinometra oblonga															1				
Echinometra spp.																			
Echinostrephus spp.															1				
Echinothrix calamaris						1		1	1	1	1				1	1	1	1	
Echinothrix diadema	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Echinothrix spp.			1	1					1					1					
Eucidaris spp.																			
Heterocentrotus mammillatus	1				1	1		1		1	1	1	1	1	1	1		1	
Heterocentrotus spp.											1								
Heterocentrotus trigonarius																			
Laganum depressum											1								
Mespilia globulus							1				1					1		1	1
Toxopneustes pileolus												1							1
Tripneustes gratilla							1				1	1		1		1		1	1
Total all invertebrate species per site	**44**	**34**	**25**	**29**	**46**	**66**	**66**	**37**	**51**	**61**	**96**	**50**	**76**	**63**	**20**	**112**	**100**	**112**	**110**

Table A3.1.5: Other species presence per site (continued)

Countries/Territories	Papua New Guinea				Samoa				Solomon Islands				Tonga			
	Andra	Panapompom	Sideia	Tsoilaunung	Manono-uta	Salelavalu	Vailoa	Vaisala	Chubikopi	Marau	Nggela	Rarumana	Ha'atafu	Koulo	Lofanga	Manuka
Number of species/site																
Nudibranchs																
Phyllidia spp.																
Number of species/site	**2**	**1**	**1**	**1**		**1**		**1**		**1**				**1**	**1**	
Octopus																
Octopus cyanea	1		1							1				1		
Octopus spp.	1	1		1		1		1							1	
Number of species/site	**5**	**5**	**4**	**7**	**3**	**5**	**3**	**4**	**6**	**6**	**8**	**6**	**5**	**4**	**3**	**6**
Starfish																
Acanthaster planci	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Archaster spp.				1												
Archaster typicus						1										1
Choriaster granulatus		1	1	1					1	1	1	1	1	1		1
Choriaster spp.	1			1												
Culcita novaeguineae	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fromia spp.						1		1	1		1	1				
Leiaster speciosus																
Linckia guildingi									1		1	1				
Linckia laevigata	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nardoa novaecaledoniae																
Nardoa spp.										1	1					
Protoreaster nodosus	1	1		1						1	1		1			1
Number of species/site	**7**	**6**	**5**	**6**	**6**	**4**	**7**	**5**	**5**	**8**	**8**	**7**	**6**	**6**	**6**	**7**
Urchins																
Diadema savignyi																
Diadema setosum																
Diadema spp.	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Echinodiscus bisperforatus																
Echinometra mathaei	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Echinometra oblonga																
Echinometra spp.																
Echinostrephus spp.																
Echinothrix calamaris	1	1	1	1	1		1	1	1	1	1	1	1			1
Echinothrix diadema	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Echinothrix spp.	1				1	1	1	1		1				1	1	
Eucidaris spp.																
Heterocentrotus mammillatus		1	1	1					1	1	1	1	1	1	1	1
Heterocentrotus spp.																
Heterocentrotus trigonarius											1					
Laganum depressum																
Mespilia globulus	1					1	1				1	1				
Toxopneustes pileolus					1		1			1						1
Tripneustes gratilla	1	1		1						1	1	1	1	1	1	1
Total all invertebrate species per site	**86**	**86**	**82**	**102**	**49**	**51**	**47**	**61**	**93**	**120**	**108**	**97**	**76**	**63**	**58**	**86**

Table A3.1.5: Other species presence per site (continued)

Countries/Territories	Tuvalu				Vanuatu				Wallis and Futuna			
	Funafuti	Niutao	Nukufetau	Vaitupu	Maskelynes	Moso	Paunagisu	Uri-Uripiv	Halalo	Leava	Vailala	Vele
Number of species/site												
Nudibranchs												
Phyllidia spp.												
Number of species/site		**1**	**1**	**1**	**1**			**1**		**1**		**1**
Octopus												
Octopus cyanea		1	1	1	1			1				
Octopus spp.										1		1
Number of species/site	**1**	**1**	**2**	**1**	**4**	**3**	**4**	**5**	**3**	**2**	**3**	**3**
Starfish												
Acanthaster planci					1		1	1	1			1
Archaster spp.												
Archaster typicus					1						1	
Choriaster granulatus						1		1				
Choriaster spp.												
Culcita novaeguineae	1		1	1	1	1	1	1	1	1	1	1
Fromia spp.		1										
Leiaster speciosus												
Linckia guildingi												
Linckia laevigata			1		1	1	1	1	1	1	1	1
Nardoa novaecaledoniae							1					
Nardoa spp.								1				
Protoreaster nodosus												
Number of species/site	**2**	**2**	**2**	**4**	**4**	**4**	**5**	**5**	**4**	**3**	**6**	**5**
Urchins												
Diadema savignyi												
Diadema setosum												
Diadema spp.						1					1	
Echinodiscus bisperforatus												
Echinometra mathaei	1	1	1	1	1	1	1	1	1	1	1	1
Echinometra oblonga												
Echinometra spp.				1								
Echinostrephus spp.												
Echinothrix calamaris								1	1	1	1	1
Echinothrix diadema	1	1	1	1	1	1	1	1	1	1	1	1
Echinothrix spp.									1		1	
Eucidaris spp.												
Heterocentrotus mammillatus				1	1	1	1	1			1	1
Heterocentrotus spp.												
Heterocentrotus trigonarius												
Laganum depressum												
Mespilia globulus												
Toxopneustes pileolus							1					1
Tripneustes gratilla					1		1	1				
Total all invertebrate species per site	**40**	**24**	**31**	**28**	**78**	**49**	**60**	**62**	**75**	**46**	**92**	**62**

3.2 Sea cucumber fisheries: a manager's tool

Australian Government
Australian Centre for
International Agricultural Research

Sea cucumber fisheries:
a manager's toolbox

K. Friedman, Secretariat of the Pacific Community
S. Purcell, WorldFish Center
J. Bell, Secretariat of the Pacific Community
C. Hair, James Cook University

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a manager's toolbox

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2008

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Foreword

Sea cucumber fisheries provide an important source of cash income to isolated coastal communities throughout the Pacific islands region through the processing and sale of 'bêche-de-mer'. Regrettably, for many communities these small-scale fisheries no longer yield the benefits they once did due to over-fishing. In areas where there are few other opportunities to earn income, this has resulted in families and, in some cases, whole villages suffering. The over-fishing has been exacerbated by the sedentary nature of sea cucumbers and the ease with which they can be collected from inshore habitats. Although more remote areas once provided some refuge from fishing for these vulnerable animals, this is no longer the case—these areas are now more readily accessed by divers using better boats and underwater breathing apparatus taking advantage of improved access to markets.

In response to the dire condition of many sea cucumber fisheries today, the Australian Centre for International Agricultural Research (ACIAR) convened the 'Papua New Guinea, Pacific Islands and Northern Australia Sea Cucumber Fisheries Management Workshop', held at Motupore Island Research Centre, Papua New Guinea, 20–23 March 2006. This booklet is a direct outcome of that workshop.

Resource managers need appropriate means to tackle the problem of deteriorating fisheries. This 'toolbox' provides them with easy-to-use decision-making tools to establish the status of local sea cucumber fisheries and identify appropriate management responses. In many places where sea cucumbers are collected, drastic and immediate action is needed. Enough sea cucumbers need to be protected to create the viable groups of spawning adults needed to restore and regularly replenish this valuable resource. Practical management systems to rebuild over-fished stocks, and to maintain those that are still in good condition, are also outlined here. This toolbox will be a valuable aid for fisheries managers, scientists, non-government organisations and all those engaged in promoting better use of the region's precious sea cucumber resources.

Peter Core
Chief Executive Officer
ACIAR

Acknowledgments

This toolbox stems from the 'Papua New Guinea, Pacific Islands and Northern Australia Sea Cucumber Fisheries Management Workshop', which was held at Motupore Island Research Centre on 20–23 March 2006. The workshop was supported by funding from the Australian Centre for International Agricultural Research (ACIAR).

Kim Friedman (Secretariat of the Pacific Community), Warwick Nash (WorldFish Center) and Barney Smith (ACIAR) were instrumental in the planning of the workshop. Subsequently, staff at SPC's Reef Fisheries Observatory and Planning Section (Kim Friedman, Johann Bell) and WorldFish Center (Steve Purcell), in conjunction with Cathy Hair (James Cook University), worked to create this toolbox, incorporating many of the ideas that had been discussed.

The other participants in the workshop (and other important contributors) were Dennis Ah-Kee, Mark Baine, Mikkel Christensen, Claudia Hand, Leonie Jenkins, Jeff Kinch, Presley Kokwaiye, Paul Lokani, Neil Loneragan, Alistair McIlgorm, Phillip Polon, Garry Preston, Chris Ramofafia, Tim Skewes, Satarak Taput and Wete Zozingao.

We thank them all for the fruitful discussions that helped us distil their collective thoughts into the indicators for assessing the health of sea cucumber fisheries, the 'best practice' management tools, and the measures needed to rebuild severely depleted stocks that are contained in this toolbox.

Thanks also to Youngimi Choi for work on the illustrations.

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Contents

Overview

The way people fish for sea cucumbers is changing rapidly. Traditional methods for catching sea cucumbers, such as gleaning on reefs at low tide or diving in shallow waters, are being replaced by the use of larger boats, diving equipment and bottom dredges. These changes allow fishers to collect most of these slow-moving animals easily, even in remote places and deep-water locations, causing widespread over-fishing of sea cucumbers.

Over-fishing is also being driven by the increasing need for cash in rural areas of the Pacific. Bêche-de-mer, produced by boiling, drying and smoking sea cucumbers, is a valuable commodity, so there are strong incentives for villagers to catch and sell sea cucumbers for income to meet their needs.

Sea cucumbers are also prone to over-fishing because of their biology. Many species grow slowly and, due to natural variability, populations are likely to have both good and poor breeding years. This means that it can take a long time for stocks to be replenished after heavy fishing.

The widespread over-exploitation of sea cucumbers is leading to a collapse of stocks. Sea cucumbers are sedentary marine invertebrates that shed their eggs and sperm into the water column. When they are over-fished below a certain (threshold) density, they cannot reproduce effectively because the males and females are too far apart for fertilisation to be successful. When this happens to any species of sea cucumber, it will eventually disappear from an area, taking the livelihoods of coastal villagers with it.

This toolbox is designed to help managers and fishers check the ‘health’ of their sea cucumber fishery. It also summarises management measures that can be used to maintain the condition of healthy fisheries and restore those that have been damaged.

The need for better management

Historically, boats from Asia visited Pacific countries to trade for bêche-de-mer, but the visits were irregular and often separated by long periods of time. This meant that stocks of sea cucumbers usually had time to recover before the next visit, and there were areas in each country that remained unfished. Today, the situation is very different, with many of the coastal villages in the Pacific having an agent for businesses that buy bêche-de-mer. Fishers now harvest more frequently over wide areas and can sell bêche-de-mer all year round. Stocks that are over-fished have little chance to recover.

In an ideal world, fishers would stop harvesting sea cucumbers when their densities became too low, allow the stocks to recover, and then start fishing again. Recent studies show that this is not happening in many places. On the contrary, fishers often harvest sea cucumbers to local extinction. In Egypt the sea cucumber fishery collapsed completely in 2002 after only 4 years of heavy fishing. At Chuuk Atoll in the Federated States of Micronesia stocks of sea cucumber fished intensely in the late 1930s had still not recovered 50 years later. In Papua New Guinea too, some stocks have disappeared after the local breeding populations were depleted.

Protecting the vitality and value of sea cucumber fisheries requires a conservative management approach. The benefits of good stewardship will be regular harvests, greater biodiversity, healthier coastal and reef ecosystems, and economic benefits for current and future generations.

How to use this toolbox

This toolbox has four sections.

Section 1 asks how familiar you are with your fishery. It illustrates the life cycle of sea cucumbers and some of the species you might find in your area.

Section 2 helps you to check the 'health' of your fishery. You will be asked a series of 'indicator questions' that, taken together, will help define the condition of the stocks. Each indicator is accompanied by case studies and a guide on how to obtain the information you need to answer the question. At the end of the six questions, you can review all your answers at the decision stage to identify the general condition of the fishery.

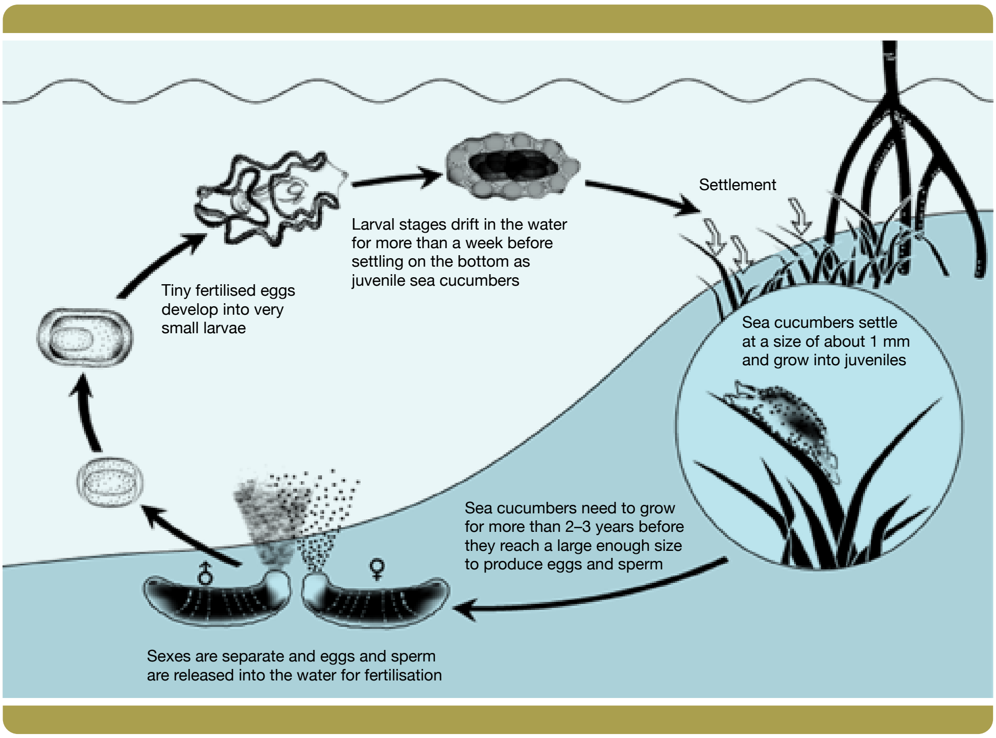
Section 3 and **Section 4** provide 'best practice' management options for maintaining sustainable harvests from a healthy fishery or restoring a severely depleted one.

There is a reference information list that provides contacts for management and scientific advice, as well as details of literature and websites for further reading.

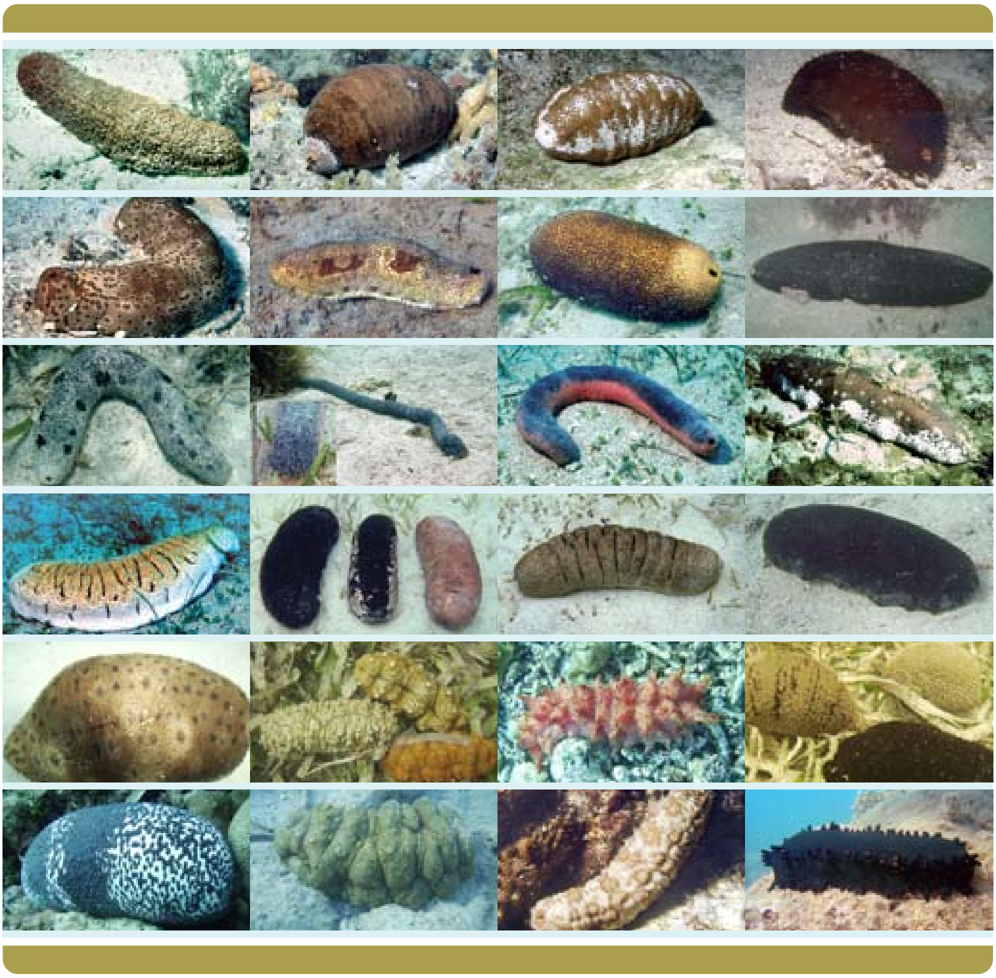
Do you know your fishery?

Before you start the ‘health check’, you should make sure you can answer the following general questions about your fishery. You will then be ready to answer the more specific indicator questions in Section 2.

- How do sea cucumbers live, reproduce and grow?
- Do you understand the ‘natural factory’ (the life cycle in the diagram below) that allows breeding adults to supply new generations of sea cucumber to local waters?



Life cycle of sea cucumber (based on sandfish example)
Source: adapted from Battaglene (1999)

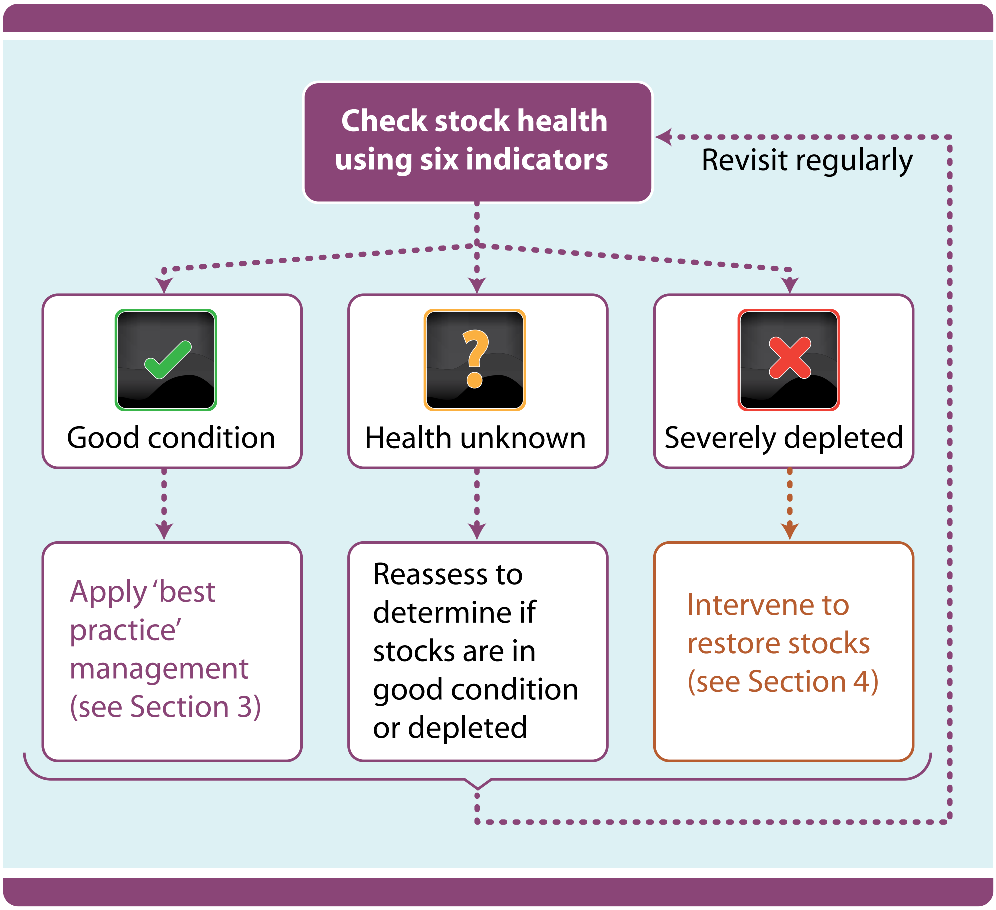


For an illustrated poster of sea cucumber species from the tropical Pacific, see Purcell et al. (in press).

- Which species are harvested?
- What areas do they come from?
- How are they caught?
- Who catches them?
- Which species have declined in abundance?
- Where do they live—on the reef, in deeper water, in mangrove or seagrass habitats?
- Are they high-value or medium-value species?
- How does the money earned from selling sea cucumbers benefit communities?
- What management 'tools' are in use? Are they working?

How healthy is your fishery?

Use the steps in the flow chart below to check the health of your sea cucumber fishery.



INDICATOR 1 – Presence of breeding groups

Are there still areas where adult sea cucumbers remain protected near the main fishing grounds?

Yes – For each of the main species in my fishery, there are still some relatively dense populations on reefs or in lagoon areas.

No – There are few, if any, relatively dense patches of each species in my fishery.

Importance of this indicator

Sea cucumbers reproduce by releasing their eggs and sperm into the water column. The eggs develop into microscopic larvae that drift in currents for weeks. The tiny juveniles then settle into shallow coastal habitats where they can hide from predators and grow into adults. This is the 'natural factory' that produces new generations of sea cucumbers and replenishes stocks (see diagram in Section 1 and Section 3.2 for more information on the life cycle of sea cucumbers).

Some areas with relatively dense numbers of adults (e.g. >100 individuals per ha in the case of sandfish) are needed to produce enough eggs to make the natural factory work. Otherwise, spawning adults cannot find each other easily and fertilisation of the eggs is poor. The areas where dense patches of sea cucumber are likely to occur are in marine reserves or 'taboo' areas where fishers tend not to harvest.

Case study (Australia)

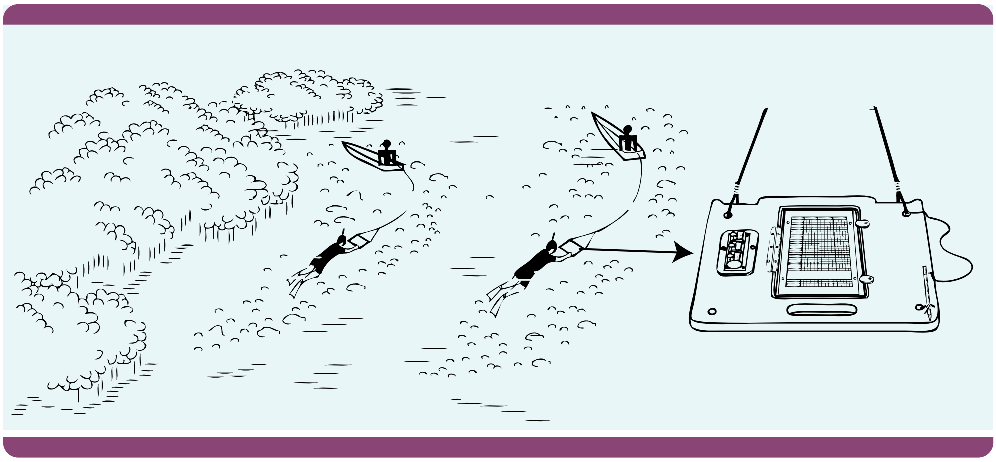
Even sea cucumber fisheries managed with ample resources, such as the one on Australia's Great Barrier Reef (GBR), have been over-fished. To prevent over-exploitation of sea cucumbers and the many other commercial fish species on the GBR, the authority responsible protected 30% of the reef from fishing. This measure will help ensure that dense patches of sea cucumber are protected as breeding groups to replenish fishing grounds.

Case study (New Caledonia)

Along the main island of New Caledonia (La Grande Terre), there are now few sites outside marine reserves and areas under strict customary protection that have high densities of sea cucumber. However, the fishery is still reasonably productive, indicating that the protected places contain enough adults to replenish stocks of sea cucumber regularly.

Finding the information

- The best way to verify this indicator is through rapid underwater visual censuses of sea cucumbers. This can be done using a 'manta technique' to estimate population densities over broad areas within the fishery (see figure below). A snorkeller is towed behind a boat and uses a hand-held 'manta board' as a writing slate to record information.
- Interview fishers to ask them if they know where sea cucumbers can still be found in high densities.
- Seek help with surveys from the Secretariat of the Pacific Community (SPC) and non-government organisations (NGOs) because they are often well placed to advise and conduct surveys.



Manta board surveys can be conducted along coastal and lagoon reefs to determine sea cucumber densities.

INDICATOR 2 – Fishing gear used

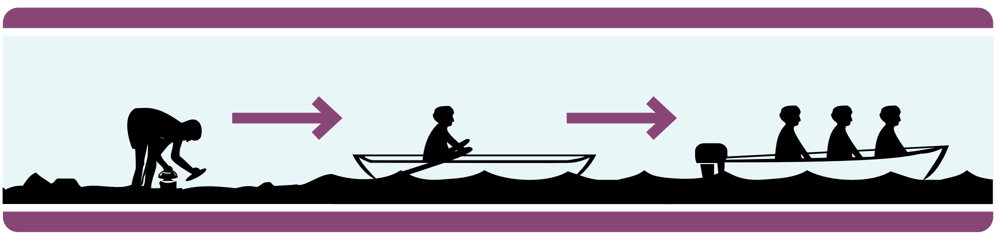
Are small-scale, traditional fishing methods mostly used to harvest sea cucumbers?

Yes – Fishery methods have not changed—they are generally small-scale and active mostly in shallow water.

No – Fishery methods are more motorised and organised—they use new gear and are more active in deeper water.

Importance of this indicator

Fishers have changed their methods from wading in the shallows to the use of sail and paddle canoes, and dinghies with outboard motors. This has resulted in greater coverage of the area where sea cucumbers live, more regular fishing, access to remote areas and the capacity to transport greater catches. Loss of much larger numbers of sea cucumbers from many areas as a result of this increased fishing pressure reduces the chances of adults remaining at densities high enough for effective reproduction. When sea cucumbers are 'thinned out' by over-fishing, they are not always able to find mates to breed with during the spawning season.



Changes in fishery methods

Case study (Solomon Islands)

Traditionally, sea cucumbers were harvested in Solomon Islands by gleaning at low tide or by free diving with 'eye glasses' (a mask). However, over the past 10 years, diving at night with torches, and the use of 'bombs' (a small spear below a lead weight tethered to a line and float), hookah and dredge nets, have increased catches both across the country and down to greater depths. The use of hookah has also claimed the lives of divers and increased the incidence of decompression sickness. Even repeated deep diving on snorkel can be fatal as it can cause divers to 'black-out'.

Finding the information

- Make independent observations of the equipment and types of boats used by fishers.
- Determine what proportion of fishers still use traditional methods and fish from simple canoes or the shore.

INDICATOR 3 – Sea cucumber abundance

Are the abundances of sea cucumbers in the fishery stable?

Yes – Fishers are finding sea cucumber as easily as they did years ago.

No – Fishers and agents are having difficulty finding sea cucumbers.

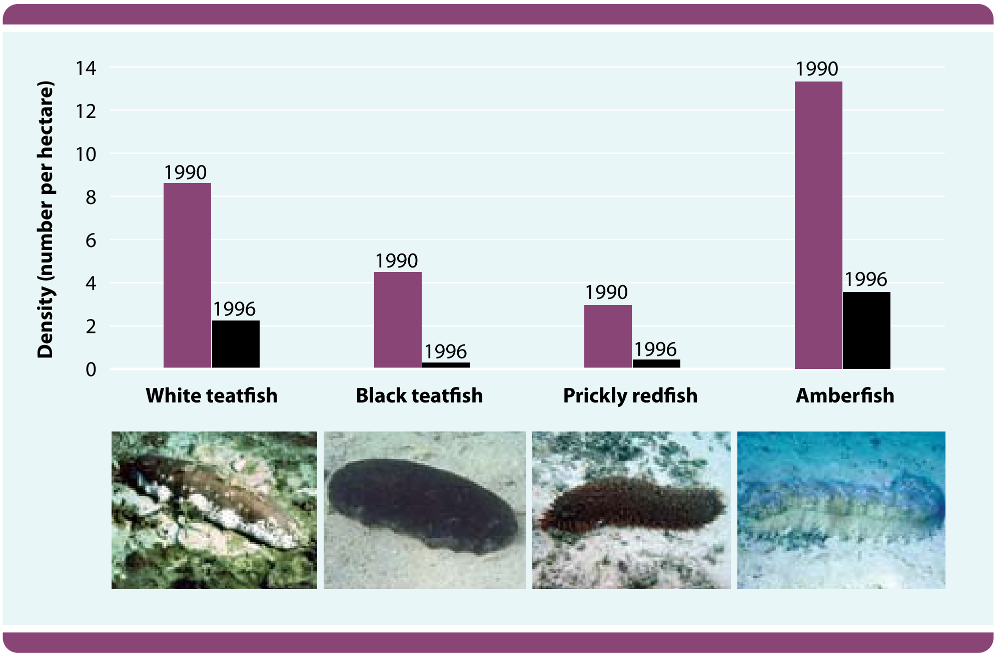
Importance of this indicator

Over-fishing of valuable sea cucumbers is being reported from many countries in the Pacific. In some cases (e.g. in Tonga, Samoa, Australia, Vanuatu and Solomon Islands) it is so severe that fisheries have been closed to allow stocks to recover.

Large declines in abundance and related fishery closures cause hardship to communities who rely on sea cucumbers for income. When abundance falls to very low levels, fishers may need to wait for many years until stocks are healthy enough to replenish themselves regularly and support some fishing again.

Case study (Tonga)

Unsustainable heavy fishing between 1990 and 1996, which reduced the density of several species of sea cucumber (see graph right), caused managers to close the fishery in 1997. It remained closed for more than 10 years.



Decrease in density of sea cucumbers in Tonga following heavy fishing between 1990 and 1996

Finding the information

- Interview fishers about their past and present catch rates and use this information to compare historical and current catch per unit effort.
- Use any past and recent data on the density of the main species from surveys, and any records from exports, to determine if there have been any local depletions.

INDICATOR 4 – Ratio of species abundance

Are high-value and medium-value species still abundant and well represented in catches?

Yes – High-value and medium-value species are relatively abundant and make up a significant proportion of the catch or exports.

No – Most of the sea cucumbers caught are low-value species.

Importance of this indicator

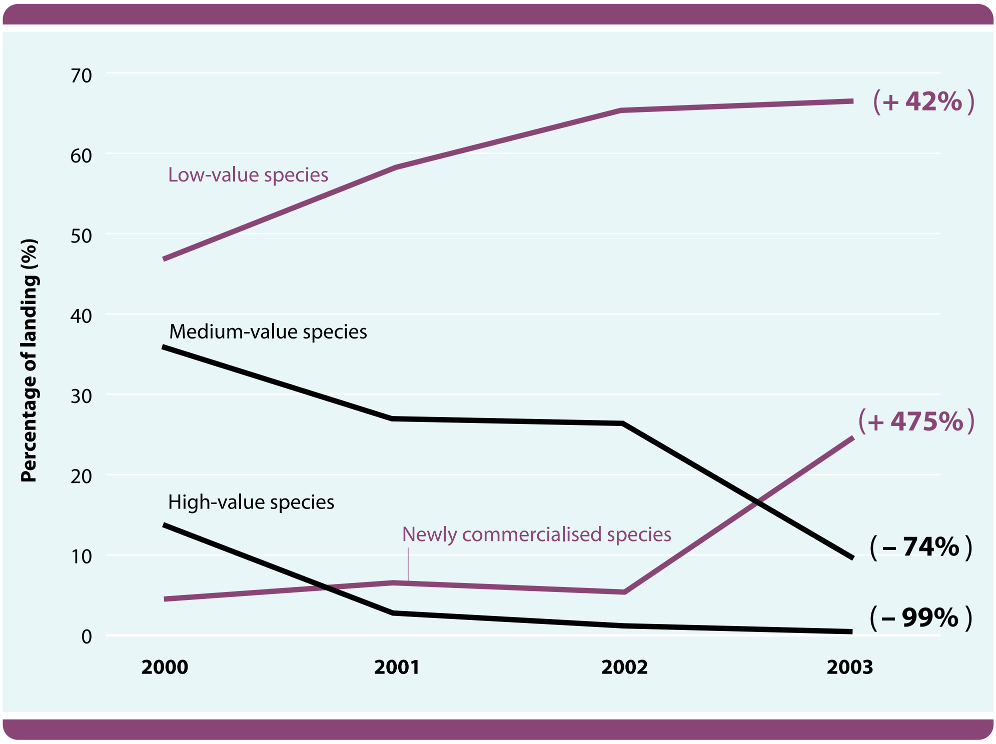
In healthy fisheries high-value species (e.g. sandfish, black teatfish, white teatfish) and medium-value species (e.g. blackfish group, surf redfish, prickly redfish) represent at least one-quarter to one-half of the total catch. If populations of these species are over-fished, fishers turn to lower value or 'new' species (e.g. greenfish, elephant trunkfish, leopardfish (tigerfish), brown sandfish, lollyfish, chalkfish) or need to use scuba or hookah methods to fish deeper. Changes in the composition and relative abundance of species are therefore a good indicator of over-fishing.

Case study (Papua New Guinea)

In Papua New Guinea the high- and medium-value species have been progressively over-fished in recent decades. There are now at least 26 species of sea cucumbers harvested, mostly of low value.

Case study (Solomon Islands)

A similar trend is reported from Solomon Islands (see graph right). The number of species exported increased from 15 in 1988 to 32 in 2004, with the additional species being of low market value. The original and 'newly commercialised' low-value species dominated catches prior to the fishery being closed recently. As a result, the price per kilogram of bêche-de-mer exported has declined steadily.



Variation in ratio of value groups of sea cucumber exported from Solomon Islands between 2000 and 2003

Finding the information

- Check bêche-de-mer export records to look for trends in the number of each species caught and its proportion of total exports.
- Use underwater visual censuses to determine the proportion of high-value and medium-value species of sea cucumbers at important fishing grounds.

INDICATOR 5 – Size of sea cucumbers

Are large-sized sea cucumbers still caught? Is mostly 'A' grade bêche-de-mer produced?

Yes – For most species, large-sized individuals are caught and sold.

No – For most species, small sizes dominate catches and exports.

Importance of this indicator

One of the first signs that sea cucumbers have been over-fished is that the large animals disappear from catches. When this happens, fishers are no longer maximising their potential sustainable earnings because large sea cucumbers are needed to produce 'A'-grade bêche-de-mer. If the majority of sea cucumbers is not left in the water to reach adult size, replenishment of the stock is unlikely to occur.

Sea cucumbers processed as bêche-de-mer—large-sized 'A'-grade bêche-de-mer is seen at left.

‘A’-grade bêche-de-mer produced from sandfish would comprise up to 15 pieces to the kilogram (kg). Examples of ‘A’-grade product (based on dry weight) for other species would be 2–3 pieces per kg for white teatfish, 3 per kg for black teatfish and prickly redfish, and up to 20 per kg for surf redfish, curryfish and stonefish.

Case study (Warrior Reef, Torres Strait)

After 3 years of unsustainable fishing pressure on sandfish at Warrior Reef, most of the larger, mature animals had been removed (graph A below). In 2004, after the fishery had been closed for 6 years, the population had a higher proportion of mature animals (graph B).

Population length profile of sandfish recorded at Warrior Reef in 1995–96 and 2004. Source: T. Skewes

Finding the information

- Examine export records to see if there has been a decrease in the proportion of ‘A’-grade product.
- Measure the average size of each species in representative catches each year and examine the trends.

INDICATOR 6 – Profit to fishers

Do the benefits from the fishery flow mainly to fishing communities?

Yes – Local people do the fishing and the processing of sea cucumbers into bêche-de-mer.

No – People in villages are not the main ones profiting from the fishery. Fishing is done mainly by groups of divers on wages. Villagers usually sell sea cucumbers to agents who process them.

Importance of this indicator

In traditional communities the majority of the local people who fish for sea cucumbers process them into bêche-de-mer themselves. This spreads income throughout the village.

If fishers begin to sell their catch to other people to process, there is the risk of over-fishing because they then need to catch more sea cucumbers to make the same amount of money that they did by processing their catch themselves. A similar situation arises when villagers join larger crews to fish for sea cucumbers on wages.

Case study (New Caledonia)

Since 2002, fishing practices in New Caledonia have evolved to be dominated (in terms of total catch) by organised fishing businesses. They operate from large boats for week-long trips and use teams of divers to collect sea cucumbers. Offshore reefs, previously too remote to fish, are particularly targeted. Commonly, the boats return to harbour with many tonnes of salted sea cucumbers from 1 week of fishing. Some artisanal fishers have also been encouraged by processors to sell their catch to them as salted product, which eliminates the value-adding component of processing locally.

Finding the information

- Determine where sea cucumbers are being processed.
- Maintain a record of sea cucumber fishers so you know how many participate in the fishery.
- Contact agents or bulk processors and find out if freshly collected, salted or dried sea cucumbers are bought.
- Use questionnaires and interviews to determine what proportion of the income from bêche-de-mer goes to the fishers and how much goes to processors and exporters.

Transition from artisanal to industrial processing. Left: artisanal sea cucumber fishers with home-dried bêche-de-mer. Right: racks of bêche-de-mer being sun dried at a processing plant.

What do your answers from the six indicator questions tell you about the 'health' of your fishery?

INDICATORS		✓	✗
1	Presence of breeding groups		
2	Fishing gear used		
3	Sea cucumber abundance		
4	Ratio of species abundance		
5	Size of sea cucumbers		
6	Profit to fishers		

Mostly ticks – Stock status is good
No drastic action required.
Review and implement 'best practice' management advice (Section 3).

Mostly crosses – Stocks are severely depleted
Immediate and strong action required.
Implement advice from Section 4 to protect remaining breeding populations of sea cucumbers. Use Section 3 as a reference for general management.

Not sure?
Immediate action required.
Follow advice from Section 4. Assume stock is depleted until you are sure about the answers to the toolbox indicators.

‘Best practice’ management

The following management tools provide practical management options for maintaining sustainable harvests from a healthy fishery.

3.1 Communicate with all stakeholders

Good management of sea cucumber fisheries depends on cooperation of all stakeholders, including fishers, processors/buyers, exporters, conservation bodies, government bodies, surveillance staff and NGOs.

Managers should help communities understand how the ‘natural factory’ that produces sea cucumbers works (see life cycle figure in Section 1) and the effects of over-fishing. Communities can then see for themselves how the production cycle can be broken, and how to modify fishing to sustain their livelihoods.

Regular communication with fishing communities to reinforce these messages and discuss practical local management arrangements is essential.

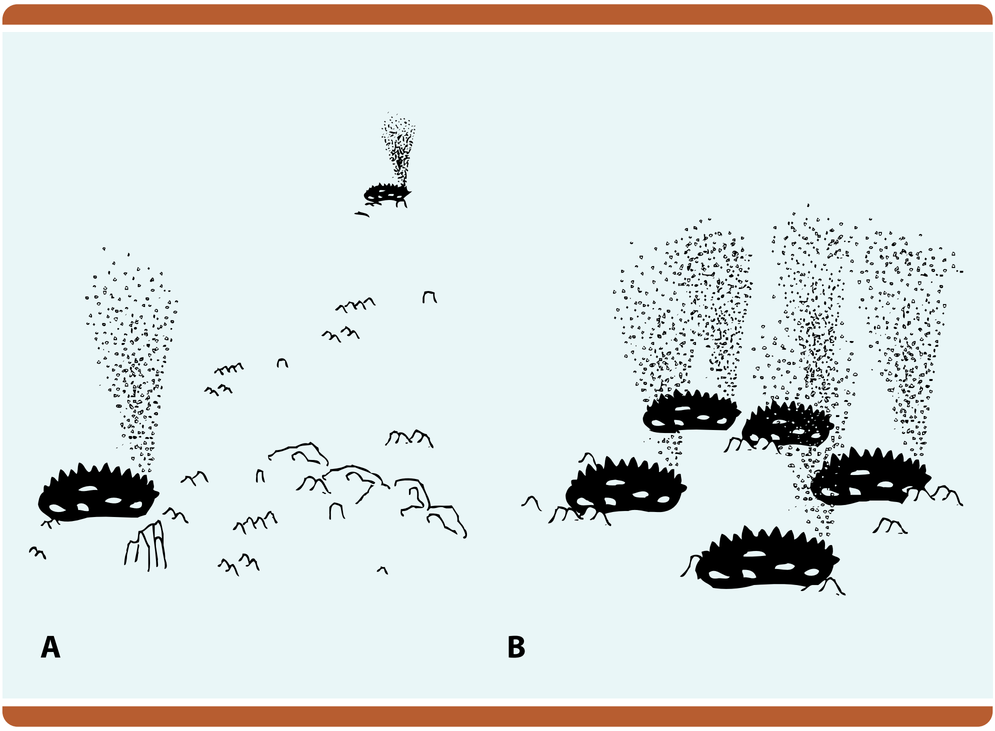
ACTION NEEDED

- **Identify all stakeholders** in local sea cucumber fisheries and establish relationships with their representatives.
- **Organise meetings with all stakeholders** to discuss how best to assess and manage their fishery.
- **Train fisheries staff, extension officers and NGOs** in how to help communities understand how the ‘natural factory’ produces sea cucumbers, and the effects of over-fishing.
- **Produce simple information resources** such as posters and booklets to help educate communities. (Useful extension materials are often available from SPC, SPREP and other regional organisations—see last page for contacts.)
- **Inform high-level decision-makers** as soon as concerns arise, and provide them with as many solutions as are possible.

3.2 Protect spawning adults

The 'natural factory' that produces sea cucumbers will break down if mature adults are too far apart to reproduce successfully. Over-harvesting to such levels will cause local fisheries to collapse.

The steps that managers and stakeholders can take to maintain sea cucumbers at the densities needed for successful reproduction are set out below.



Sea cucumbers are separate male and female individuals. If adults are too far apart (A), they cannot reproduce successfully. They need to be in close proximity for successful breeding (B).

ACTION NEEDED

- **Declare and enforce no-take zones** in areas where sea cucumbers are known to spawn to protect adequate numbers of adults. If permanent no-take zones are difficult to establish, use temporary or rotational fishing closures for periods of 5–10 years instead. The larvae produced in no-take zones will replenish nearby fishing grounds. Ask scientists to advise on the number and size of no-take zones needed (see last page for contact details).

- **Apply minimum size limits** to sea cucumbers outside no-take zones so that they can reproduce before they are harvested. Size limits also help fishers earn more for each sea cucumber they catch (see **Section 3.4**). Size limits should be applied to processed (dried) product at export gateways but fishers should also be provided with corresponding size limits for live animals so that they know which ones to collect. Ask scientists to recommend the appropriate live size (length or weight) limit for each species and then estimate the corresponding size limit for well-processed bêche-de-mer produced from each species.
- **Inspect all exports of bêche-de-mer** to check that they comply with size limits. Impose heavy penalties (including loss of export licence) on exporters who break the rules. Limit the number of enterprises licensed to export to make it easier to inspect all bêche-de-mer leaving the country.
- **Restrict fishing methods** for sea cucumbers. Ban the use of compressed air (scuba and hookah) and small dredge nets. Work with communities to limit, where necessary, night fishing with lights and the use of weighted spears ('bombs'), to protect vulnerable species. These restrictions will help maintain the natural 'refuges' of species created by their distribution and behaviour.

3.3 Promote high-quality processing

The Asian market for bêche-de-mer is very discerning and involves different grades and prices. The best prices are paid for 'A'-grade bêche-de-mer, which is well-processed and presented product of a large size. Fishers will maximise their earnings if they produce 'A'-grade bêche-de-mer because it fetches a higher price per kilogram.

On the other hand, fishers will receive only a fraction of the potential value of their resources if they catch small animals and/or process sea cucumbers poorly. In the worst case scenario, poor-quality bêche-de-mer will be rejected by buyers and the fisher will earn nothing.

ACTION NEEDED

- **Inform fishers about how the markets for sea cucumbers operate.**
- **Arrange training** for fishers in how to process sea cucumbers to produce 'A'-grade bêche-de-mer (see images below). Seek assistance for this training from SPC's Coastal Fisheries Programme and major processors—see last page for contacts.
- **Provide up-to-date price information for different grades of bêche-de-mer** to empower fishers to negotiate fair prices (contact SPC's Coastal Fisheries Programme for regional price lists).

The difference between well-processed (A) and poorly processed (B) bêche-de-mer has a marked effect on its value. Here are leopardfish (tigerfish) (A) and blackfish (B) either correctly (left examples) or poorly (right examples) processed. Photos: E. Aubry and R. Ram

3.4 Develop and implement management plans

The arrangements outlined in this section should be assembled by stakeholders into simple management plans that they all support. The management plans should be implemented at scales that are realistic both for the 'natural factory' that produces the target species of sea cucumbers and for existing systems of local governance.

In addition to identifying how best to appropriately implement the measures outlined in **Sections 3.2 and 3.3**, management plans should specify how to achieve the following outcomes.

Limit access to the fishery. Governments need to confer 'ownership' of resources on the people who harvest them. This will give fishers incentives to collect sea cucumbers in ways that maximise their financial benefits over the long term. Customary marine tenure (CMT) provides the framework for 'ownership' of coastal fisheries resources throughout much of the Pacific. Where CMT is breaking down, communities should be encouraged to strengthen these traditional systems. Where CMT does not operate, managers should develop other ways of dedicating access to coastal areas to local fishing communities.

Safeguard the interests of all fishers in the country. Sea cucumbers in one area may supply larvae to replenish stocks fished by distant communities, and vice versa. All fishers should agree to national regulations (e.g. size limits) designed to sustain sea cucumbers in all areas.

Monitor catches and stocks. Exporters should be required to provide information on the numbers and sizes (or weights) of each species of sea cucumber they buy from each of the main fishing areas. Underwater visual censuses and other indicators (**see Section 2**) should also be used to monitor the status of stocks.

Ensure compliance with size limits and requirements to supply information. This is the single most powerful tool for managing sea cucumber fisheries. Staff from national fisheries agencies must inspect every shipment of bêche-de-mer exported to ensure that it conforms to the size limits. They must also collect the information required from exporters on the number and size of each species. Compliance can be achieved by charging a substantial security deposit for an export licence and confiscating both the deposit and the licence if the rules are broken.

Develop triggers for management interventions. Agreement must be reached on threshold levels for all indicators of the status of a fishery, and the actions to be taken if indicators fall outside these levels. If and when a pre-agreed threshold level is reached, it should 'trigger' the appropriate management measure. An example of a threshold might be an agreed percentage decline in the average size/weight of an important species in catches from a designated fishing area. A local community example might be the time that fishers take to make reasonable catches. Once the pre-agreed size/weight decline is identified, or the agreed fishing time is exceeded, it is evident that depletion of the fishery is occurring. This should trigger appropriate remedial action, e.g. temporal and spatial closures, until stocks recover in the depleted areas.

Restoration of severely depleted stocks

The following management tools provide practical management options for restoring severely depleted fisheries.

4.1 Situations where some spawning of animals is still thought to be possible

ACTION NEEDED

- **Explain to communities the urgent need to stop all harvesting** of the target species.
- **Impose a moratorium (ban) on exports of over-fished species**, either for the whole country or for just the over-fished areas, provided there will be compliance with local bans. The moratorium should last until the stocks have increased to the level required to reopen the fishery.
- **Conduct regular surveys to determine when target species are restored** to levels where they can be harvested again. Use underwater surveys and interviews with fishers to do this. Seek assistance from scientists to interpret the information.
- **Before reopening the fishery**, ensure that all relevant components of 'best practice' management (**Section 3**) have been put in place. Otherwise, over-fishing will reoccur.

4.2 Situations where densities are too low for any effective spawning, or where no recovery occurs following an extended moratorium

In such situations the measures described in **Section 3** and **Section 4.1** will not help restore production because the sea cucumbers will still be too sparse for mates to find each other and reproduce. Managers and stakeholders must either accept that the fishery has been lost (probably for several decades) or take more active steps to rebuild it.

ACTION NEEDED TO REBUILD A FISHERY

- **Place some of the remaining sea cucumbers from each species group close together in no-take zones** to form spawning aggregations. Each aggregation should have 20–50 individuals placed 2–5 m apart. This technique is still unproven but is expected to be successful in rebuilding stocks for species usually found at high density (e.g. sandfish, surf redfish). These aggregations should only be made in areas where fishers used to catch these species, to ensure the animals have suitable conditions for growth and reproduction.
- **Consider using restocking methods** to form spawning aggregations in no-take zones if the target species is so rare that only a few specimens can be found. Seek advice from scientists to: 1) decide whether it is responsible to collect adults from a stock at another location and translocate them to your area to rebuild a breeding group, and 2) assess the feasibility and cost of hatchery-based restocking activities to re-create spawning populations at a number of locations. (Note that hatchery technology currently exists for only a couple of species, is expensive and has a variable rate of success when juveniles are placed in the wild.)

Reference information

Key contacts for management and scientific advice

Secretariat of the Pacific Community (SPC), Coastal Section, Reef Fisheries Observatory;
email: reeffishobs@spc.int

The WorldFish Center - PO Box 438, Honiara, Solomon Islands;
email: worldfish-solomon@cgiar.org

Other information

Agudo N. 2007. Sandfish hatchery techniques. Australian Centre for International Agricultural Research (ACIAR), the Secretariat of the Pacific Community (SPC) and the WorldFish Center: Noumea, New Caledonia.

Battaglene S.C. 1999. Culture of tropical sea cucumbers for stock restoration and enhancement. NAGA 22(4), 4–11.

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Kinch J., Purcell S., Uthicke S. and Friedman K. 2008. Population status, fisheries and trade of sea cucumbers in the Western Central Pacific. Pp. 7-55 in 'Sea cucumbers: a global review of fisheries and trade', ed. by V. Toral-Granda, A. Lovatelli and M. Vasconcellos. FAO Fisheries Technical Paper No. 516.

Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.-F. and Mercier A. 2004. Advances in sea cucumber aquaculture and management. FAO Fisheries Technical Paper No. 463. Food and Agriculture Organization of the United Nations: Rome', p. 426. At: <ftp://ftp.fao.org/docrep/fao/007/y5501e/y5501e00.pdf>.

Preston G. 1993. Chapter 11: Bêche-de-mer. Pp. 371–407 in 'Inshore marine resources of the South Pacific: information for fishery development and management', ed. by A. Wright and L. Hill. FFA/USP Press: Fiji.

Purcell S., Tardy E., Desurmont A. and Friedman K. in press. Commercial holothurians of the tropical Pacific (Poster). WorldFish Center and Secretariat of the Pacific Community: Noumea, New Caledonia.

SPC. Sea cucumber booklet is accessible at: <www.spc.int/coastfish/Fishing/BDM_HdBook18/HdBook18E.htm>.

SPC. Sea cucumber identification guides (cards) are accessible at: <www.spc.int/coastfish/Fishing/BDM-ID/BDM-IDcards.htm>.

Websites

PROCFish_COFish projects
www.spc.int/donors/procfish/proc_coastal.html

Reef Fisheries Observatory of SPC's Coastal Fisheries Programme
www.spc.int/coastfish/Sections/reef/index.htm

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ACIAR Monograph No. 135

3.3 Suggested minimum live lengths and maximum 'piece' rate for dry product for export of 'Premium' species groups

Species group	Scientific name/s	Min live length (cm)	Wet weight of required product (g)	Recovery rate wet/live to dry (%)	Dry weight of bêche-de-mer (g)	Max dry pieces per kilo rate
Black teatfish (BTF)	*Holothuria whitmaei*	30	2400	7.0	168.0	6
White teatfish (WTF)	*Holothuria fuscogilva*	38	2500	8.0	200.0	5
Prickly redfish (PRF)	*Thelonota ananas*	55	3500	5.0	175.0	6
Sandfish (SandF)	*Holothuria scabra*	22	750	5.0	37.5	28
Golden Sandfish (GSandF)	*Holothuria lessoni*	30	1400	5.0	70.0	15
Surf redfish (SRF)	*Actinopyga varians*	20	850	5.5	46.75	22
Stonefish (StoneF)	*Actinopyga lecanora*	18	650	5.5	35.75	30
Blackfish (BF) *	*Actinopyga miliaris* and *Actinopyga. spinea**	n/a	500	5.5	27.5	37
Large blackfish (BF) *	*Actinopyga palauensis**	n/a	1500	5.5	82.5	12
Deepwater redfish (DRF)	*Actinopyga echinites*	20	400	5.5	22.0	45
Leopardfish or tiger (TF)	*Bohadschia argus*	35	1000	4.0	40.0	27
Curryfish (CF)	*Stichopus herrmanni*	38	2100	4.0	84.0	14
Amberfish (AF)	*Thelonota anax*	55	3500	5.5	192.5	5
Greenfish (GF)	*Stichopus chloronotus*	22	300	3.0	9.0	115
Elephant trunkfish (ETF)	Holothuria fuscopunctata	45	2000	10.0	200.0	5
Brown sandfish (BSF)	*Bohadschia vitiensis*	30	1000	4.0	40.0	26
Lollyfish (LF)	*Holothuria atra*	20	These species are small and numerous and are typically not sold at a 'piece per kilo' rate (too numerous to count); however, size and quality of processing will result in different price grades in the bêche-de-mer market.			
Pinkfish (PF)	*Holothuria edulis*	20				
Snakefish (SnakeF)	*Holothuria coluber*	n/a				
Flowerfish (FF)	*Pearsonothuria graeffei*	35				
Chalkfish (CF)	*Bohadschia similis*	18				
Peanutfish (PF)	*Stichopus horrens* group	13				

* The blackfish group contains both smaller species that are often found aggregated in large numbers (e.g. *A. miliaris* and *A. spinea*) and larger solitary species (e.g. *A. palauensis*); n/a: no information available.

3.4 Management advice to countries/territories

Various advice and information were delivered upon request of countries/territories to assist with information needed for management decision-making by national fisheries authorities. These include preliminary results of certain resource surveys based on the main PROCFish/C and CoFish surveys, extra site assessment surveys, and other relevant information. Actions are being taken based on the advice provided, such as development measures for the management of invertebrate fisheries. These activities are detailed below:

Country/Territory	Requested assistance	Objective	Status
Cook Islands	• Preliminary trochus resource status for Aitutaki • Invertebrate resources assessment at Mangaia port area	• Trochus resource management and impact assessment of Aitutaki MPA • Baseline information for port development at Mangaia Island	• Advisory reports have been provided to Cook Islands Ministry of Fisheries in 2007 • *Report provided to: Mr Ian Bartram*
French Polynesia	• Review of existing trochus harvest management policies and regulations	• Independent view of existing management measures and their effectiveness for the certification of trochus shell products during the 2008 open season	• Review comments provided which assisted FP to secure deal with European shell buyer • *Report provided to: Mr Arsene Stein*
Niue	• Review report on coconut crab and provide management advice as requested	• Develop measures for the management and conservation of coconut crab resource	• Report completed in 2007 and sent to Niue Fisheries • *Report provided to: Ms Vanessah Marsh*
Marshall Islands	• Baseline assessment of the invertebrate resources near the Majuro Pearl Oyster farm • Invertebrate resource status in Ailuk MPA	• Environmental impact assessment for pearl oyster farming in Majuro Atoll • MPA impact assessment	• Advisory reports provided to Marshall Islands Ministry of Fisheries in 2007 • *Report provided to: Mr Glen Joseph*
Palau	• Monitoring assessment of MPA areas at Narchelong and Ngatpang • Conduct sea cucumber management workshop • Status report for the subsistence sea cucumber fishery in Palau	• MPA impact assessment • Develop national sea cucumber fishery management plan • Assess the status of sea cucumber resources used in the subsistence fishery in Palau	• Sea cucumber management plan completed and sent to Palau in November 2008. • Subsistence sea cucumber fishery status report completed and sent to Palau 2009 (Pakoa *et al.* 2009)
FSM	• Trochus resources surveys at Pohnpei and Kosrae • Conduct sea cucumber management workshop • Develop sea cucumber management regulations for Yap • Sea cucumber resource survey for Yap	• Trochus resource status information and recommendations for management • Develop sea cucumber management plan and regulations for Yap	• Surveys and reporting completed • (Tardy *et al.* 2009a, Tardy *et al.* 2009b) and sent to Pohnpei and Kosrae in December 2008, Actions are being taken to develop a trochus harvest plan and COT cleanup based on recommendations • Sea cucumber management plan and regulations completed, new regulations have been instituted in Yap (Tardy and Pakoa 2009)
Tonga	• Sea cucumber resource surveys at Ha'apai • Trochus resource surveys at Tongatapu	• Provide sea cucumber advisory report • Baseline assessment of newly introduced trochus resource and impact assessment of juvenile seeding activities	• Currently developing measures for 2008–2009 sea cucumber open season • Trochus report completed and management advice provided

Country/Territory	Requested assistance	Objective	Status
New Caledonia	• Invertebrate resources assessment at Kone and Voh • Trochus survey at Phare Amédée	• Baseline assessment for the Koniabo nickel-mining development • Assess trochus stocks	• Completed in 2006
Fiji Islands	• Resources surveys inside the existing village MPAs	• MPA impact assessment	• Results of MPA surveys presented for 2 sites in the Fiji Islands PROCFish country report.
Vanuatu	• Sea cucumber resources status trends at Moso, Paunagisu, Uri-Uripiv, advisory report • Trochus and sea cucumber resources management at Epi Island	• Management decision making • Baseline resource information and recommendations for management	• Ban on sea cucumber fishery instituted in 2008 and sea cucumber fishery management plan being developed • Trochus resource reporting completed in Dec 2008, trochus management plan being developed
Other productions	Collaborate to develop invertebrate posters Policy brief at Forum Meeting in 2008	Education and awareness Highlight the plight of invertebrate fisheries and need for management	Invertebrate poster in 2007 Sea cucumber poster in 2008
Provision of survey equipment	Writing slates Pohnpei - 2, Kosrae - 2, Vanuatu -2 Fiji Islands – 2		

APPENDIX 4: SOCIOECONOMIC ASSESSMENT DATA AND ANALYSIS METHODS

4.1 Key socioeconomic and fishery parameters for each of the 63 survey sites

4.1.1 Discussion of socioeconomic and fishery parameters

As widely acknowledged, the per capita consumption of marine products is in the Pacific region among the highest in the world, as confirmed by our survey data. On average, the per capita consumption of fresh finfish amounts to 67.8 kg/year (±4.4) (Figure A4.1.1), invertebrate consumption (edible meat only) to 7.5 kg/year (±0.8) (Figure A4.1.2), and the canned fish per capita consumption adds another 8.9 kg/year (±1.1) (Figure A4.1.3). It should be noted that the per capita invertebrate consumption may be underestimated as some of the catch is opportunistically consumed on-site rather than brought home and accounted for as a formal meal.

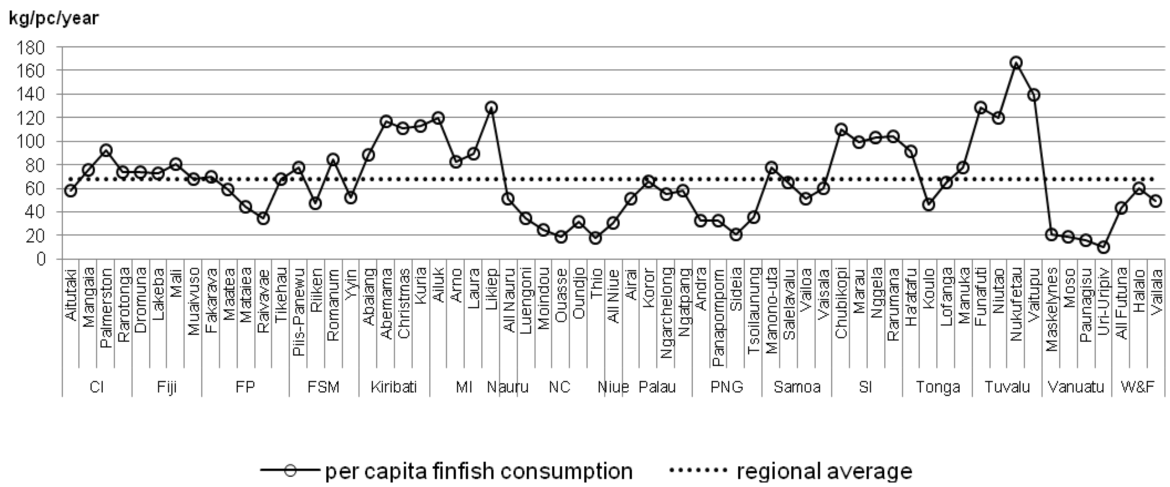


Figure A4.1.1: Fresh finfish per capita consumption (kg/year) across all 63 communities surveyed, and as compared to the regional average.

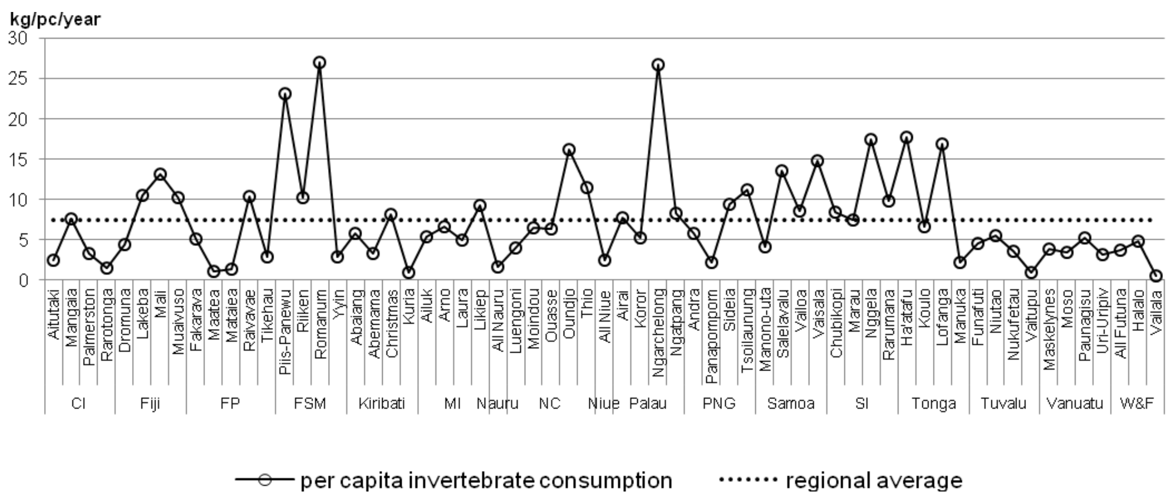


Figure A4.1.2: Invertebrate (edible meat only) per capita consumption (kg/year) across all 63 communities surveyed, and as compared to the regional average.

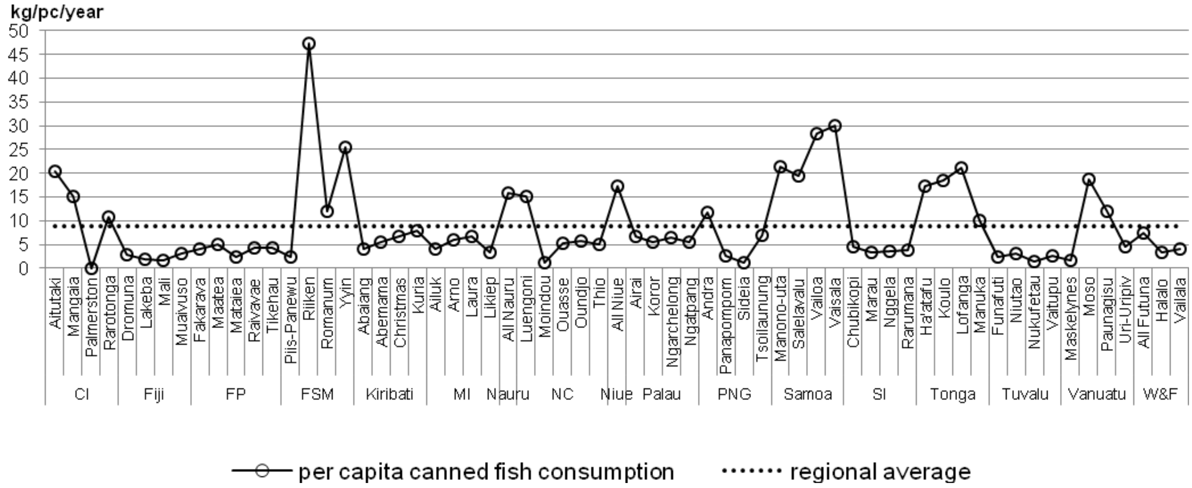


Figure A4.1.3: Canned fish per capita consumption (kg/year) across all 63 communities surveyed, and as compared to the regional average.

The high degree to which people in coastal rural communities of PICTs are self-sufficient in the provision of finfish and invertebrates consumed, and thus substantially cover their main protein and calorific demand, is made visible in Figures A4.1.4 and A4.1.5 showing the proportion of finfish and invertebrates consumed that is either caught by a household member, received on a non-monetary basis or bought. Percentages of finfish and invertebrates that are bought are rarely as important as those of invertebrates sourced from subsistence fisheries.

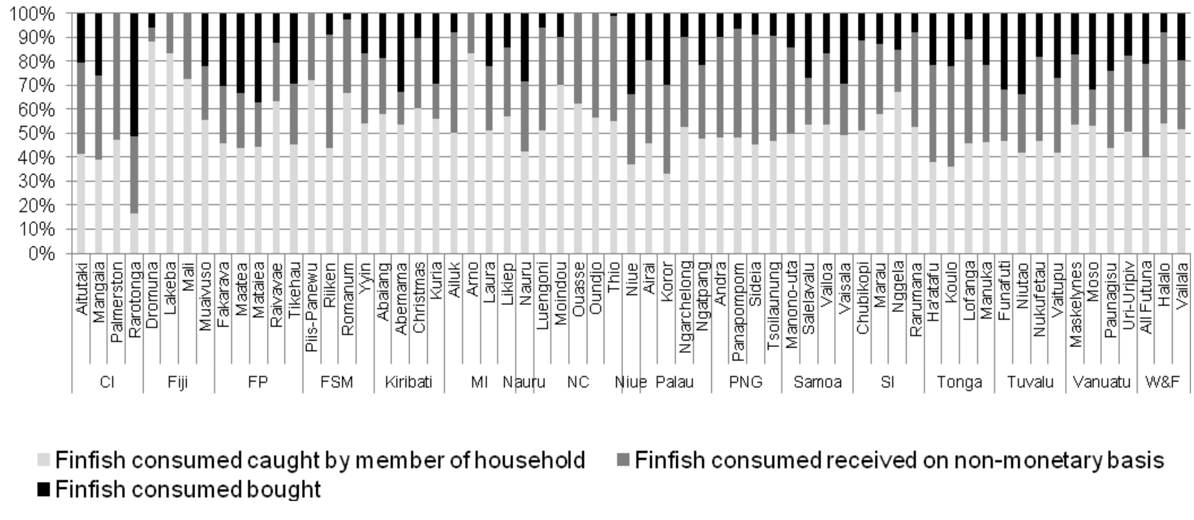


Figure A4.1.4: Proportion of finfish consumed in households of each community that has been caught by a household member, received on a non-monetary basis or bought.

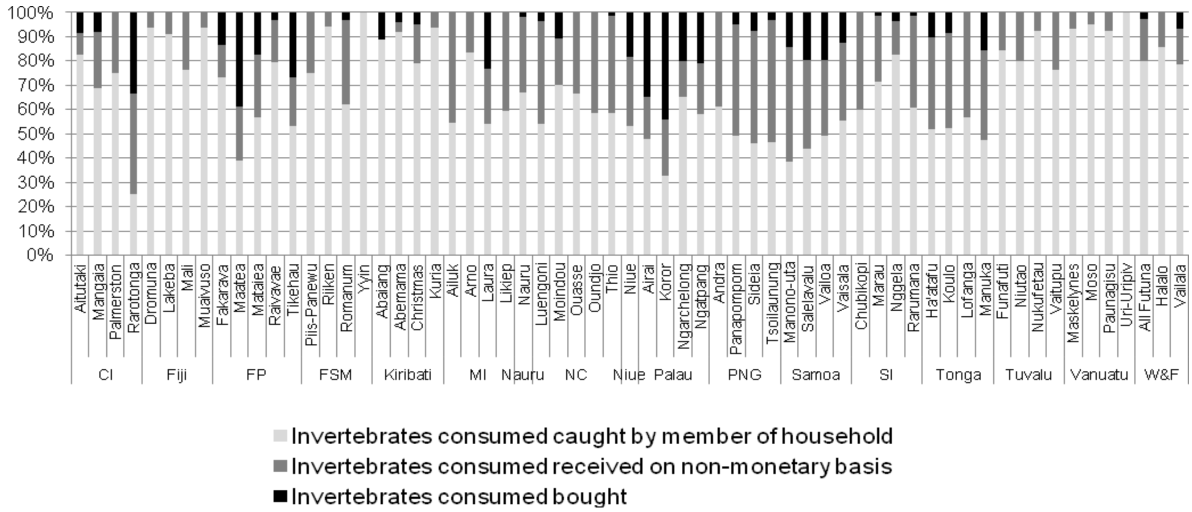


Figure A4.1.5: Proportion of invertebrates consumed in households of each community that has been caught by a household member, received on a non-monetary basis or bought.

Dependency on marine resources

Income dependency on marine resources is a question of traditions and alternatives, particularly given the increasing demand for cash income due to improvements in lifestyle, infrastructure development, dependency on imported goods, and fuel prices. Figures A4.1.6 to A4.1.9 demonstrate the percentage of households in each community surveyed that depend on fisheries or salaries, for primary or secondary income. On average, about half of all households surveyed depend on fisheries for income, with an average of 29.5% (±3.3) as primary income, and 20.2% (±1.8) as secondary income. On average, 39% of all households depend on salaries, with 32.5% (±3.1) as primary income, and 6.5% (±0.8) as secondary income.

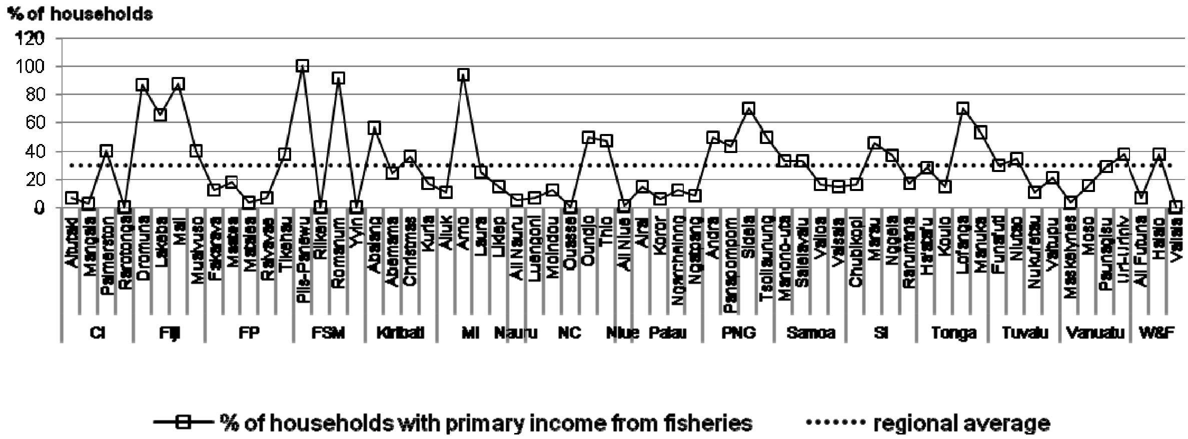


Figure A4.1.6: Proportion of households earning primary income from fisheries across 63 communities surveyed, and compared to the regional average.

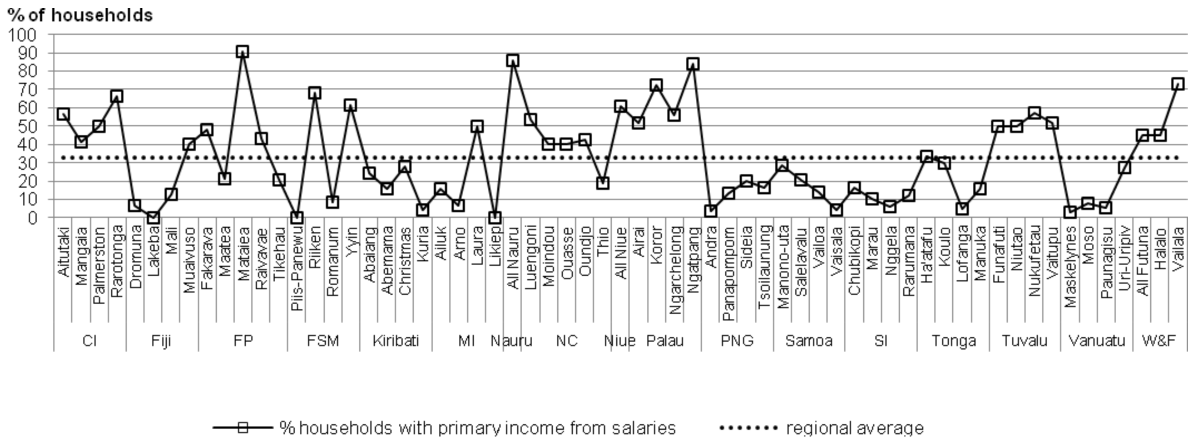


Figure A4.1.7: Proportion of households earning primary income from salaries across 63 communities surveyed, and compared to the regional average.

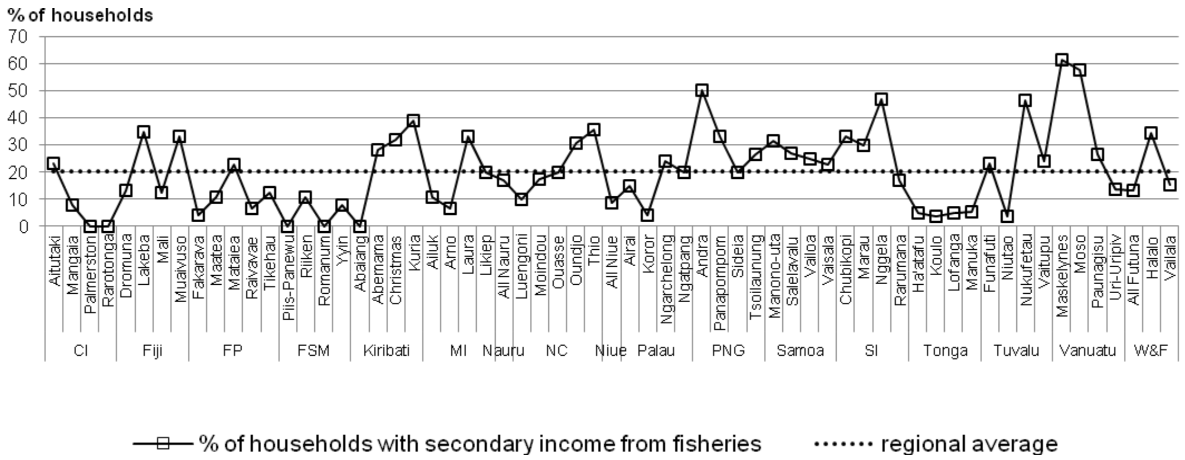


Figure A4.1.8: Proportion of households earning secondary income from fisheries across 63 communities surveyed, and compared to the regional average.

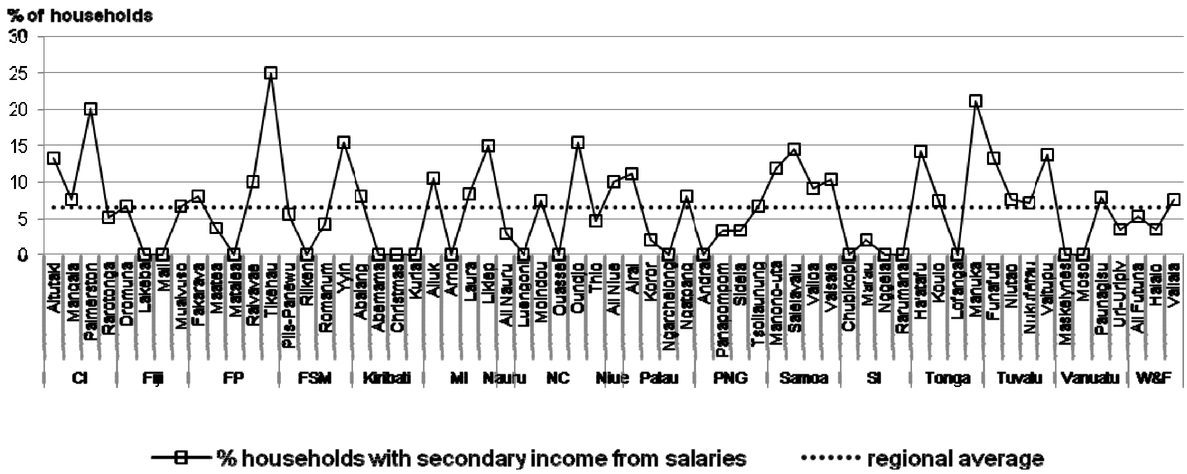
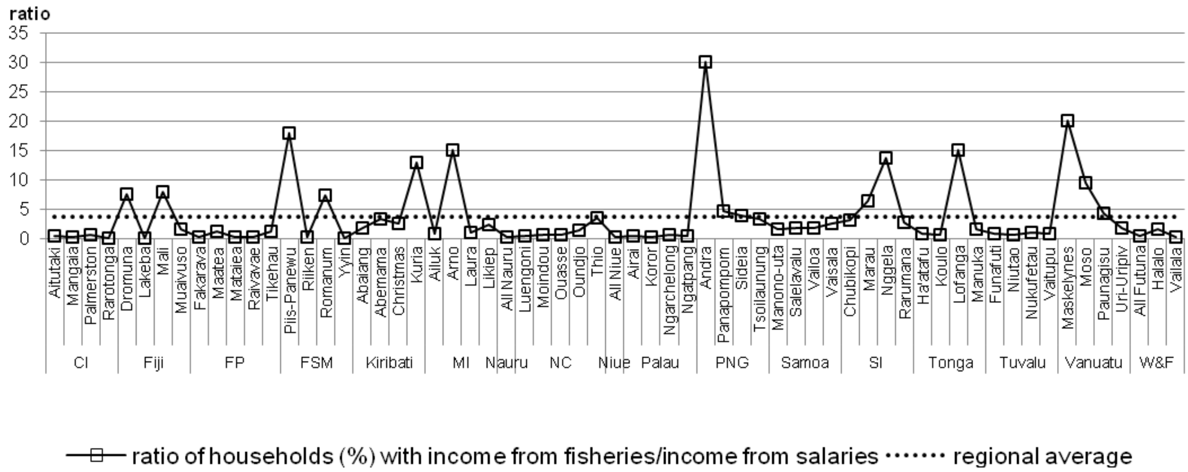


Figure A4.1.9: Proportion of households earning secondary income from salaries across 63 communities surveyed, and compared to the regional average.

To illuminate the importance of fisheries, the ratio between the proportion of households in each community that is dependent on fisheries and on salaries for primary and secondary income is shown in Figure A4.1.10. For ratios above 1, fisheries are more important, for ratios below 1, salaries are more important. In total, 34 communities (54%) show a higher or exclusive (Lakeba, Fiji Islands) dependence on fisheries.



Note: Rarotonga, Cook Islands has no income from fisheries; Lakeba, Fiji Islands has no income from salaries.

Figure A4.1.10: Ratio between the proportion of households in each community surveyed that depend on fisheries (primary and secondary) and those that depend on salaries (primary and secondary) for income.

Diversification of household income may be considered as an adaptive risk strategy. Survey data revealed that at the regional average, most households, 44.9% (±1.7), depend at least on two income sources; however, a considerable share 36.6% (±2.4) on only one income, and much less, i.e. 18.4% (±1.9) on three or more income sources. The individual characteristics of each community surveyed are shown in Figures A4.1.11 to A4.1.13.

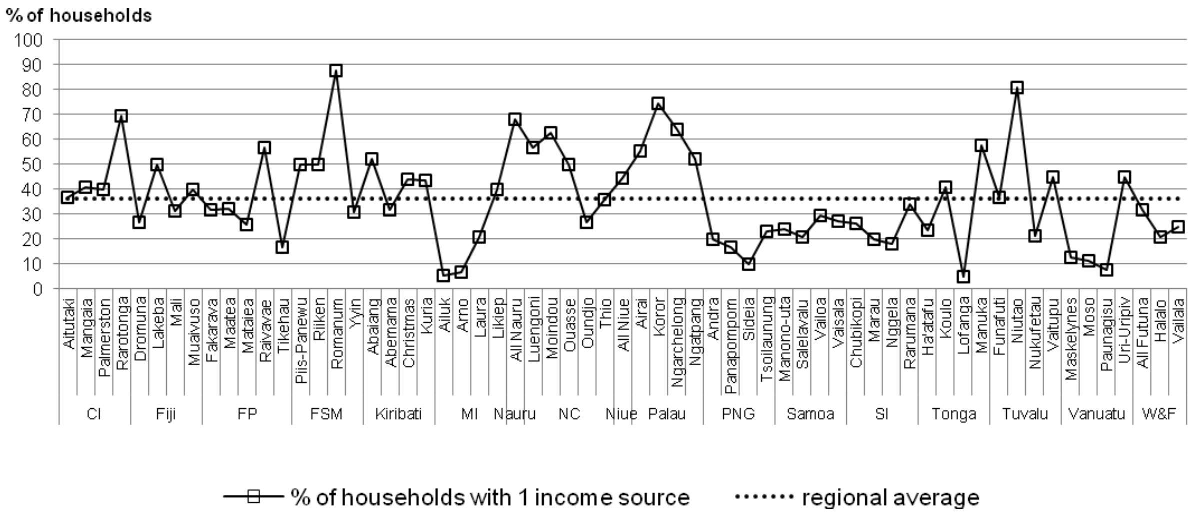


Figure A4.1.11: Proportion of households in each community that depend on one income source only, and the regional average.

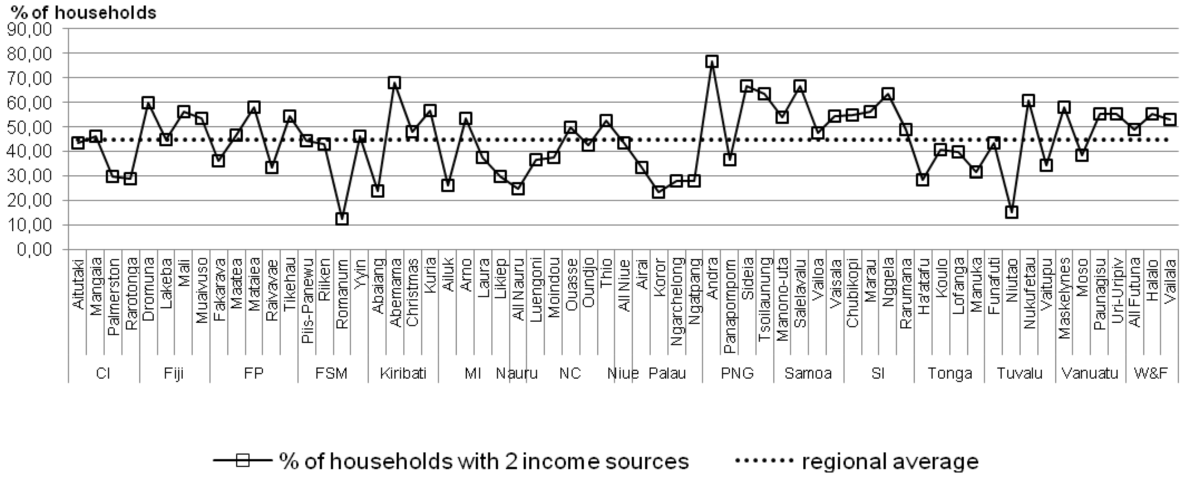


Figure A4.1.12: Proportion of households in each community that depend on two income sources, and the regional average.

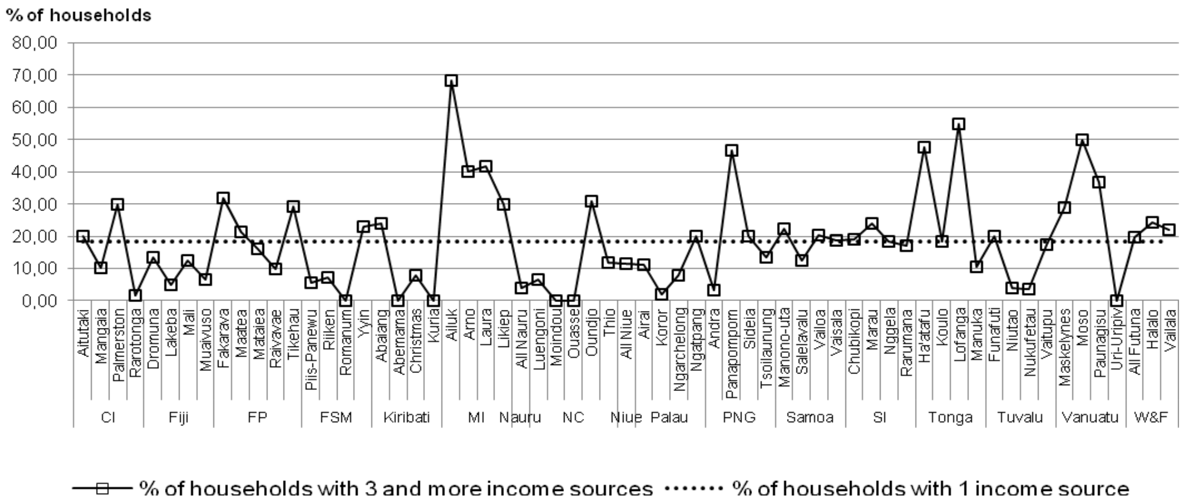


Figure A4.1.13: Proportion of households in each community that depend on three or more one income sources, and the regional average.

Access to alternative income sources may not only require land resources, as in the case of agriculture, but also special skills. Education is acknowledged as a major indicator for development.

Agricultural potential was assessed in terms of the importance of income generated from agricultural activities that are mainly crop-production systems, including copra. Access to agricultural land for subsistence needs (gardens, small plots), and small livestock potential (in terms of pigs and chickens owned by each household) were used as complementary information. Figure A4.1.14 shows that, on average, 15.3% (±2.5) households generate primary income from agriculture, while another 17.8% (±0.9) of all households receive secondary income from this sector. By comparison, *handicrafts and small business*, such as shops, local transport, bars, etc., play an important role for 23.9% (±2.2) and 18.0% (±1.7) of all households surveyed, by providing primary and secondary income respectively (Figure A4.1.15).

On average, more than half of all households have pigs (55.1% ±4.0) (Figure A4.1.16), and a lower proportion of 43.5% (±4.0) have chickens (Figure A4.1.17) to complement protein supply for the family or, in the case of pigs, to contribute to feasts and special celebrations, as well as for income purposes.

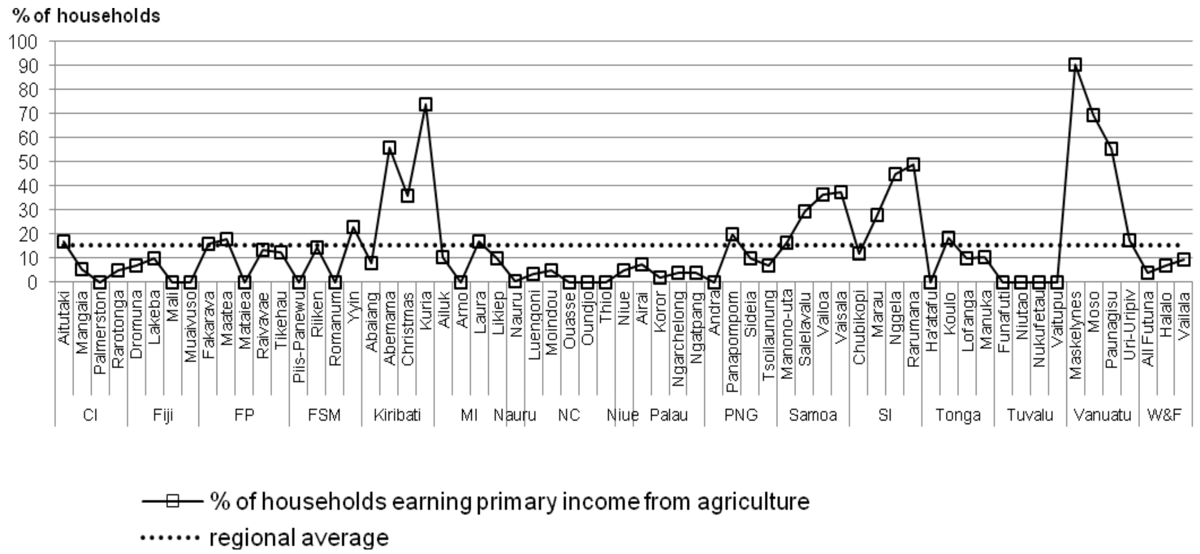


Figure A4.1.14: Proportion of households in each community earning primary income from agriculture, and the regional average.

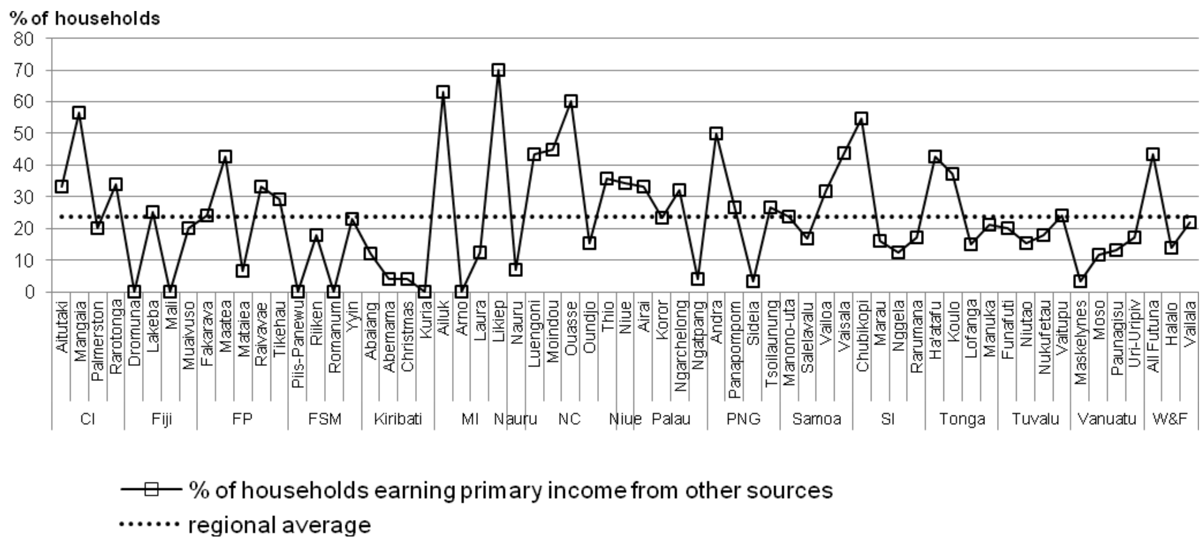


Figure A4.1.15: Proportion of households in each community earning primary income from other sources (handicrafts, small, private businesses), and the regional average.

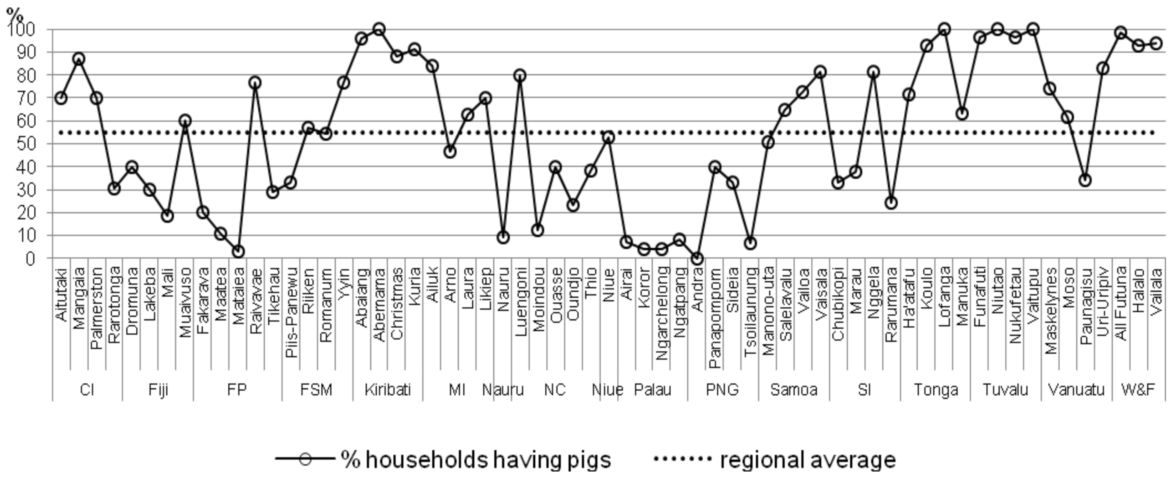


Figure A4.1.16: Proportion of households in each community surveyed having pigs, and the regional average.

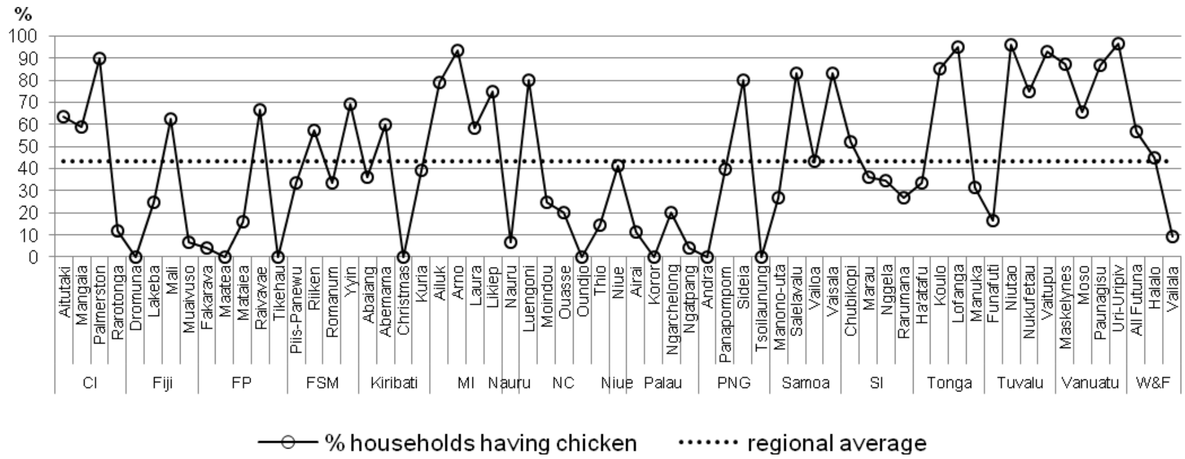


Figure A4.1.17: Proportion of households in each community surveyed having chickens, and the regional average.

Overall, the educational level in rural coastal communities is relatively low. This argument is supported by the regional average of adult education levels that have a high proportion of primary (48.3% ±3.1) and secondary (42.3% ±2.6), rather than tertiary education (9.4% ±1.2).

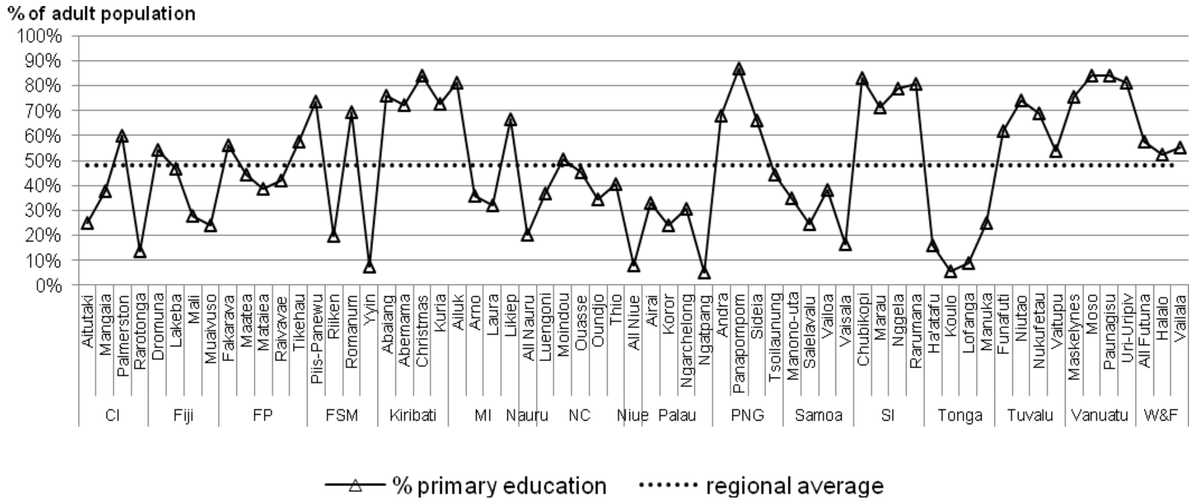


Figure A4.1.18: Proportion of adults in each community having acquired primary education level only, and the regional average.

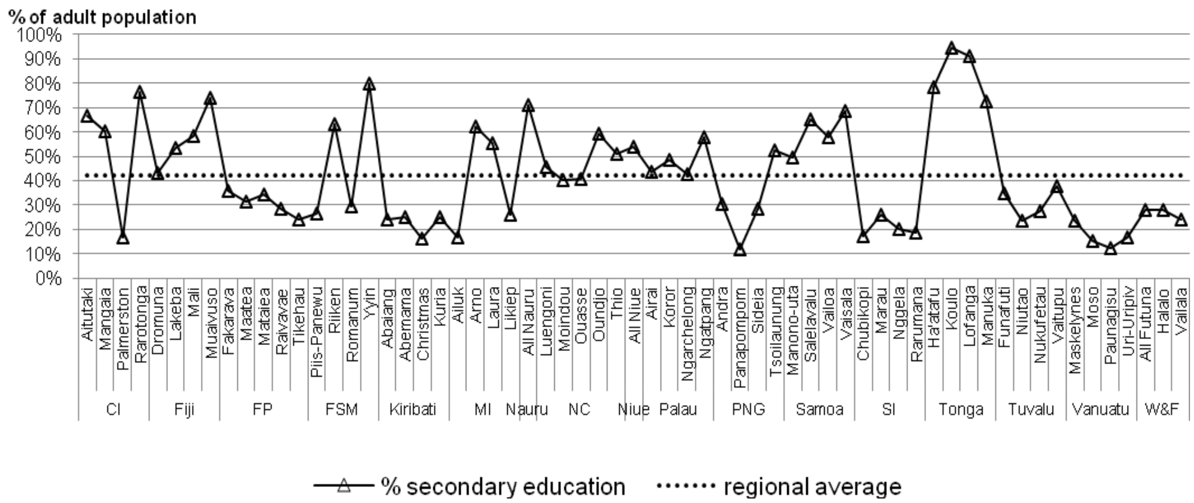


Figure A4.1.19: Proportion of adults in each community having acquired secondary education level only, and the regional average.

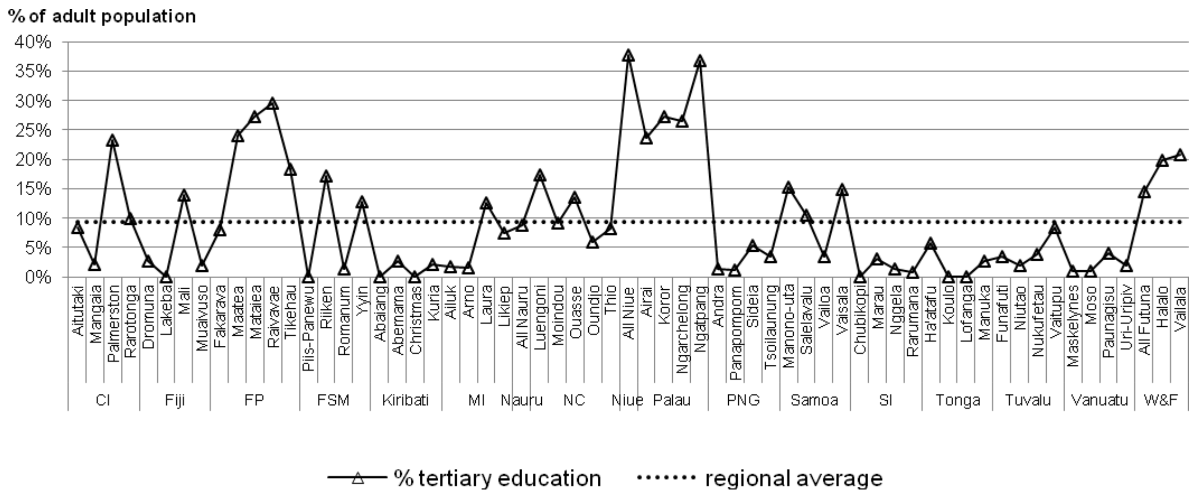


Figure A4.1.20: Proportion of adults in each community having acquired tertiary education level, and the regional average.

Given the overall high but also very variable dependency on fisheries for subsistence and income, complemented by agricultural crop and small livestock production, and salaries, the *average household expenditure level* is considered as a means to assess the comparative lifestyle, the contribution of the household's subsistence production, and the availability of cash income. Figure A4.1.21 shows the average household expenditure level converted in USD/year to make it possible to compare each community to the regional average, amounting to USD 3925 /household (HH)/year (±438.2). While differences among sites within the same country are usually negligible, important differences exist among countries.

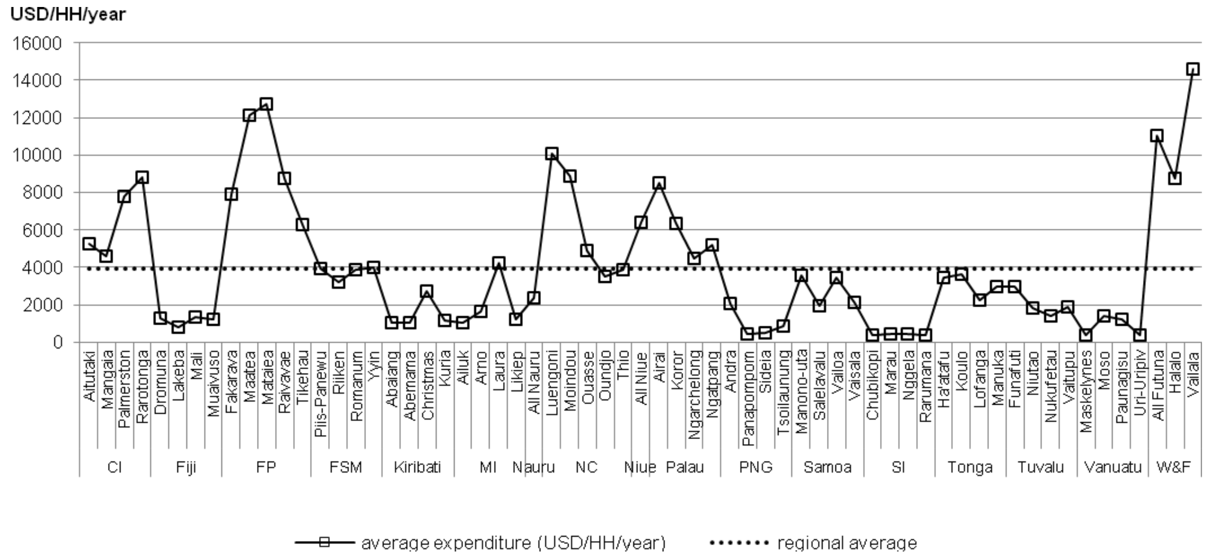


Figure A4.1.21: Average annual household expenditure (USD) per each community surveyed, and the regional average.
HH = household.

Migration to urban centres or overseas to seek cash income opportunities is a well known phenomenon in PICTs, and is particularly common in remote and rural communities where cash opportunities from the traditional fishery and/or agricultural sectors are limited due to market access, resource or production limitations and lack of alternative income opportunities. The importance of *remittances* in the rural coastal context of PICTs is highlighted in Figures A4.1.22 and A4.1.23, showing the percentage of households (30.7% on average ±3.5) that receive remittances, and the average amount of remittances received by these (USD 1081 /HH/year on average, ±118.5). The fact that, on average, the remittances received may cover about 43.4% (±5.6) of the average household expenditures, further highlights the importance of remittances in the region (Figure A4.1.24).

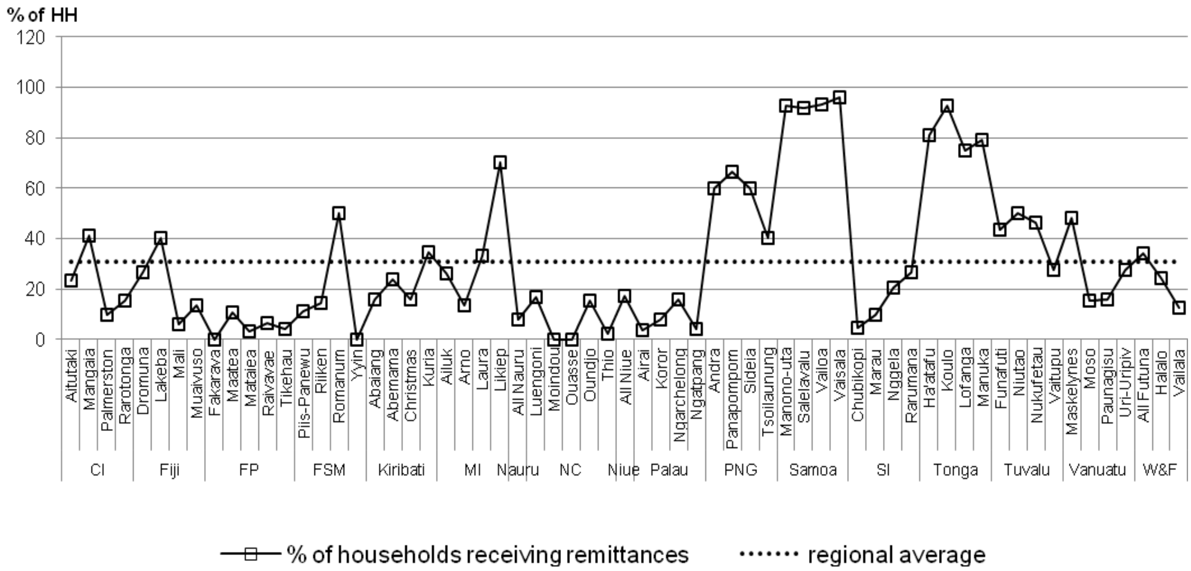


Figure A4.1.22: Proportion of households in each community surveyed that receive remittances, and the regional average.
HH = household.

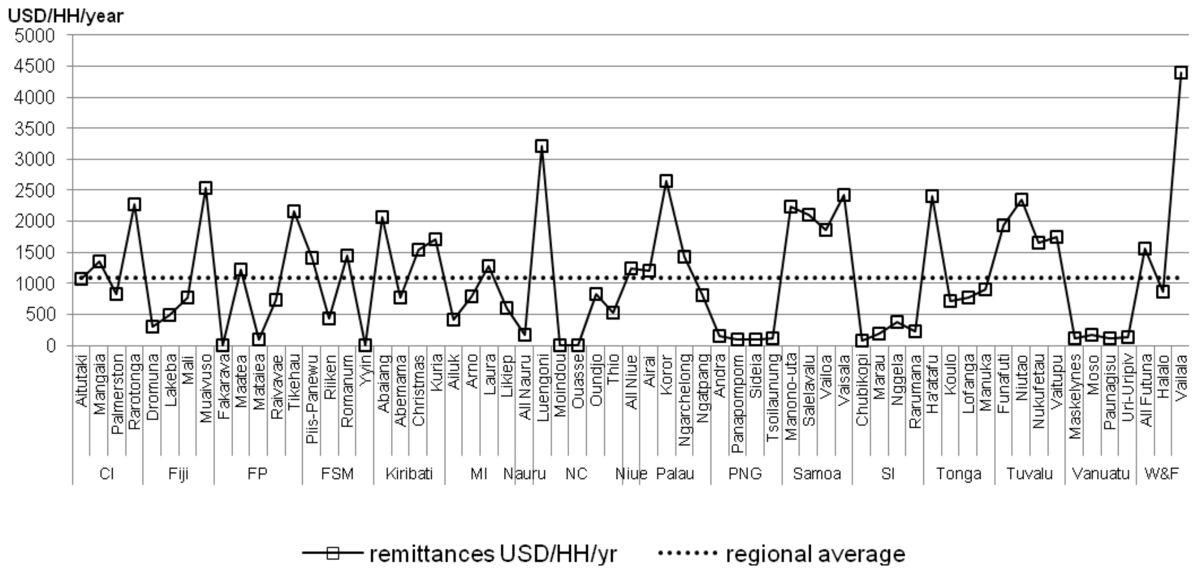


Figure A4.1.23: Average annual amount of remittances received by households benefiting from such transfer at the individual community level, and the regional average.
HH = household.

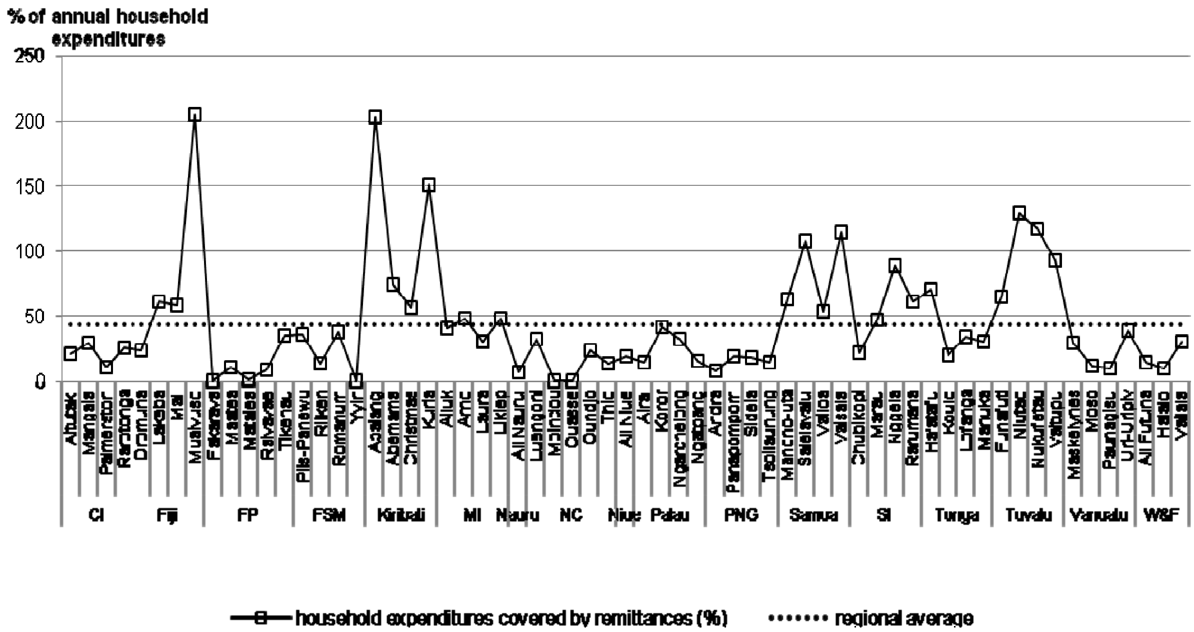


Figure A4.1.24: Proportion of average annual household expenditures covered by annual amount of remittances received by households for each community surveyed, and the regional average.

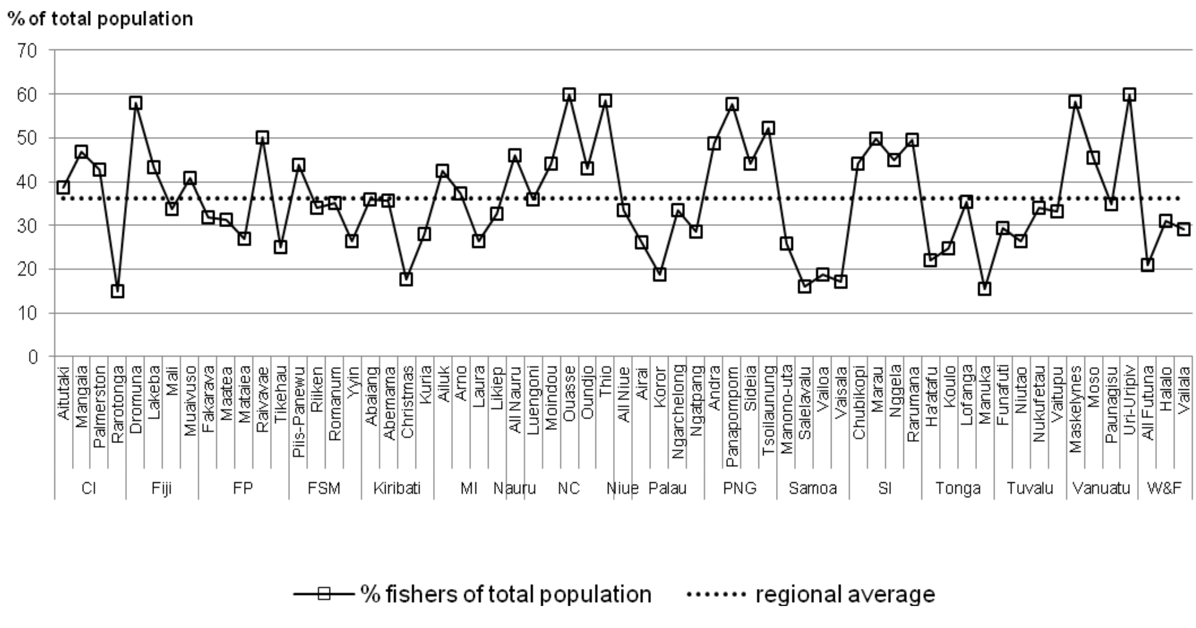
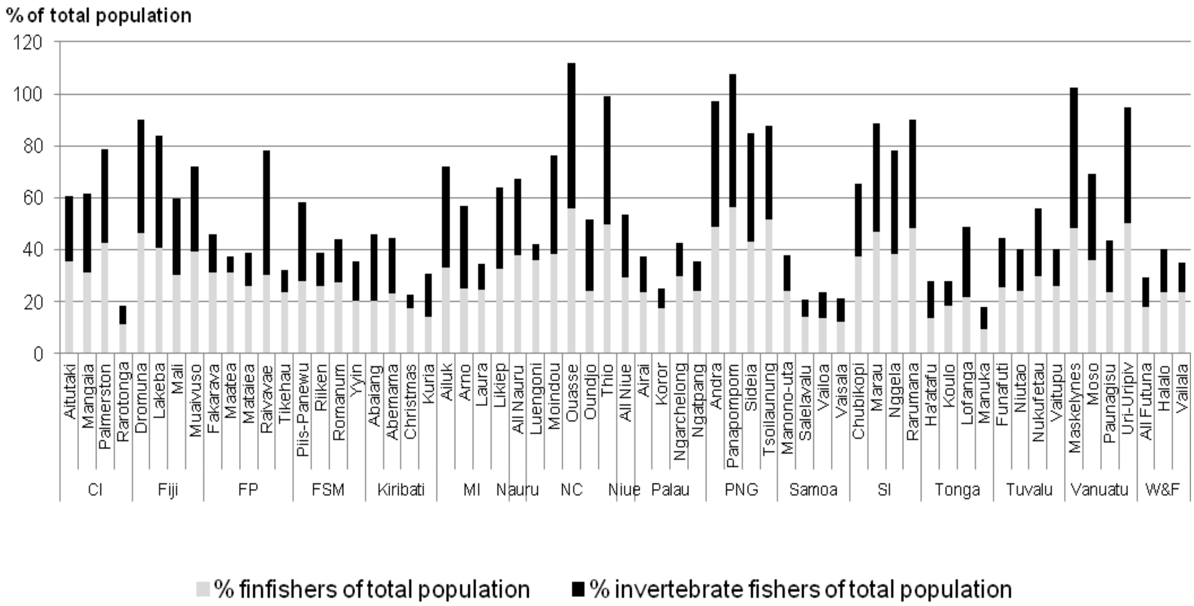


Figure A4.1.25: Proportion of fishers (male and female, finfish and invertebrate fishers) in the population of communities surveyed, and the regional average.

The communities selected for the survey fulfilled – *inter alia* – the criterion of having a high dependency on the traditional, small-scale and artisanal fishery sector for subsistence and/or for income purposes. This selection criterion is visible in Figure A4.1.25, showing a regional average of 36.1% (±1.5) *fishers per community*. The proportion of total *finfish and invertebrate fishers* is shown in Figure A4.1.26, with a regional average of 30% (±1.5) and 25% (±1.8) of total population respectively.



Note: percentages of finfish and invertebrate fishers may exceed 100% as some people do both finfish and invertebrate fishing and, therefore, have been counted twice.

Figure A4.1.26: Proportion of finfish fishers (males and females) and invertebrate fishers (males and females) in the population of communities surveyed.

The accessibility and choice of habitats, as well as access to markets are determined by the availability of *boat transport*, notably motorised boat transport. On average for the region, households own 0.7 boats (±0.06) (Figure A4.1.27) and 57% (±4.5) of all boats are motorised (Figure A4.1.28).

There are *three main habitats* targeted and usually distinguished by small-scale subsistence and artisanal fishers, (1) the sheltered coastal reef (the most accessible and, which also includes mangroves, and intertidal flats where applicable), (2) the lagoon with coral reef heads, soft bottom and including the back-reef area, and (3) the outer reef, which includes passages. Often, fishing trips combine several of these habitats if available, and in an opportunistic way, depending on tidal, weather and sea conditions, and previous success at selected fishing spots. The outer reef and passage habitats are usually the furthest away, requiring more time and fuel, and their access may be restricted mainly due to weather and sea conditions given the predominantly small open boats and small outboard engines fitted (25–40 HP). Out of all the communities surveyed, 11 do not have sheltered coastal reef habitats (17.5% of all sites), and four lack lagoon areas (6% of all sites). Outer-reef habitat is available to all communities surveyed. The proportion of the available habitat, i.e. the total fishing ground of each community, is shown in Figure A4.1.29. At the regional scale, the average fishing ground area is ~134 km^2 (±20.3) (Figure A4.1.30), and the available total reef area ~51 km^2 (±6.4) (Figure A4.1.31).

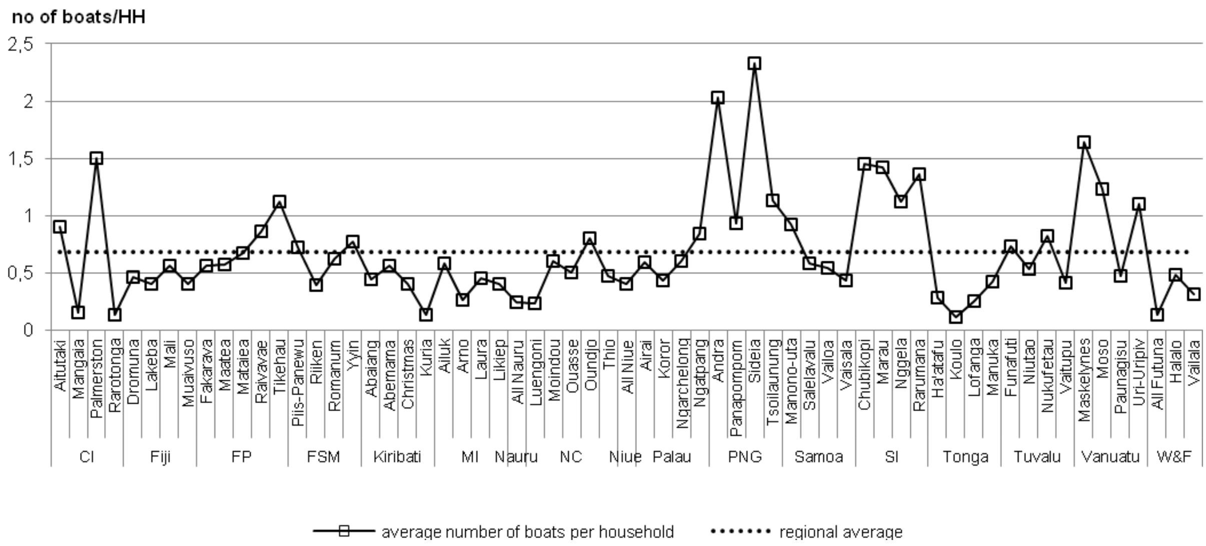


Figure A4.1.27: Average number of boats per household in each community surveyed, and the regional average.
HH = household.

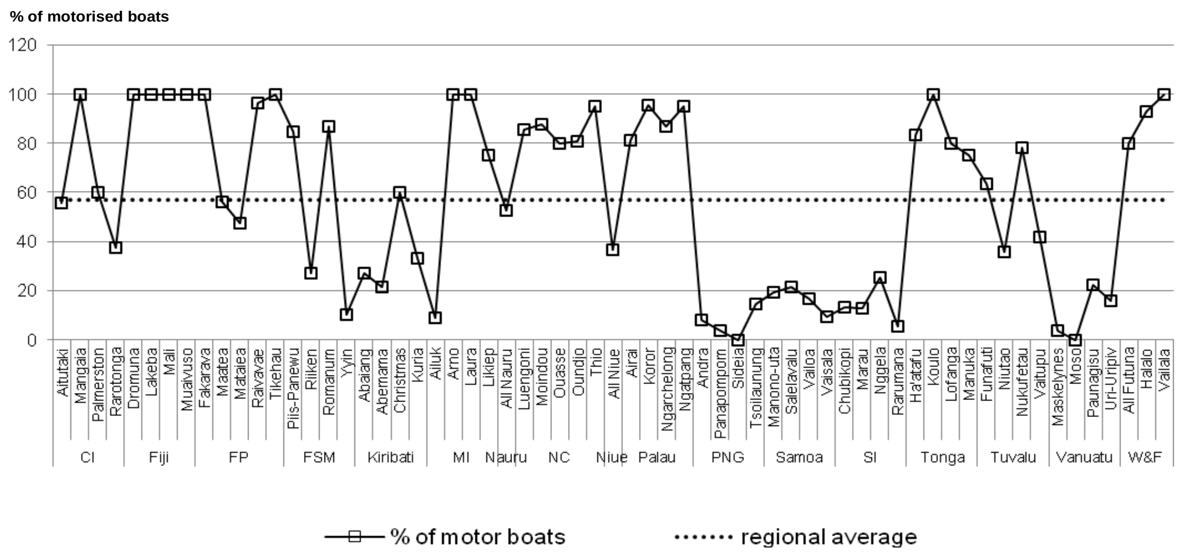


Figure A4.1.28: Proportion of motorised boats in each community surveyed, and the regional average.
HH = household.

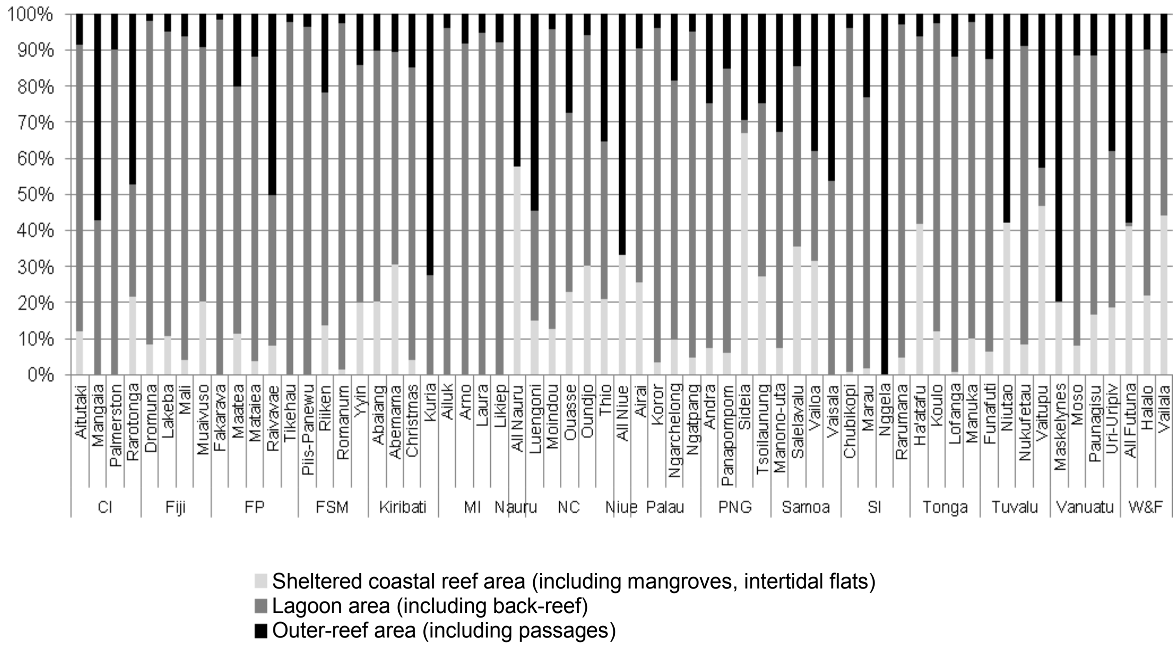


Figure A4.1.29: Proportion of available major habitats of total fishing grounds per each community surveyed.

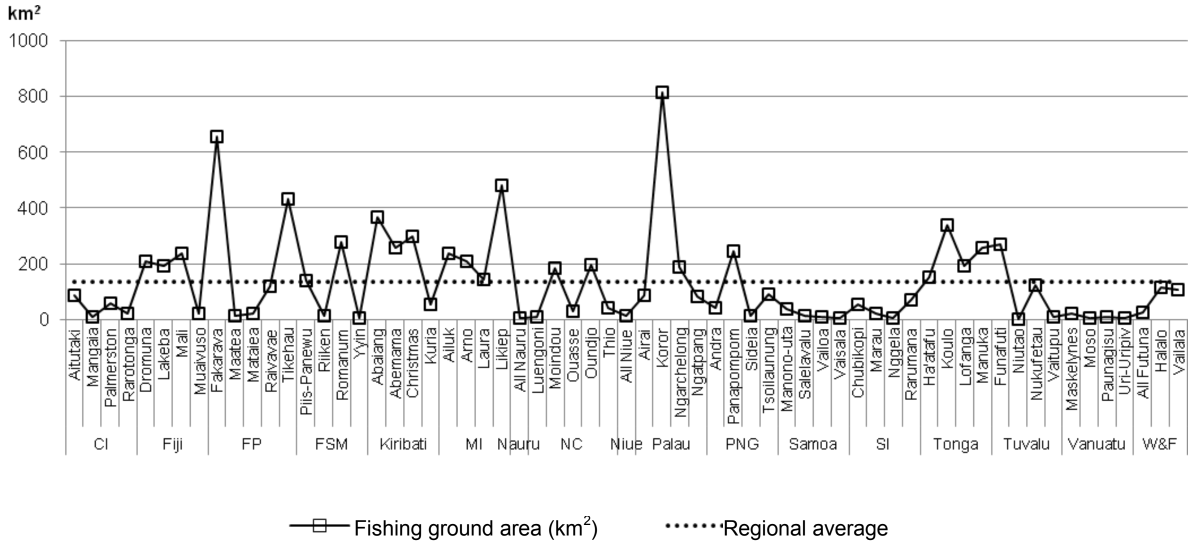


Figure A4.1.30: Total fishing ground area (km^2) appropriated by each community surveyed, and the regional average.

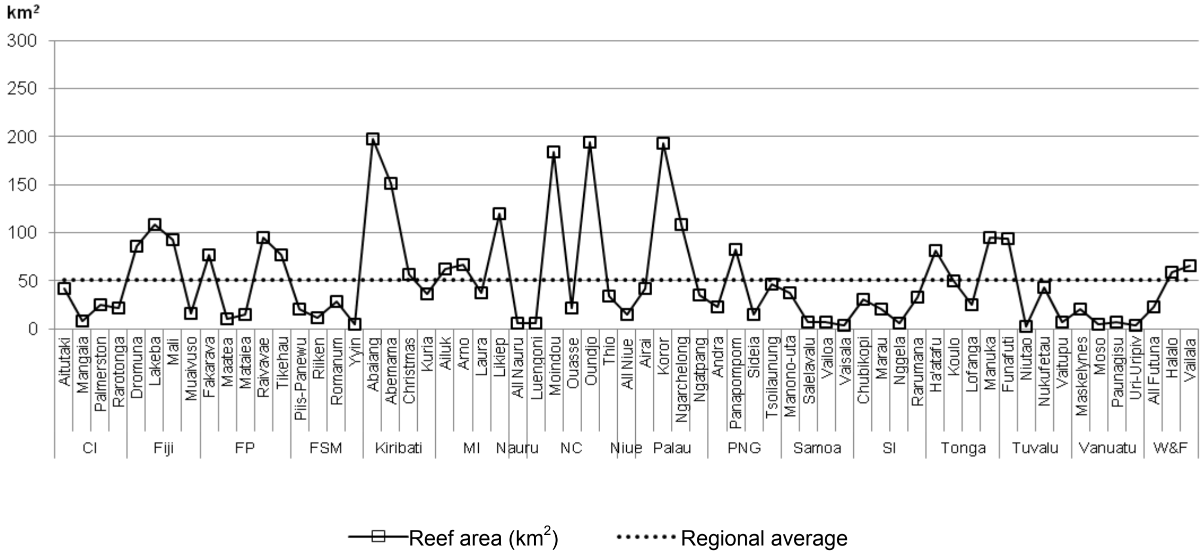


Figure A4.1.31: Total reef area (km²) appropriated by each community surveyed, and the regional average.

Finfish production is highly variable depending on the size of the population, and its dependency on finfish fisheries for subsistence and income. On average, the *total annual extrapolated finfish catch* per community is 267 t (±67.2); however, extremes range from 1.5 t/year to >1000 t/year. The proportion of the total annual finfish used for the *subsistence and commercial* purposes of each community surveyed provides a better basis to compare communities and countries at the regional scale. In fact, on average for the region, subsistence finfish catches are less than commercial catches, representing 44.4% (±3.3) and 55.6% (±3.3) respectively. However, these proportions vary considerably among sites and countries (Figure A4.1.32).

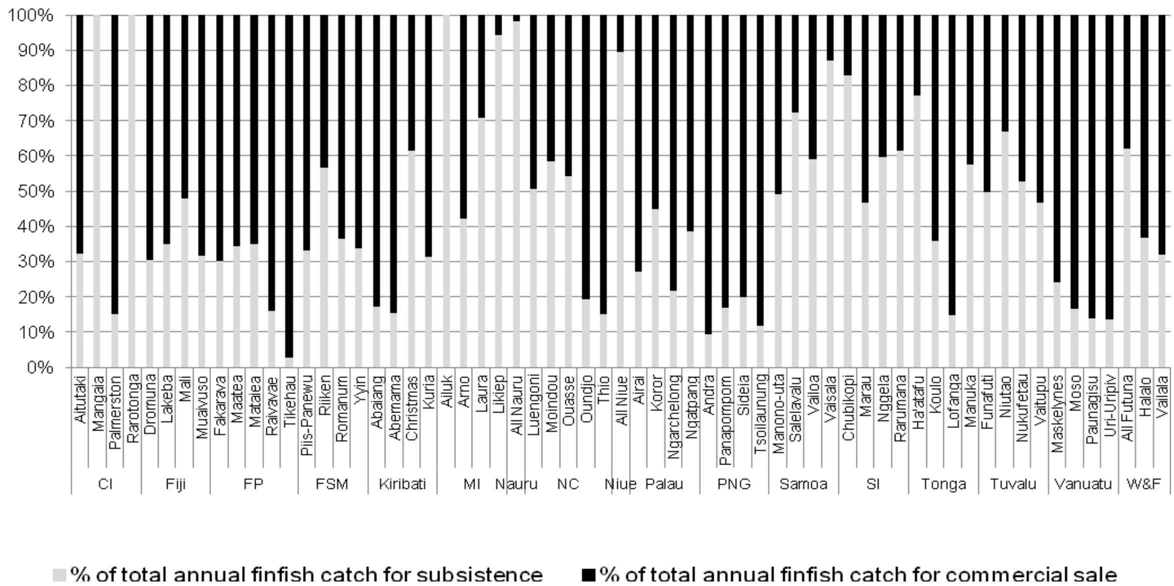


Figure A4.1.32: Proportion of total annual finfish catch for subsistence and for commercial purposes per each community surveyed.

Finfish fisheries in PICTs are regarded as *multi-technique* and *multi-species fisheries*, and this general characterisation is largely confirmed by our results. Handlines including fishing rods (artisanal and modern gear) (30.2% ±2.1), speardiving and handheld spearing (artisanal and modern gadgets) (28.8% ±1.7), gillnetting (18.3% ±2.0) and castnets (5.7% ±0.9) are the most commonly used fishing techniques on average across the region. In addition are used deep-bottom lines (regional average 3.5% ±0.8) and other techniques (13.5% ±2.0), which include such techniques as artisanal and modern fish traps, stone throwing, the use of scoop nets, fish poisoning using the traditional *Derris derris,* knives, etc. However, although the use of techniques is shown in disaggregated percentage figures, often two or more fishing techniques are used during one fishing trip. The relative use of the most important techniques, i.e. handlines, speardiving and handheld spearing, gillnets, and castnets is shown for each community and in comparison to the regional average figure in Figures A4.1.33 to A4.1.36.

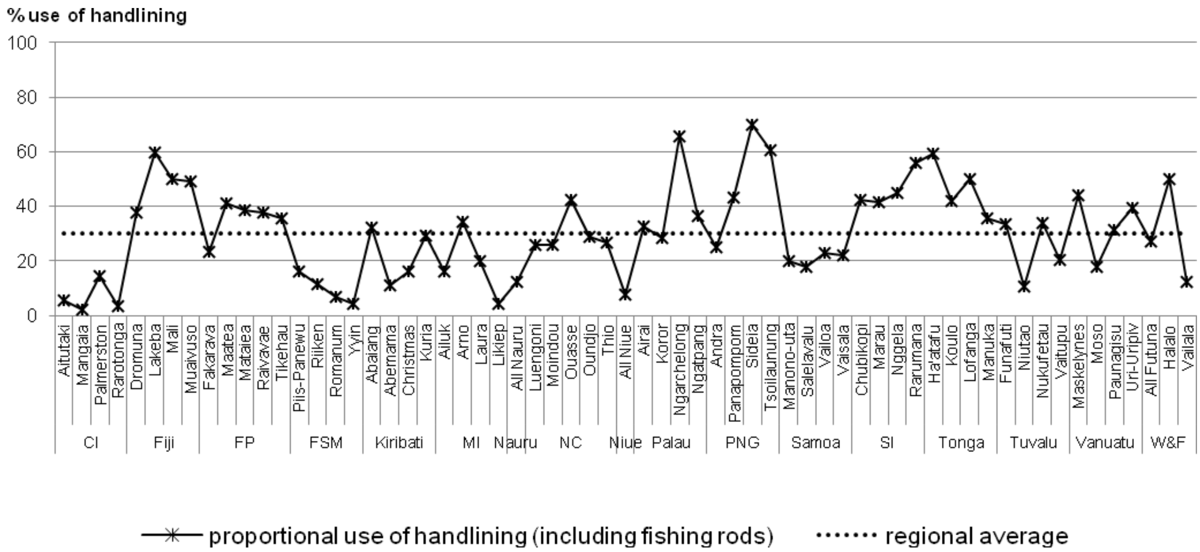


Figure A4.1.33: Proportional use of handlines (including fishing rods, both artisanal and modern gear) for each community surveyed, and the regional average.

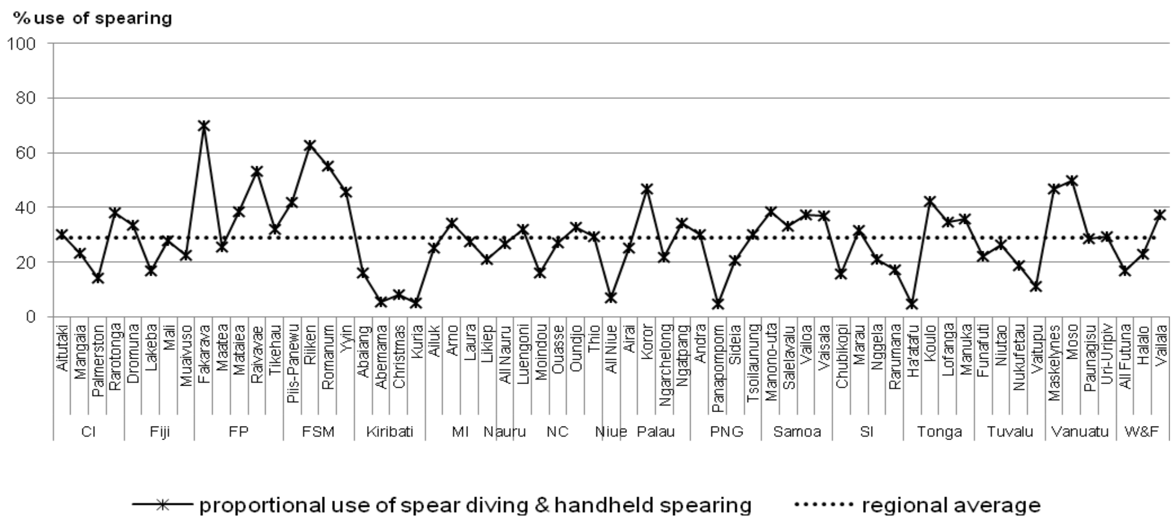


Figure A4.1.34: Proportional use of speardiving and handheld spearing (artisanal and modern gear) for each community surveyed, and the regional average.

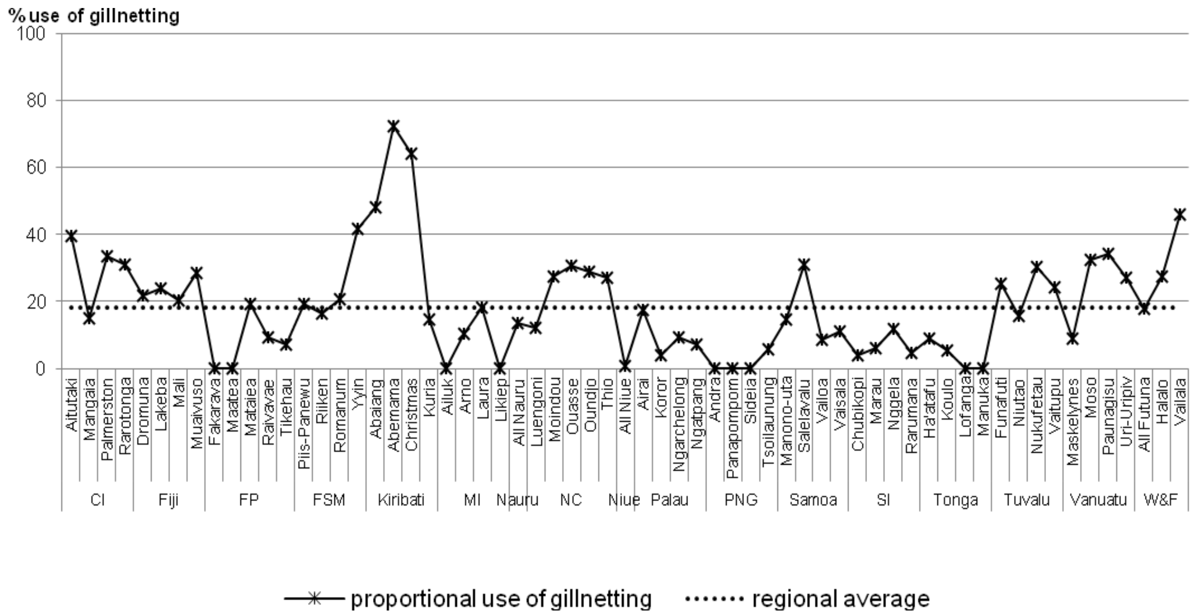


Figure A4.1.35: Proportional use of gillnets for each community surveyed, and the regional average.

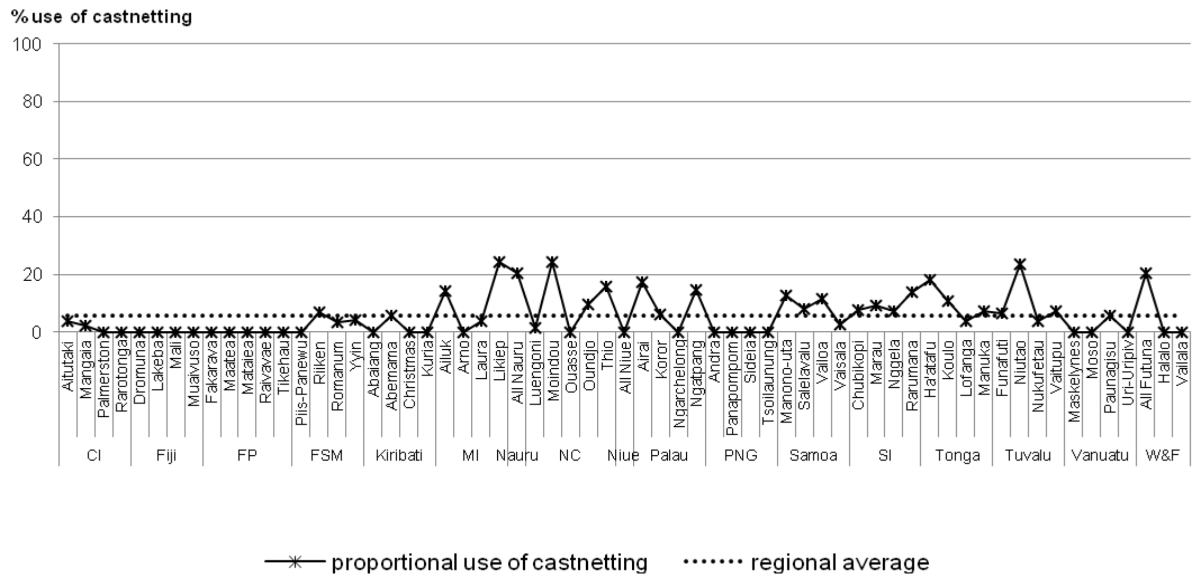


Figure A4.1.36: Proportional use of castnets for each community surveyed, and the regional average.

On average, *CPUE* amounts to 2.4 kg/hour of fishing trip (±0.4); however, average figures for each community may vary considerably, as shown in Figure A4.1.37.

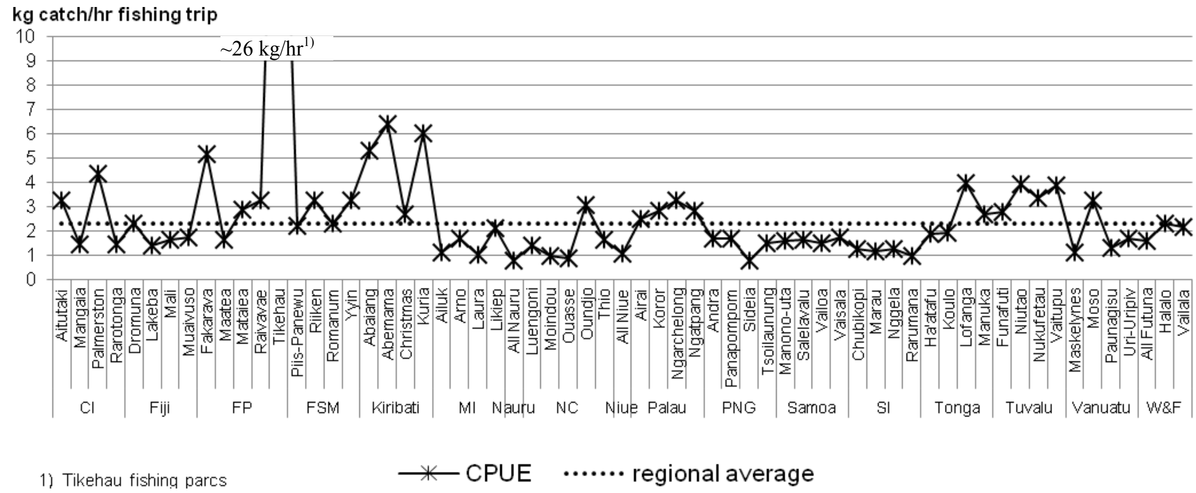


Figure A4.1.37: Average CPUE (kg finfish catch/hour of fishing trip) for each community, and the regional average.

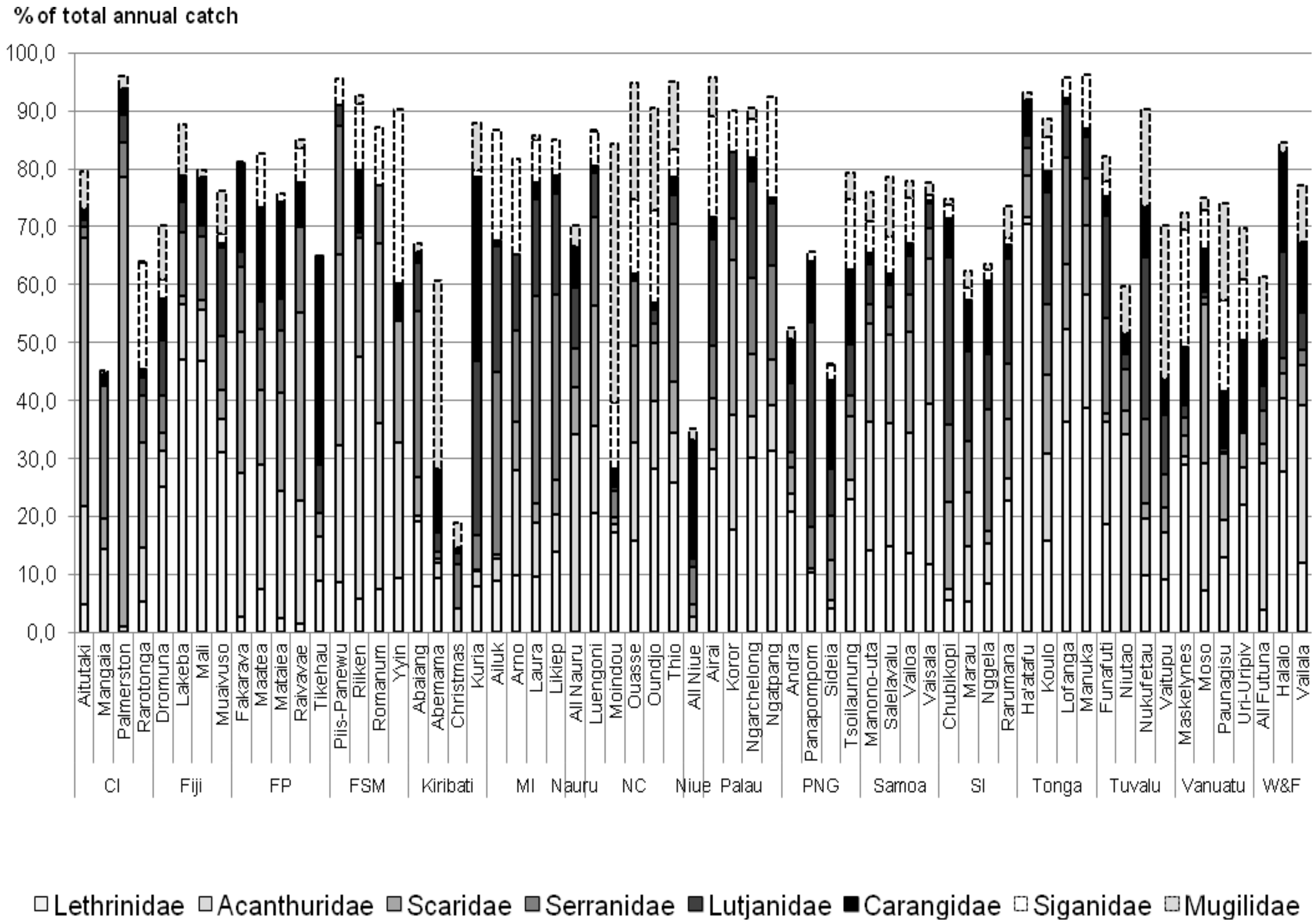


Figure A4.1.38: Proportional contribution of the eight major finfish families to reported annual catch per community surveyed.

From all reported *catch compositions*, thirteen fish families emerged frequently, and eight of these represent on average >5% of the total reported catch. There are a number of other finfish families that were occasionally reported, or that are site-specific, and these are summarised under 'others'. The eight major finfish families represented in most, if not all, reported finfish catches over the region include on average Lethrinidae (15.5% ±1.7), Acanthuridae (12.8%± 1.2), Scaridae (12.0% ±1.6), Serranidae (10.0% ±1.0), Lutjanidae (8.8% ±1.0), Carangidae (6.9% ±0.9), Siganidae (5.8% ±0.8) and Mugilidae (5.5% ±1.1). The remaining five finfish families that constitute each less than 5% of the average regional catch composition include Holocentridae, Mullidae, Kyphosidae, Labridae and Balistidae. Others, including a wide range of different finfish families that are inconsistently represented, represent on regional average about 11% (±1.6) of the reported catch. Figure A4.1.38 shows the proportional distribution of the eight most important finfish families in average reported catches per each community surveyed. Proportionate catch composition data is provided per site and averaged per country and cultural group in Appendix 4.3.

Invertebrate fisheries in PICTs include two major activities: *gleaning*, which is considered to serve mainly subsistence and perhaps small-income interests, and *free-diving*, which is mainly commercially oriented. Gleaning activities target a number of different habitats, including soft benthos, such as seagrass beds, mangroves, intertidal zones, and reeftops. Free-diving activities target coral reefs and soft-benthos habitats at greater depth, but mainly deeper slopes of back- and outer-reef areas, targeting predominantly trochus, giant clams, octopus, lobsters and bêche-de-mer. Bêche-de-mer could be naturally found at any depth, depending on species and habitat requirements. However, due to past and still ongoing fishing pressure on bêche-de-mer, particularly for the export industry, this fishery requires more and more free-diving to access the remaining stocks at greater depth. Bêche-de-mer, trochus fisheries and, to some extent, also lobster and other invertebrate resources, are often subject to pulse fisheries, or longer-term protection measures. Availability on fisher data on these species groups is therefore subject to whether the bêche-de-mer and trochus seasons were open during the time period when surveys were conducted. The resulting limitations in the data are indicated in the following where necessary.

The total annual time spent in invertebrate fishing (regardless of activity or target species) averages to about 37,680 hours (±5913) and differences among sites and countries are demonstrated in Figure A4.1.39. The proportion of total invertebrate-fishing time accounted for by subsistence needs of each community surveyed and commercial interests (meaning invertebrates mainly targeted for export sales), varies considerably between sites and countries (Figure A4.1.40). Because the main commercial export invertebrate species are bêche-de-mer, the sites where the proportion of commercial invertebrate fishing time is high coincide mainly with countries where the bêche-de-mer fishery is not subject to pulse fishery, or where the fishery was opened during the time of the survey.

The overall average number of invertebrate scientific families reported on the basis of vernacular names is 16 (±1.3). However, a much higher diversity was reported particularly in Papua New Guinea and in Solomon Islands, which may reflect the proximity of these countries to the centre of biodiversity (CoB) (Figure A4.1.41).

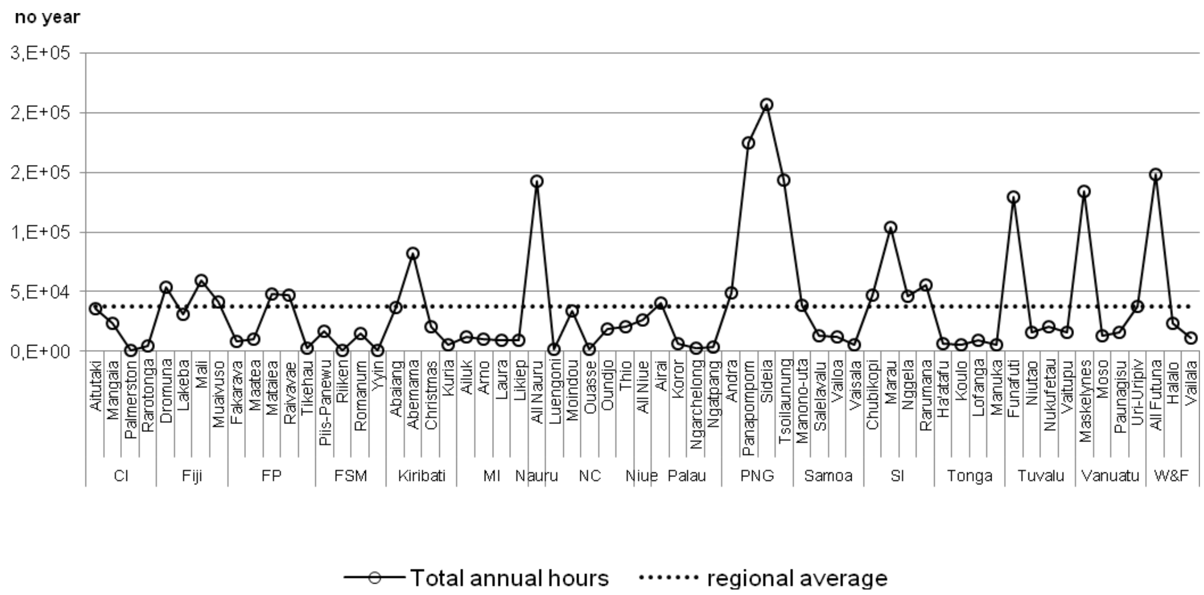


Figure A4.1.39: Total annual hours spent invertebrate fishing in each community surveyed, and the regional average.

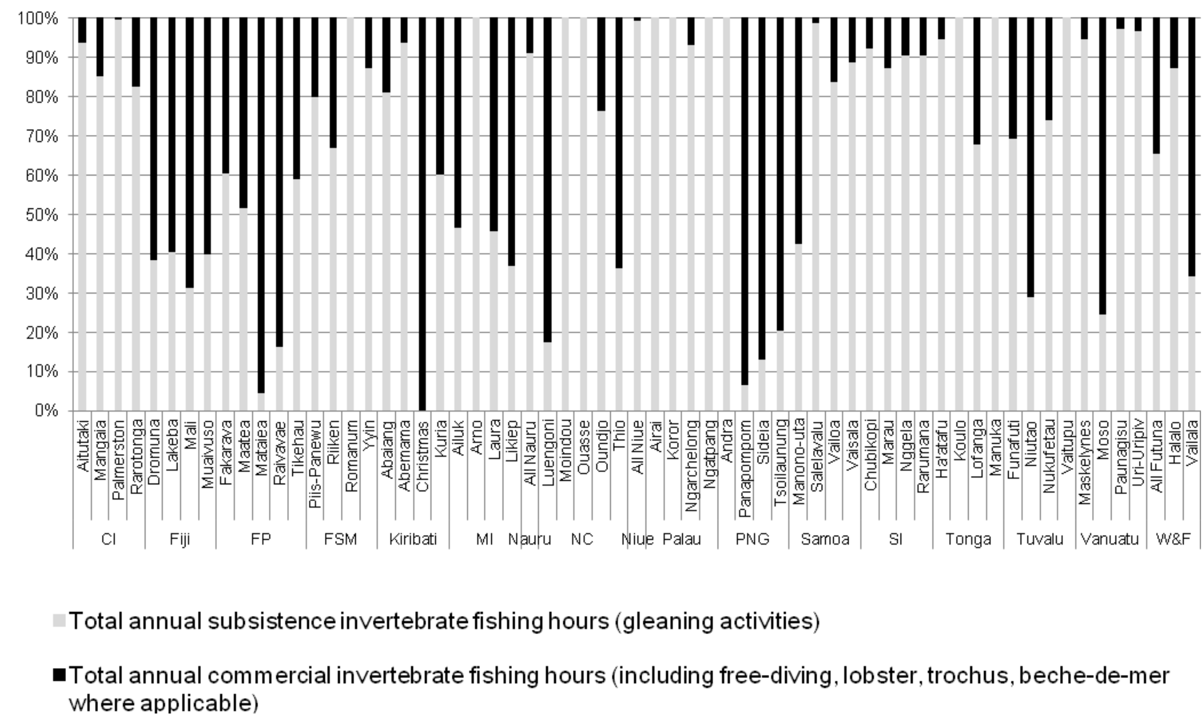


Figure A4.1.40: Proportion of time spent invertebrate fishing for mainly subsistence and commercial interests of total annual invertebrate fishing hours per each community surveyed.

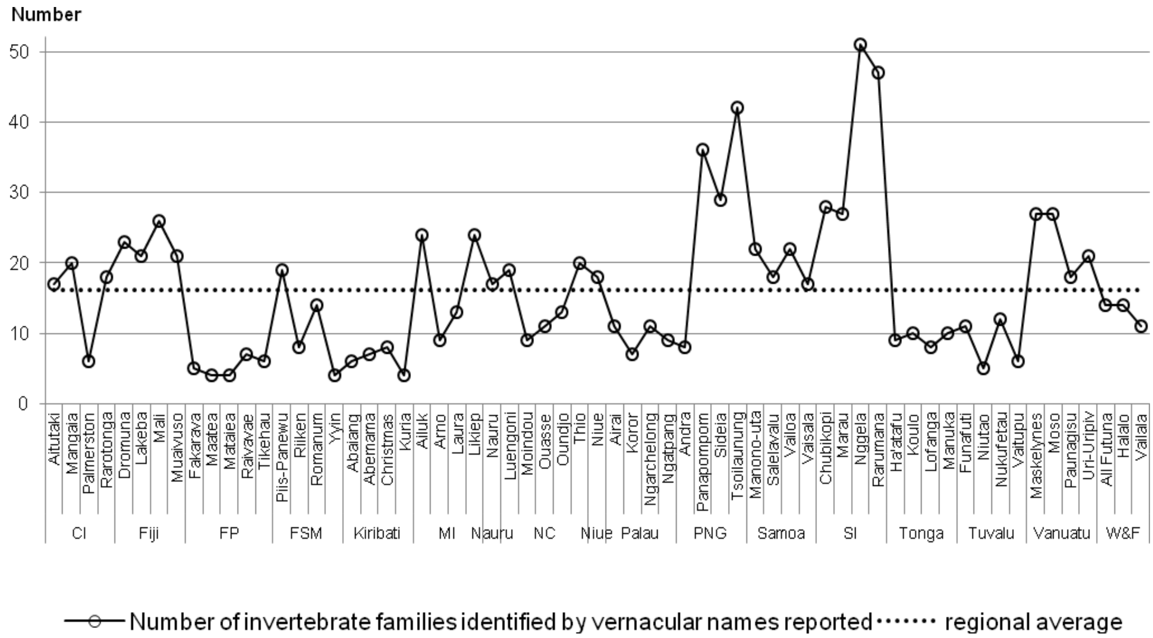


Figure A4.1.41: Total number of invertebrates as identified by scientific families reported on the basis of vernacular names for each community surveyed, and the regional average.

A general overview of the reported invertebrate catch composition according to the 10 major invertebrate species groups defined and for each community surveyed is provided in Figure A4.1.42, figures are shown in Table A4.1.1 (Note that sea urchins have been combined with ‘others’.).

Extrapolated annual catches (by numbers) by major species groups are provided in Figures A4.1.43 to A4.1.50 for each community and in comparison to the regional average. Regional averages of annual catches (by numbers) are ~216,200 (±52,147) for bivalves (Figure A4.1.43), ~588,9400 (±149,550) for gastropods (Figure A4.1.44), ~51,180 (±9927) for giant clams (Figure A4.1.45), ~25,346 (±7271) for crustaceans (Figure A4.1.46), ~68,420 (±24,274) for bêche-de-mer (Figure A4.1.47), ~21,706 (±7380) for trochus (Figure A4.1.48), ~7580 (±1763) for lobsters (Figure A4.1.49), and 5240 (±1027) for octopus (Figure A4.1.50). As already indicated by the large values for standard errors, variability in total catch (by numbers) is high. Again, such differences may be due to a number of reasons, such as closure of fisheries during survey (bêche-de-mer, trochus), availability of habitats to support certain fisheries (mangroves, soft benthos), relative importance of the various invertebrate target groups (bivalves, gastropods, octopus, lobster) particularly for subsistence purposes, and natural differences in abundance (giant clams).

Table A4.1.1: Proportions (%) of major invertebrate species groups of total annual catch by community surveyed

Country/Territory	Site	Bivalves	Crustaceans (except lobsters)	Gastropods (except giant clams)	Giant clams	Lobsters	Octopus	BdM	Trochus	Other
Cook Islands	Aitutaki	0.5	9.1	30.3	39.5	14.6	0.0	4.9	0.4	0.8
	Mangaia	0.0	0.6	26.1	24.6	7.7	0.9	35.6	0.0	4.6
	Palmerston	9.0	5.7	2.3	43.8	32.8	6.4	0.0	0.0	0.0
	Rarotonga	1.4	1.8	2.8	15.2	5.9	1.9	57.3	2.9	10.9
Fiji Islands	Dromuna	12.2	2.3	3.5	0.8	3.2	0.9	75.6	1.1	0.4
	Lakeba	9.9	1.9	1.0	8.5	1.9	4.1	71.1	1.6	0.0
	Mali	2.1	12.4	2.6	10.1	5.3	2.6	61.5	3.1	0.3
	Muaivuso	8.9	1.8	3.1	0.9	0.0	9.7	68.2	4.8	2.6
French Polynesia	Fakarava	0.0	0.0	4.9	83.7	11.4	0.0	0.0	0.0	0.0
	Maatea	0.0	7.3	0.3	87.1	0.0	0.0	0.0	0.0	5.3
	Mataiea	0.0	0.0	2.3	27.0	68.8	0.0	0.0	0.0	1.9
	Raivavae	0.5	0.7	0.0	84.0	14.5	0.1	0.0	0.0	0.2
	Tikehau	0.0	0.0	10.4	63.7	25.9	0.0	0.0	0.0	0.0
Federated States of Micronesia	Piis-Panewu	0.4	3.9	0.8	22.1	26.9	16.0	20.2	9.8	0.0
	Riiken	2.0	0.0	1.9	10.3	85.9	0.0	0.0	0.0	0.0
	Romanum	0.0	10.1	0.5	10.5	14.8	7.7	35.6	20.8	0.0
	Yyin	0.2	0.0	5.1	94.6	0.0	0.0	0.0	0.0	0.0
Kiribati	Abaiang	0.0	0.0	0.0	80.5	4.8	0.0	0.0	0.0	14.6
	Abemama	7.7	0.0	6.2	22.0	12.6	0.0	0.0	0.0	51.4
	Kiritimati	0.0	0.0	0.0	80.5	1.0	4.2	14.2	0.0	0.0
	Kuria	1.1	7.9	0.0	59.9	31.2	0.0	0.0	0.0	0.0
Marshall Islands	Ailuk	1.5	11.2	55.9	20.3	7.0	4.1	0.0	0.0	0.0
	Arno	0.0	0.0	10.5	73.8	0.0	15.7	0.0	0.0	0.0
	Laura	0.0	2.7	63.9	14.0	13.6	5.8	0.0	0.0	0.0
	Likiep	3.5	26.5	27.2	25.5	14.1	3.2	0.0	0.0	0.0
Nauru	Nauru	0.8	33.5	28.6	0.0	10.5	13.4	12.3	0.7	0.0

BdM = bêche-de-mer; SE = standard error; Other includes all sea urchins, *Dolabella* sp., *Dolabella auricularia*, *Sipunculus* sp., *Sipunculus indicus*, *Acanthopleura* sp. and *Acanthopleura gemmata*.

Table A4.1.1: Proportions (%) of major invertebrate species groups of total annual catch by community surveyed (continued)

Country/Territory	Site	Bivalves	Crustaceans (except lobsters)	Gastropods (except giant clams)	Giant clams	Lobsters	Octopus	BdM	Trochus	Other
New Caledonia	Luengoni	1.6	6.2	8.4	8.1	69.9	1.5	0.0	4.4	0.0
	Moindou	3.6	95.5	0.3	0.5	0.0	0.1	0.0	0.0	0.0
	Ouassé	6.7	0.0	23.3	35.5	3.6	14.6	0.0	16.3	0.0
	Oundjo	23.1	39.7	2.0	2.5	2.5	0.3	13.0	16.9	0.0
	Thio	0.3	0.8	6.4	4.4	15.8	15.9	14.5	41.9	0.0
Niue	Niue	1.3	5.8	72.1	5.0	10.6	1.2	3.9	0.0	0.2
Palau	Airai	0.0	2.1	0.0	34.8	1.5	0.0	61.7	0.0	0.0
	Koror	0.0	0.0	0.0	47.2	0.0	0.0	52.8	0.0	0.0
	Ngarchelong	0.0	0.7	0.0	15.5	1.0	0.0	82.9	0.0	0.0
	Ngatpang	0.0	4.8	0.0	16.5	0.4	0.0	78.4	0.0	0.0
Papua New Guinea	Andra	12.4	0.0	22.2	41.3	0.0	24.2	0.0	0.0	0.0
	Panapompom	0.0	0.7	9.4	4.5	0.4	0.0	84.8	0.1	0.0
	Sideia	2.8	4.5	29.6	2.8	0.0	0.0	60.3	0.0	0.0
	Tsoilaunung	3.0	9.3	1.9	6.5	12.5	0.5	63.1	3.1	0.0
Samoa	Manono-uta	2.2	6.6	2.8	37.8	2.9	6.6	38.5	2.4	0.1
	Salelavalu	3.1	10.5	4.1	7.7	1.6	1.9	67.3	1.7	2.1
	Vailoa	4.4	12.1	2.1	30.4	2.7	5.6	42.6	0.0	0.1
	Vaisala	2.8	0.4	0.5	61.5	1.3	1.4	31.7	0.2	0.2
Solomon Islands	Chubikopi	6.9	23.6	10.6	46.6	9.6	0.4	0.0	1.9	0.4
	Marau	2.9	16.9	8.4	42.8	3.4	0.9	0.4	16.8	7.4
	Nggela	7.3	4.3	5.3	60.8	6.1	1.4	2.1	12.7	0.0
	Rarumana	9.1	6.7	26.5	49.1	2.7	0.7	0.4	4.8	0.0
Tonga	Ha'atafu	0.1	0.0	29.0	0.0	0.0	40.0	20.1	0.0	10.9
	Koulo	0.0	0.0	2.9	34.0	0.0	37.7	24.9	0.0	0.5
	Lofanga	0.0	0.0	7.1	64.8	0.0	26.6	1.5	0.0	0.0
	Manuka	3.5	0.0	18.4	0.2	33.8	9.3	22.9	0.0	11.9

BdM = bêche-de-mer; SE = standard error; Other includes all sea urchins, *Dolabella* sp., *Dolabella auricularia*, *Sipunculus* sp., *Sipunculus indicus*, *Acanthopleura* sp. and *Acanthopleura gemmata*.

Table A4.1.1: Proportions (%) of major invertebrate species groups of total annual catch by community surveyed (continued)

Country/Territory	Site	Bivalves	Crustaceans (except lobsters)	Gastropods (except giant clams)	Giant clams	Lobsters	Octopus	BdM	Trochus	Other
Tuvalu	Funafuti	6.1	1.0	75.0	8.1	9.8	0.0	0.0	0.0	0.0
	Niutao	0.0	0.0	4.2	5.5	90.3	0.0	0.0	0.0	0.0
	Nukufetau	0.1	0.0	66.8	16.5	10.0	6.5	0.0	0.0	0.0
	Vaitupu	44.6	12.1	38.6	0.0	0.0	4.7	0.0	0.0	0.0
Vanuatu	Maskelynes	11.1	9.2	64.7	7.5	0.0	5.5	0.0	2.0	0.0
	Moso	11.0	0.3	1.9	4.7	0.6	1.1	79.5	0.9	0.0
	Paunagisu	19.6	38.2	33.3	4.6	0.0	3.4	0.0	0.4	0.5
	Uri-Uripiv	30.5	8.4	46.0	4.0	0.0	6.8	0.0	0.1	4.1
Wallis and Futuna	All Futuna	0.0	0.6	9.6	38.8	25.4	2.1	0.3	23.0	0.0
	Halalo	9.1	26.2	0.5	4.5	0.0	4.3	0.0	55.3	0.0
	Vailala	0.3	0.0	13.0	3.0	66.9	0.1	5.4	11.3	0.0
Regional average		**4.6**	**7.7**	**14.9**	**28.0**	**12.7**	**5.1**	**20.8**	**4.2**	**2.1**
SE		**1.0**	**1.8**	**2.6**	**3.4**	**2.6**	**1.1**	**3.6**	**1.2**	**0.0**

BdM = bêche-de-mer; SE = standard error; Other includes all sea urchins, *Dolabella* sp., *Dolabella auricularia*, *Sipunculus* sp., *Sipunculus indicus*, *Acanthopleura* sp. and *Acanthopleura gemmata*.

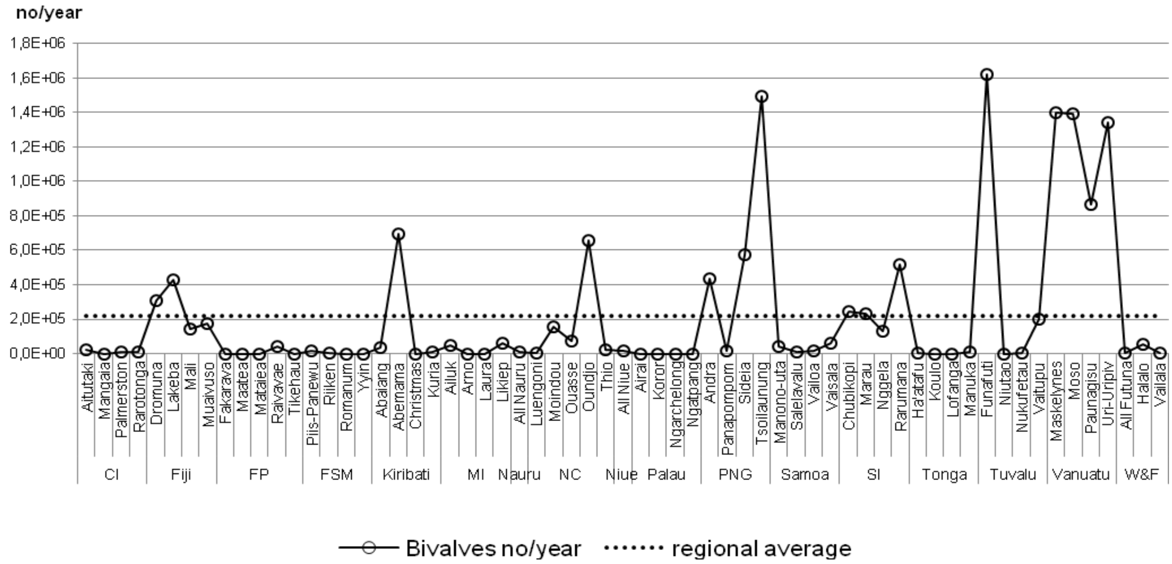


Figure A4.1.43: Extrapolated annual catch (numbers) of bivalves for each community surveyed, and the regional average.

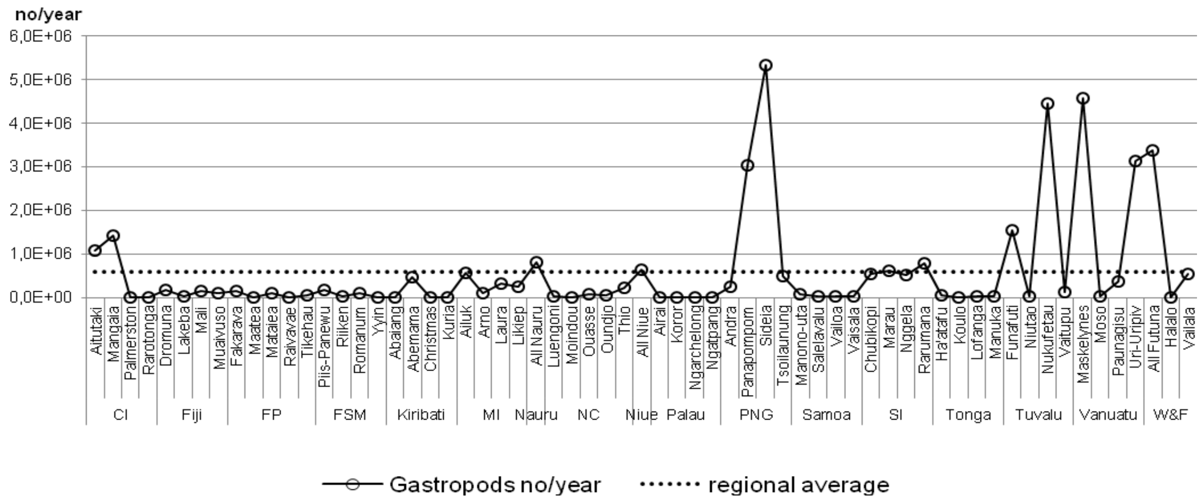


Figure A4.1.44: Extrapolated annual catch (numbers) of gastropods for each community surveyed, and the regional average.

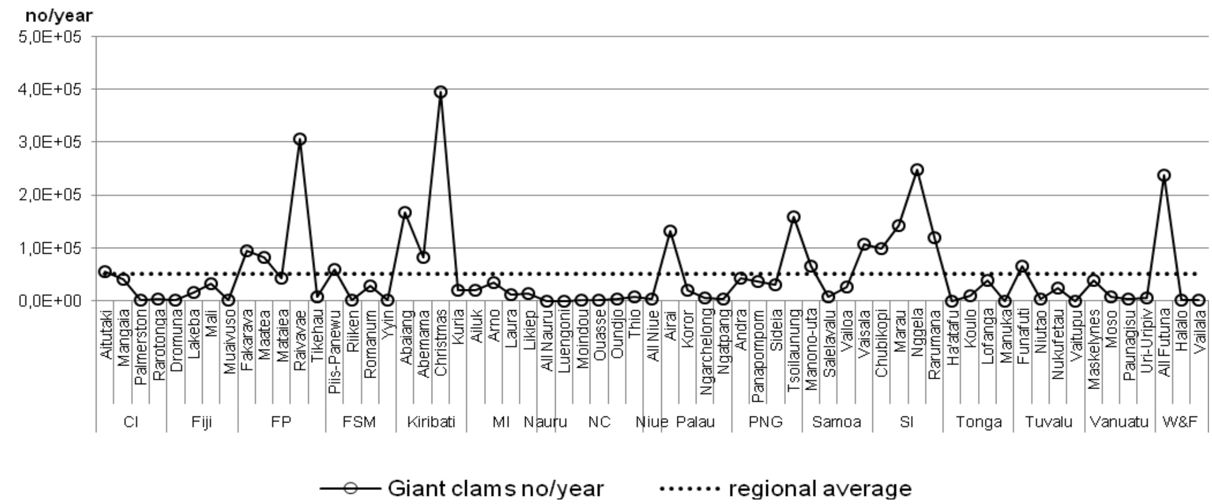


Figure A4.1.45: Extrapolated annual catch (numbers) of giant clams for each community surveyed, and the regional average.

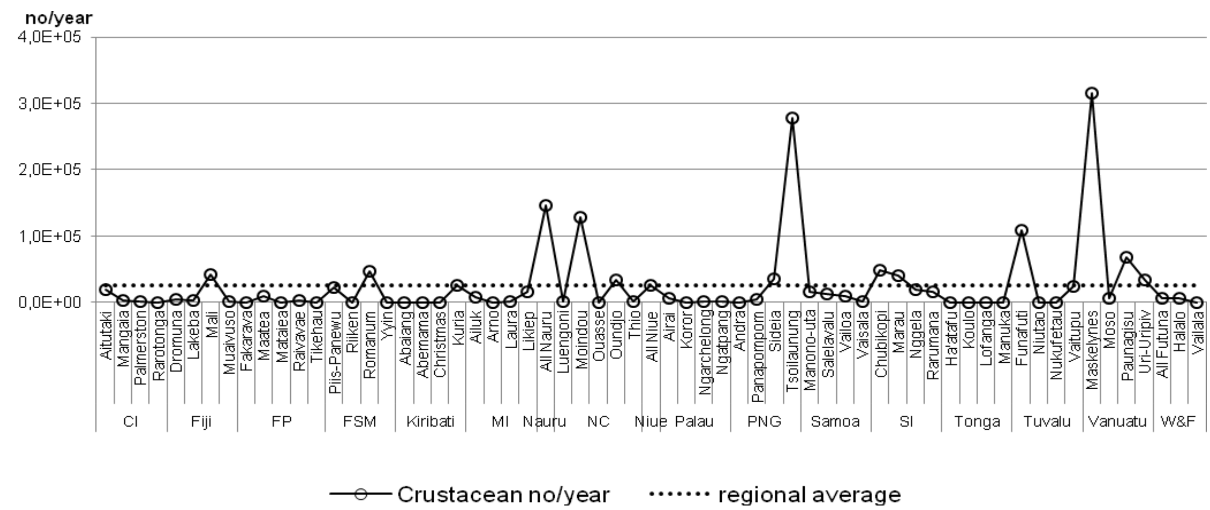


Figure A4.1.46: Extrapolated annual catch (numbers) of crustaceans for each community surveyed, and the regional average.

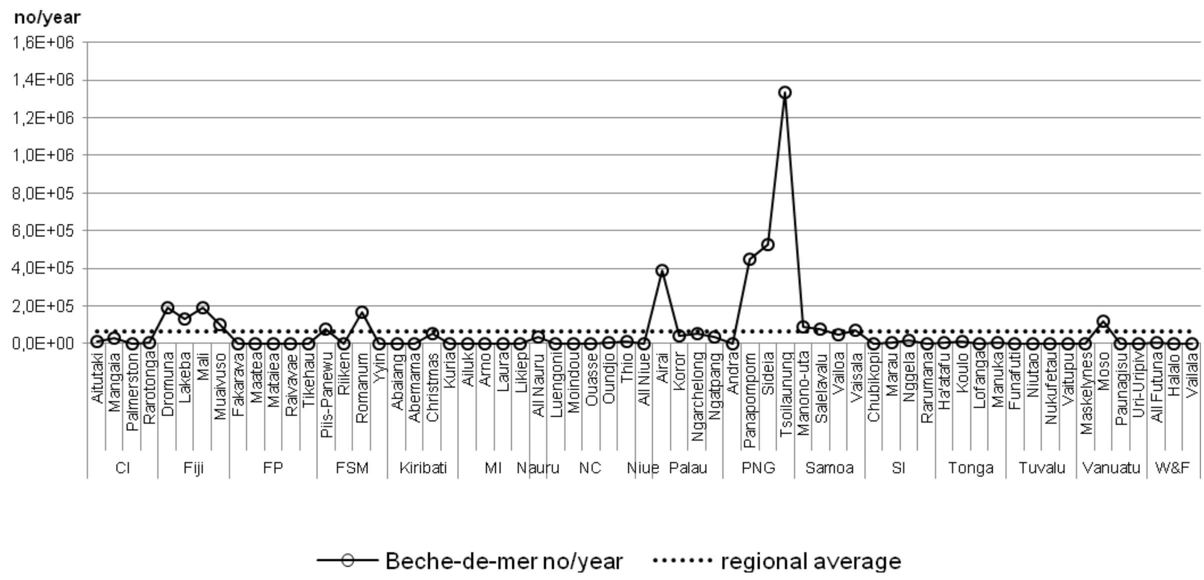


Figure A4.1.47: Extrapolated annual catch (numbers) of bêche-de-mer for each community surveyed, and the regional average.

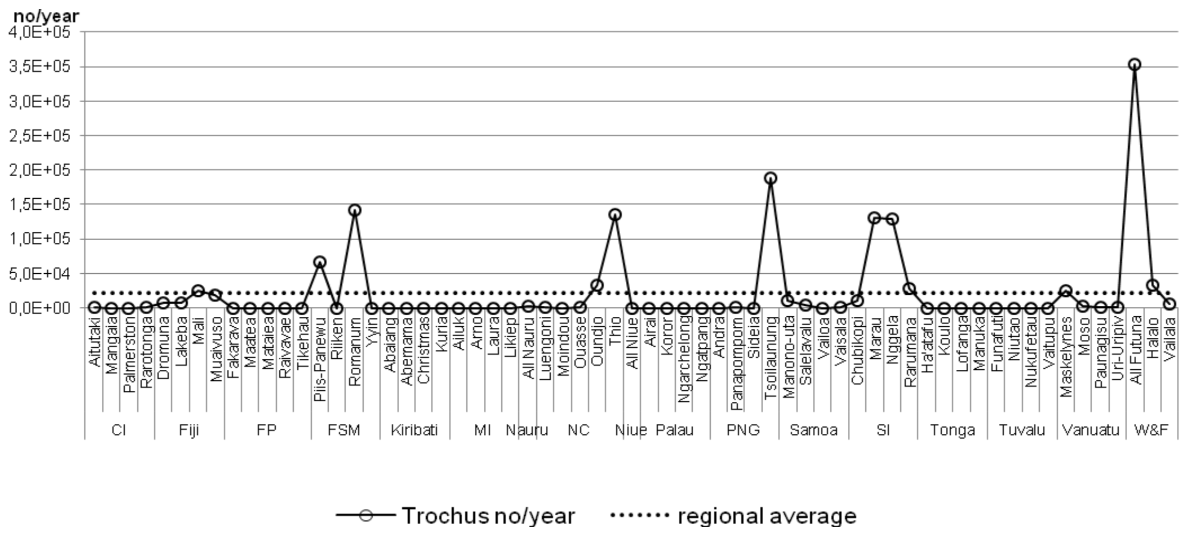


Figure A4.1.48: Extrapolated annual catch (numbers) of trochus for each community surveyed, and the regional average.

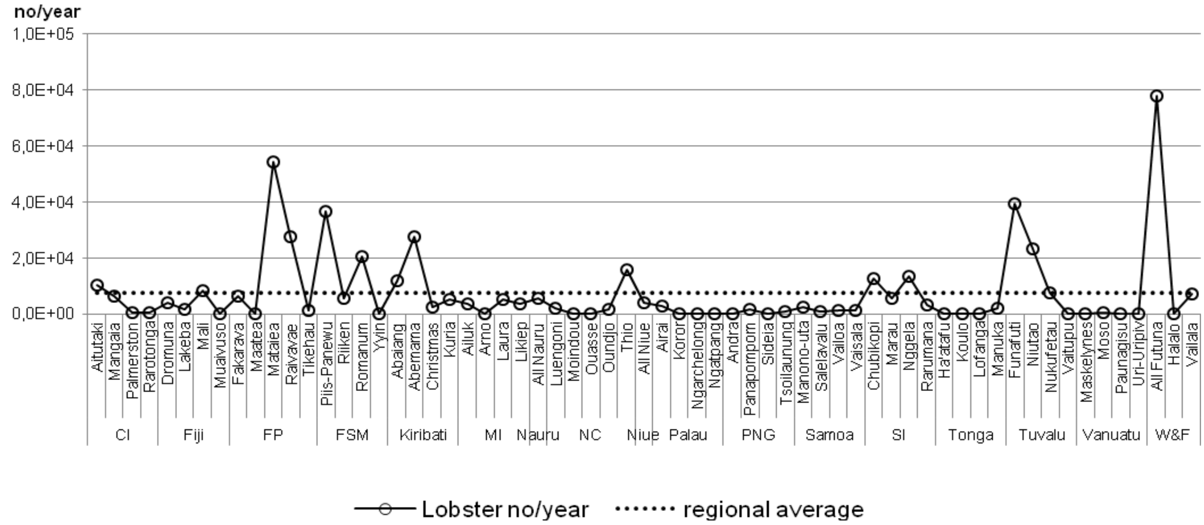


Figure A4.1.49: Extrapolated annual catch (numbers) of lobster for each community surveyed, and the regional average.

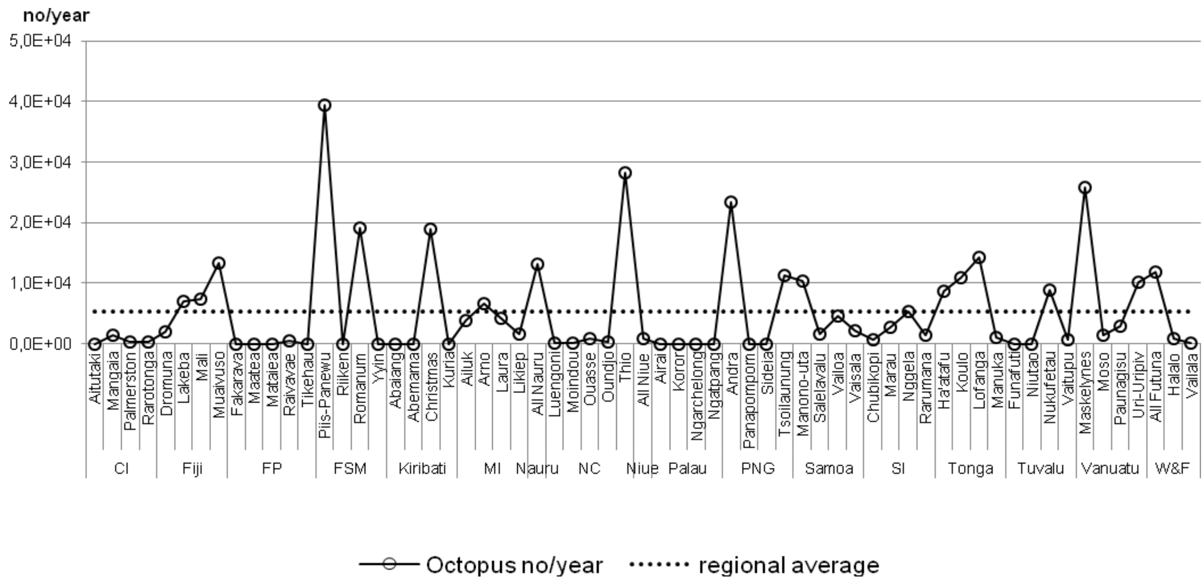


Figure A4.1.50: Extrapolated annual catch (numbers) of octopus for each community surveyed, and the regional average.

The consequences of current fishing activities are the major concern for fisheries management in view of resource conservation and maintaining livelihood of people, in particular for coastal communities that are highly dependent on marine resources for food, income and social stability. The *population and fisher density* figures shown in Figures A4.1.51 to A4.1.54 for each community surveyed, and the regional average, provide a first insight into the potential *fishing pressure* that the communities studied impose on their appropriated fishing grounds and reef areas. Please note that the figures for Nauru have been excluded due to the fact that Nauru's available reef area, and its fishing ground classified as coastal habitat suitable for subsistence and small-scale artisanal fisheries is very limited, rendering population and fisher density figures 25–30 and 38–46 times higher than the regional average for people and fisher densities per km^2 reef and fishing ground, respectively (Nauru: 1705 people/km^2 and 784 fisher/km^2 fishing ground and reef area). The regional average for population and fisher densities thus includes only 62 communities.

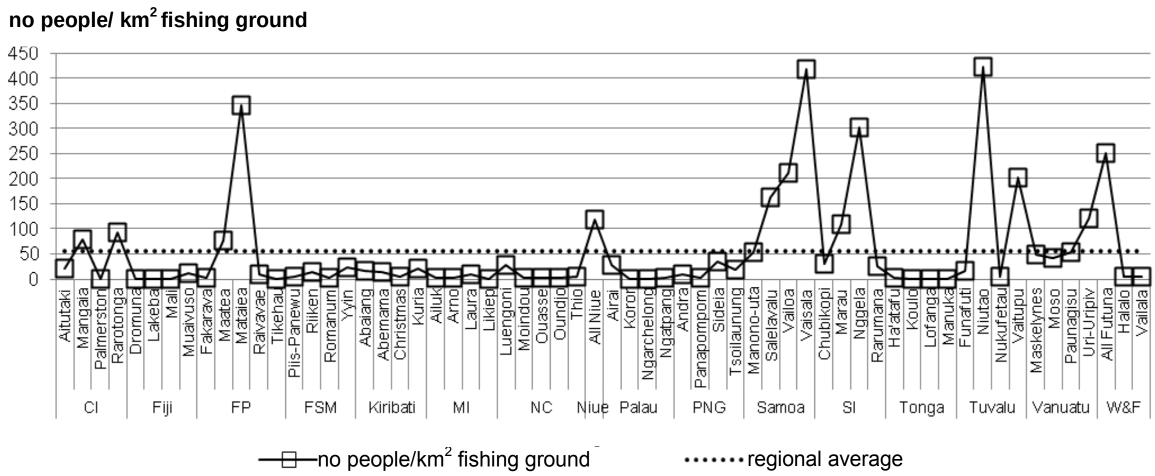


Figure A4.1.51: Population density for fishing grounds (people/km^2) of each community surveyed, and the regional average.

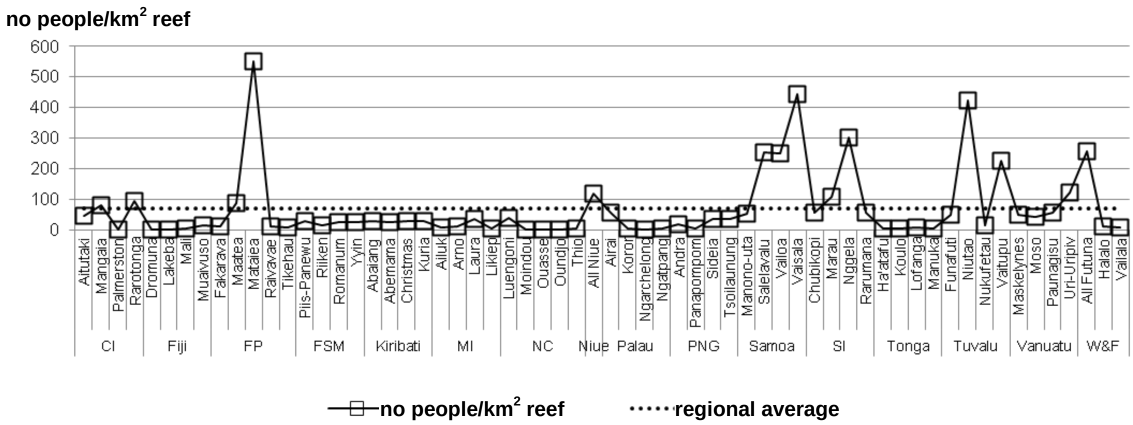


Figure A4.1.52: Population density for total reef surface area (people/km^2) of each community surveyed, and the regional average.

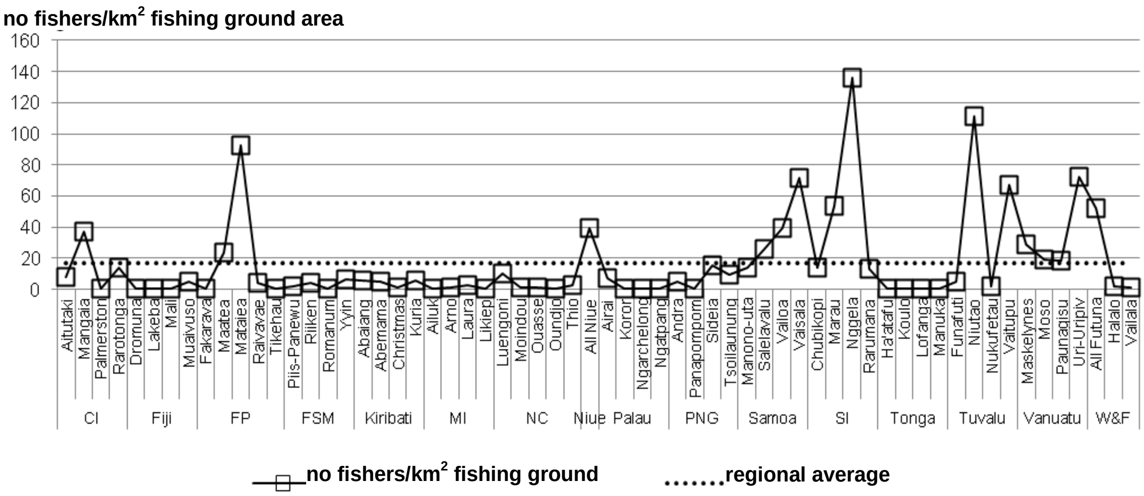


Figure A4.1.53: Fisher density for fishing grounds (fishers/km^2) of each community surveyed, and the regional average.

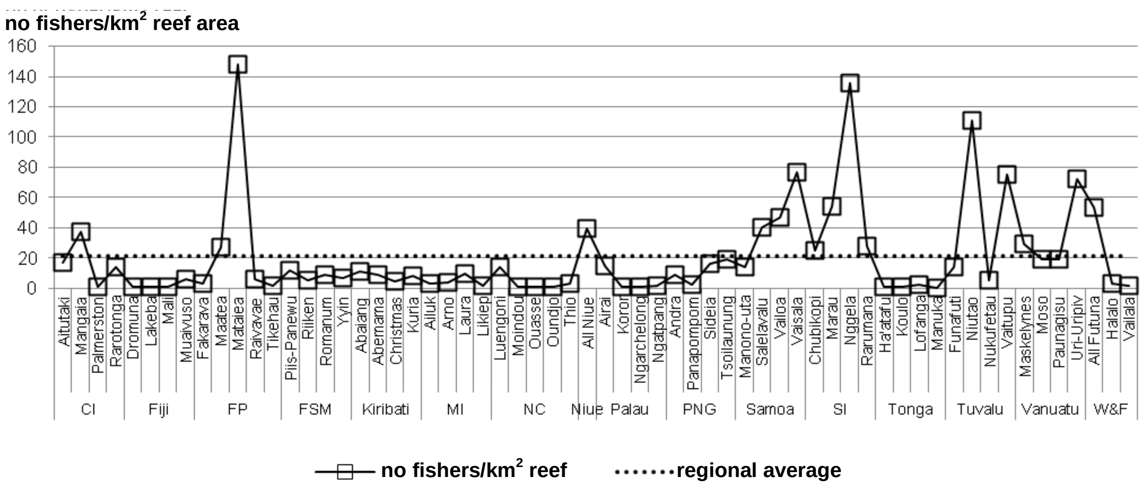


Figure A4.1.54: Fisher density for total reef surface area (fishers/km^2) of each community surveyed, and the regional average.

Population and fisher densities (Figures A4.1.51 to A4.1.54) show that, while a large number of communities surveyed have relatively low population and fisher densities, several communities (rather than countries) are exeptions to this observation. While population and fisher densities are proxies for fishing pressure, total catch per fishing ground or reef area is a more direct measure to relate and compare possible impact in relation to the available production surfaces. Catch rates (total annual catch t/km^2 fishing ground and total reef area) are demonstrated in Figures A4.1.55 and A4.1.56. On average over the region annual finfish catch rates amount to 8.5 t/km^2 fishing ground (±2.1), and 10.7 t/km^2 total reef surface area (±2.3). Both catch rates are comparatively high; however, these indicators vary considerably among sites. An in-depth analysis of fishing pressure, its use for fisheries management and monitoring, and possible implications are presented in the combined socioeconomic and fisheries section in the main body of the report.

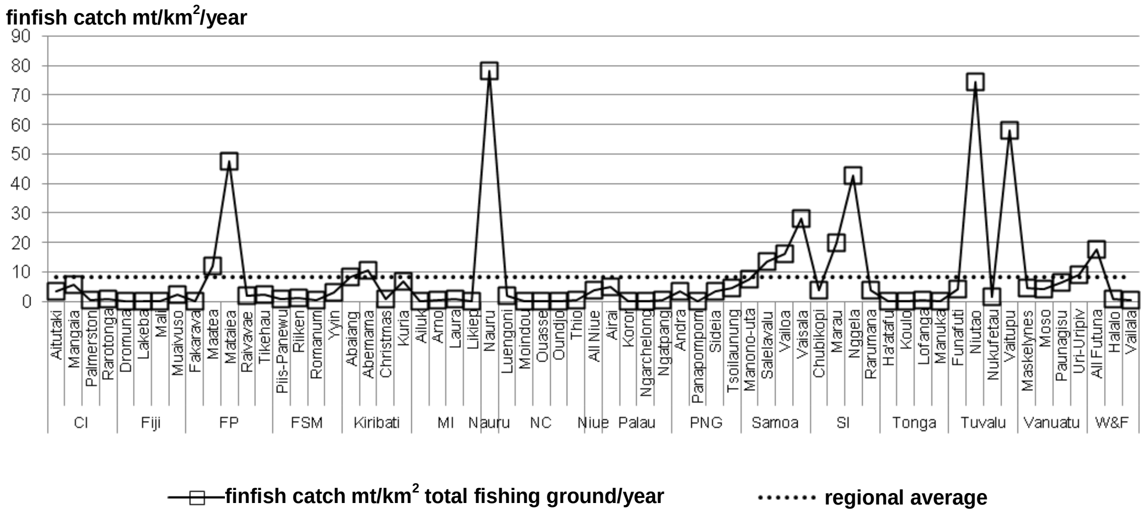


Figure A4.1.55: Finfish catch rates (t/km²/year) per fishing ground of each community surveyed, and the regional average.

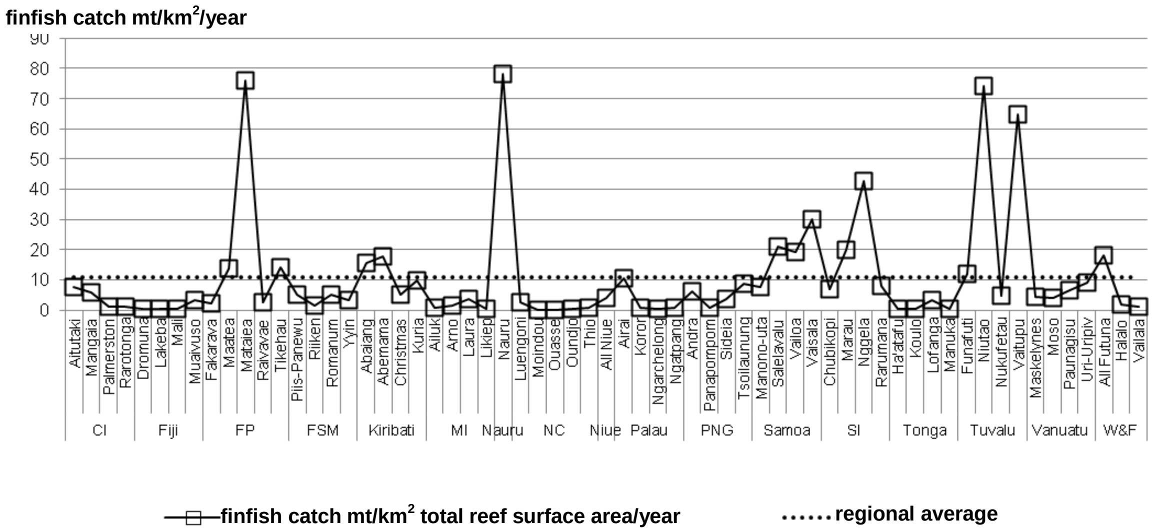


Figure A4.1.56: Finfish catch rates (t/km²/year) per total reef area of each community surveyed, and the regional average.

4.1.2 Seafood consumption data tables

Table A4.1.2: Proportion of households consuming finfish, invertebrates and canned fish in 63 communities surveyed, and the regional average

Country/Territory	Site	Percentage of households consuming:		
		Finfish	Invertebrates	Canned fish
Cook Islands	Aitutaki	100.0	63.3	73.3
	Mangaia	100.0	92.3	79.5
	Palmerston	100.0	70.0	0.0
	Rarotonga	98.3	61.0	81.4
Fiji Islands	Dromuna	100.0	100.0	80.0
	Lakeba	100.0	100.0	80.0
	Mali	100.0	100.0	81.3
	Muaivuso	100.0	100.0	93.3
French Polynesia	Fakarava	100.0	88.0	88.0
	Maatea	100.0	46.4	57.1
	Mataiea	100.0	96.8	96.8
	Raivavae	100.0	93.3	73.3
	Tikehau	100.0	79.2	70.8
Federated States of Micronesia	Piis-Panewu	100.0	100.0	66.7
	Riiken	100.0	57.1	100.0
	Romanum	100.0	83.3	100.0
	Yyin	100.0	69.2	92.3
Kiribati	Abaiang	100.0	68.0	32.0
	Abemama	100.0	96.0	68.0
	Kiritimati	100.0	68.0	84.0
	Kuria	100.0	65.2	82.6
Marshall Islands	Ailuk	100.0	100.0	100.0
	Arno	100.0	100.0	100.0
	Laura	100.0	83.3	91.7
	Likiep	100.0	100.0	90.0
Nauru	All Nauru	100.0	74.7	91.8
New Caledonia	Luengoni	100.0	50.0	90.0
	Moindou	100.0	97.5	57.5
	Ouassé	100.0	100.0	90.0
	Oundjo	100.0	96.2	88.5
	Thio	100.0	100.0	95.2
Niue	All Niue	99.1	84.4	91.7
Palau	Airai	100.0	66.7	77.8
	Koror	98.0	66.7	92.2
	Ngarchelong	100.0	80.0	76.0
	Ngatpang	100.0	60.0	88.0
Papua New Guinea	Andra	100.0	100.0	100.0
	Panapompom	100.0	96.7	100.0
	Sideia	100.0	100.0	90.0
	Tsoilaunung	100.0	100.0	100.0
Samoa	Manono-uta	100.0	97.0	97.0
	Salelavalu	100.0	68.8	95.8
	Vailoa	100.0	86.4	97.7
	Vaisala	100.0	79.2	100.0

Table A4.1.2: Proportion of households consuming finfish, invertebrates and canned fish in 63 communities surveyed, and the regional average (continued)

Country/Territory	Site	Percentage of households consuming:		
		Finfish	Invertebrates	Canned fish
Solomon Islands	Chubikopi	100.0	88.1	95.2
	Marau	100.0	98.0	64.0
	Nggela	100.0	98.0	61.2
	Rarumana	100.0	97.6	85.4
Tonga	Ha'atafu	100.0	95.2	90.5
	Koulo	100.0	51.9	92.6
	Lofanga	100.0	95.0	90.0
	Manuka	100.0	73.7	84.2
Tuvalu	Funafuti	96.7	73.3	63.3
	Niutao	100.0	38.5	84.6
	Nukufetau	100.0	42.9	57.1
	Vaitupu	100.0	58.6	62.1
Vanuatu	Maskelynes	100.0	96.8	93.5
	Moso	100.0	76.9	96.2
	Paunagisu	100.0	68.4	89.5
	Uri-Uripiv	100.0	100.0	100.0
Wallis and Futuna	All Futuna	100.0	42.1	94.7
	Halalo	100.0	82.8	55.2
	Vailala	96.9	34.4	65.6
Regional (n = 63)	**Minimum**	**96.7**	**34.4**	**0.0**
	Maximum	**100.0**	**100.0**	**100.0**
	Average	**99.8**	**80.9**	**82.6**
	Standard Error	**0.08**	**2.39**	**2.28**

Table A4.1.3: Average frequency of finfish, invertebrates and canned fish consumption per each community surveyed, and the regional average

Country/ Territory	Site	Frequency of consumption (days/week)			Standard error (SE)		
		Finfish	Invertebrates	Canned fish	Finfish	Invertebrates	Canned fish
Cook Islands	Aitutaki	3.3	0.2	1.6	0.3	0.1	0.4
	Mangaia	3.2	0.7	1.1	0.3	0.1	0.2
	Palmerston	5.3	0.3	0.0	0.4	0.2	0.0
	Rarotonga	1.8	0.3	1.2	0.2	0.1	0.2
Fiji Islands	Dromuna	2.9	1.6	0.5	0.1	0.2	0.1
	Lakeba	3.4	2.8	0.4	0.1	0.3	0.1
	Mali	3.6	2.1	0.5	0.1	0.3	0.1
	Muaivuso	2.7	1.7	0.6	0.1	0.2	0.1
French Polynesia	Fakarava	3.7	0.2	0.6	0.4	0.1	0.2
	Maatea	3.9	0.3	1.3	0.3	0.1	0.4
	Mataiea	2.7	0.1	0.3	0.4	0.0	0.1
	Raivavae	2.3	1.1	0.5	0.3	0.3	0.1
	Tikehau	4.0	0.2	0.7	0.4	0.1	0.2
Federated States of Micronesia	Piis-Panewu	3.9	2.3	0.6	0.1	0.3	0.2
	Riiken	2.3	0.4	4.0	0.3	0.1	0.3
	Romanum	5.6	1.4	2.5	0.3	0.3	0.4
	Yyin	2.8	0.3	3.1	0.5	0.1	0.7
Kiribati	Abaiang	5.5	0.9	0.4	0.4	0.2	0.2
	Abemama	6.3	0.8	0.8	0.3	0.2	0.2
	Kiritimati	4.9	0.7	0.9	0.3	0.1	0.2
	Kuria	5.7	0.3	0.8	0.4	0.1	0.2
Marshall Islands	Ailuk	4.5	1.1	0.8	0.2	0.1	0.1
	Arno	3.2	1.4	1.2	0.2	0.2	0.2
	Laura	2.4	0.7	1.5	0.1	0.2	0.3
	Likiep	4.3	0.7	0.9	0.2	0.1	0.2
Nauru	All Nauru	3.8	0.5	2.4	0.1	0.0	0.1
New Caledonia	Luengoni	2.8	0.6	2.8	0.4	0.2	0.4
	Moindou	1.4	0.6	0.4	0.2	0.1	0.1
	Ouassé	2.1	0.9	1.0	0.3	0.2	0.7
	Oundjo	3.1	1.5	1.6	0.3	0.2	0.3
	Thio	2.5	1.0	1.2	0.2	0.1	0.2
Niue	All Niue	2.0	0.5	2.0	0.1	0.0	0.1
Palau	Airai	4.0	0.9	2.1	0.4	0.2	0.4
	Koror	4.4	0.9	2.1	0.3	0.2	0.2
	Ngarchelong	4.3	0.7	1.6	0.5	0.1	0.3
	Ngatpang	4.1	0.6	1.7	0.3	0.1	0.2
Papua New Guinea	Andra	3.8	1.1	1.7	0.3	0.1	0.2
	Panapompom	2.8	0.8	0.5	0.3	0.1	0.2
	Sideia	3.0	2.5	0.2	0.3	0.2	0.0
	Tsoilaunung	3.8	1.6	1.2	0.3	0.2	0.2
Samoa	Manono-uta	4.2	0.5	2.3	0.1	0.1	0.2
	Salelavalu	4.3	0.4	2.9	0.2	0.1	0.2
	Vailoa	3.3	0.6	3.4	0.2	0.1	0.2
	Vaisala	3.7	0.5	3.0	0.2	0.1	0.2

Table A4.1.3: Average frequency of finfish, invertebrates and canned fish consumption per each community surveyed, and the regional average (continued)

Country/ Territory	Site	Frequency of consumption (days/week)			Standard error (SE)		
		Finfish	Invertebrates	Canned fish	Finfish	Invertebrates	Canned fish
Solomon Islands	Chubikopi	3.6	0.9	1.0	0.1	0.1	0.1
	Marau	3.7	1.3	0.7	0.1	0.1	0.1
	Nggela	3.5	1.2	0.8	0.1	0.1	0.2
	Rarumana	3.5	1.3	0.9	0.1	0.1	0.1
Tonga	Ha'atafu	3.8	1.3	2.0	0.3	0.2	0.3
	Koulo	2.8	0.9	2.3	0.3	0.2	0.3
	Lofanga	2.9	1.8	2.1	0.2	0.2	0.3
	Manuka	4.4	0.6	1.4	0.5	0.2	0.2
Tuvalu	Funafuti	5.6	0.7	0.6	0.4	0.2	0.2
	Niutao	5.5	0.4	0.5	0.4	0.2	0.1
	Nukufetau	6.7	0.2	0.3	0.1	0.1	0.1
	Vaitupu	6.4	0.4	0.6	0.3	0.1	0.1
Vanuatu	Maskelynes	3.1	1.7	0.6	0.3	0.2	0.2
	Moso	1.4	0.3	3.5	0.2	0.1	0.4
	Paunagisu	1.7	0.7	3.2	0.2	0.1	0.4
	Uri-Uripiv	1.3	2.0	1.2	0.2	0.3	0.2
Wallis and Futuna	All Futuna	3.1	0.4	1.6	0.2	0.1	0.2
	Halalo	4.5	0.9	0.6	0.3	0.2	0.1
	Vailala	3.2	0.2	0.7	0.3	0.1	0.1
Regional (n = 63)	**Average**	**3.6**	**0.9**	**1.4**	**0.3**	**0.1**	**0.2**
	SE	**0.2**	**0.1**	**0.1**	**0.0**	**0.0**	**0.0**

Table A4.1.4: Average annual per capita consumption (kg) of finfish, invertebrates and canned fish per each community surveyed, and the regional average (Per capita figures are age–gender corrected.)

Country/ Territory	Site	Per capita consumption of:			Standard error (SE)		
		Finfish	Invertebrates	Canned fish	Finfish	Invertebrates	Canned fish
Cook Islands	Aitutaki	58.1	2.5	20.4	6.9	0.9	5.2
	Mangaia	75.7	7.6	15.1	15.4	2.0	3.2
	Palmerston	92.8	3.3	0.0	14.0	2.8	0.0
	Rarotonga	74.2	1.5	10.9	26.9	0.6	2.0
Fiji Islands	Dromuna	74.1	4.4	2.9	6.3	0.7	0.8
	Lakeba	73.1	10.5	1.9	4.5	1.7	0.5
	Mali	80.7	13.1	1.8	4.8	5.3	0.4
	Muaivuso	67.9	10.2	3.0	8.4	2.7	0.9
French Polynesia	Fakarava	69.8	5.2	4.1	11.2	2.5	1.3
	Maatea	58.7	1.1	5.1	6.2	0.4	1.4
	Mataiea	44.0	1.4	2.4	5.8	0.4	1.2
	Raivavae	34.6	10.3	4.3	6.9	2.7	1.2
	Tikehau	67.8	2.8	4.3	8.9	1.2	1.4
Federated States of Micronesia	Piis-Panewu	77.7	23.2	2.4	10.4	7.2	0.7
	Riiken	47.3	10.3	47.2	7.6	3.2	6.3
	Romanum	84.9	27.1	11.9	7.9	8.0	2.9
	Yyin	52.1	2.9	25.5	13.5	2.6	5.7
Kiribati	Abaiang	88.1	5.8	4.0	9.8	3.0	2.2
	Abemama	116.7	3.3	5.5	11.1	1.3	1.1
	Kiritimati	111.1	8.2	6.6	9.7	1.8	1.5
	Kuria	113.3	0.9	7.8	12.0	0.5	2.1
Marshall Islands	Ailuk	119.7	5.3	4.1	9.8	1.0	1.0
	Arno	82.5	6.6	6.0	12.1	1.5	1.2
	Laura	89.5	4.9	6.8	17.9	1.3	1.7
	Likiep	128.2	9.3	3.4	13.5	3.5	0.6
Nauru	All Nauru	51.2	1.6	15.9	2.9	0.2	1.1
New Caledonia	Luengoni	34.2	4.0	15.2	6.2	1.3	4.1
	Moindou	24.6	6.6	1.2	5.3	1.3	0.4
	Ouassé	18.9	6.4	5.4	4.0	2.3	3.9
	Oundjo	31.4	16.2	5.8	5.1	3.5	1.3
	Thio	17.8	11.5	4.9	2.5	2.4	0.8
Niue	All Niue	31.0	2.5	17.2	2.0	0.3	1.3
Palau	Airai	51.6	7.7	6.6	8.9	3.1	1.9
	Koror	65.6	5.2	5.6	7.3	2.1	0.8
	Ngarchelong	55.3	26.7	6.5	8.7	13.5	1.5
	Ngatpang	57.8	8.3	5.5	10.4	2.8	1.0
Papua New Guinea	Andra	32.9	5.8	11.8	4.9	1.1	1.7
	Panapompom	33.0	2.2	2.7	4.3	0.6	0.9
	Sideia	20.6	9.5	1.2	2.4	2.2	0.2
	Tsoilaunung	35.6	11.3	6.9	4.7	3.0	1.1
Samoa	Manono-uta	77.5	4.1	21.4	4.7	0.7	4.6
	Salelavalu	65.4	13.6	19.3	5.3	3.9	2.5
	Vailoa	51.3	8.5	28.3	5.0	2.1	2.8
	Vaisala	60.3	14.8	30.1	5.3	4.6	3.7

Table A4.1.4: Average annual per capita consumption (kg) of finfish, invertebrates and canned fish per each community surveyed, and the regional average (Per capita figures are age–gender corrected.) (continued)

Country/ Territory	Site	Per capita consumption of:			Standard error (SE)		
		Finfish	Invertebrates	Canned fish	Finfish	Invertebrates	Canned fish
Solomon Islands	Chubikopi	109.9	8.5	4.5	5.9	2.4	0.5
	Marau	99.3	7.5	3.2	6.8	1.3	0.8
	Nggela	103.4	17.5	3.6	6.6	2.2	0.6
	Rarumana	104.5	9.8	3.8	9.4	1.4	0.7
Tonga	Ha'atafu	91.8	17.7	17.2	17.1	7.3	3.3
	Koulo	46.6	6.7	18.6	8.5	1.8	2.9
	Lofanga	65.2	16.8	21.2	13.0	2.7	3.7
	Manuka	77.6	2.3	10.0	10.7	0.7	2.2
Tuvalu	Funafuti	128.9	4.6	2.3	11.0	1.2	0.9
	Niutao	119.5	5.6	3.0	11.1	2.6	0.9
	Nukufetau	167.2	3.6	1.5	7.7	1.5	0.5
	Vaitupu	139.3	0.9	2.5	10.3	0.3	0.6
Vanuatu	Maskelynes	21.1	3.9	1.6	3.3	0.7	0.5
	Moso	18.4	3.4	18.8	4.2	1.1	4.1
	Paunagisu	16.3	5.3	12.1	2.7	2.7	2.0
	Uri-Uripiv	9.7	3.2	4.6	2.3	0.9	1.0
Wallis and Futuna	All Futuna	43.2	3.7	7.3	4.5	0.8	0.7
	Halalo	60.3	4.8	3.3	8.3	2.4	1.1
	Vailala	48.9	0.6	4.2	8.4	0.3	1.1
Regional (n = 63)	**Average**	**67.8**	**7.5**	**8.9**	**8.1**	**2.3**	**1.8**
	SE	**4.4**	**0.8**	**1.1**	**0.6**	**0.3**	**0.2**

4.1.3 Income data tables

Country/ Territory	Site	Percentage of households with:							
		Primary income				Secondary income			
		Fisheries	Salaries	Agriculture	Others	Fisheries	Salaries	Agriculture	Others
Cook Islands	Aitutaki	6.7	56.7	16.7	33.3	23.3	13.3	6.7	10.0
	Mangaia	2.6	41.0	5.1	56.4	7.7	7.7	12.8	23.1
	Palmerston	40.0	50.0	0.0	20.0	0.0	20.0	0.0	30.0
	Rarotonga	0.0	66.1	5.1	33.9	0.0	5.1	6.8	13.6
Fiji Islands	Dromuna	86.7	6.7	6.7	0.0	13.3	6.7	33.3	20.0
	Lakeba	65.0	0.0	10.0	25.0	35.0	0.0	10.0	5.0
	Mali	87.5	12.5	0.0	0.0	12.5	0.0	6.3	50.0
	Muaivuso	40.0	40.0	0.0	20.0	33.3	6.7	13.3	6.7
French Polynesia	Fakarava	12.0	48.0	16.0	24.0	4.0	8.0	24.0	32.0
	Maatea	17.9	21.4	17.9	42.9	10.7	3.6	10.7	42.9
	Mataiea	3.2	90.3	0.0	6.5	22.6	0.0	6.5	45.2
	Raivavae	6.7	43.3	13.3	33.3	6.7	10.0	16.7	16.7
	Tikehau	37.5	20.8	12.5	29.2	12.5	25.0	12.5	33.3
Federated States of Micronesia	Piis-Panewu	100.0	0.0	0.0	0.0	0.0	5.6	5.6	38.9
	Riiken	0.0	67.9	14.3	17.9	10.7	0.0	35.7	3.6
	Romanum	91.7	8.3	0.0	0.0	0.0	4.2	4.2	4.2
	Yyin	0.0	61.5	23.1	23.1	7.7	15.4	38.5	0.0
Kiribati	Abaiang	56.0	24.0	8.0	12.0	0.0	8.0	24.0	16.0
	Abemama	24.0	16.0	56.0	4.0	28.0	0.0	36.0	4.0
	Kiritimati	36.0	28.0	36.0	4.0	32.0	0.0	24.0	0.0
	Kuria	17.4	4.3	73.9	0.0	39.1	0.0	21.7	0.0
Marshall Islands	Ailuk	10.5	15.8	10.5	63.2	10.5	10.5	52.6	21.1
	Arno	93.3	6.7	0.0	0.0	6.7	0.0	60.0	26.7
	Laura	25.0	50.0	16.7	12.5	33.3	8.3	25.0	8.3
	Likiep	15.0	0.0	10.0	70.0	20.0	15.0	25.0	0.0
Nauru	All Nauru	4.9	85.7	0.4	6.9	17.1	2.9	1.2	6.9
New Caledonia	Luengoni	6.7	53.3	3.3	43.3	10.0	0.0	20.0	13.3
	Moindou	12.5	40.0	5.0	45.0	17.5	7.5	2.5	7.5
	Ouassé	0.0	40.0	0.0	60.0	20.0	0.0	0.0	30.0
	Oundjo	50.0	42.3	0.0	15.4	30.8	15.4	3.8	26.9
	Thio	47.6	19.0	0.0	35.7	35.7	4.8	2.4	19.0
Niue	All Niue	1.4	61.0	5.0	34.4	8.7	10.1	12.8	22.5
Palau	Airai	14.8	51.9	7.4	33.3	14.8	11.1	3.7	14.8
	Koror	5.9	72.5	2.0	23.5	3.9	2.0	0.0	17.6
	Ngarchelong	12.0	56.0	4.0	32.0	24.0	0.0	8.0	4.0
	Ngatpang	8.0	84.0	4.0	4.0	20.0	8.0	4.0	16.0
Papua New Guinea	Andra	50.0	3.3	0.0	50.0	50.0	0.0	0.0	26.7
	Panapompom	43.3	13.3	20.0	26.7	33.3	3.3	6.7	40.0
	Sideia	70.0	20.0	10.0	3.3	20.0	3.3	53.3	3.3
	Tsoilaunung	50.0	16.7	6.7	26.7	26.7	6.7	13.3	30.0
Samoa	Manono-uta	32.8	28.4	16.4	23.9	31.3	11.9	14.9	17.9
	Salelavalu	33.3	20.8	29.2	16.7	27.1	14.6	35.4	2.1
	Vailoa	15.9	13.6	36.4	31.8	25.0	9.1	29.5	4.5
	Vaisala	14.6	4.2	37.5	43.8	22.9	10.4	35.4	4.2

Others referes to small private businesses, transport, shops, bakeries etc.

4.1.3 Income data tables (continued)

Country/ Territory	Site	Percentage of households with:							
		Primary income				Secondary income			
		Fisheries	Salaries	Agriculture	Others	Fisheries	Salaries	Agriculture	Others
Solomon Islands	Chubikopi	16.7	16.7	11.9	54.8	33.3	0.0	21.4	19.0
	Marau	46.0	10.0	28.0	16.0	30.0	2.0	36.0	12.0
	Nggela	36.7	6.1	44.9	12.2	46.9	0.0	32.7	2.0
	Rarumana	17.1	12.2	48.8	17.1	17.1	0.0	36.6	17.1
Tonga	Ha'atafu	28.6	33.3	0.0	42.9	4.8	14.3	28.6	23.8
	Koulo	14.8	29.6	18.5	37.0	3.7	7.4	14.8	33.3
	Lofanga	70.0	5.0	10.0	15.0	5.0	0.0	30.0	60.0
	Manuka	52.6	15.8	10.5	21.1	5.3	21.1	10.5	5.3
Tuvalu	Funafuti	30.0	50.0	0.0	20.0	23.3	13.3	0.0	26.7
	Niutao	34.6	50.0	0.0	15.4	3.8	7.7	0.0	7.7
	Nukufetau	10.7	57.1	0.0	17.9	46.4	7.1	3.6	7.1
	Vaitupu	20.7	51.7	0.0	24.1	24.1	13.8	0.0	13.8
Vanuatu	Maskelynes	3.2	3.2	90.3	3.2	61.3	0.0	9.7	16.1
	Moso	15.4	7.7	69.2	11.5	57.7	0.0	26.9	3.8
	Paunagisu	28.9	5.3	55.3	13.2	26.3	7.9	39.5	15.8
	Uri-Uripiv	37.9	27.6	17.2	17.2	13.8	3.4	24.1	13.8
Wallis and Futuna	All Futuna	6.6	44.7	3.9	43.4	13.2	5.3	22.4	31.6
	Halalo	37.9	44.8	6.9	13.8	34.5	3.4	6.9	34.5
	Vailala	0.0	73.1	9.4	21.9	15.4	7.7	18.8	34.4
Regional (n = 63)	**Average**	**29.5**	**32.5**	**15.3**	**23.9**	**20.2**	**6.5**	**17.8**	**18.0**
	SE	**3.3**	**3.1**	**2.5**	**2.2**	**1.8**	**0.8**	**1.9**	**1.7**

Others refers to small private businesses, transport, shops, bakeries etc.

4.1.4 Finfish catch data tables

Table A4.1.5: Average proportion (%) of major finfish families in extrapolated total annual catch by site, and the regional average for the 63 communities studied

Country/ Territory	Site	Leth.	Serr.	Acan.	Cara.	Lutja.	Mug.	Scar.	Holo.	Mull.	Siga.	Kyph.	Labri.	Bali.	Other
Melanesia															
Fiji Islands	Dromuna	25.0	6.6	6.3	7.1	9.5	9.5	3.0	4.9	2.3	3.3	0.0	0.0	4.3	18.2
	Lakeba	47.0	10.9	9.6	4.6	5.2	8.7	1.4	0.0	2.0	0.0	0.0	0.0	1.0	9.5
	Mali	46.8	10.9	9.0	7.8	1.9	1.2	1.7	0.0	0.2	0.6	0.0	0.0	0.2	19.8
	Muaivuso	30.9	9.2	5.8	0.8	15.3	7.4	5.2	2.4	3.8	1.7	0.0	0.0	1.9	15.7
New Caledonia	Luengoni	20.5	15.4	15.0	1.2	7.5	0.2	20.8	0.0	8.0	6.0	0.0	0.0	0.0	5.3
	Moindou	17.3	4.5	1.5	3.0	0.6	44.7	1.2	0.0	9.9	11.5	0.0	0.6	0.0	5.2
	Ouassé	15.8	11.1	16.9	1.1	0.0	20.0	16.8	0.0	1.4	13.0	0.0	0.0	0.0	3.9
	Oundjo	28.2	3.4	11.8	1.1	2.3	17.6	9.9	0.0	1.7	16.1	0.0	0.0	0.0	7.9
	Thio	25.9	27.1	8.6	3.0	5.1	11.7	8.7	0.0	1.0	4.9	0.0	0.0	0.0	3.9
Papua New Guinea	Andra	20.7	2.6	3.1	7.6	12.0	1.9	4.6	0.0	5.4	0.1	0.0	0.4	1.2	40.3
	Panapompom	10.4	7.2	0.0	10.5	35.2	0.0	0.7	0.7	0.5	1.8	0.0	1.5	1.7	29.9
	Sideia	4.2	7.5	1.4	15.4	8.1	0.3	7.0	2.3	2.4	2.5	7.2	0.0	3.2	38.5
	Tsoilaunung	22.9	3.6	3.3	12.9	8.7	4.3	11.1	0.1	0.0	12.3	0.0	0.7	2.1	17.9
Solomon Islands	Chubikopi	5.4	13.2	1.9	6.7	28.9	1.0	15.2	1.1	0.4	2.4	0.0	3.6	4.6	15.6
	Marau	5.4	8.8	9.5	8.7	15.7	2.8	9.2	2.8	1.9	2.2	0.0	2.2	3.0	27.8
	Nggela	8.4	21.0	6.9	12.6	9.7	0.8	2.1	9.3	1.3	2.0	0.3	1.4	2.2	22.0
	Rarumana	22.7	9.4	3.8	2.3	18.1	5.4	10.4	0.0	3.8	1.3	0.0	8.5	6.2	8.1
Vanuatu	Maskelynes	28.9	3.1	1.4	10.0	2.1	3.0	3.6	0.4	9.0	20.2	1.5	0.0	3.8	12.9
	Moso	7.3	1.1	21.9	7.3	1.0	2.2	27.5	1.8	5.5	6.7	0.0	0.0	3.3	14.5
	Paunagisu	12.9	0.4	6.4	9.9	0.6	16.8	11.4	1.4	10.4	15.7	2.1	0.1	8.8	3.1
	Uri-Uripiv	22.1	0.6	6.4	15.3	0.0	8.8	5.9	1.0	5.7	10.6	13.8	0.0	2.2	7.6

Leth. = Lethrinidae; Serr. = Serranidae; Acan. = Acanthuridae; Cara. = Carangidae; Lutja. = Lutjanidae; Mug. = Mugilidae; Scar. = Scaridae; Holo. = Holocentridae; Mull. = Mullidae; Siga. = Siganidae; Kyph. = Kyphosidae; Labri. = Labridae; Bali. = Balistidae; Other refers to any other fish family not specifically included in this table for which catch data was reported at any one time, or at very few of the sites surveyed, and whose contribution to the total catch was minor or not significant, for example, Caesionidae, Chanidae, Sphyraenidae, Cirrhitidae, Exocoetidae, Gerreidae, Hemiramphidae.

Table A4.1.5: Average proportion (%) of major finfish families in extrapolated total annual catch by site, and the regional average for the 63 communities studied (continued)

Country/ Territory	Site	Leth.	Serr.	Acan.	Cara.	Lutja.	Mug.	Scar.	Holo.	Mull.	Siga.	Kyph.	Labri.	Bali.	Other
Micronesia															
Federated States of Micronesia	Piis-Panewu	8.5	22.1	23.8	0.0	3.5	0.0	32.9	0.0	3.3	4.5	0.0	0.8	0.0	0.5
	Riiken	5.8	0.0	41.7	10.7	1.1	1.4	20.4	0.6	1.9	11.5	0.0	1.1	0.0	3.7
	Romanum	7.5	10.0	28.4	0.0	0.0	0.0	31.1	0.0	3.8	10.0	0.0	2.1	0.0	7.0
	Yyin	9.3	0.1	23.3	6.3	0.0	0.0	21.2	0.0	2.6	29.9	0.0	0.0	0.0	7.3
Kiribati	Abaiang	19.1	28.5	0.9	1.6	8.4	1.3	6.9	6.4	2.9	0.3	0.8	4.0	0.0	19.0
	Abemama	9.3	1.2	2.7	11.0	3.4	32.4	0.7	0.1	8.0	0.0	0.0	0.0	0.0	31.2
	Kiritimati	0.4	7.5	3.7	1.0	1.9	4.4	0.0	1.0	1.4	0.0	0.0	0.0	0.0	78.6
	Kuria	7.8	5.9	2.6	31.7	30.1	8.0	0.3	0.5	2.1	1.3	0.4	0.0	0.6	8.7
Marshall Islands	Ailuk	8.8	31.6	3.9	1.0	21.6	0.0	0.6	0.0	8.7	19.0	2.1	0.0	0.3	2.3
	Arno	9.8	15.7	18.3	0.0	13.2	0.0	8.2	5.5	1.5	16.4	10.2	0.6	0.0	0.5
	Laura	9.5	35.8	9.3	3.0	16.6	0.6	3.3	5.7	1.0	7.4	4.1	0.0	0.0	3.5
	Likiep	13.9	32.1	6.5	3.1	17.4	0.0	5.8	0.9	3.5	6.1	5.8	0.0	0.9	3.9
Nauru	All Nauru	0.0	6.6	34.1	7.1	10.4	3.8	8.3	10.9	0.0	0.0	4.5	0.0	4.0	10.3
Palau	Airai	28.3	9.0	3.3	3.7	18.5	6.6	8.8	1.0	1.2	17.4	0.4	0.0	0.0	1.7
	Koror	17.8	7.2	19.6	0.0	11.6	0.0	26.8	2.0	4.4	7.0	1.1	0.2	0.2	2.2
	Ngarchelong	30.1	13.1	7.3	4.0	16.8	1.8	10.6	0.2	1.9	6.7	0.1	1.2	0.0	6.2
	Ngatpang	31.2	16.3	7.9	0.9	10.6	0.0	7.9	0.5	4.8	17.5	0.0	1.2	0.0	1.2

Leth. = Lethrinidae; Serr. = Serranidae; Acan. = Acanthuridae; Cara. = Carangidae; Lutja. = Lutjanidae; Mug. = Mugilidae; Scar. = Scaridae; Holo. = Holocentridae; Mull. = Mullidae; Siga. = Siganidae; Kyph. = Kyphosidae; Labri. = Labridae; Bali. = Balistidae; Other refers to any other fish family not specifically included in this table for which catch data was reported at any one time, or at very few of the sites surveyed, and whose contribution to the total catch was minor or not significant, for example, Caesionidae, Chanidae, Sphyraenidae, Cirrhitidae, Exocoetidae, Gerreidae, Hemiramphidae etc.

Table A4.1.5: Average proportion (%) of major finfish families in extrapolated total annual catch by site, and the regional average for the 63 communities studied (continued)

Country/ Territory	Site	Leth.	Serr.	Acan.	Cara.	Lutja.	Mug.	Scar.	Holo.	Mull.	Siga.	Kyph.	Labri.	Bali.	Other
Polynesia															
Cook Islands	Aitutaki	4.9	2.0	16.8	1.9	1.2	6.4	46.2	0.6	12.3	0.0	2.4	0.0	0.0	5.2
	Mangaia	0.0	23.0	14.4	1.9	0.0	0.6	5.2	10.5	2.0	0.1	29.4	9.2	0.0	3.6
	Palmerston	0.0	5.9	1.1	4.6	4.8	2.2	77.4	2.8	0.1	0.0	1.1	0.0	0.0	0.0
	Rarotonga	5.3	8.0	9.2	1.4	3.2	0.2	18.3	5.7	1.8	18.5	25.1	0.0	0.0	3.4
French Polynesia	Fakarava	2.7	11.2	24.7	15.3	2.6	0.0	24.5	16.1	0.0	0.0	0.0	0.0	0.0	2.9
	Maatea	7.3	10.4	21.5	16.3	4.7	0.0	13.0	6.1	7.2	9.1	0.2	1.0	0.0	3.0
	Mataiea	2.4	10.6	22.1	16.6	5.7	0.0	16.8	15.6	3.4	1.4	1.5	3.8	0.0	0.2
	Raivavae	1.5	14.9	21.1	7.7	0.0	1.6	32.4	5.3	1.0	5.8	8.5	0.0	0.0	0.2
	Tikehau	8.9	0.1	7.7	35.9	8.4	0.0	4.0	7.0	8.8	0.0	0.0	0.0	0.0	19.3
Niue	All Niue	0.3	6.4	2.4	20.7	1.3	1.9	2.2	22.3	1.2	0.0	25.0	4.7	0.3	11.4
Samoa	Manono-uta	14.1	3.2	22.2	1.9	7.0	4.8	17.1	6.3	5.2	5.5	1.2	1.6	0.5	9.4
	Salelavalu	14.8	4.9	21.1	1.9	3.9	10.4	15.3	9.5	3.0	6.2	0.8	0.7	0.6	6.9
	Vailoa	13.7	6.4	20.6	2.2	6.6	2.9	17.6	6.2	3.8	7.8	0.7	4.3	1.0	6.3
	Vaisala	11.7	5.4	27.7	0.5	4.2	2.2	25.0	10.3	3.0	0.9	0.0	1.2	1.2	6.7
Tonga	Ha'atafu	70.5	4.8	1.2	6.2	2.1	1.1	7.1	0.0	0.0	0.0	2.4	1.8	0.0	2.8
	Koulo	15.7	12.2	15.2	3.7	19.1	3.0	13.5	0.7	4.6	6.1	3.7	1.2	0.0	1.3
	Lofanga	36.3	18.2	15.9	1.0	9.4	0.0	11.3	1.0	1.1	3.4	0.0	1.4	0.0	0.9
	Manuka	38.7	8.3	19.5	1.3	7.1	0.0	11.9	1.7	0.0	9.3	0.0	0.9	0.8	0.4
Tuvalu	Funafuti	18.7	16.4	17.7	3.3	17.6	4.4	1.3	0.6	0.0	2.7	7.5	0.0	0.1	9.7
	Niutao	0.0	7.2	34.1	3.6	2.6	8.0	4.1	8.4	0.0	0.0	18.2	0.4	0.0	13.4
	Nukufetau	9.9	14.4	9.6	8.2	28.1	16.7	2.8	3.3	0.4	0.5	1.2	0.0	0.0	4.8
	Vaitupu	9.1	5.8	8.1	6.2	10.3	26.4	4.3	4.3	2.8	0.0	7.9	0.0	0.0	14.8
Wallis and Futuna	All Futuna	3.9	5.6	25.2	7.8	4.3	11.0	3.5	6.1	3.4	0.0	4.8	0.0	0.0	24.5
	Halalo	27.6	2.6	12.8	17.0	18.3	1.8	4.3	1.6	2.9	0.0	1.0	0.1	0.1	9.6
	Vailala	11.9	2.8	27.3	12.0	6.3	9.9	6.8	1.6	1.7	0.0	0.3	0.0	0.2	19.0
Regional average		**15.5**	**10.0**	**12.8**	**6.9**	**8.8**	**5.5**	**12.0**	**3.4**	**3.2**	**5.8**	**3.1**	**1.0**	**1.0**	**11.0**
SE		**1.7**	**1.0**	**1.2**	**0.9**	**1.0**	**1.1**	**1.6**	**0.6**	**0.4**	**0.8**	**0.8**	**0.2**	**0.2**	**1.6**

Leth. = Lethrinidae; Serr. = Serranidae; Acan. = Acanthuridae; Cara. = Carangidae; Lutja. = Lutjanidae; Mug. = Mugilidae; Scar. = Scaridae; Holo. = Holocentridae; Mull. = Mullidae; Siga. = Siganidae; Kyph. = Kyphosidae; Labri. = Labridae; Bali. = Balistidae; Other refers to any other fish family not specifically included in this table for which catch data was reported at any one time, or at very few of the sites surveyed, and whose contribution to the total catch was minor or not significant , for example, Caesionidae, Chanidae, Sphyraenidae, Cirrhitidae, Exocoetidae, Gerreidae, Hemiramphidae etc.

Table A4.1.6: Average proportion (%) of major finfish families in extrapolated total annual catch by country and cultural group, and overall regional average 63 sites)

Country/Territory	Leth.	Serr.	Acan.	Cara.	Lutja.	Mug.	Scar.	Holo.	Mull.	Siga.	Kyph.	Labri.	Bali.	Other
Melanesia														
Fiji Islands	37.4	9.4	7.7	5.1	8.0	6.7	2.8	1.8	2.1	1.4	0.0	0.0	1.8	15.8
New Caledonia	21.5	12.3	10.7	1.9	3.1	18.8	11.5	0.0	4.4	10.3	0.0	0.1	0.0	5.3
Papua New Guinea	14.5	5.2	1.9	11.6	16.0	1.6	5.8	0.7	2.1	4.2	1.8	0.7	2.1	31.7
Solomon Islands	10.5	13.1	5.5	7.6	18.1	2.5	9.2	3.3	1.8	2.0	0.1	3.9	4.0	18.4
Vanuatu	17.8	1.3	9.0	10.6	0.9	7.7	12.1	1.2	7.6	13.3	4.4	0.0	4.5	9.5
Average (Melanesia)	**20.4**	**8.5**	**7.2**	**7.1**	**8.9**	**8.0**	**8.4**	**1.3**	**3.6**	**6.4**	**1.2**	**0.9**	**2.4**	**15.6**
SE (n = 21)	**2.6**	**1.5**	**1.2**	**1.0**	**2.1**	**2.3**	**1.5**	**0.5**	**0.7**	**1.3**	**0.7**	**0.4**	**0.5**	**2.4**
Micronesia														
Federated States of Micronesia	7.8	8.1	29.3	4.2	1.2	0.4	26.4	0.1	2.9	14.0	0.0	1.0	0.0	4.6
Kiribati	9.2	10.8	2.5	11.3	11.0	11.5	2.0	2.0	3.6	0.4	0.3	1.0	0.1	34.4
Marshall Islands	10.5	28.8	9.5	1.8	17.2	0.2	4.5	3.0	3.7	12.2	5.6	0.2	0.3	2.6
Nauru	0.0	6.6	34.1	7.1	10.4	3.8	8.3	10.9	0.0	0.0	4.5	0.0	4.0	10.3
Palau	26.8	11.4	9.5	2.2	14.4	2.1	13.5	0.9	3.1	12.1	0.4	0.6	0.1	2.8
Average (Micronesia)	**12.8**	**14.3**	**14.0**	**5.0**	**10.9**	**3.6**	**11.4**	**2.1**	**3.1**	**9.1**	**1.7**	**0.7**	**0.3**	**11.1**
SE (n = 17)	**2.3**	**2.8**	**3.0**	**1.9**	**2.1**	**1.9**	**2.6**	**0.8**	**0.6**	**2.1**	**0.7**	**0.3**	**0.2**	**4.6**
Polynesia														
Cook Islands	2.6	9.7	10.4	2.4	2.3	2.4	36.8	4.9	4.1	4.6	14.5	2.3	0.0	3.1
French Polynesia	4.6	9.4	19.4	18.4	4.3	0.3	18.1	10.0	4.0	3.3	2.0	1.0	0.0	5.1
Niue	0.3	6.4	2.4	20.7	1.3	1.9	2.2	22.3	1.2	0.0	25.0	4.7	0.3	11.4
Samoa	13.6	5.0	22.9	1.6	5.4	5.1	18.7	8.1	3.7	5.1	0.7	1.9	0.8	7.3
Tonga	40.3	10.9	12.9	3.1	9.4	1.0	11.0	0.8	1.4	4.7	1.5	1.3	0.2	1.4
Tuvalu	9.4	10.9	17.4	5.3	14.7	13.9	3.1	4.1	0.8	0.8	8.7	0.1	0.0	10.7
Wallis and Futuna	14.5	3.7	21.8	12.3	9.7	7.6	4.9	3.1	2.7	0.0	2.0	0.0	0.1	17.7
Average (Polynesia)	**13.2**	**8.4**	**16.8**	**8.0**	**7.2**	**4.6**	**15.4**	**6.1**	**2.8**	**3.1**	**5.7**	**1.3**	**0.2**	**7.2**
SE (n = 25)	**3.2**	**1.1**	**1.7**	**1.7**	**1.4**	**1.3**	**3.4**	**1.1**	**0.6**	**0.9**	**1.8**	**0.4**	**0.1**	**1.3**
Regional average	**15.5**	**10.0**	**12.8**	**6.9**	**8.8**	**5.5**	**12.0**	**3.4**	**3.2**	**5.8**	**3.1**	**1.0**	**1.0**	**11.0**
SE (n = 63)	**1.7**	**1.0**	**1.2**	**0.9**	**1.0**	**1.1**	**1.6**	**0.6**	**0.4**	**0.8**	**0.8**	**0.2**	**0.2**	**1.6**

Leth. = Lethrinidae; Serr. = Serranidae; Acan. = Acanthuridae; Cara. = Carangidae; Lutja. = Lutjanidae; Mug. = Mugilidae; Scar. = Scaridae; Holo. = Holocentridae; Mull. = Mullidae; Siga. = Siganidae; Kyph. = Kyphosidae; Labri. = Labridae; Bali. = Balistidae; Other refers to any other fish family not specifically included in this table for which catch data was reported at any one time, or at very few of the sites surveyed, and whose contribution to the total catch was minor or not significant , for example, Caesionidae, Chanidae, Sphyraenidae, Cirrhitidae, Exocoetidae, Gerreidae, Hemiramphidae etc.

4.1.5 Invertebrate catch data tables

Table A4.1.7: Total extrapolated catch in percentage of total reported catch (wet weight) by invertebrate group, and cultural group, and the overall average for the 63 communities studied

Country/ Territory	Site	Bivalves	Crustaceans	Gastropods	Giant clams	Lobsters	Octopus	BdM	Others	Sea urchins	Trochus
Melanesia											
Fiji Islands	Dromuna	12.2	2.3	3.5	0.8	3.2	0.9	75.6	0.4	0.0	1.1
	Lakeba	9.9	1.9	1.0	8.5	1.9	4.1	71.1	0.0	0.0	1.6
	Mali	2.1	12.4	2.6	10.1	5.3	2.6	61.5	0.3	0.0	3.1
	Muaivuso	8.9	1.8	3.1	0.9	0.0	9.7	68.2	2.6	0.0	4.8
New Caledonia	Luengoni	1.6	6.2	8.4	8.1	69.9	1.5	0.0	0.0	0.0	4.4
	Moindou	3.6	95.5	0.3	0.5	0.0	0.1	0.0	0.0	0.0	0.0
	Ouassé	6.7	0.0	23.3	35.5	3.6	14.6	0.0	0.0	0.0	16.3
	Oundjo	23.1	39.7	2.0	2.5	2.5	0.3	13.0	0.0	0.0	16.9
	Thio	0.3	0.8	6.4	4.4	15.8	15.9	14.5	0.0	0.0	41.9
Papua New Guinea	Andra	12.4	0.0	22.2	41.3	0.0	24.2	0.0	0.0	0.0	0.0
	Panapompom	0.0	0.7	9.4	4.5	0.4	0.0	84.8	0.0	0.0	0.1
	Sideia	2.8	4.5	29.6	2.8	0.0	0.0	60.3	0.0	0.0	0.0
	Tsoilaunung	3.0	9.3	1.9	6.5	12.5	0.5	63.1	0.0	0.0	3.1
Solomon Islands	Chubikopi	6.9	23.6	10.6	46.6	9.6	0.4	0.0	0.4	0.0	1.9
	Marau	2.9	16.9	8.4	42.8	3.4	0.9	0.4	7.4	0.0	16.8
	Nggela	7.3	4.3	5.3	60.8	6.1	1.4	2.1	0.0	0.0	12.7
	Rarumana	9.1	6.7	26.5	49.1	2.7	0.7	0.4	0.0	0.0	4.8
Vanuatu	Maskelynes	11.1	9.2	64.7	7.5	0.0	5.5	0.0	0.0	0.0	2.0
	Moso	11.0	0.3	1.9	4.7	0.6	1.1	79.5	0.0	0.0	0.9
	Paunagisu	19.6	38.2	33.3	4.6	0.0	3.4	0.0	0.5	0.0	0.4
	Uri-Uripiv	30.5	8.4	46.0	4.0	0.0	6.8	0.0	4.1	0.0	0.1
Average (Melanesia)		**8.8**	**13.5**	**14.8**	**16.5**	**6.5**	**4.5**	**28.3**	**0.7**	**0.0**	**6.3**
SE		**1.7**	**4.8**	**3.7**	**4.3**	**3.3**	**1.4**	**7.5**	**0.4**	**0.0**	**2.2**

SE = standard error; BdM = bêche-de-mer; Others include *Dolabella* sp., *Dolabella auricularia*, *Sipunculus* sp., *Sipunculus indicus*, *Acanthopleura* sp. and *Acanthopleura gemmata*.

Table A4.1.7: Total extrapolated catch in percentage of total reported catch (wet weight) by invertebrate group, and cultural group, and the overall average for the 63 communities studied

Country/ Territory	Site	Bivalves	Crustaceans	Gastropods	Giant clams	Lobsters	Octopus	BdM	Others	Sea urchins	Trochus
Micronesia											
Federated States of Micronesia	Piis-Panewu	0.4	3.9	0.8	22.1	26.9	16.0	20.2	0.0	0.0	9.8
	Riiken	2.0	0.0	1.9	10.3	85.9	0.0	0.0	0.0	0.0	0.0
	Romanum	0.0	10.1	0.5	10.5	14.8	7.7	35.6	0.0	0.0	20.8
	Yyin	0.2	0.0	5.1	94.6	0.0	0.0	0.0	0.0	0.0	0.0
Kiribati	Abaiang	0.0	0.0	0.0	80.5	4.8	0.0	0.0	14.6	0.0	0.0
	Abemama	7.7	0.0	6.2	22.0	12.6	0.0	0.0	51.4	0.0	0.0
	Kiritimati	0.0	0.0	0.0	80.5	1.0	4.2	14.2	0.0	0.0	0.0
	Kuria	1.1	7.9	0.0	59.9	31.2	0.0	0.0	0.0	0.0	0.0
Marshall Islands	Ailuk	1.5	11.2	55.9	20.3	7.0	4.1	0.0	0.0	0.0	0.0
	Arno	0.0	0.0	10.5	73.8	0.0	15.7	0.0	0.0	0.0	0.0
	Laura	0.0	2.7	63.9	14.0	13.6	5.8	0.0	0.0	0.0	0.0
	Likiep	3.5	26.5	27.2	25.5	14.1	3.2	0.0	0.0	0.0	0.0
Nauru	Nauru	0.8	33.5	28.6	0.0	10.5	13.4	12.3	0.0	0.0	0.7
Palau	Airai	0.0	2.1	0.0	34.8	1.5	0.0	61.7	0.0	0.0	0.0
	Koror	0.0	0.0	0.0	47.2	0.0	0.0	52.8	0.0	0.0	0.0
	Ngarchelong	0.0	0.7	0.0	15.5	1.0	0.0	82.9	0.0	0.0	0.0
	Ngatpang	0.0	4.8	0.0	16.5	0.4	0.0	78.4	0.0	0.0	0.0
Average (Micronesia)		**1.0**	**6.1**	**11.8**	**36.9**	**13.3**	**4.1**	**21.1**	**3.9**	**0.0**	**1.8**
SE		**0.5**	**2.4**	**4.9**	**7.2**	**5.1**	**1.4**	**7.2**	**3.1**	**0.0**	**1.3**

SE = standard error; BdM = bêche-de-mer; Others include *Dolabella* sp., *Dolabella auricularia*, *Sipunculus* sp., *Sipunculus indicus*, *Acanthopleura* sp. and *Acanthopleura gemmata*.

Table A4.1.7: Total extrapolated catch in percentage of total reported catch (wet weight) by invertebrate group, and cultural group, and the overall average for the 63 communities studied

Country/ Territory	Site	Bivalves	Crustaceans	Gastropods	Giant clams	Lobsters	Octopus	BdM	Others	Sea urchins	Trochus
Polynesia											
Cook Islands	Aitutaki	0.5	9.1	30.3	39.5	14.6	0.0	4.9	0.0	0.8	0.4
	Mangaia	0.0	0.6	26.1	24.6	7.7	0.9	35.6	0.0	4.6	0.0
	Palmerston	9.0	5.7	2.3	43.8	32.8	6.4	0.0	0.0	0.0	0.0
	Rarotonga	1.4	1.8	2.8	15.2	5.9	1.9	57.3	0.0	10.9	2.9
French Polynesia	Fakarava	0.0	0.0	4.9	83.7	11.4	0.0	0.0	0.0	0.0	0.0
	Maatea	0.0	7.3	0.3	87.1	0.0	0.0	0.0	0.0	5.3	0.0
	Mataiea	0.0	0.0	2.3	27.0	68.8	0.0	0.0	0.0	1.9	0.0
	Raivavae	0.5	0.7	0.0	84.0	14.5	0.1	0.0	0.0	0.2	0.0
	Tikehau	0.0	0.0	10.4	63.7	25.9	0.0	0.0	0.0	0.0	0.0
Niue	Niue	1.3	5.8	72.1	5.0	10.6	1.2	3.9	0.0	0.2	0.0
Samoa	Manono-uta	2.2	6.6	2.8	37.8	2.9	6.6	38.5	0.1	0.0	2.4
	Salelavalu	3.1	10.5	4.1	7.7	1.6	1.9	67.3	2.1	0.0	1.7
	Vailoa	4.4	12.1	2.1	30.4	2.7	5.6	42.6	0.1	0.0	0.0
	Vaisala	2.8	0.4	0.5	61.5	1.3	1.4	31.7	0.2	0.0	0.2
Tonga	Ha'atafu	0.1	0.0	29.0	0.0	0.0	40.0	20.1	10.9	0.0	0.0
	Koulo	0.0	0.0	2.9	34.0	0.0	37.7	24.9	0.5	0.0	0.0
	Lofanga	0.0	0.0	7.1	64.8	0.0	26.6	1.5	0.0	0.0	0.0
	Manuka	3.5	0.0	18.4	0.2	33.8	9.3	22.9	11.9	0.0	0.0
Tuvalu	Funafuti	6.1	1.0	75.0	8.1	9.8	0.0	0.0	0.0	0.0	0.0
	Niutao	0.0	0.0	4.2	5.5	90.3	0.0	0.0	0.0	0.0	0.0
	Nukufetau	0.1	0.0	66.8	16.5	10.0	6.5	0.0	0.0	0.0	0.0
	Vaitupu	44.6	12.1	38.6	0.0	0.0	4.7	0.0	0.0	0.0	0.0
Wallis and Futuna	All Futuna	0.0	0.6	9.6	38.8	25.4	2.1	0.3	0.0	0.0	23.0
	Halalo	9.1	26.2	0.5	4.5	0.0	4.3	0.0	0.0	0.0	55.3
	Vailala	0.3	0.0	13.0	3.0	66.9	0.1	5.4	0.0	0.0	11.3
Average (Polynesia)		**3.6**	**4.0**	**17.0**	**31.5**	**17.5**	**6.3**	**14.3**	**1.0**	**1.0**	**3.9**
SE		**1.8**	**1.3**	**4.6**	**5.7**	**4.9**	**2.2**	**4.1**	**0.6**	**0.5**	**2.4**

SE = standard error; BdM = bêche-de-mer; Others include *Dolabella* sp., *Dolabella auricularia*, *Sipunculus* sp., *Sipunculus indicus*, *Acanthopleura* sp. and *Acanthopleura gemmata*.

Table A4.1.8: Total extrapolated catch in percentage of total reported catch (wet weight) by invertebrate group, and cultural group, and the overall average for the 63 communities studied

Country/Territory	Giant clams	BdM	Gastropods	Lobsters	Crustaceans	Octopus	Bivalves	Trochus	Others	Sea urchins
Melanesia										
Fiji Islands	5.1	69.1	2.5	2.6	4.6	4.3	8.3	2.7	0.8	0.0
New Caledonia	10.2	5.5	8.1	18.3	28.4	6.5	7.1	15.9	0.0	0.0
Papua New Guinea	13.8	52.1	15.8	3.2	3.6	6.2	4.6	0.8	0.0	0.0
Solomon Islands	49.8	0.7	12.7	5.5	12.9	0.8	6.6	9.1	2.0	0.0
Vanuatu	5.2	19.9	36.5	0.1	14.0	4.2	18.1	0.8	1.2	0.0
Average (Melanesia)	**16.5**	**28.3**	**14.8**	**6.5**	**13.5**	**4.5**	**8.8**	**6.3**	**0.7**	**0.0**
SE (n = 21)	**4.3**	**7.5**	**3.7**	**3.3**	**4.8**	**1.4**	**1.7**	**2.2**	**0.4**	**0.0**
Micronesia										
FSM	34.4	13.9	2.1	31.9	3.5	5.9	0.7	7.6	0.0	0.0
Kiribati	60.7	3.6	1.5	12.4	2.0	1.1	2.2	0.0	16.5	0.0
Marshall Islands	33.4	0.0	39.4	8.7	10.1	7.2	1.2	0.0	0.0	0.0
Nauru	0.0	12.3	28.6	10.5	33.5	13.4	0.8	0.7	0.0	0.0
Palau	28.5	68.9	0.0	0.7	1.9	0.0	0.0	0.0	0.0	0.0
Average (Micronesia)	**36.9**	**21.1**	**11.8**	**13.3**	**6.1**	**4.1**	**1.0**	**1.8**	**3.9**	**0.0**
SE (n = 17)	**7.2**	**7.2**	**4.9**	**5.1**	**2.4**	**1.4**	**0.5**	**1.3**	**3.1**	**0.0**
Polynesia										
Cook Islands	30.8	24.4	15.4	15.3	4.3	2.3	2.7	0.8	0.0	4.0
French Polynesia	69.1	0.0	3.6	24.1	1.6	0.0	0.1	0.0	0.0	1.5
Niue	5.0	3.9	72.1	10.6	5.8	1.2	1.3	0.0	0.0	0.2
Samoa	34.4	45.0	2.4	2.1	7.4	3.9	3.1	1.1	0.6	0.0
Tonga	24.7	17.4	14.3	8.5	0.0	28.4	0.9	0.0	5.8	0.0
Tuvalu	7.5	0.0	46.1	27.5	3.3	2.8	12.7	0.0	0.0	0.0
Wallis and Futuna	15.4	1.9	7.7	30.8	9.0	2.2	3.1	29.9	0.0	0.0
Average (Polynesia)	**31.5**	**14.3**	**17.0**	**17.5**	**4.0**	**6.3**	**3.6**	**3.9**	**1.0**	**1.0**
SE (n = 25)	**5.7**	**4.1**	**4.6**	**4.9**	**1.3**	**2.2**	**1.8**	**2.4**	**0.6**	**0.5**
Regional average	**28.0**	**20.8**	**14.9**	**12.7**	**7.7**	**5.1**	**4.6**	**4.2**	**1.7**	**0.4**
SE (n = 63)	**3.4**	**3.6**	**2.6**	**2.6**	**1.8**	**1.1**	**1.0**	**1.2**	**0.9**	**0.2**

SE = standard error; BdM = bêche-de-mer; Others include *Dolabella* sp., *Dolabella auricularia*, *Sipunculus* sp., *Sipunculus indicus*, *Acanthopleura* sp. and *Acanthopleura gemmata*.

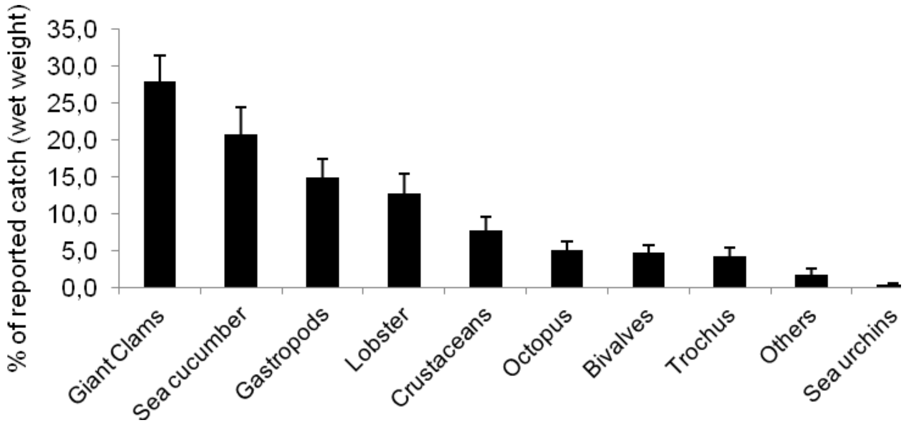


Figure A4.1.57: Regional average (n = 63) of proportional invertebrate catches by species group in percentage of reported catch (wet weight).

4.1.6 Fishing ground data tables

Table A4.1.9: Fishing ground, total reef area and habitat area for 63 communities studied and as defined by socioeconomic and fisher surveys

Country/ Territory	Site	Fishing ground area (km^2)	Reef area (km^2)	Sheltered coastal reef area (km^2) (including mangroves, intertidal flats)	Lagoon area (km^2) (including back-reef)	Outer-reef area (km^2) (including passages)
Cook Islands	Aitutaki	88.1	42.3	10.6	69.9	7.5
	Mangaia	8.4	8.4	0.0	3.6	4.8
	Palmerston	59.4	25.0	0.0	53.5	5.9
	Rarotonga	21.3	21.3	4.6	6.6	10.1
Fiji Islands	Dromuna	208.6	86.5	17.4	186.9	4.3
	Lakeba	190.2	108.5	20.4	160.7	9.1
	Mali	238.5	92.6	9.6	213.8	15.1
	Muaivuso	20.0	16.1	4.1	14.1	1.8
French Polynesia	Fakarava	653.7	76.7	0.0	642.7	10.9
	Maatea	12.4	10.9	1.4	8.5	2.5
	Mataiea	23.0	14.4	0.9	19.4	2.7
	Raivavae	117.4	95.0	9.4	49.2	58.8
	Tikehau	432.2	76.5	0.0	422.8	9.4
Federated States of Micronesia	Piis-Panewu	139.0	20.0	0.0	134.2	4.8
	Riiken	12.8	11.6	1.8	8.3	2.8
	Romanum	277.1	28.2	3.5	266.6	7.0
	Yyin	5.4	5.1	1.1	3.6	0.8
Kiribati	Abaiang	368.5	197.4	74.8	256.4	37.2
	Abemama	257.1	151.0	78.8	151.0	27.3
	Kiritimati	297.3	56.5	12.2	240.9	44.2
	Kuria	52.3	36.8	0.0	14.4	37.9
Marshall Islands	Ailuk	238.3	62.6	0.0	228.9	9.5
	Arno	207.5	66.6	0.4	190.2	16.9
	Laura	142.7	36.9	0.0	135.0	7.6
	Likiep	481.6	119.5	0.0	443.9	37.7
Nauru	All Nauru	5.9	5.9	3.4	0.0	2.5

SE = standard error.

Table A4.1.9: Fishing ground, total reef area and habitat area for 63 communities studied and as defined by socioeconomic and fisher surveys (continued)

Country/ Territory	Site	Fishing ground area (km^2)	Reef area (km^2)	Sheltered coastal reef area (km^2) (including mangroves, intertidal flats)	Lagoon area (km^2) (including back-reef)	Outer-reef area (km^2) (including passages)
New Caledonia	Luengoni	7.8	5.7	1.0	2.1	3.7
	Moindou	184.6	184.6	23.5	153.4	7.7
	Ouassé	27.5	22.0	6.3	13.6	7.6
	Oundjo	194.2	194.2	58.5	124.3	11.4
	Thio	41.9	33.7	8.8	18.3	14.7
Niue	All Niue	15.0	15.0	5.0	0.0	10.1
Palau	Airai	86.4	41.4	22.2	55.9	8.2
	Koror	814.0	193.4	28.8	752.2	33.0
	Ngarchelong	186.0	108.0	18.1	133.3	34.6
	Ngatpang	80.3	35.5	3.7	72.5	4.0
Papua New Guinea	Andra	39.9	22.5	3.0	27.0	9.9
	Panapompo m	244.5	82.6	15.2	192.6	36.7
	Sideia	14.9	14.6	10.0	0.6	4.4
	Tsoilaunung	89.1	46.4	24.4	42.7	22.0
Samoa	Manono-uta	37.2	37.2	2.7	22.4	12.2
	Salelavalu	11.3	7.3	4.0	5.6	1.7
	Vailoa	8.3	7.0	2.6	2.5	3.2
	Vaisala	3.6	3.4	0.0	1.9	1.7
Solomon Islands	Chubikopi	55.6	30.4	0.3	53.2	2.1
	Marau	20.7	20.7	0.4	15.6	4.8
	Nggela	6.3	6.3	0.0	0.0	6.3
	Rarumana	68.7	32.5	3.2	63.6	1.9
Tonga	Ha'atafu	151.7	81.2	63.6	78.7	9.4
	Koulo	339.3	49.5	40.3	289.8	9.2
	Lofanga	191.9	24.6	1.6	167.3	23.0
	Manuka	255.6	94.9	23.0	201.9	5.1
Tuvalu	Funafuti	268.5	93.6	17.2	218.1	33.2
	Niutao	2.0	2.0	0.8	0.0	1.1
	Nukufetau	124.1	43.1	10.3	102.9	10.9
	Vaitupu	7.2	6.4	3.4	0.8	3.1
Vanuatu	Maskelynes	20.3	20.3	4.1	0.1	16.2
	Moso	4.4	4.4	1.8	18.3	2.7
	Paunagisu	7.3	7.1	1.2	5.2	0.8
	Uri-Uripiv	4.1	4.1	1.4	3.2	2.8
Wallis and Futuna	All Futuna	23.5	23.2	9.6	0.3	13.6
	Halalo	114.1	58.7	25.0	77.9	11.2
	Vailala	106.2	65.3	46.8	47.9	11.6
Regional (n = 63)	**Average**	**133.6**	**50.7**	**11.8**	**109.4**	**12.3**
	SE	**20.3**	**6.4**	**2.3**	**18.9**	**1.6**

SE = standard error.

4.2 Socioeconomic drivers and indicators for artisanal coastal fisheries in Pacific Island countries and territories and their use for fisheries management strategies

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Abstract

This is the first regional study of artisanal fisheries in Pacific Island countries and territories that demonstrated that the future of the region's artisanal fishery sector and the livelihood of coastal communities will be highly dependent on alternative subsistence and income sources, which are necessary to reduce fishing pressure to a sustainable level to maintain ecosystem services and food security. The overall objective of this study was to identify socioeconomic indicators and drivers to improve the understanding of the dynamics between socioeconomic conditions and current exploitation levels of finfish and invertebrates of coastal communities in 17 Pacific Island countries and territories. We showed that exploitation rates and thus possible overexploitation are not solely the consequence of a simple demographic growth process but are in fact a result of the choices people have. Our results confirmed a close relationship between resource exploitation rates and economic development at the national level and the availability of alternative income opportunities at the community level. Multivariate analysis results suggest that communities in countries with somewhat unfavourable conditions and limited access to alternatives and fishing households in communities with overall favourable economic conditions are at highest vulnerability as they have the highest dependence on coastal fisheries resources. Alternative economic opportunities at the national scale and availability of alternative income at the community level vary significantly between cultural groups. Based on our results, the development of management strategies with realistic expectations of ensuring livelihood of coastal communities and sustainable resource use in Pacific Island countries and territories requires a hierarchical and integral approach. Major drivers identified at the regional, cultural and local levels should be used to identify priorities, to assess overall advantages and limitations at the different levels as well as the vulnerability of communities targeted, and to develop strategies accordingly.

Keywords: socioeconomic survey; fisheries; indicators; drivers; South Pacific; fisheries management

Introduction

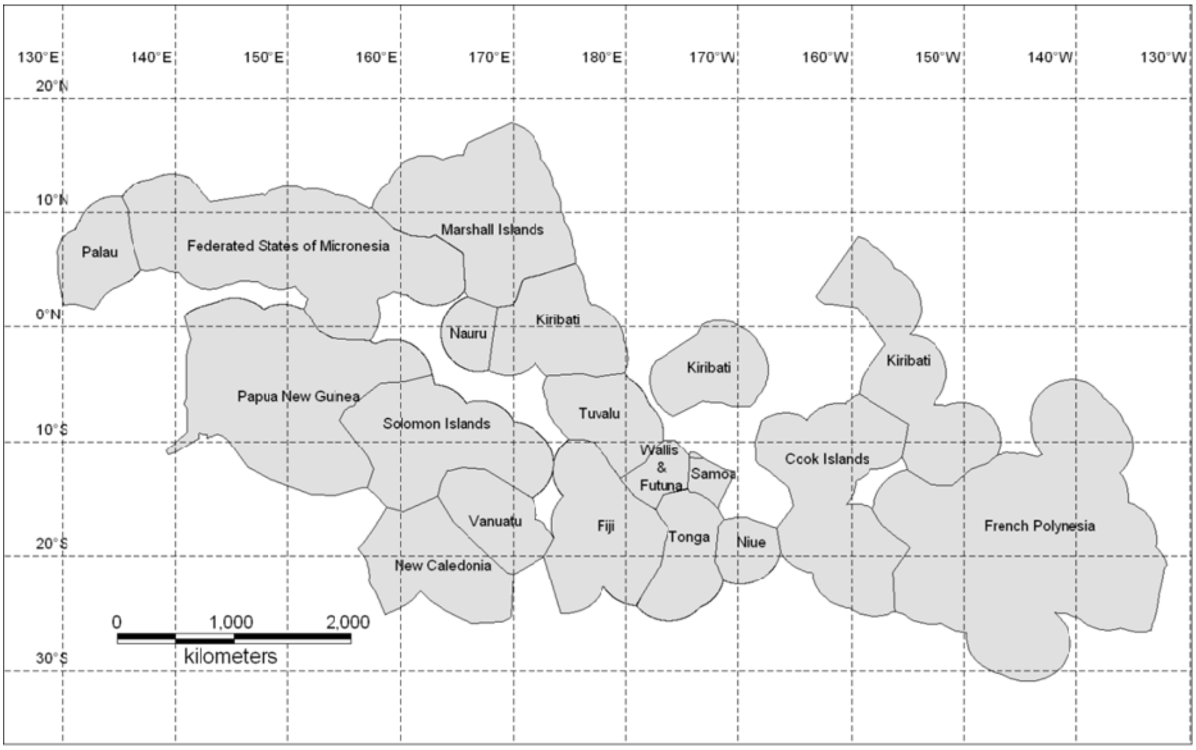
Coastal fisheries in Pacific Island countries and territories (PICTs) are predominantly low-investment, multi-species and multi-gear fisheries [1]. Low-level artisanal fishing has over the past decades, if not millennia, contributed to depletion of stocks and degradation of ecosystems [2]. Population growth [3], the introduction of westernised cash-based economy and urbanisation processes [4], the introduction of more efficient fishing gear, motorised boats [5], processing facilities, and improved marketability [6, 7], increase pressure on marine resources and are recognised causes for their decrease. PICTs have experienced important demographic development over the past decades and rapid population growth is expected in the future [8]. They also have one of the world's highest rates of consumption of seafood, particularly finfish [9, 10]. In addition, fish and other living marine resources are in many places the only renewable resource and thus the primary income source for economic security [11]. On the other hand, detrimental effects of development, and changes to more urbanised lifestyles contribute to habitat degradation, pollution, and the decline of resources and catches [12]. While it is difficult to gauge, Asian Development Bank (ADB) [13] and United Nations Development Programme (UNDP) [14] analysis show that poverty is growing in the Pacific Islands [15]. Climate change effects are likely to put further pressure on economic development, resources and livelihoods [16-19]. Fisheries managers face the challenge of finding effective strategies to ensure livelihoods for the growing populations depending on coastal resources while adjusting exploitation to sustainable levels. Management tools for wild-caught fisheries are only effective if they are readily adopted and therefore need to blend into the local socioeconomic and socio-ecological context [20, 21].

The South Pacific has one of the largest expanses of coral reef in the world, and a high proportion of the region's population depends directly on this resource. This dependency renders local economies and communities highly vulnerable [22] as coral reef systems are among the most endangered ecosystems in the world [23]. We know relatively little about what drives reef-associated social systems, and we know even less about how these social systems interact with the complex biological systems of coral reefs [24]. Past changes in socioeconomic and resource status are obscured by the lack of official statistics due to the spatially dispersed nature of the fishery, limited financial and human resources [10], and shifting baseline perceptions by users linked to a loss of social memory [25], or by scientists [26, 27]. A better understanding of socioeconomic dynamics driving resource use [28], including cultural [29] and non-demographic factors [30] and using multiple scales [20, 31, 32], is required for successful intervention to prevent overexploitation [33].

The aim of this paper is to disclose the socioeconomic context, major drivers and indicators to improve the understanding of the dynamics between socioeconomic conditions and current exploitation levels, and to assess vulnerability as a function of dependency on coastal resources in order to develop more effective fisheries management strategies to ensure the livelihoods of coastal communities in PICTs. We assessed which socioeconomic factors drive exploitation levels, particularly regarding income dependency, how these factors differ between cultural groups and their consequences in terms of vulnerability of coastal communities.

This regional analysis, based on a comparative spatial approach, is challenged by the diversity of geographic, demographic, cultural and economic conditions that characterizes the individuals and groups in the 17 PICTs included in the study (Figure 1). The region encompasses a huge area with a distance of 10,900 km between the western and the eastern boundaries and 5,400 km between the northern to the southern boundaries of the exclusive economic zones (EEZs) controlled by the 17 PICTs studied. Each of the 17 PICTs belongs to one of the three main cultural groups: Melanesia, Micronesia and Polynesia. These cultural groups are clustered to some extent by latitude and longitude. Land surface of PICTs included varies between 0.02 and 462.8 thousand km^2, total population varies between 0.0016 and 5.7 million people, the per capita gross domestic product (nominal GDP) ranges from USD 521 to 17,436, and annual export–import balances are usually negative, ranging from approximately 0 to USD –5.2 million.

Figure 1: Pacific Island countries and territories



Data and methods

Field research to collect a standardised set of socioeconomic and fishery data was conducted between 2002 and 2008 using fully structured household and fishery questionnaire surveys in a snapshot approach. A total of 63 rural coastal communities were surveyed in 17 PICTs (Cook Islands, Federated States of Micronesia [Yap and Chuuk], Fiji Islands, French Polynesia, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu and Wallis and Futuna). Communities were selected so as to best represent major small-scale subsistence and artisanal fishery systems, habitats and socioeconomic conditions in each country.

Socioeconomic and fishery questionnaires and methodologies applied are described in Kronen *et al.* [34, 35].

Finfish catches are comparable between communities and countries studied due to the multi-species character of this sector. However, in order to make invertebrate fishery data comparable, only species targeted for subsistence and small-scale artisanal fisheries were considered. Commercial export target species (mainly bêche-de-mer and trochus) are subject to pulse fishing — periodic or long-term closure — which would restrict survey data for these fisheries to the few sites where no restrictive regulation applied at the time of the survey. Due to difficulties in matching vernacular names with scientific classification, great variations in natural variability and abundance, invertebrate species reported and scientifically identified were aggregated into six major groups, i.e. gastropods (excluding trochus, i.e. *Trochus* spp.), bivalves (excluding any clams, i.e. *Tridacna* spp., *Hippopus* spp.), crustaceans, octopus, clams (*Tridacna* spp., *Hippopus* spp.) and lobster.

Subsistence catch is defined as the proportion of the total annual catch that is consumed by the community studied, while commercial catch is the proportion sold outside the community, be it at a local or national or international market.

In addition, a set of national variables was selected characterising current economic and demographic conditions, and including the available land surface for each of the 17 PICTs concerned. Variables selected and published by SPC [36] include consumer price index (CPI), per capita GDP, percentage of urban population, per capita export–import balance (USD), total national population (mid-year 2008 estimate), population density (people.km^{-2} land surface), growth rate (in % for 2008), dependency ratio (age 15–64 years), gross migration (%), and total land surface (km^{2}).

A marketability index was developed to classify each community into three categories describing ease of access to markets: easy, possible or difficult [37].

Linear and multi-linear regression analysis – redundancy analysis (RDA) using CANOCO 4.5 [38]; Canonical analysis of principal coordinates (CAP) [39] in PERMANOVA + for Primer [40] – were employed to determine any relationship between demographic and socioeconomic variables and catch rates. ANOVA was used to test for significant differences between groups. (A detailed description of statistical multivariate analysis used and results obtained are provided online in supplementary material).

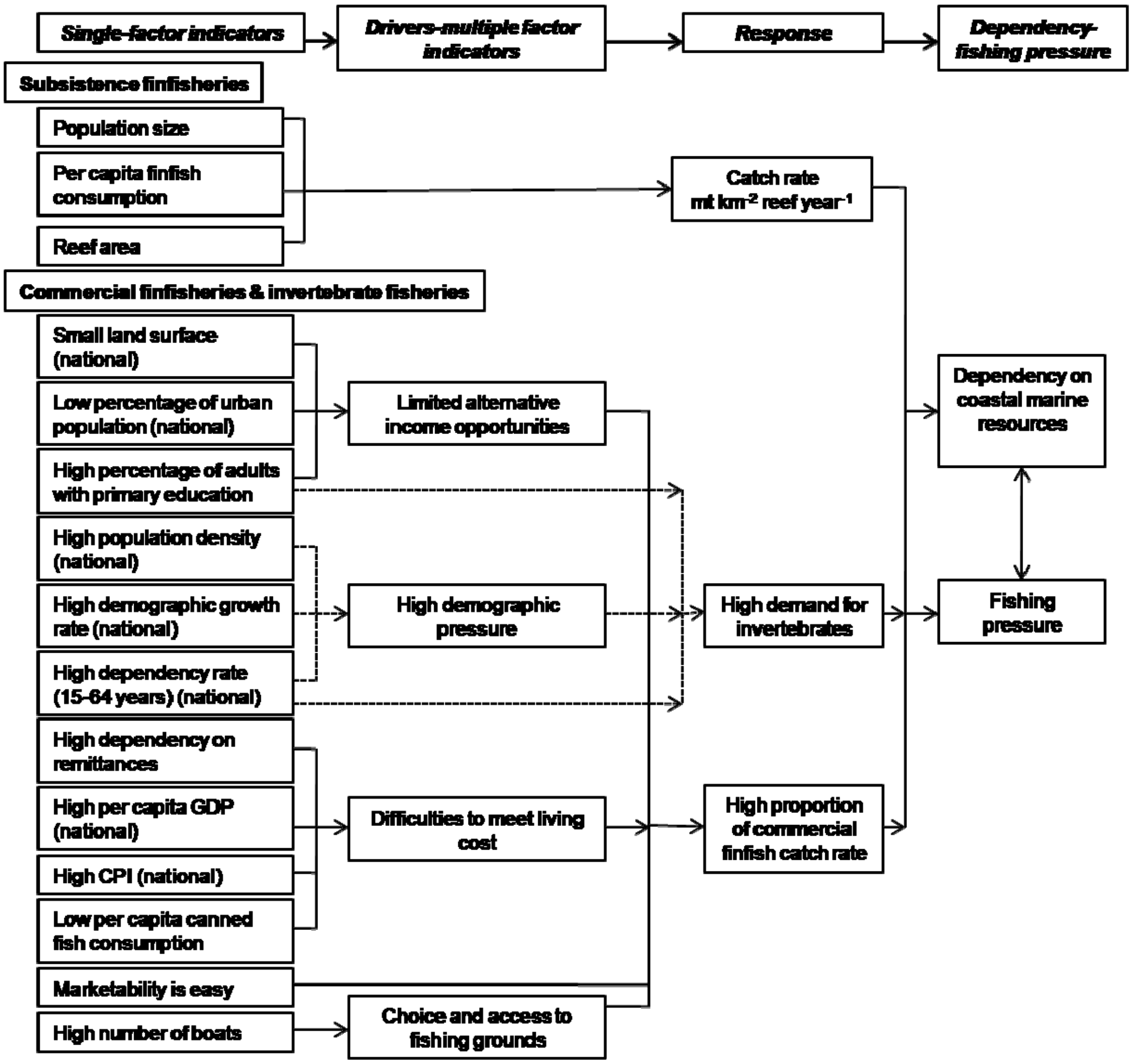
Results and discussions

Our study revealed the complexity of the subsistence and small-scale artisanal fishery systems in PICTs from a socioeconomic point of view. The number of people in a context of high dependency on fishery resources is a factor determining exploitation level as demonstrated by statistically highly significant correlations between finfish catch rates (subsistence and commercial use), lobster, clam and crustacean catches and the population size of communities (Table 1). But our results also showed that non-fishing factors at the community and national levels are as important, if not more important. Results of multivariate unconstrained (RDA) and constrained (CAP) analysis (refer to online supplementary materials for details of statistical analysis and results) of finfish (most importantly commercial finfish catch rates) and invertebrate catch rates among all 63 communities studied yielded a number of single-factor indicators and multi-factor indicators or drivers in relation to their quantifiable responses, ultimately explaining dependency of coastal marine resources and fishing pressure among the 63 communities studied (Figure 2). Contrasting with the logical expectation that subsistence catch rates would correlate strongly with population size and seafood consumption levels, as well as latitudinal differences influencing biodiversity [30, 41], variables characterising the economic situation of the household – most importantly the availability of alternative income opportunities and the household's potential to meet living costs, and demographic and economic variables at the national level, including population density, demographic growth, CPI and GDP, were found to be the most decisive drivers for commercial finfish and overall invertebrate exploitation levels. Results showed that population is only one of several factors leading to marine resource decline or depletion [3, 42-44], with a number of factors and processes working outside the domain of the fishery and influenced by the broader society [30, 45].

Table 1: Linear regression results between population size of communities and catch rates of finfish and invertebrates

		R^2	P-value
Finfish	Subsistence catch	0.51	<0.0001
($t.km^{-2}$ $reef.yr^{-1}$)	Commercial catch	0.33	<0.0001
	Lobster	0.25	<0.0001
Invertebrates	Clams	0.15	<0.001
($no.km^{-2}$ $reef.yr^{-1}$)	Crustaceans	0.09	<0.05
	Bivalves	0.01	n.s.
	Gastropods	0.01	n.s.
	Octopus	0.01	n.s.

Figure 2: Indicators and major drivers determining responses of catch rates, dependency on coastal marine resources (subsistence and income) and fishing pressure



Consequently, exploitation rates and thus possible overexploitation are not solely the consequence of a simple demographic growth process but are a result of the choices people make [46], or more precisely, the choices they have.

Our results confirm that there is a close relationship between economic development and resource exploitation level and/or resource status of small-scale artisanal fisheries [29, 47, 48]. It should be borne in mind that fishing in PICTs studied is a choice, not purely a necessity [49]. Small-scale subsistence and artisanal fishing in PICTs is low-technology and opportunistic by nature, adjusting to the available resources and to market conditions [6].

Our arguments suggesting that the more a community is dependent on fisheries for income, the less the economic conditions at the community and at the national level tend to be favourable are further underpinned by multivariate results (Table 2). We found negative linear correlations with canned fish consumption ($P<0.01$), a commercial commodity that demands purchasing power, and high household income diversification ($P<0.001$), i.e. lower proportions of households being dependent on one income source only. The latter often applies to communities where good access to salary-based income exists. Disadvantaged macro-economic conditions are suggested by the positive correlations for dependency ratios ($P<0.03$) i.e. people aged 15–64 years; negative per capita export-import per capita balance ($P<0.001$); and gross migration figures ($P<0.03$) – i.e. the higher any of these factors, the higher the proportion of households in the community depending on fisheries for income. The total population size of a community and the total commercial finfish catch rate ($t.km^{-2}$ $reef.yr^{-1}$) provide small but negative signal, suggesting that the demographic size of a coastal community in PICTs does not necessarily lead to a high proportion of households depending on fisheries for income but that in larger communities better opportunities for alternative income may exist. This result is further supported by negative correlation of commercial finfish catch rate ($P<0.03$) with the percentage of households depending on fisheries for primary and secondary income, suggesting that it is not the proportion of households depending on fisheries for income that causes higher finfish fishing pressure accounted for by the commercial finfish catch rates but the necessity to catch more for commercial purposes if fishery dependent households operate in an economically advantaged social environment.

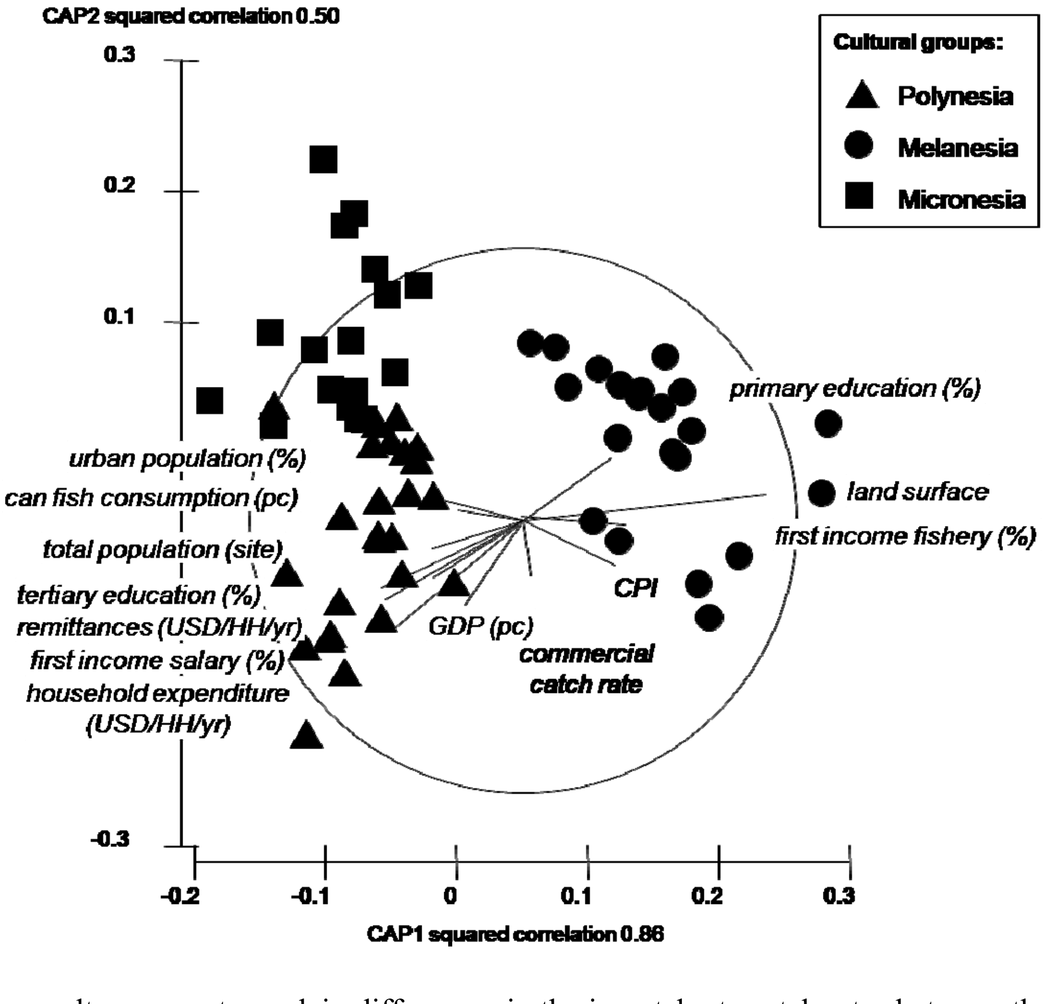
Table 2: Summary of major drivers for high dependency on income from fisheries in PICTs

Scale	Indicator	Dependency on income from fisheries: low	high
National	Per capita export–import balance (negative)	–––	+++
	Dependency rate (15–59 years)	–––	+++
	Gross migration	–––	+++
Community	Population size	+	–
	Commercial finfish catch rate ($t.km^{-2}$ $reef.yr^{-1}$)	+	–
	Proportion of households with 1 income source	+++	–––
	Per capita canned fish consumption	+++	–––

We also found significant contribution of cultural effects on the finfish catch for sale and the overall invertebrate catch, and again these are closely associated with major single-factor and multi-factor (drivers) indicators at the community and at the national levels. Constrained multivariate analysis (CAP) (Figure 3) demonstrated that the highest likelihood of communities with a high proportion of commercial finfish catch is shared between Melanesian and Polynesian communities. Limited availability of alternative income sources in the primary sector due to small land surfaces mainly applies for Polynesia, while lack of alternative income sources in the secondary and tertiary sectors (low education level, low income from salaries, low urban population) mainly applies to Melanesian communities.

Polynesian commercial finfish fishers may represent a rather disadvantage group in their communities – communities have generally a high proportion of households with primary income from salaries, high adult education level – under relatively favourable national economic conditions (high per capita GDP) as they are exposed to high living costs (high average household expenditure) and high dependence on remittances. On the other hand, Melanesian commercial finfish fishers may have access to land and thus agricultural production as an alternative to fisheries; but nevertheless, it seems that finfish fishing for income is more important than agricultural production for coastal communities. The fact that a high proportion of the adult population has only acquired primary education makes access to alternative income, particularly overseas, more difficult (low benefit from remittances). Micronesian communities are very different from those in Melanesia and more likely to be characterised as similar to Polynesian communities as shown by a tendency to a rather high proportion of urban population, high per capita canned fish consumption (suggesting purchasing power to acquire commercial food items), low CPI at the national scale, and low dependency on income from fisheries at the community level.

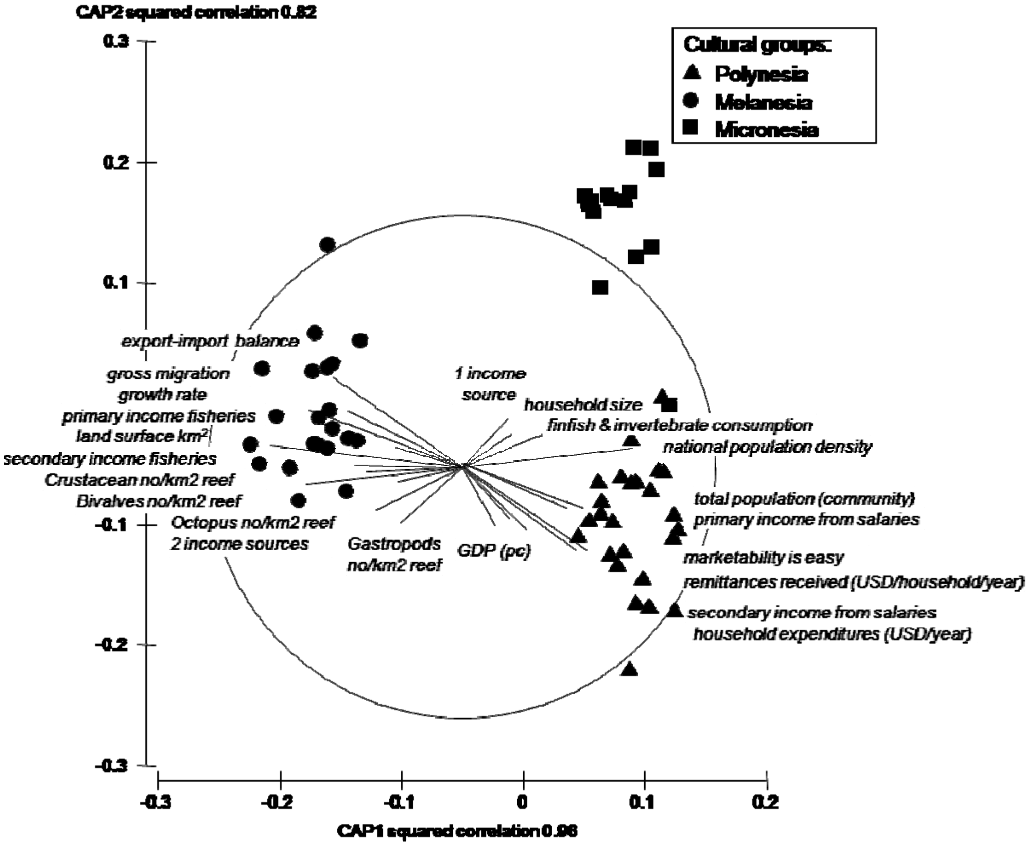
Figure 3: Socioeconomic drivers for finfish caught for sale, by culture across PICTs; canonical analysis of principal coordinates



Similar results emerge to explain differences in the invertebrate catch rates between the three cultural groups (Figure 4). For Melanesian countries the fact that they have the advantage of a high diversity in invertebrate species shows in the high dependency of people on gastropods, bivalves, crustaceans and also octopus for subsistence and complementary earnings. In

Polynesia, people who are dependent on fisheries also highly dependent on invertebrate resources for subsistence purposes. However, partly due to the geographical situation of these communities, but also due to macro and micro-economic conditions, exploitation rates of invertebrate resources are rather low. By comparison, most Micronesian communities are naturally disadvantaged, and do not have the same invertebrate exploitation rates as fishing communities of the other two cultural groups. However, Micronesian communities show an overall high per capita consumption of finfish and invertebrates.

Figure 4: Socioeconomic drivers for invertebrate catch rates, by culture across PICTs; canonical analysis of principal coordinates



In addition, Micronesian communities studied have a high proportion of households that rely on one income source only. Usually, households in rural areas of PICTs have diverse income sources, including fisheries, agricultural production where possible, handicrafts and small village businesses such as shops and bakeries. Reliance on only one income source indicates an increase in salary-based income, reducing needs for complementary income. We confirmed significant differences (ANOVA) between cultural groups in the proportion of households dependent on one, two or three (and more) income sources, and the percentage of households earning income primarily from fisheries and salaries (Table 3). On average, the percentages of households relying on salaries for primary income were found to be at least twice as high in Polynesian and Micronesian communities as in Melanesian communities. In parallel, the proportion of households relying on only one income source is on average highest in Micronesia with 46%, followed by Polynesia (35%) and Melanesia (30%).

Table 3: ANOVA results for cultural differences in proportions of households in the source of primary income and the degree of household income diversification

		F-statistic	P-value
	primary income from fisheries	2.46	0.09
Percentage of households in the community with:	primary income from salaries	5.75	0.005
	one income source	3.64	0.03
	two income sources	7.92	0.0008
	three or more income sources	0.23	n.s.

Our results confirmed that fisheries are often adversely affected by broader political, institutional and economic drivers of global and national economies [50-52], as income levels in fisheries are linked to income levels in other parts of the economy. As demonstrated in our study, artisanal fisher households are quite flexible; income sources are diversified and household members may move between sectors [53] for a number of reasons not related to fisheries.

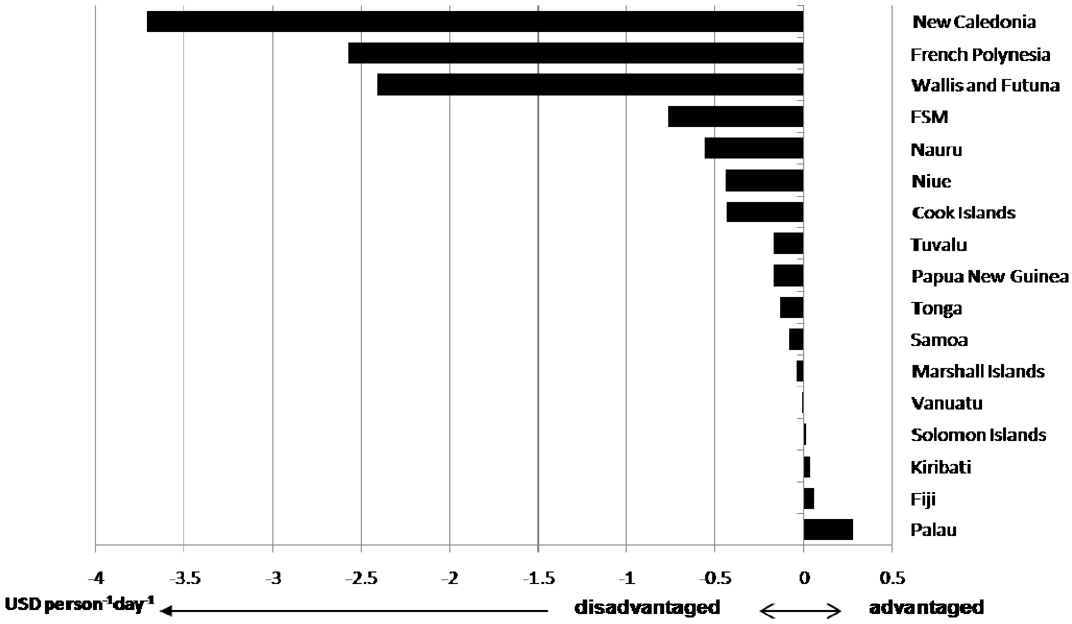
The connection between fishery exploitation levels, macro- and micro-economic conditions leads to the often cited link of fisheries dependency and poverty [54]. But poverty is not easy to define or measure [55]. Dimensions of poverty may transcend the formerly widely accepted income level of USD 1 per day as a basic measure. However, our results demonstrated that about half of all communities studied spend less than 1 USD/person/day (Table 4). The spread of the cash-based economy, together with new forms of employment and urbanisation, has restructured national and household economies in PICTs and accentuated economic differences in the process [14]. These differences were illustrated by our results at the regional and the community levels. Linear regressions of average household per capita expenditure and catch rates of finfish (commercial) and each of the invertebrate groups were statistically highly significant ($P<0.01–0.001$), with the exception of lobster catch rates, for which no significant relationship was found. The clearly demonstrated relationship – the lower the average per capita household expenditure level the higher the commercial finfish, clam, crustacean, bivalve, gastropod and octopus catch rates – makes clear that current reef resource exploitation levels in PICTs are closely related to economic conditions, possibly including poverty. Region-wide comparison of average per capita daily household expenditures between households surveyed in each country depending on fishery or other sectors for primary income revealed that people depending on cash income generated from primarily non-fishery activities spent 56% more on a daily basis than those people who generate their primary income from fishery activities, i.e. USD 3.4 person^{-1} day^{-1} versus USD 1.5 person^{-1} day^{-1}. The variation in daily per capita expenditure of cash is further highlighted in Figure 5 showing that in two-thirds of all PICTs studied people depending on fishing for their primary income are financially disadvantaged, spending less.

Table 4: Percentage of communities by average household expenditure (USD/person/day) classes

USD.person^{-}1.day^{-1}:	< 1	1–2	2–5	>5
% of communities studied (n=63):	48	19	22	11

Socioeconomic drivers and indicators for artisanal coastal fisheries in Pacific Island countries and territories and their use for fisheries management strategies

Figure 5: Regional overview of the degree to which households depending primarily on income from fishery activities are disadvantaged in their average daily expenditures (USD.person^{-1}.day^{-1}) as compared to households with other main income sources.



While we refrain from arguing whether fishery dependent households in PICTs are either poor or at the poorest level of society [56], we conclude that even under relatively favourable economic conditions at the national level, households within communities that are heavily dependent on fishing for income may represent an economically disadvantaged group.

Communities within countries with unfavourable conditions and limited access to alternatives, and fishing households within communities embedded in favourable overall economic conditions are most vulnerable as they have the highest dependence on coastal fisheries resources [48]. Hence, relationships in PICTs between different stages of welfare and resource exploitation [47] not only apply for fisheries households within communities, but also at the community level.

In summary, multivariate and bivariate results all suggest that unfavourable economic conditions at the national scale often go hand in hand with limited access to alternative income sources, putting more importance on coastal marine resources and leading to higher dependency on them, which triggers high resource exploitation. Results underline the social and economic importance of this sector, suggesting that there is a high level of dependency on coastal marine resources across the region [48] and that they make an important contribution to the local well-being of coastal communities.

It is widely acknowledged that today's catch rates are significantly determined by human footprints [2, 25, 57], which may have led to major direct and indirect shifts in community structure [67-71], and coral reef fisheries conditions [61, 62]. Consequently, variations in these direct and indirect shifts may further explain differences in current exploitation levels as the use of marine resources has always been part of the culture of Pacific Island people [63]. An important proportion of coastal communities in PICTs will continue to be highly dependent on marine resources for meeting their basic needs [64]. Bearing in mind current and predicted population growth in PICTs [8], urbanisation and possible impacts of climate change, pressures on coastal marine resources in the region will increase [57], increasing the vulnerability of its dependent communities [56].

Fisheries management must ensure both the livelihood of coastal communities and sustainable resource use [60]. As shown, these objectives are associated with access to resources and the alternative income and employment opportunities [65] provided by widened rural economic bases, which occur as an integral part of an expanded national economy [66, 67]. Efforts have been undertaken to increase cash income for coastal village residents by either excercising their property rights over resources to demand monetary compensation from tuna vessel owners – as in the case of bait fishing grounds in Papua New Guinea [68] – or levies for outsiders accessing resources of a customary fish right area – as in the case of Fiji Islands [69] – to obtain a proportion of the financial benefits from the development of industrial scale fisheries. However, financial benefits from such projects represent only a fraction of the total revenues of industrialised fishery operations, but they also apply only to very localised areas, benefitting only a few of the PICT coastal communities concerned. Strategies proposed also include increasing the distribution of dividends from access fee charges from the Western and Central Pacific tuna fishery to improve cash income for local populations and to reduce fishing pressure on local resources [70]. Aquaculture in PICTs is still experimental, and the economic viability of the large majority of aquaculture ventures in the region has yet to be demonstrated [71].

Longitudinal and latitudinal variations in PICTs coincide to some extent with the geographic distribution of cultural groups, and the effect of culture is strong [29]. However, it is argued that the overall national socioeconomic situation determines access to and availability of alternative and more lucrative income opportunities outside the fishery sector, and that these are the major decisive factors for small-scale subsistence and artisanal fishery systems in PICTs [47, 48]. Our results suggest that communities explore and develop alternative economic opportunities if they exist. Availability of alternative sources of income, however, varies significantly between cultural groups. While economic development and provision of alternative income prospects are conducive to reducing fishing pressure [72], they may not be regarded as a guarantee of achieving sustainable resource use.

This is the first regional study of artisanal fisheries in PICTs that demonstrated that the future of PICTs' artisanal fishery sector and the livelihood of coastal communities will depend to a large extent on access to and potential of alternative subsistence and income sources, which are necessary to reduce fishing pressure to a sustainable level to maintain ecosystem services and food security. The harmonisation of objectives for resource use and development requires the promotion of diversification, including alternatives to coastal wild-caught fisheries, and demands management strategies that make artisanal coastal fisheries an integral part of domestic rural development [18, 67]. Artisanal fisheries can no longer be managed independently of other resource uses and their environmental [73] and socioeconomic impact. The adoption of an approach integrating development strategies in other sectors will be an effective means to reducing dependence on the resource, reducing fishing pressure and making restrictive management easier or less controversial for the affected stakeholders [22, 74].

Conclusions and recommendations

Based on our results, the development of management strategies with realistic expectations in terms of ensuring livelihoods in coastal communities and sustainable resource use in PICTs requires a hierarchical and integrated approach. Major indicators and drivers identified at the regional, cultural and local levels (Figure 2, Table 2) should be used to identify priorities, to assess overall advantages and limitations at the various levels and vulnerability of communities targeted, and to develop strategies to tailor regional coastal fisheries management strategies to:

- The socioeconomic (dependency on coastal marine resources) and demographic (population density, growth and migration) characteristics of cultural groups (Melanesia, Micronesia, Polynesia);
- the overall national economic situation, using indicators at the national scale that indicate conditions for high subsistence catch rates, high demand for invertebrates and a high proportion of commercial finfish catch rates;
- the socioeconomic and economic conditions of the community, taking into account the combined sets of national and community-based factors indicating limited alternative income opportunities, high demographic pressure, difficulties meeting living costs and choice of and access to fishing grounds;
- the relative economic situation of fishery dependent households within coastal communities using indicators for dependency on fisheries for income and the available and accessible alternatives; and
- the relative importance of major fisheries (i.e. finfish fisheries, invertebrate) and species groups contributing to both subsistence and complementary income, with quantities and by impact (total catch.km^{-2} reef.yr^{-1}), quality (catch composition) and value (monetary and non-monetary).

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Supplementary material (online)

Multivariate statistical methods

Redundancy analysis (RDA) employing a forward selection (R^2) approach was first used to identify the most important variables. To explain variation of the proportion of commercial annual finfish rates Monte-Carlo permutation test-based regression analysis in CANOCO 4.5 [1] was applied. The variation of the complete dataset that was explained by the regression model was further analysed by doing partial tests by fitting groups of variables under a reduced (null) model [2] at national scale after fitting the community dataset and vice-versa. The same approach was used to verify the importance of preselected economic, demographic and resource use variables on income dependency. Socioeconomic drivers for annual finfish and invertebrate catch rates were determined using canonical analysis of principal coordinates (CAP) [3] in PERMANOVA + for Primer [4]. Euclidean-based distance matrices were produced after data was log (X+1) transformed and normalised. Spearman correlations of individual variables with canonical axis 1 were used for interpretation if absolute correlation was >0.20. Differences between groups were tested for by PERMANOVA, using 9999 permutations.

Multivariate analysis results

Most of the variation (65%) in the **commercial finfish catch rate** is determined by a by a set of nine principal socioeconomic and physical parameters at the community and national levels (Table 1). By applying partial RDA, we found that most effects are due to differences at the community level (34.2%), less variation is accounted for by factors at the country level (7%), and shared effects of all variables explain the remaining 23.8% of the total variation.

Table 1: Explained variation of commercial finfish catch rates (t km^{-2} reef yr^{-1})

Scale	Explanatory variables	Correlation	Variation explained (%) (P<0.002)
Community	Number of boats	+	34.2
	Adult population with primary education (%)	+	
	Easy marketability	+	
	Remittances (USD.household^{-1}.year^{-1})	+	
	Canned fish consumption (kg.pp^{-1}.year^{-1})	–	
National	Urban population (%)	–	7.0
	Consumer price index (CPI)	+	
	Gross domestic product (USD.pp^{-1})	+	
	Land surface (km^2)	–	
Community & national	shared effects		23.8
	Total explained variation		65.0
	Unexplained		35.0

Between 40% and 66% of the **variation in the various invertebrate catch rates** (RDA) was explained (Table 2) by different sets of geographic and socioeconomic factors at the national and community levels (Table 3). Longitudinal and latitudinal gradients are important factors determining biodiversity and consequently explaining part of the variation in catch rates of gastropods, bivalves and octopus. Demographic and macroeconomic characteristics at the national scale — the latter basically per capita GDP and export–import balance — have effects on some catch rates including those of bivalves and gastropods. The population size of communities is a factor; however, it is not the most important factor influencing catch rates, except for lobster catch rates. Also, per capita consumption of finfish and invertebrates explains only part of the variation in crustacean and lobster catches. The most important factors explaining this variation are income related variables — the higher the dependency of households on earning income from fisheries (not from salaries) and the lower the household income diversification, the higher the catch rates for most invertebrates.

Table 2: Results from partial multiple regression explaining the total annual catch (numbers) per invertebrate fishery

	Variation explained (%)	Geographic and socioeconomic variables at national scale (n)	Socioeconomic survey variables (n)	Total variables used (n)
Bivalves[1]	66	4	4	8
Clams[2]	53	2	6	8
Crustaceans	40	0	8	8
Gastropods[3]	59	5	4	9
Lobster	44	2	6	8
Octopus	55	2	5	7

[1] Excluding clams, i.e. Tridacna spp, Hippopus spp.; [2] Tridacna spp, Hippopus spp.; [3] excluding Trochus spp.

Table 3: Geographic and socioeconomic variables at national level, and socioeconomic survey variables used to explain variation in annual catch rates of invertebrate fisheries; variables are ranked in importance, positive or negative partial correlation in parentheses

Geographic, and socioeconomic variables at national level	**Invertebrate fishery**					
Geographic data:	Bivalves	Clams	Crustaceans	Gastropods	Lobster	Octopus
Latitude of study area	2 (+)			3 (+)		
Longitude of study area	4 (+)			8 (+)		3 (+)
Total land surface area (km^2)		7 (+)				
National demographic data:						
Population density (km^2 land surface)					3 (+)	
Dependency ratio (15–59 years)		5 (+)		1 (+)		
Growth rate (%)	6 (+)					
Gross migration				7 (–)		
National economic data:						
Consumer price index				2 (+)		
Export–import balance (per capita [PC])	1 (–)					
GDP (PC)					8 (–)	1 (+)
Socioeconomic survey variables						
Total population of community	7 (–)		5 (–)	4 (+)	1 (+)	4 (+)
Total number of boats		1 (+)				
Household size (average)			2 (–)			
Total annual finfish catch			4 (+)	6 (–)		2 (–)
Marketability is easy						7 (+)
Marketability is difficult		3 (+)				
Secondary education (% adults)	3 (–)	6 (–)			5 (–)	
Finfish and invertebrate consumption (PC)			3 (+)		2 (+)	
Canned fish consumption (PC)		4 (+)			4 (–)	
Household expenditures (USD $household^{-1}$ $year^{-1}$)	8 (–)					
Households receiving remittances (%)				6 (+)		
Remittances received (USD $household^{-1} year^{-1}$)			7 (–)			
Primary income from fishing (% households)			6 (+)		7 (+)	
Secondary income from fishing (% households)			1 (–)			
Primary income from salary (% households)		2 (–)				5 (–)
Secondary income from salary (% households)		8 (+)	8 (–)			
Households with 1 income source (%)					6 (+)	
Households with 2 income sources (%)	5 (–)			5 (+)		
Households with 3 and more income sources (%)						6 (–)
Total variables used:	8	8	8	9	8	7

Summarising the major indicators and drivers identified in both analyses highlights the multivariate nature of the relationship between resource exploitation and geographic and socioeconomic variables. Main drivers for finfish and invertebrate subsistence fisheries are demographic pressure and food dependency on marine produce mainly for subsistence catch rates, while factors that represent limited alternative income opportunities and difficulty meeting living costs determine high commercial finfish and small-scale artisanal invertebrate catch. Access to and choice of fishing grounds and easy marketability are important factors, in particular for commercial finfish catch rates.

To explain variation of dependency on income from fisheries multiple regression employing a forward selection (R^2) approach (Table 4) was used that yielded the nine most important variables, including five socioeconomic variables at the community level, four at the national level, and latitudinal differences, which explain 62.4% of the total variation in income dependency on fisheries for primary and secondary income. If we remove the effects of variables at the national level, socioeconomic and latitudinal characteristics found at the community level explain 27.5% alone. If we remove the socioeconomic and latitudinal variables at the community level, national demographic and economic variables alone explain 20.3% of the variation. The shared effects of all variables account for 14.6%.

Table 4: Explained variation of dependency on income from fisheries (proportion of households in the community depending on fisheries for primary and secondary income) by partial multivariate regression

Scale	Explanatory variables	Correlation	Variation explained (%) ($P<0.002$)
Community	Canned fish consumption (kg pp^{-1} $year^{-1}$)	–	27.5
	Households with one income source (%)	–	
	Average household size	+	
	Total population of the community	–	
	Export finfish catch rate (t km^{-2} reef)	–	
	Latitude	+	
National	Export–import balance (PC)	+	20.3
	Dependency ratio (15–59 years)	+	
	Gross migration (%)	+	
Community & national	Shared effects		14.6
	Total explained variation		62.4
	Unexplained		37.6

Multivariate results suggest (Table 5) that the more a community is dependent on fisheries for income, the less the economic conditions at the community and at the national level tend to be favourable. This argument is supported by negative linear correlations with canned fish consumption ($P<0.01$), a commercial commodity that demands purchasing power, and high household income diversification ($P<0.001$), i.e. low proportions of households being dependent on one income source only. The latter often applies to communities where good access to salary-based income exists. Disadvantaged macro-economic conditions are suggested by the positive correlations between dependency ratios ($P<0.03$), i.e. people aged 15–59 years; negative export–import per capita balance ($P<0.001$); and gross migration figures ($P<0.03$) — i.e. the higher any of these factors, the higher the proportion of households in the community depending on fisheries for income. The total population size of a community and the total commercial finfish catch rate (t km^{-2} reef yr^{-1}) provide small but negative signal, suggesting that the demographic size of a coastal community in PICTs does not necessarily lead to a high proportion of households depending on fisheries for income but that in larger communities better opportunities for alternative income may exist. This result is further supported by the negative correlation of commercial finfish catch rate ($P<0.03$) with the percentage of households depending on fisheries for primary and secondary income, suggesting that it is not the proportion of households depending on fisheries for income that causes higher fishing pressure accounted for by the commercial finfish catch rates but the necessity to catch more for commercial purposes if fishery dependent households operate in an economically advantaged social environment.

Table 5: Summary of major drivers for high dependency on income from fisheries in PICTs

	Indicator	dependency on income from fisheries	
Scale		low	high
National	Per capita export–import balance (negative)	——	+++
	Dependency rate (15–59 years)	——	+++
	Gross migration	——	+++
Community	Population size	+	–
	Commercial finfish catch rate (t km^{-2} reef yr^{-1})	+	–
	Proportion of households with 1 income source	+++	——
	Per capita canned fish consumption	+++	——

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4.3 Fishing pressure and fishery indicators

4.3.1 Reef finfish fishing pressure risk model for Pacific Island countries and territories

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Reef finfishing pressure risk model for Pacific Island countries and territories

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ABSTRACT

A reef finfishing pressure risk assessment model was developed to predict the status of reef and lagoon fisheries in terms of the current likelihood for sustainable or unsustainable finfishing for any given rural coastal community and its associated reef area in the Pacific Island countries and territories (PICTs). The prediction model aimed at developing a robust system that allows planners to confidently classify any coastal rural site within PICTs with a minimum and relatively easy-to-obtain dataset as being exposed to four classes of low to high finfishing pressure. This model is a response to limitations on data regarding current resource and user status in PICTs that make it difficult to ascertain fish supply for food security and livelihood of coastal communities. The model is based on the latest reef productivity scenarios developed based on a global review of currently known landing data and ecological footprints, reported likelihood of reduced reef productivity in PICTs due to ecological and human factors, and the use of current finfish catch rates collected as a proxy for fishing pressure. The prediction model was developed on the basis of a regional dataset including 63 study sites in 17 PICTs using linear discriminant analysis. The smallest feasible model with a leave-one-out error rate of 14.3% demands nine input variables that can be easily obtained and require only a minimum survey effort. Statistically significant response of decreasing fish length in six fish families important to artisanal fisheries in PICTs (Acanthuridae, Lethrinidae, Mullidae, Scaridae, Serranidae and Siganidae) to increasing catch rates or increasing fishing pressure proxies was used as an independent external factor to validate our hypothesis and the model developed. The reported catch length for Acanthuridae, Scaridae and Serranidae was statistically significantly different between the four finfishing pressure risk groups defined. Due to the lack of data on the natural status and productivity of the coral reefs in question and their historic use, care should be taken in interpretation of current catch rate figures. Classification of sites at low current finfishing pressure risk may reflect catch rates that are adapted to low stocks, either caused by previous depletion or due to natural unfavorable conditions. At the same time, sites classified as being at potentially high finfishing pressure risk may indeed be subject to current overfishing, but may as well feature high natural stock and productivity assets that allow for higher catch rates than elsewhere.

1. Introduction

Fisheries management in Pacific Island countries and territories (PICTs) is faced with declining coastal resources caused by overfishing due to population and socio-economic growth (Adams, 2006; Dalzell et al., 1996; Hickey, 2008; Kronen et al., 2003; Pauly, 1994; Ruddle and Hickey, 2008; Sale et al., 2008; Zann and Vuki, 2000). It has been shown that low-level artisanal fishing can dramatically affect populations of slow-growing, late-maturing animals, deplete stocks (Jennings and Polunin, 1996), and degrade or cause the collapse of ecosystems (Bunce et al., 2008; Jackson et al., 2001; Myers et al., 2007; Pandolfi et al., 2003; Pinnegar and Engelhard, 2008). Determining the degree and exact cause of coastal resource decline and the potential risk imposed by actual resource use remains problematic. First, baseline data and reference points for past resource and user status are insufficiently known (Dalzell et al., 1996), documentation is scattered, and small-scale catches are only partly considered and are generally underestimated in official statistics (Zeller et al., 2007a,b). Second, available data may be incompatible and thus difficult to compare due to the use of different methodological approaches. Third, little is known regarding whether changes documented or obtained by comparing available information are due to natural or anthropogenic factors. The lack of information is not surprising given the high species diversity on the resource side and the multiplicity of fishing gear and craft on the user side (Bundy and Pauly, 2001; Larkin, 1996). The

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complexity of both types of factors requires a wide range of information on the structure and function of reef assemblages (Tsehaye and Nagelkerke, 2008) as well as a wide range of information to capture interactions due to fisheries-induced impact. In addition, small-scale artisanal fisheries in PICTs have their own dynamics, targeting a wide range of different coral reef and lagoon fish species, with high variations between fishing trips concerning objectives (commercial to recreational aspects) (Craig et al., 1993), length of trips (hours to days), the use of boat transport, habitats targeted, fishing gear used, size of fishing party, day or nighttime fishing, and a range of regular and irregular landing sites. Lack of data, or underestimation of the social and economic contributions made by coastal marine resources are thought to add to the marginalisation of small-scale fisheries, often already disadvantaged by their socio-economic, physical, and political remoteness (Pauly, 1997). Today's discussion on possible effects of climate change on coral reefs and their associated resources (Bell et al., 2006; Munday et al., 2008) and the need to ascertain fish supply for food security and livelihood of coastal communities in PICTs (Andrew et al., 2007; Bell et al., 2009) further highlights the dilemma of data limitations for policy-makers and fisheries managers alike. Taking into account Johannes (1998) arguments for taking a precautionary approach for data-less fisheries management, unarguably, assessment of current fishing impact is necessary to prioritise fishing grounds and communities for fisheries management interventions and allocation of limited resources. With limited ecological data, this objective requires development and use of a systematic planning tool (Ban et al., 2009) that is less parameter intensive and that allows ad hoc assessment of the status of fisheries (Bundy and Pauly, 2001; Tsehaye and Nagelkerke, 2008).

The objective of the present study is to develop a reef finfishing pressure risk assessment model that allows the prediction of the likelihood of sustainable or unsustainable current artisanal finfishing in PICTs for any given rural coastal community and its appropriated reef area. To predict the likelihood of sustainable and unsustainable finfish exploitation rates we applied the major hypothesis that the higher the current finfish catch rate, the higher the likelihood of unsustainable fisheries. This hypothesis is based on the huge range of current finfish catch rates (<0.1 to >50 mt km^{-2} reef $year^{-1}$) identified by the socio-economic and fishery component of the regional coastal fishery and resources database (the first of its kind) across 17 PICTs. This regional database was established by the coastal component of the Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C), a European Union-funded project implemented by the Secretariat of the Pacific Community's (SPC)'s Reef Fishery Observatory. Due to the absence of consistent, region-wide coral reef productivity data that could be applied at study site level, we discussed the usefulness of historic reef productivity data available for PICTs as compared to productivity scenarios developed by Newton et al. (2007).

The most exhaustive summary of observed reef finfish yields done by Adams et al. (1997) uses estimates that date as far back as the early 1980s, suggesting a range of 0.3–64 mt km^{-2} $year^{-1}$ (mean = 7.7 mt km^{-2} $year^{-1}$) and a possible sustainable yield of 10 mt km^{-2} $year^{-1}$ where reefs are subject to low human influence (Jennings and Polunin, 1996). Serious doubts about what level of exploitation may in fact be sustainable, and under which conditions, were already expressed in 1999 (Adams et al., 1999). These doubts are consistent with contemporary survey results suggesting much lower estimated yields: 2.3 mt km^{-2} $year^{-1}$ for American Samoa (Craig et al., 2008), and 2.9–3.7 mt km^{-2} $year^{-1}$ for Fiji (Kuster et al., 2005). The fact that coral reefs in the Pacific and elsewhere have been subject to a varying degree of fishing intensity and that degradation has reduced potential productivity is widely accepted (Alcala and Gomez, 1985; Russ, 1991; Hughes, 1994; Jackson et al., 2001; Alacala and Russ, 2002; McClanahan et al., 2002; Hawkins and Roberts, 2004). However, the long-term historic sequence is unknown for any reef (Pandolfi et al., 2003), and little is known about which reefs are overfished (Sadovy, 2005). In view of the existing uncertainties, we opted to apply the productivity scenarios of coral reefs as suggested by Newton et al. (2007) as a proxy to assess the likelihood of sustainable to unsustainable finfisheries, as they take into account current records of landing data, the available reef area, and modeling of historic footprints in 49 island countries, including all of the 17 PICTs we studied. Using the different scenarios described (Newton et al., 2007), we distinguished four possible finfishing pressure risk groups to represent a scale from a pessimistic, low natural productivity scenario of <1 mt km^{-2} reef $year^{-1}$ (A) to a very optimistic productivity scenario of >10 mt km^{-2} reef $year^{-1}$ (D), with two intermediate risk groups, i.e. low to medium productivity of 1–5 mt km^{-2} reef $year^{-1}$ (B) and medium to high productivity of 5–10 mt km^{-2} reef $year^{-1}$ (C). Based on our recent region-wide catch data, applying a precautionary approach, and given the magnitude of pessimistic to optimistic production scenarios, we suggest that current exploitation levels of <1 mt km^{-2} reef $year^{-1}$ have a high likelihood to use resources sustainably, while any catch rate exceeding 10 mt km^{-2} reef $year^{-1}$ is regarded as having a high likelihood of being unsustainable. Further to Newton et al.'s (2007) scenarios, the lower intermediate group (1–5 mt km^{-2} $year^{-1}$) uses a loss of 50% of the assumed sustainable reef productivity in PICTs (Adams et al., 1997; Jennings and Polunin, 1996) over the past 25–30 years as the upper threshold. Based on the same argument, the upper medium risk group (5–10 mt km^{-2} reef $year^{-1}$) is not regarded as likely to sustainably use finfish resources but instead is considered to represent a high probability of overfishing. We used our finfish catch rates expressed in mt km^{-2} reef $year^{-1}$ fished to classify each of our sites studied into any of the four finfishing pressure risk groups accordingly.

To validate our hypothesis we selected from our regional database average fish size by family of target species collected from respondents as best indicator for fishing impact. While other variables from finfish resource and socio-economic fishery surveys may also proof our hypothesis, average reported catch size by family is the easiest to collect information and therefore best suited for application of our model elsewhere. The proposed indicator of average fish size is based upon numerous observations and studies showing that increasing fishing pressure results in smaller fish sizes (Roberts, 1995; Pet-Soede et al., 2001; Halpern, 2003; Amand et al., 2004; Hawkins and Roberts, 2004; Ashworth and Ormond, 2005; Jennings, 2007; Craig et al., 2008; Stallings, 2009), or growth-overfishing (Alacala and Russ, 2002; Froese, 2004).

The prediction model aimed at developing a robust system that allows planners to confidently classify any coastal rural site within PICTs with a minimum and relatively easy-to-obtain dataset as being exposed to low, low to medium, medium to high or high finfishing pressure, corresponding to a likelihood of increasingly unsustainable use from groups A to D.

2. Methods

2.1. Study sites

During the period 2003 to 2008 usually four study sites were selected and surveyed in each of the 17 PICTs that belong to one of the three major cultural groups Melanesia, Micronesia and Polynesia, i.e. Cook Islands, the Federated States of Micronesia (Yap and Chuuk), Fiji Islands, French Polynesia, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Palau, Papua New Guinea, Samoa,

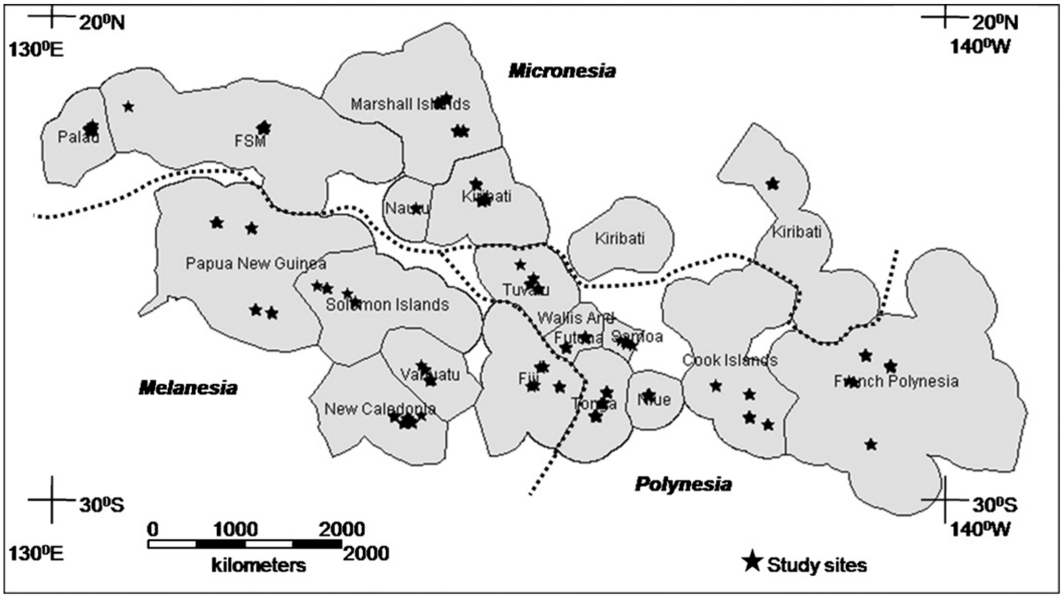

Fig. 1. Location of 17 Pacific Island countries and territories and 63 study sites by cultural groups.

Solomon Islands, Tonga, Tuvalu, Vanuatu and Wallis and Futuna (Fig. 1). Each study site was defined as the ensemble of a defined community and its associated fishing ground. A community could include one or several villages, a conglomeration of houses and settlements, the total population of a small island, or – as in rare cases – a sub-urban area. The major criteria for the defined unit of a 'community' are a relative socio-economic homogeneity, an important dependence on fisheries relative to the overall situation of the country concerned, and the joint interest in and sharing of a defined fishing ground. The defined fishing ground that each community is associated with may be subject to different tenures and governance regimes, which largely depend on traditional values and cultures. Generally, study sites in each country were selected to represent major or important coastal fisheries systems, including socio-economic and habitat characteristics. Study sites represent to different degrees the socio-economic and physical variability at the country level across PICTs, which is a consequence of the great variation in land size, reef and lagoon areas, and socio-economic and physical endowment.

Fishing grounds were defined in consultation with the local communities and governmental fisheries institutions taking into account boundaries that are either established by customary tenure or, in the case of open access systems (*de facto* and *de jure*), represent the actual fishing area targeted by the selected community. For this study, fishing grounds were divided into reef and total fishing ground surface areas. The latter included lagoon and mangrove habitat areas. Reef surface calculation was based on Andréfouët et al. (2005), lagoon and mangrove habitat surface areas were defined from satellite imagery. Undoubtedly, the influence of habitat on fish abundance (Gillanders and Kingsford, 1998; Thrush et al., 2002) and reef fish assemblage structure (Frazer and Lindberg, 2006; Willis and Anderson, 2003) is important, as mangroves and sea grass beds are essential fish habitats (Thorsten et al., 2006) and nursery biotopes for juveniles (Nagelkerken et al., 2000). However, measurement of habitat structure and diversity is complicated, cost- and time-consuming. In pursuit of developing the easiest possible approach to predict current finfishing pressure risk, the wide range of possible habitats was therefore reduced to two major units, both relatively simple to determine, and tested for their suitability.

2.2. Socio-economic questionnaire surveys

Socio-economic surveys were performed using a standard fully structured closed questionnaire survey in all communities studied across the region (Kronen, 2003; Kronen et al., 2007). Questionnaire surveys included three major components: household surveys, finfisher interviews and invertebrate fisher interviews. The head of the household or a senior person in charge of managing the household was selected to respond to household surveys. Finfishers and invertebrate fishers of both genders were selected as respondents in households for which household surveys were obtained. This design ensured fishery data were linked with socio-economic data for analysis. Complementary data were obtained from interviews with key persons, agents, middlemen and shop owners for communities where applicable.

The household survey component mainly aimed to characterise each community in terms of demographic structure by age and gender groups, ranked sources of income, average and basic household expenditure level, access to agricultural or garden land, educational level, consumption patterns (frequency and amount) of finfish (mainly reef and lagoon species), invertebrates and canned fish, as well as the ranked sources for finfish and invertebrates consumed by the household.

Finfisher interviews captured the major habitats targeted, fishing strategies (use of fishing techniques, boat transport, size of fishing parties, use of ice during fishing trips, timing of fishing trips), frequency of trips (times per week, months fished), purpose of fishing and the proportion of catch used accordingly (subsistence, non-monetary distribution, income generation), and composition and frequency of average length (using standardized charts with 8 cm length intervals) for target species identified by vernacular names translated into corresponding scientific nomenclature, at species or family level. Generally, over 80% of the reported catches are accounted for by nine fish families with Lethrinidae (15.5%, S.E. 1.7), Acanthuridae (12.8%, S.E. 1.6), Serranidae (10%, S.E. 1.1) and Lutjanidae (8.8%, S.E. 1.0) representing the largest proportions, followed by Carangidae (6.9%, S.E. 0.9), Siganidae (5.8%, S.E. 0.8), Mugilidae (5.5, S.E. 1.1) and Mullidae (3.2% S.E. 0.4).

2.3. Marketability

A qualitative system was developed to classify each site studied according to a set of criteria into three categories describing ease of access to markets: easy, possible or difficult. Criteria that prompted classification into each of these three categories are shown below.

Easy	Possible	Difficult
Abundance of shops, markets and market outlets	Irregular flight and boat connections limit market access	Ciguatera widespread
Governmental or community operated marketing centres (may be subsidised)	Relatively isolated (boat and perhaps air transport exist but are rather irregular)	Fish prices are higher than prices for alternative protein sources
Road access to market(s)	Marketing is organised via agents who control flow	Long distances to any selling point for fresh fish
Short distance by boat transport to market(s)	Very limited local selling capacity and market is quite far away	Transport is chronically difficult to access or is too expensive
Demand exceeds supply	No real established commercialisation of reef fish, however demand to purchase finfish is developing	No visiting agents
Guaranteed transport volumes and prices for finfish produce to target market in case of air transport	Combination of road and boat transport needed	Very limited freezing capacities in isolated location
Reliable and regular buying agent system established		Traditionally no commercial sale of reef and lagoon finfish
		Isolated location, long and expensive boat transport is only option

2.4. Geographic variation

Taking into account the geographical scale and consequently the important north–south and west–east gradients, including significant differences in distance from centre of biodiversity, climatic and sea temperature conditions, island size, island geomorphology, and diversity of habitat across sites, variables for correcting these effects were tested for modeling. To correct for these possible variations, island area; the presence or absence of coastal reef, lagoon and back reef; geomorphological classification of the study site as a volcanic, atoll or coral island with no lagoon; and longitude and latitude variables were input.

2.5. Statistical analysis

A set of socio-economic variables was selected on the basis of linear and multivariate analysis. Principal component analysis (Euclidean-based distance matrix) was done using PERMANOVA+ for Primer (Anderson et al., 2008) to assess the relative importance of individual variables out of a comprehensive socio-economic variable set. Data were log, or where necessary log(X + 1), transformed. The isolation index classifying each site as having easy, possible or difficult marketability conditions for finfish was obtained from the United Nations Environment Programme (UNEP) islands website (islands.unep.ch/isldir.htm). Verification of importance of preselected socio-economic and geographic variables was done using log(log(X + 1)) transformed data in Monte-Carlo permutation test-based regression analysis in CANOCO 4.5 (Ter Braak and Šmilauer, 2002). The explained variation of the complete dataset was further analysed by applying partial tests under a reduced (null) model (Anderson and Legendre, 1999) and by defining the socio-economic on the geographical dataset and vice versa as covariables.

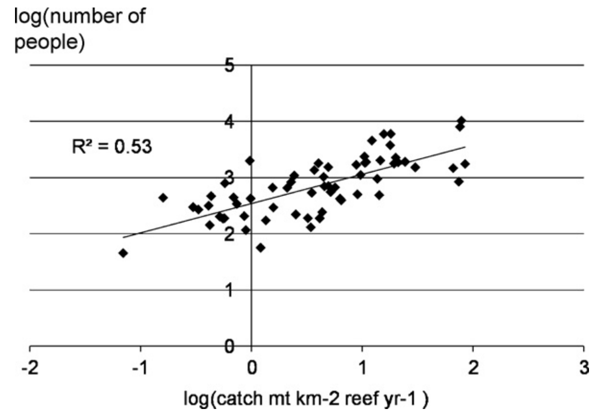

Fig. 2. Regression of total population and finfish catch density.

For defining the classification model itself, we used a number of different approaches using the statistical language R (R Development Core Team, 2008), including linear discriminant analysis, and a method based on linear prediction of the log(total finfish catch), which then used the class limits of catch defined in the introduction. Due to the problem of too many variables in comparison with the total sample size, an automated variable selection procedure (all possible subsets selection – Miller, 2002) was used (R library: leaps – Lumley, 2008). The three fit criteria: adjusted R^2, Bayesian information criterion (BIC), and Mallow's Cp (Seber and Lee, 2003), were used to help choose the smallest feasible model with an adequate performance. This model was then fitted to the data and the classification error rate estimated using a leave-one-out strategy. Each observation was classified using the model fitted to the remaining data, thus avoiding an over-optimistic bias.

3. Results

3.1. Selection of input variables

Linear data analysis showed a highly significant positive correlation between total population and finfish catch density. This relationship was strongest for catch rates per reef surface unit ($R^2 = 0.53$; $p < 0.0001$) (Fig. 2) rather than per total fishing ground surface unit ($R^2 = 0.47$; $p < 0.0001$). Lower, but still highly significant correlations existed when total number of households, fishers, finfishers or boats were substituted for total population (Table 1). This is not surprising if we take into account that study sites were selected according to their relative dependence on coastal fisheries. Hence, at least to some degree, collinearity between boat numbers and population size is to be expected. However, for any of the variables tested, response to catch rates per reef surface unit was always stronger as compared to total fishing ground surface unit.

All sites studied across the 17 PICTs included in this survey were classified according to their catch rates (mt km^{-2} reef year^{-1}) into the corresponding reef finfishing pressure risk group (A, B, C or D). The average figures of all sites classified in each of the four reef finfishing pressure risk groups for total population, total reef surface and population density (people km^{-2} reef) are depicted in Fig. 3. The p-values in Table 2 show that there are significant differences between average total population, reef surface and population density between the two extreme risk groups A and D, i.e. corresponding to a finfishing pressure <1 mt km^{-2} reef year^{-1}

Table 1
Regression results of total population, households, fishers, finfishers and boats and finfish catch density per reef and total fishing ground surface areas.

	Log(catch rate mt km^{-2} year^{-1})			
	Reef surface		Total fishing ground surface	
	R^2	p	R^2	p
Total population	0.53	<0.0001	0.47	<0.0001
Total number of households	0.43	<0.0001	0.42	<0.0001
Total number of fishers	0.50	<0.0001	0.47	<0.0001
Total number of finfishers	0.50	<0.0001	0.46	<0.0001
Total number of boats	0.42	<0.0001	0.41	<0.0001

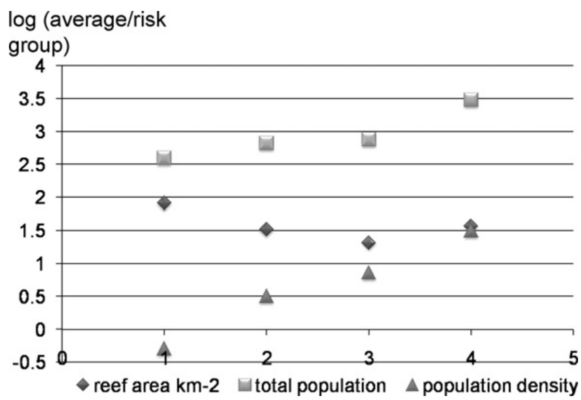

Fig. 3. Relationship of total population, reef area and population density for each of the four reef finfishing pressure risk groups, using site-specific data across all sites studied.

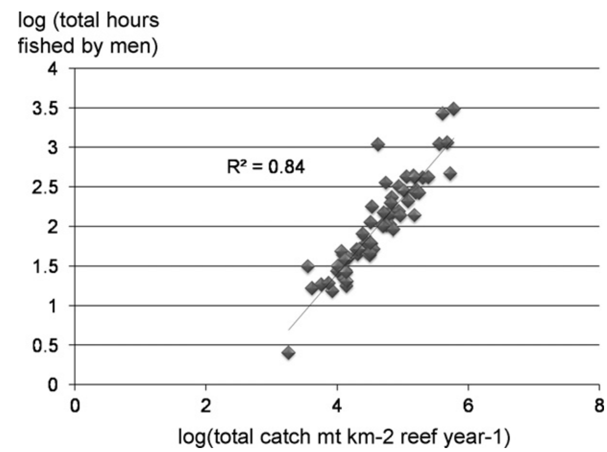

Fig. 4. Regression of total finfishing hours fished by fishermen and total annual finfish catch.

and >10 mt km^{-2} reef year^{-1}, respectively. However, total population increment from A to B, i.e. finfishing pressure risk groups corresponding to <1 and 1–5 mt km^{-2} reef year^{-1} is not significant, and the same is true of the decline of average total reef surface between risk groups B and C (1–5 and 5–10 mt km^{-2} reef year^{-1}), B and D (1–5 and >10 mt km^{-2} reef year^{-1}), C and D (5–10 and >10 mt km^{-2} reef year^{-1}). On the other hand, and most importantly, the population density steadily and significantly increases from risk group A to B and C to D. These observations underline that fishing pressure is a function of both population, a proxy for the combined catch rates for subsistence and income dependencies, and reef surface sizes, a proxy for productivity, a consideration that is important in developing the prediction model.

Linear regression also revealed that impact can be expressed best by total hours fished by fishermen ($R^2 = 0.84$; $p < 0.0001$) (Fig. 4) rather than total hours fished, i.e. including both gender groups – fishermen and fisherwomen (Fig. 5). The small impact of fisherwomen may be explained by the fact that due to cultural taboos, women in some sites studied were not at all engaged in finfishing activities. However, after removing sites ($n = 11$) where women do not participate at all in finfishing, the regression coefficient is highly significant ($R^2 = 0.33$; $p < 0.0001$) but much weaker than the strong correlation obtained for the impact due to fishermen's fishing hours.

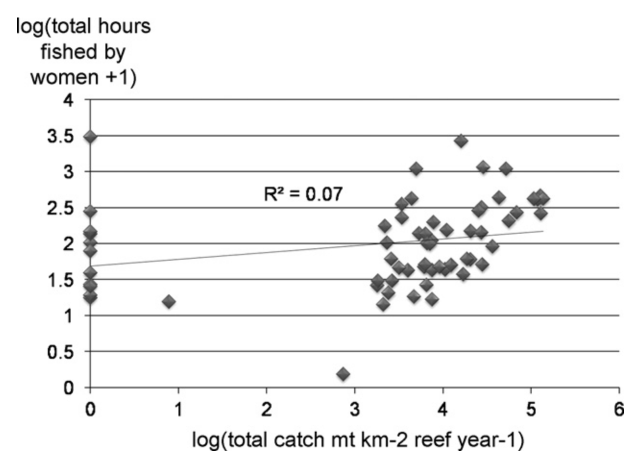

Fig. 5. Regression of total finfishing hours fished by fisherwomen and total annual finfish catch.

Results of principal component analysis (PCA) depicted in Table 3 show that the first three principal components (PCs) explain a cumulative variation of 76.9%. Variables selected according to their relative importance in all or most of the three PCs as input to modeling include: total population, total number of fishers and its

Table 2
t-Test analysis comparing total population, total reef area and population density between finfishing pressure risk groups.

Finfishing pressure risk group	Total population	Total reef area (km^2)	Population density (number of people/km^2 reef)
A/B	n.s.	<0.0001	<0.0001
A/C	<0.001	<0.0001	<0.0001
A/D	<0.0001	<0.001	<0.0001
B/C	<0.05	n.s.	<0.01
B/D	<0.0001	n.s.	<0.001
C/D	<0.01	n.s.	<0.05

Table 3
List of selected, most important variables from PCA, including explained and cumulative variation (%) by PC1–PC3.

Cumulative variation of PC1 to PC3 = 76.9%	PC1 (51.4%)	PC2 (17.4%)	PC3 (8.1%)
Total population	−0.286	−0.037	−0.176
Total number of households	−0.254	−0.056	−0.227
Total number of fishers	−0.275	−0.035	−0.106
Total number of finfishers	−0.277	−0.042	−0.105
Total number of boats	−0.277	−0.030	−0.066
Total annual catch (mt year^{-1})	−0.324	0.165	0.048
Catch density (mt km^{-2} total fishing ground year^{-1})	−0.227	−0.312	0.173
Catch density (mt km^{-2} reef year^{-1})	−0.248	−0.215	0.186
Total hours fished by men (year^{-1})	−0.320	0.076	0.014
Total hours fished	−0.316	0.061	0.033
Fishing ground surface area (km^2)	0.041	0.625	−0.227
Reef surface area (km^2)	0.022	0.429	−0.208
% of households earning primary income from fishing	−0.032	0.282	0.481
% of households earning primary income from salaries	−0.024	−0.107	−0.435

substitute total number of boats, reef and fishing ground surface area and the population density per fishing ground and reef surface area, total hours fished and the share by gender participation, i.e. total hours fished by fishermen and by fisherwomen, the percentage of households earning primary income from fisheries (and the opposite figure showing the percentage of households earning primary income from salaries).

In addition, the marketability indicator was used to distinguish qualitatively between sites. Longitude and latitude coordinates were included to correct for north–south and west–east variation.

We then tested sets of preselected variables including both socio-economic and geographical data explaining total annual finfish catch in view of further reducing the total number of possible input variables. Partial, multivariate regression revealed that the first preselected dataset, including a total of 14 variables (7 socio-economic, and 7 geographic variables), explains 75.1% of total annual finfish catch data; approximately 25% remains unexplained by the dataset selected. Given the limited number of observations ($n = 63$), we further reduced variables using an automated forward selection process. A final selection of three socio-economic and three geographic variables explained 71% of the total variation. Parceling out the effects of the combined socio-economic (three variables), and the combined geographical variables (three variables) further showed that socio-economic variables (total hours fished by fishermen, per capita consumption of finfish, and easy access to markets) are strongest as they alone explain 45.2% of the total variation ($p = 0.002$). Purely geographical variables (volcanic island, longitude, and latitude) do not themselves explain much of the variation of total annual finfish catch (variation: 5.6%, $p = 0.02$), but if combined with socio-economic variables, both significantly ($p = 0.002$) account for 20.3% of the total variation (Fig. 6).

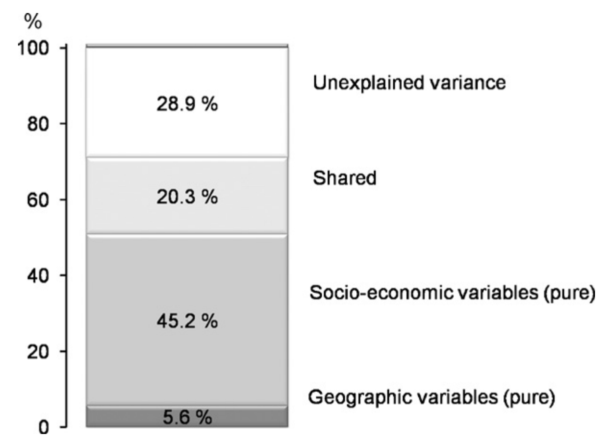

Fig. 6. Variation of total annual finfish catch ($n = 63$) explained by pure socio-economic (3 variables), pure geographic (3 variables) and shared (both) datasets using partial multivariate regression.

3.2. Prediction model

Preliminary investigations of linear discriminant analysis as a method of classifying villages into finfishing pressure risk groups were disappointing (high leave-one-out error rates). A method based on linear prediction of the log(total finfish catch), which then used the class limits of catch defined in the introduction, was used with greater success. As mentioned in the methodological section above, the main problem for the analysis was that there were so many variables but relatively few observations. Even after the initial selection described above there were still too many variables for a robust model. We used the automated variable selection procedure described earlier to identify the smallest feasible model. The resulting model had a leave-one-out error rate of 14.3% (valid prediction 85.7%):

Log(total finfish catch) ~ country + percentage of households earning primary income from fisheries + total hours fished by fishermen + presence/absence of a back reef + presence/absence of volcanic island geomorphology + latitude + longitude + total reef surface area km^2

As shown in Table 4, when there were differences between the predicted placement of sites and actual classification into finfishing pressure risk groups, they were usually limited to a few sites being grouped into the next or previous class.

Bearing in mind that the best applicable model is one that requires not only fewer parameters but also parameters that are

Table 4
Comparison of error rates of sites classified and predicted in each of the four finfishing pressure risk groups (A–D) using total hours fished by fishermen.

Classified finfishing pressure risk group	Predicted finfishing pressure risk group				Total
	A: <1 mt km^{-2} reef year^{-1}	B: 1–5 mt km^{-2} reef year^{-1}	C: 5–10 mt km^{-2} reef year^{-1}	D: >10 mt km^{-2} reef year^{-1}	
A	**15**	3	0	0	18
B	0	**17**	1	0	18
C	0	1	**8**	2	11
D	0	0	2	**14**	16
Total	15	21	11	16	63

Table 5
Comparison of error rates of sites classified and predicted in each of the four finfishing pressure risk groups (A–D) using total population.

Classified finfishing pressure risk group	Predicted finfishing pressure risk group				Total
	A: <1 mt km^{-2} reef year^{-1}	B: 1–5 mt km^{-2} reef year^{-1}	C: 5–10 mt km^{-2} reef year^{-1}	D: >10 mt km^{-2} reef year^{-1}	
A	**15**	2	1	0	18
B	2	**15**	1	0	18
C	0	4	**5**	2	11
D	0	0	3	**13**	16
Total	17	21	10	15	63

Table 6
Results of statistically significant correlations between reported average fish length and finfishing pressure proxies across 63 study sites in PICTs.

Fishing pressure proxy	Total finfish catch (mt km^{-2} reef year^{-1})		Total finfishing hours (h year^{-1})		Total fishermen finfishing hours (h year^{-1})		Population density (people km^{-2} reef)	
Familiy	R^2	p	R^2	p	R^2	p	R^2	p
Acanthuridae	0.10	<0.01	0.08	<0.02	0.07	<0.03		n.s.
Lethrinidae	0.08	<0.03		n.s.		n.s.	0.15	<0.001
Mullidae	0.06	<0.06	0.07	<0.03	0.07	<0.03	0.09	<0.02
Scaridae		n.s.		n.s.		n.s.	0.07	<0.04
Serranidae		n.s.		n.s.		n.s.	0.04	<0.09
Siganidae	0.08	<0.02		n.s.		n.s.	0.05	<0.06

easily obtainable, we tried to replace total finfishing hours spent by fishermen by a variable that does not require field survey work. Based on the strong linear correlations found between total population and catch rates, total population was used as an input for total finfishing hours spent by fishermen. The resulting prediction model gives an error rate of 23.8% (valid prediction 76.2%) (Table 5), i.e.

Log(total finfish catch) ~ country + percentage of households earning primary income from fisheries + total population + presence/absence of a back reef + presence/absence of volcanic island geomorphology + latitude + longitude + total reef surface area km^2

3.3. Average fish length

Detrimental impact of increased finfishing pressure was revealed by the response of decreased fish length with increased finfishing pressure for six families (Table 6). Highly statistically significant correlations exist for decreased average reported finfish length of Acanthuridae, Lethrinidae and Siganidae, and a weaker correlation for Mullidae in direct response to increased finfish catch rate. This relationship is further confirmed by a correlation between decreasing length of Acanthuridae and Mullidae and increases in the total annual finfishing hours or finfishing hours accounted for by fishermen only. Finally, population density, a proxy for the potentially increased finfishing pressure of coastal resource-dependent communities, showed a statistically significant correlation with decreases in fish length of Lethrinidae, Mullidae and Scaridae, with a weaker correlation for Siganidae and Serranidae.

Testing for differences in the reported average finfish length by family and the four finfishing pressure risk groups (ANOVA) proved statistically significant for Acanthuridae and Scaridae, with a weaker signal for Siganidae (Table 7). No significant differences in fish length as response to the four finfishing pressure risk groups were found for Lethrinidae, Mullidae, and Serranidae.

4. Discussion

It is generally believed that coral reef fisheries are unsustainable (Pauly et al., 2002; Bellwood et al., 2004). However, with a lack of site-specific data, and variation within sites of coral and seagrass bed coverage (Munro, 1984), much uncertainty about current stocks or biomass, productivity and consequently levels of maximum sustainable yield (MSY) remains. Most authors question sustainability levels (Adams et al., 1997; Dalzell et al., 1996) in view of the future human population growth and maintenance of high fish consumption levels as typical for PICTs, or as in the case of Jennings and Polunin (1996), already noted differences in finfisheries sustainability in relation to human impact. Finfishing pressure risk groups defined here are based on the analysis done by Newton et al. (2007) as it represents best the latest and most comprehensive account of the current status of coral reefs and their likely productivity in response to ecological footprints. Although scenarios developed by Newton et al. are based on a global scale, major thresholds used for this study are defensible if compared to productivity estimates made as far back as the 1980s (Jennings and Polunin, 1996; Adams et al., 1997, 1999; Dalzell and Adams, 1996) and contemporary yield assessments for PICTs (Craig et al., 2008; Kuster et al., 2005).

Application of thresholds from <1 to >10 mt km^{-2} reef year^{-1} using pessimistic to optimistic productivity scenarios from Newton et al. (2007) allowed us to develop a model that is as statistical results suggest relatively robust and reliable in its prediction of finfishing pressure risk groups. Comparison of catch rates across the 63 sites studied shows variation from sites with catch rates as low as <0.1 to as high as >50 mt km^{-2} reef year^{-1}. Detrimental effects of increased finfishing pressure in decrease of average fish length caught were demonstrated for six fish families that are important to artisanal catches in PICTs (Dalzell et al., 1996; Gillett and Lightfoot, 2001). Using average fish length as a proxy for increased finfishing pressure gave negative response for the six families for increasing fishing pressure from lowest to highest finfishing pressure risk groups. Using average reported fish length as an independent and widely acknowledged measure for growth-overfishing (Roberts and Polunin, 1991; Jennings and Polunin, 1996; Chapman and

Table 7
Analysis of variance (ANOVA) comparing average reported fish length for six fish families for four finfishing pressure risk groups <1 to >10 mt km^{-2} reef year^{-1}.

Family	*F*-statistic	p
Acanthuridae	8.10	<0.0001
Lethrinidae	0.89	n.s.
Mullidae	1.48	n.s.
Scaridae	3.56	<0.02
Serranidae	1.66	n.s.
Siganidae	2.40	<0.08

Kramer, 1999; Welcomme, 1999; Pet-Soede et al., 2001; Galal et al., 2002; Halpern, 2003; Ashworth and Ormond, 2005; Stallings, 2009; Lokrantz, 2009) confirms our initial hypothesis that the higher the finfish catch rate the higher the likelihood of unsustainable finfisheries. However, it should be borne in mind that the model does not predict total annual catch rates, but instead predicts, with an error margin of 14.3%, the finfishing pressure risk group a site is likely to belong to, thus accommodating a range of possible current catch rates. This is particularly important for the highest finfishing pressure group, D, which has by definition no upper limit but groups any site with a catch rate of >10 mt km^{-2} reef $year^{-1}$.

Another uncertainty lies in the use of current finfish catch data over reef surface areas as a proxy, as it does not take into consideration footprints of historic exploitation, or the biological potential of reef areas considered. Although results suggest that coral reef ecosystems have suffered massive, long-term decline in abundance, diversity, and habitat structure due to overfishing and pollution (Hughes, 1994; Jackson et al., 2001; McClanahan et al., 2002), or at least since the late 1980s (Jennings and Polunin, 1996; Pauly et al., 1998), detailed ecological descriptions of reef ecosystems are less than 50 years old (Connell et al., 1997) and the long-term historic sequence of ecosystem decline is unknown for any reef (Pandolfi et al., 2003). Therefore, care should be taken in the interpretation of current catch rate figures. In other words, classification of a site as at low current finfish pressure risk may reflect catch rates that are adapted to low stocks, due to either previous depletion or natural unfavorable conditions. Also, sites classified as at potentially high finfishing pressure risk may indeed be subject to current overfishing, but may as well represent high natural stock and productivity assets that allow for higher catch rates than elsewhere.

The input dataset required comprises either available information or variables that require a minimum survey effort. In the case of the model with the lowest error rate, data collection is required to allow extrapolation of the total numbers of fishermen and the average frequency and duration of their fishing trips in a year in order to come up with figures for total hours fished by fishermen. These data can be obtained with a few questions from a representative sample size for the community(ies) in question. Alternatively, total population data, which are much more easily available in PICTs, can be employed, taking into consideration an increment in potential error rate from 14.3% to 23.8%.

Accuracy of the results from this model is also scale-dependent. First, input data refer to relatively remote coastal fishing communities and fishing grounds. Thus, application of this model is best where comparable situations are found. Application of this model in urban conditions or areas subject to many important factors other than fisheries, such as coastal development or mining for example – which may have detrimental effects on marine coastal resources – is likely to produce questionable predictions. Island size and nature, as well as geographic endowment and population distribution, pose another challenge to the application of this model. Small islands with homogenous demographic and socio-economic structure, and most importantly comparative dependency on and access to reef and lagoon resources, can be regarded as one unit, which allows application of the island's total population figures and associated variables over the total available reef area. In the case of larger islands, in particular high islands, and where populations have different dependencies on and access to reef and lagoon resources, portions of the total population must be considered along with their spatial distribution, and appropriated reef areas must be partitioned and allocated first to allow capture of spatial impacts and variations in the current likelihood of finfishing pressure risk. This is particularly important in view of fishing pressure gradients due to distance from major market centres. Scale-dependency also includes the issue of defining reef surface areas – a determining factor in our catch rates and in the definition of finfishing pressure risk groups. According to Spalding and Grenfell (1997) the most widely quoted figures for global and regional reef area are those derived from estimated areas of shallow ocean (less than 30 m) and estimates of the proportion of reef frontage within 10° 'squares' of latitude and longitude (Smith, 1978). Zeller et al. (2007a) defined surface areas of coral reefs to a depth of 183 m (100 fathoms) using a method established by Rohmann et al. (2005). Newton et al. (2007) used UN Food and Agriculture Organization (FAO) statistics that largely define reef surface as shelf area of 10–100 m depth (FAO, 2006). Other publications may employ area catch rates with no information provided on how reef surface data used were obtained (Craig et al., 2008; Meyer, 2007). The habitat classification method used in this paper (Andréfouët et al., 2005) considers coral reef surfaces detectable between 0 and 30 m, with a maximum overall depth of 50 m.

5. Conclusion

The model developed to classify any coastal community and its appropriated fishing grounds into one of the four defined finfishing pressure risk groups fulfills the intention to provide a robust and easy-to-use tool to help policy-makers and fisheries managers identify priority areas for fisheries management interventions and to identify possible surplus and deficit fishing grounds for future food security and rural development planning. Our hypothesis that higher finfish catch rates are associated with higher likelihood of unsustainable use was demonstrated by effects of growth-overfishing using decreasing average length of six important fish families in response to increasing catch rates or proxies for finfishing pressure. Statistically significant differences in the reported average fish length between finfishing pressure risk groups were found for three families, i.e. Acanthuridae, Scaridae and Siganidae. The application of the model requires identification of consistent units that represent a total population with the required socio-economic and geographic factors and the surface area of the reef appropriated by the population. The identification of units is scale-dependent and a consequence of the diversity and size of the island considered.

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4.3.2 Socioeconomic and fishery indicators: further analysis, results and discussions

What is the current situation of coastal fisheries in PICTs?

Each of the 63 Pacific Island communities studied was classified by using the total annual finfish catch data per km^2 of available reef area in any of the four finfish fishing pressure risk groups defined (Kronen *et al.* 2009, Newton *et al.* 2007). Finfish fishing pressure risk groups of <1 t/km^2 reef/year and 1–5 t/km^2 reef/year are regarded as sites that are subject to currently low and low-to-moderateexploitation level, while sites classified under finfish fishing pressure risk groups of 5–10 and >10 t/km^2 reef/year as subject to moderate-to-high and high exploitation levels. As demonstrated in Table A4.3.1, current annual catch rates determine that 32% of all communities studied currently have a moderate-to-high risk of unsustainable coastal fisheries production, and this situation is significantly determined by the combined effects of both subsistence and commercial catches (Figure A4.3.1).

Table A4.3.1: Relative percentage of communities classified according to their current likelihood of sustainable or unsustainable coastal fisheries using finfish fishing pressure risk groups and selected scenarios

	Finfish fishing pressure risk group (total finfish catch t/km^2 reef/year)				n
Finfish catch:	**<1**	**1–5**	**5–10**	**>10**	
Total (subsistence and commercial)	29	29	17	25	63
Subsistence	48	32	6	14	63
Commercial	35	33	19	13	63
Sourced from sheltered coastal reef	35	8	16	41	51
Sourced from lagoon	61	20	7	12	59
Sourced from outer reef	30	25	19	25	63
Minimum protein supply	44	38	3	14	63

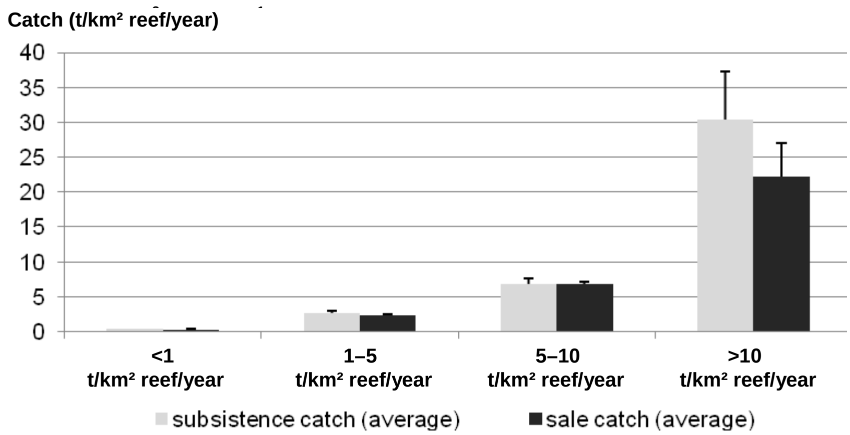

Figure A4.3.1: Proportion of finfish catch rates due to subsistence and sale in each of the four finfish fishing pressure risk groups.

Overall, the extent of the current fishing pressure is made visible by depicting the 43% surplus and 57% deficit communities based on optimistically assuming an average reef productivity of 5 t/km^2 reef/year. In other words, more than half of all rural coastal communities studied are likely to be extracting more than the annual productivity of their reef areas.

Regarding the reported and extrapolated total annual finfish catch per habitat surface area, the highest likelihood of unsustainable coastal fisheries is on the sheltered coastal reef (57% of all 51 communities studied have access to this habitat.) and the outer reef (43% of all 63 communities). Overall, lagoon habitats are currently most likely to have sustainable coastal fisheries as less than 20% of lagoons in all communities studied are considered under moderate-to-high finfish fishing pressure risk.

The severity of the situation is further highlighted if applying the scenario of the minimum protein supply for good nutrition (34 kg/person/year corrected for non-edible parts to 37 kg/person/year, Kronen *et al.* (in press) – Bell *et al.* (2009) sourced from coastal fisheries to satisfy the current population size in the 63 communities studied. Even under this much lower exploitation scenario, still 17% of all communities studied exposed their coastal resources to a high likelihood of unsustainable use (>5 t catch/km^2 reef/year).

In summary, even under a minimum food security scenario, currently 17% of all communities studied are likely to practise unsustainable coral reef finfish fisheries that are causing detrimental effects to the resource. This percentage is lower than the current exploitation rate due to subsistence needs only (21% of all sites studied). Taking into account the current exploitation levels to satisfy both, subsistence and income needs of the communities studied, 43% of all sites are subject to moderate-to-high finfish fishing pressure, with a quarter of all sites studied being exposed to extreme catch rates (>10 t/km^2 reef/year) that are unlikely to be sustained naturally.

The relationship between island type and finfish fishing pressure risk, and socioeconomic, resource, and fishery parameters

To reveal the impacts of physical and anthropogenic factors, differences and commonalities among the 63 communities were further analysed, using major drivers identified for total annual finfish catch and the reported H_s/C_s and measured H_b/C_b ratio, comparing the percentage of fishing hours using line and speardiving techniques, and adding habitat diversity as found by the underwater surveys in the wider proximity (10 km) of reefs targeted by fishers. We first tested for the effects of the different island types and, second, current finfish fishing pressure risk as these factors were found to be significant in our regional dataset
(63 sites in 17 PICTs) in multivariate analysis (CAP).

Results of the first analysis, using *island type* as a factor, show differences among sites located on any of the four island types using the Spearman rank correlation vectors of individual variables if R^2 >0.3 with the CAP axes in Table A4.3.2.

Table A4.3.2: Summary of results from multivariate analysis indicating association of communities grouped by island type with individual and important variables

Variables	Island type			
	Atoll	**Complex**	**Oceanic**	**Small lagoon**
CPUE	High	Medium-high	Low-medium	Low
H_s/C_s	Low	Medium-high	Medium-low	High
Spearfishing hours (%)	Low	Medium-high	Medium-low	High
Population of community	Low	Low-medium	High	High
Urban population (%) at national scale	High	Medium-low	Medium-high	Low
Habitat diversity (10 km)	Medium	High	Low	Medium
Acanthuridae average biomass	Low	Medium-high	High-medium	High
Balistidae average biomass	Low-medium	Low	High	Medium-low
Serranidae average biomass	High	Medium-low	Medium-high	Low
Siganidae average biomass	Medium	High	Low	Medium
Scaridae average biomass	Medium	High	Low	Medium

CPUE = catch per unit effort; Hs/Cs = catch ratio of herbivores over carnivores.

Results of the second analysis aiming at differentiating among communities grouped using current finfish fishing pressure risk levels and major drivers are summarised in Table A4.3.3.

Table A4.3.3: Summary of results from multivariate analysis indicating association of communities grouped by finfish fishing pressure risk groups with individual and important variables

Variables	Finfish fishing pressure risk group (t/km^2 reef/year)			
	<1 (low)	**1–5 (low-medium)**	**5–10 (medium-high)**	**>10 (high)**
H_s/C_s	Low	Medium-low	High	High-medium
Line-fishing hours (%)	High-medium	High-medium	High-medium	Medium
Spear fishing hours (%)	Low	Low-medium	Low	Low-medium
Population of community	Low	Low-medium	Medium	High
Easy marketability	Low	Low-medium	Medium	High
Difficult marketability	Medium-high	High-medium	Low	Low
Urban population (%) at national scale	High	High-medium	High	Medium
Balistidae average biomass	Low	Low	Medium	Medium-high
Labridae average biomass	High	High	Medium	Medium-low
Kyphosidae average biomass	Low-medium	Medium	Low	Low-medium
Mullidae average biomass	High	High	Medium	Medium-low
Siganidae average biomass	High	High	Medium	Medium-low

H_s/C_s = catch ratio of herbivores over carnivores.

Combining both factors (island type and finfish fishing pressure risk groups) in one analysis showed that:

- Both island type and finfish fishing pressure risk group are significant factors but their effects are independent from each other, as we did not find any significant interaction between the two. This confirms the importance of two basic factors: physical conditions and anthropogenic effects of fishing. While physical parameters determine distribution and diversity of species and biomass, fishing as the major anthropogenic factor considered here impacts in quantity, quality and over time on what naturally is being provided. Thus, the effects of both island type and current finfish fishing pressure risk groups need to be taken into account to predict the likelihood of sustainable or unsustainable fisheries, and its natural potential for future and realistic fisheries management achievements.

Some of these major drivers show a linear relationship among finfish fishing pressure risk groups. Community population, easy marketability, consumer price index, and the representation of oceanic and small lagoon islands increase significantly from lowest to highest finfish fishing pressure risk groups, while habitat diversity in the wider proximity of habitats targeted by fishers, the H_b/C_b ratio, and the representation of complex islands decrease (Table A4.3.4).

Table A4.3.4: Average values (SE) for drivers per each finfish fishing pressure risk group

	Finfish fishing pressure risk group (t/km^2 reef/year)			
	<1 (low)	**1–5 (low-medium)**	**5–10 (medium-high)**	**>10 (high)**
Drivers				
Population of community	394 (101)	665 (121)	1153 (200)	3336 (702)
Easy marketability (% of communities)	0.33 (0.11)	0.33 (0.11)	0.55 (0.16)	0.94 (0.06)
CPI	159 (35.8)	199 (58.9)	265 (78.3)	301 (87.2)
H_b/C_b ratio	2.35 (0.33)	2.27 (0.31)	2.64 (0.67)	2.00 (0.29)
Island type (% of communities)				
Atoll	0.17 (0.09)	0.33 (0.11)	0.36 (0.28)	0.25 (0.11)
Complex	0.78 (0.10)	0.33 (0.11)	0.45 (0.16)	0.13 (0.09)
Oceanic	0.05 (0.05)	0.22 (0.10)	0.36 (0.15)	0.38 (0.13)
Small lagoon	0 (0)	0.11 (0.07)	0.18 (0.12)	0.25 (0.11)

CPI = consumer price index; H_b/C_b = biomass ratio of herbivores over carnivores.

Indicators versus current finfish fishing pressure risk groups

The island types defined distinguish sites according to naturally favourable or unfavourable conditions. Sites in each island type group were then classified according to finfish fishing pressure risk, as to compare sites with low (<1–5 t/km^2 reef/year) and high (>5 t/km^2 reef/year) finfish fishing pressure. Thus we could compare average data for each of the two finfish fishing pressure risk groups in each island type group, or between the expected and the actual low or high finfish fishing pressure. Results (Table A4.3.5) show that finfish fishing pressure can be unsustainable or sustainable despite naturally rich or poor conditions. The major factors are thus not natural conditions, but the ratio between the available production surface – particularly the reef area – and the number of fishers (closely associated with the population size in fishery-dependent communities). We found that, even under the most favourable natural conditions (atoll islands), some communities are in the 'unsustainable use' category. In other words, although communities on atoll islands show statistically higher CPUE and lower H_b/C_b, and have larger total reef, sheltered coastal and outer-reef surface areas, those that have significantly larger populations and higher total finfish fisher numbers have such high annual catch rates as a result, that their coastal fisheries are no longer sustainable. Similarly, communities with larger fishing ground surface areas, smaller population sizes and lower numbers of fishers had much lower annual catch rates, meaning that a number of communities even in the oceanic island types (least rich natural conditions), can fish at sustainable levels.

An index of all 63 communities studied and their classification by island type and current finfish fishing pressure risk group is provided in Table A4.3.6.

Table A4.3.5: ANOVA results between low (<5 t/km^2 reef/year) and high (>5 t/km^2 reef/year) finfish fishing pressure risk sites in each island type group for selected parameters

Variables	Island type			
	Small lagoon	Oceanic	Complex	Atoll
Population size of community	X	X	F 45.45, P<0.0001	F 17.27, P<0.001
Number of fishers (total)	X	X	F 42.87, P<0.0001	F 15.60, P<0.002
Total annual finfish catch	X	F 3.33, P<0.09	F 59.92, P<0.0001	F 34.74, P<0.0001
Fishing ground size	X	X	X	X
Reef area size	X		F 4.22, P<0.05	F 10.12, P<0.008
Sheltered coastal reef size	X		X	F 6.64, P<0.02
Lagoon size	X	X	X	
Outer-reef size	X		X	F 3.55, P<0.08
Finfish consumption (pc)		X	F 3.11, P<0.08	
Use of deep-bottom lines (%)	X	X	F 2.82, P<0.10	
Latitude	X	X	X	
CPUE	X			
Hb/Cb				F 3.22, P<0.10

CPUE = catch per unit effort; H_b/C_b = biomass ratio of herbivores over carnivores; pc = per capita.

Table A4.3.6: Index of communities studied and classified according to island type and current finfish fishing pressure risk group

Finfish fishing pressure risk group	Small lagoon	Oceanic	Complex	Atoll
<1 t/km^2 reef/year		Rarotonga (CI)	Dromuna (Fiji Islands)	Ailuk (MI)
			Lakeba (Fiji Islands)	Likiep (MI)
			Mali (Fiji Islands)	Koulo (Tonga)
			Moindou (NC)	
			Ouassé (NC)	
			Oundjo (NC)	
			Thio (NC)	
			Koror (Palau)	
			Ngarchelong (Palau)	
			Ngatpang (Palau)	
			Panapompom (PNG)	
			Ha'atafu (Tonga)	
			Manuka (Tonga)	
			Vailala (W&F)	
1–5 t/km^2 reef/year	Muaivuso (Fiji Islands)	Kiritimati (Kiribati)	Riiken (FSM)	Palmerston (CI)
	Raivavae (FP)	Luengoni (NC)	Romanum (FSM)	Fakarava (FP)
		Niue (Niue)	Yyin (FSM)	Arno (MI)
		Moso (Vanuatu)	Sideia (PNG)	Laura (MI)
			Maskelynes (Vanuatu)	Lofanga (Tonga)
			Halalo (W&F)	Nukufetau (Tuvalu)
5–10 t/km^2 reef/year	Manono-uta (Samoa)	Mangaia (CI)	Aitutaki (CI)	
		Kuria (Kiribati)	Piis-Panewu (FSM)	
		Paunagisu (Vanuatu)	Andra (PNG)	
		Uri-Uripiv (Vanuatu)	Tsoilaunung (PNG)	
			Chubikopi (SI)	
			Rarumana (SI)	
>10 t/km^2 reef/year	Maatea (FP)	Vailoa (Samoa)	Airai (Palau)	Tikehau (FP)
	Mataiea (FP)	Nggela (SI)	Marau (SI)	Abaiang (Kiribati)
	Salelavalu (Samoa)	Niutao (Tuvalu)		Abemama (Kiribati)
	Vaisala (Samoa)	Vaitupu (Tuvalu)		Funafuti (Tuvalu)
		Futuna (W&F)		
		Nauru (Nauru)		

Impacts of current finfish catch rates on resource status

Comparing both H/C ratios, i.e. H_s/C_s (catch) and H_b/C_b (biomass) (Figure A4.3.2) shows a highly statistically significant correlation, which confirms that the reported current finfish catch composition well represents the actual trophic composition measured in the underwater resource surveys.

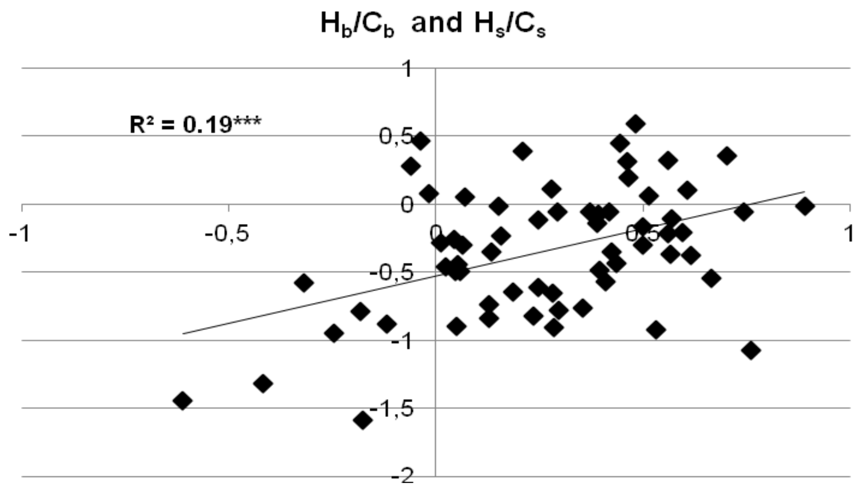

Figure A4.3.2: Linear regression between the biomass (H_b/C_b) and catch (H_s/C_s) ratios of herbivores over carnivores across 63 communities studied (Data are $\log_{+1}$ transformed.).

Linear correlations between current catch rates (t/km^2 reef/year) and the average biomass found per fish family (% of total biomass) for each major fish family (Table A4.3.7) showed positive relationships for Balistidae and Acanthuridae, and negative relationships for Siganidae, Scaridae and Labridae. No significant relationships were found between current catch rates and average biomass for Holocentridae, Kyphosidae, Lethrinidae, Lutjanidae, Mullidae and Serranidae.

Table A4.3.7: Effects of catch rates (finfish fishing pressure) on the average biomass of fish families

Fish family	R^2	P	Correlation
Balistidae	0.40	<0.0001	+
Acanthuridae	0.08	<0.02	+
Siganidae	0.22	<0.0001	-
Scaridae	0.20	<0.0002	-
Labridae	0.05	<0.06	-

Comparison between these results and linear correlations between current catch rates (t/km^2 reef/year) and the proportion of each fish family in the reported catch (Table A4.3.8) suggests that the decreasing average biomass as a function of increased catch rates of Siganidae and Labridae shows fishing impact. While impact on Siganidae could also be detected in reduced proportions in catch composition due to increased catch rates, the opposite is true for Labridae. There is also a strong signal for Acanthuridae, which are increasingly represented and exploited with increased fishing pressure. Scaridae show strong impact of fishing pressure; however, no corresponding signal was found between current catch rates and representation of Scaridae in catch composition. Carangidae are increasingly exploited with increasing fishing pressure, suggesting that increasing catch rates go hand in hand with increased targeting of pelagic and large-bodied fish (Figure A4.3.3).

Table A4.3.8: Proportional (by weight) representation of fish families in total catch in response to catch rates (finfish fishing pressure)

Fish family	R^2	P	correlation
Holocentridae	0.20	<0.0002	+
Lethrinidae	0.22	<0.0001	-
Carangidae	0.07	<0.04	+
Siganidae	0.08	<0.02	-
Acanthuridae	0.05	<0.08	+
Labridae	0.04	<0.10	+

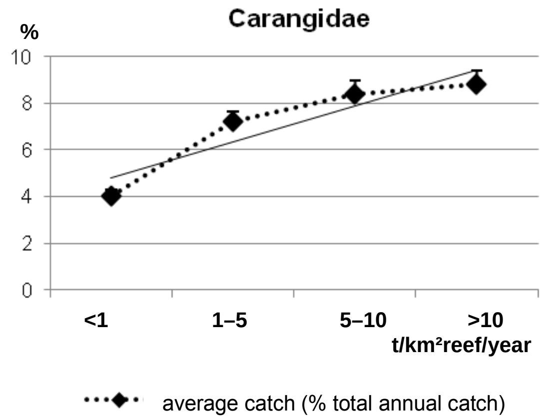

Figure A4.3.3: Proportion (weight) of Carangidae in catch with increasing fishing pressure (average by finfish fishing pressure risk groups).

The above arguments are further illustrated when average biomass and average catch are compared (% of total catch by weight) for selected fish families by finfish fishing pressure risk group (Table A4.3.9). For Acanthuridae (Figure A4.3.4) the increment of both average biomass and proportion (weight) in catch with increasing finfish fishing pressure is visible, as the opposite is true for Scaridae (Figure A4.3.5) and Siganidae (Figure A4.3.6).

Table A4.3.9: Correlations between increasing catch rates comparing lowest (<1 t/km² reef/year) and highest (>10 t/km² reef/year) finfish fishing pressure risk groups and average biomass by fish family

Average biomass	Finfish fishing pressure risk group	
	<1 t/km² reef/year	>10 t/km² reef/year
Acanthuridae	+	+
Balistidae	+	+ (R^2 0.20, P<0.08)
Holocentridae	+	-
Lethrinidae	+	-
Lutjanidae	+	-
Mullidae	+	-
Scaridae	-	-
Serranidae	+	-
Siganidae	-	-
Kyphosidae	+ (R^2 0.19, P<0.06)	-
Labridae	- (R^2 0.17, P<0.09)	(R^2 0.18, P<0.10)

+ = positive correlation; - = negative correlation.

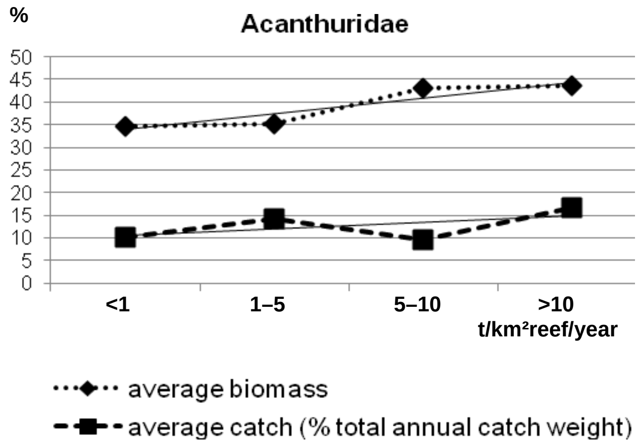

Figure A4.3.4: Proportion (weight) of Acanthuridae in catch and average biomass with increasing fishing pressure (average by finfish fishing pressure risk groups).

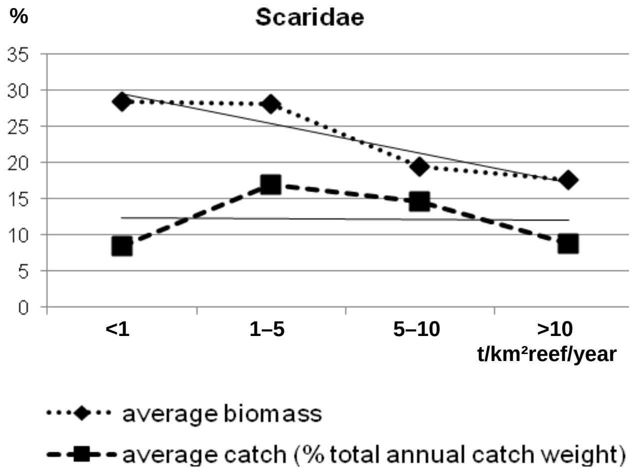

Figure A4.3.5: Proportion (weight) of Scaridae in catch and average biomass with increasing fishing pressure (average by finfish fishing pressure risk groups).

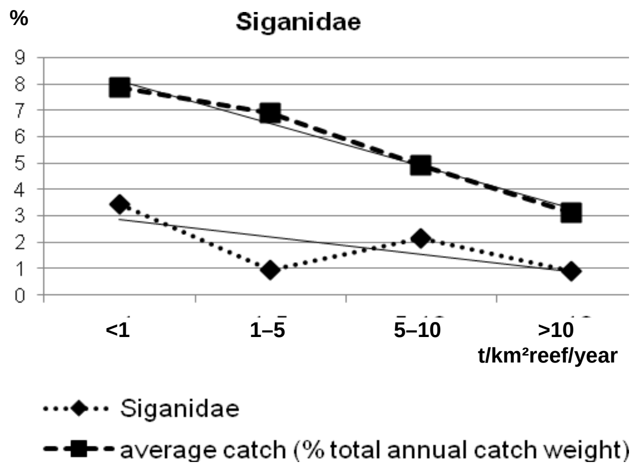

Figure A4.3.6: Proportion (weight) of Siganidae in catch and average biomass with increasing fishing pressure (average by finfish fishing pressure risk groups).

Impact of fishing techniques on trophic structure and fish family (average biomass)

Coastal finfish fishing in PICTs is multi-technique in nature, and no significant differences in the proportional use of the major techniques were found among all four finfish fishing pressure risk groups. Nevertheless, effects of the main fishing techniques used could be seen to some extent. Line-fishing results in more piscivores (Lutjanidae, Serranidae) and carnivores (Lethrinidae), and less herbivores (Acanthuridae, Scaridae) in catches (Table A4.3.10). Gillnetting showed least effects on catch composition; however, it results in less piscivores and carnivores (Labridae). Speardiving, as expected, increases the proportion of herbivores (Acanthuridae, Scaridae and Siganidae) and planktivores in the catch, and decreases the proportion of carnivores.

Table A4.3.10: Effects of fishing techniques used (in per cent of total annual fishing hours) and the percentage of catch by trophic group and fish family (linear regression)

Fishing technique	Trophic group	Fish family	R^2	P	Correlation
Line-fishing	Herbivores		0.23	<0.0001	-
	Piscivores		0.23	<0.0001	+
	Carnivores		0.11	<0.007	+
		Acanthuridae	0.28	<0.0001	-
		Lethrinidae	0.07	<0.04	+
		Lutjanidae	0.16	<0.001	+
		Scaridae	0.11	<0.008	-
		Serranidae	0.15	<0.001	+
Gillnetting	Piscivores		0.11	<0.009	-
		Labridae	0.11	<0.008	-
Speardiving	Herbivores		0.24	<0.0001	+
	Carnivores		0.05	<0.07	-
	Planktivores		0.06	<0.06	+
		Acanthuridae	0.32	<0.0001	+
		Scaridae	0.14	<0.002	+
		Siganidae	0.14	<0.002	+

Regarding the impact of fishing technique on the average biomass (finfish resource data), little effect was seen for total hours fished with line techniques (Table A4.3.11). However, the average biomass of Holocentridae (planktivores) and Scaridae (herbivores) decreased with increasing hours of gillnet fishing. The average biomass of Scaridae, Serranidae, Siganidae and Labridae also decreased the more hours were spent fishing using speardiving. In contrast, the average biomass of Lutjanidae increased with increasing hours of gillnet fishing, and the average biomass of Lethrinidae increased with increasing hours spent speardiving.

Table A4.3.11: Effects of fishing techniques (total hours/year) on average biomass by fish family (linear regression)

Fishing technique (total hours/year)	Fish family	Predominant trophic level	R^2	P	Correlation
Gillnetting	Holocentridae	Planktivore	0.16	<0.001	-
	Scaridae	Herbivore	0.07	<0.03	-
	Lutjanidae	Piscivore	0.09	<0.01	+
Speardiving	Scaridae	Herbivore	0.09	<0.02	-
	Serranidae	Piscivore	0.10	<0.01	-
	Siganidae	Herbivore	0.07	<0.04	-
	Lethrinidae	Carnivore	0.06	<0.05	+

Further investigations into the effects of fishing techniques used on the trophic composition by finfish fishing pressure risk groups confirmed that most detectable effects go hand in hand with increased fishing pressure. For the lowest finfish fishing pressure risk group (<1 t/km^2 reef/year), only the average biomass of Lethrinidae decreased as a function of increased hours fished with line techniques. For the low-to-moderate finfish fishing pressure risk group (1–5 t/km^2 reef/year), line-fishing techniques, speardiving, and gillnetting effects were detected as a decreasing average biomass of Scaridae; line and speardiving techniques were related to a decrease in biomass of Siganidae. The same effects on Scaridae were also confirmed for the moderate-to-high (5–10 t/km^2 reef/year) finfish fishing pressure risk groups. In addition, increased use of speardiving showed a negative impact on the average biomass of Holocentridae, Serranidae and Kyphosidae, and so did gillnetting on Holocentridae and Serranidae. A significant decrease in average biomass in the highest finfish fishing pressure risk group (>10 t/km^2 reef/year) was found for Mullidae in relation to line-fishing and gillnetting, and for Lutjanidae in relation to gillnetting.

Impacts of current finfish catch rates on the reported fish size

Multilinear regression between the annual finfish catch per habitat (t/km^2 habitat surface areas/year) and the 13 major fish families reported by fishers across all communities studied in PICTs showed a highly statistically significant relationship (sheltered coastal reef R^2 0.53, P <0.001; lagoon R^2 0.71, P <0.0001; outer reef R^2 0.46, P <0.008). Negative correlations within this multilinear regression were found for Holocentridae, Lutjanidae, Mullidae, Serranidae and Siganidae sourced from sheltered coastal reef; Scaridae and Serranidae caught in lagoon areas; and Balistidae, Scaridae, Serranidae and Siganidae from outer-reef areas.

Per family, statistically significant relationships between increased fishing pressure and a decrease in the reported average fish size (length) exist for four fish families: Acanthuridae, Lethrinidae, Mullidae and Siganidae (Table A4.3.12). Population density can be used as a parameter for finfish fishing pressure, except for Acanthuridae; and provides a negative response in the average reported fish length for Scaridae and Serranidae.

The average reported fish sizes caught for Acanthuridae, Scaridae and Siganidae for each finfish fishing pressure risk group are shown in Figure A4.3.7.

Table A4.3.12: Linear regression results of reported average fish length and finfish fishing pressure proxies, and of ANOVA comparing the average reported fish length for four finfish fishing pressure risk groups <1 to >10 t/km²/year

Fish family	Catch rate (t/km² reef/year)		Population density		Differences in fish length between finfish fishing pressure risk groups (ANOVA)	
	R^2	P	R^2	P	F-statistic	P
Acanthuridae	0.10	<0.01			8.10	<0.0001
Lethrinidae	0.08	<0.03	0.15	<0.001	0.89	ns
Mullidae	0.06	<0.06	0.09	<0.02	1.48	ns
Scaridae			0.07	<0.04	3.56	<0.02
Serranidae			0.04	<0.09	1.66	ns
Siganidae	0.08	<0.02	0.05	<0.07	2.40	<0.08

ns = non significant; ANOVA = analysis of variance.

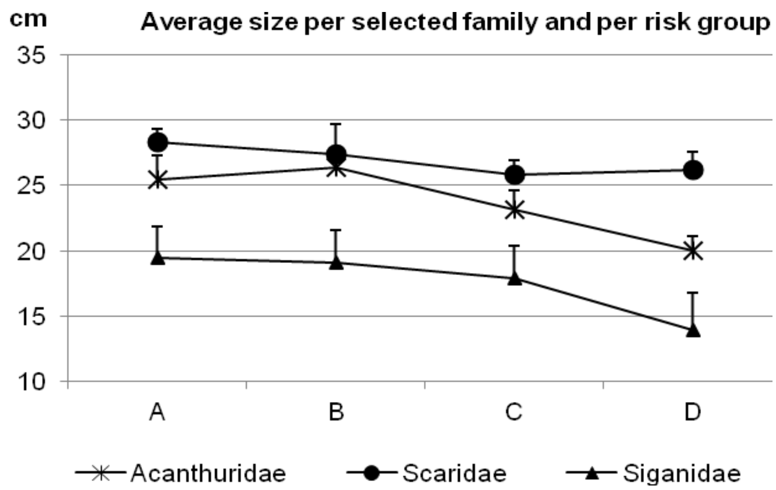

Figure A4.3.7: Average reported fish size caught per family and finfish fishing pressure risk group (SE included).
A to D = four finfish fishing pressure risk groups <1 to >10 t/km²/year.

Applying the reported average fish length by family and for each of the four finfish fishing pressure risk groups revealed statistically significant (ANOVA) for:

- Acanthuridae and Scaridae, with a weaker response for Siganidae only.

Using the ratio between the reported average fish size length caught and the maximum obtainable size (FishBase) by fish family in linear regression with catch rate revealed a statistically significant decrease with increasing fishing pressure for:

- Scaridae (R^2 0.97, P <0.04), and an increase in the size ratio;
- Holocentridae (R^2 0.08, P <0.05) and Labridae (R^2 0.15, P <0.02).

Multivariate analysis of major drivers using island type and finfish fishing pressure risk groups as a factor

Multivariate regression (redundancy analysis, RDA) was used to identify major socioeconomic and resource drivers to explain the variation in catch rates and H_s/C_s (catch) rates each. Seven variables explained 81% of the variation in catch rates. These included four socioeconomic variables: total population, marketability, CPI, and CPUE that alone explain 48% of the variation if the effects of the resource data are separated out. There are three resource variables, namely the surface areas of the back-reef and the outer reef, and the small-lagoon island type; these account for 24% of the variation alone, if the socioeconomic variables are separated out. The effects that are common to both the socioeconomic and resource variables explain 9% of the total variation.

A total of 62% of the variation in the H_s/C_s ratio is explained by five socioeconomic variables (% of hours line-fishing, marketability, total number of boats, % of urban population at national scale, total population) and two resource variables, i.e. average H_b/C_b ratio and lagoon reef surface areas.

These socioeconomic and resource variables were input into a discriminant-type of canonical correlation analysis (CAP) to characterise groups of sites studied, to visualise the differences among them and to assess how distinct these groups are from one another. Groups were defined using island type and, in a second step, finfish fishing pressure risk groups. In order to avoid co-linearity, variables concerning particular reef surface areas, i.e. back-, lagoon and outer reef, were excluded as they are included in catch rate (t/km^2 reef/year). Total population (community) was chosen rather than total number of boats. However, the H_s/C_s (catch) from the socioeconomic dataset and average biomass by fish family from the resource dataset were input. In addition, the percentage of hours spearfished was included. Vectors corresponding to Spearman rank correlations (R^2 >0.3) of individual variables with the resulting CAP axes were superimposed to identify which variables characterise the differences among sites and groups.

Permutation tests suggest that the axes distinguishing groups using island type as a factor are highly significant (P <0.0001) in the multivariate space. The CAP plot with superimposed vectors (Figure A4.3.8) shows that the island type is a strong distinguishing factor. The permutational multivariate analysis of variance (PERMANOVA) comparing the four island-type groups was highly statistically significant (P <0.0001) and these strong effects are further confirmed by PERMANOVA pair-wise tests (oceanic/complex F = 2.05, P <0.001; oceanic/atoll F = 1.53, P <0.001; oceanic/small F = 1.42, P <0.01; complex/atoll F = 1.28, P <0.04; complex/small F = 1.31, P <0.05; atoll/small F = 1.20, P <0.10).

Exploring the superimposed vectors shows that atoll island sites are highly associated with high CPUE, higher percentages of urban population, lower population of communities, lower proportions of spearfishing hours (%), a low H_s/C_s ratio, and a higher average biomass of Serranidae, but a lower average biomass of Acanthuridae.

Communities studied that are located on complex islands have a rather high habitat diversity (10 km radius), a higher average biomass of Siganidae and Scaridae, and a lower average biomass of Serranidae. The proportion of spearfishing hours (%) is relatively high.

Communities on islands of the oceanic type have a high population of communities, low habitat diversity, relatively low average biomass of Scaridae, Siganidae and Serranidae, but higher average biomass of Acanthuridae and Balistidae.

Finally, the few communities on small-lagoon islands are strongly associated with a high percentage of spearfishing hours, low average biomass of Serranidae, relatively high average biomass of Scaridae and Acanthuridae, low CPUE, and low percentage of urban population at national scale.

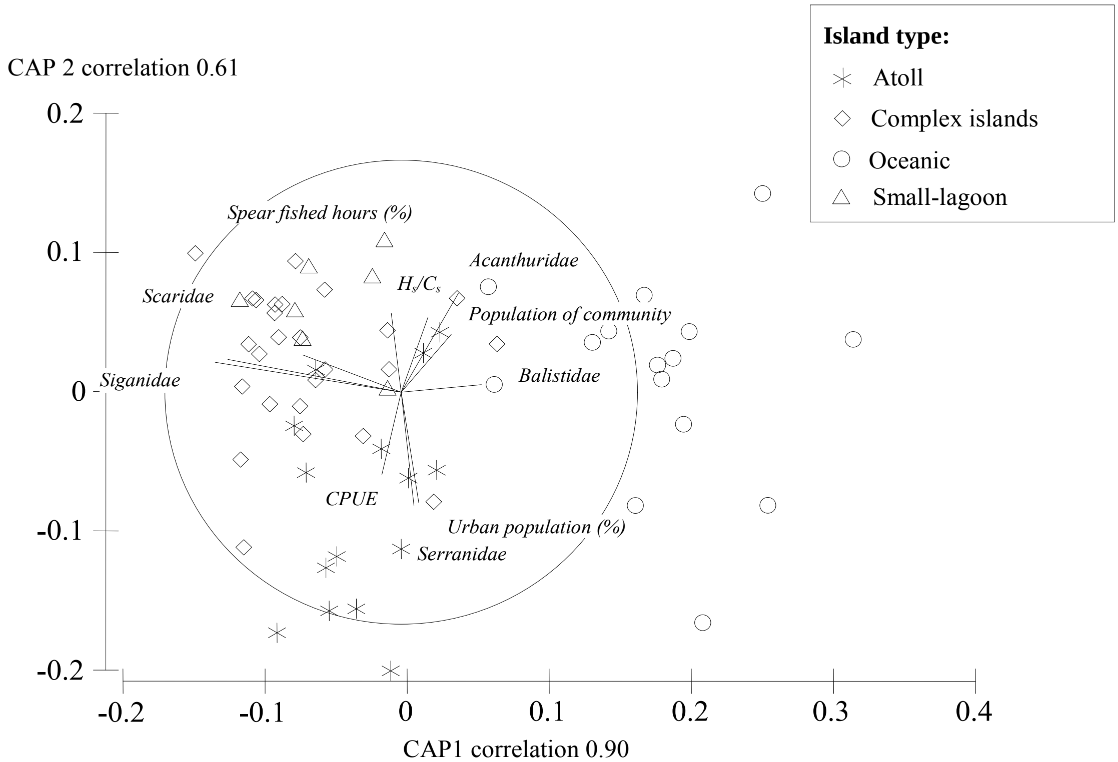

Figure A4.3.8: Canonical analysis of principal coordinates (CAP) of catch rates (t/km^2 reef/year), and socioeconomic, fishery and resource variables, using island type as a factor.

For the second step, the same discriminant-type of canonical correlation analysis (CAP) was employed to characterise groups of sites studied and their differentiation by major socioeconomic and resource drivers, using finfish fishing pressure risk groups as a factor. The resulting CAP axes distinguish groups highly statistically significant (P <0.0001). The CAP plot of the first two axes (total number of axes = 3) with superimposed vectors (Figure A4.3.9) shows distinct groups of sites classified into the same finfish fishing pressure risk category. PERMANOVA confirms highly significant distinction among all finfish fishing pressure risk groups (P <0.0001), and between most pairs (P <0.06–0.001), except for the two groups 1–5 and 5–10 t/km^2 reef/year.

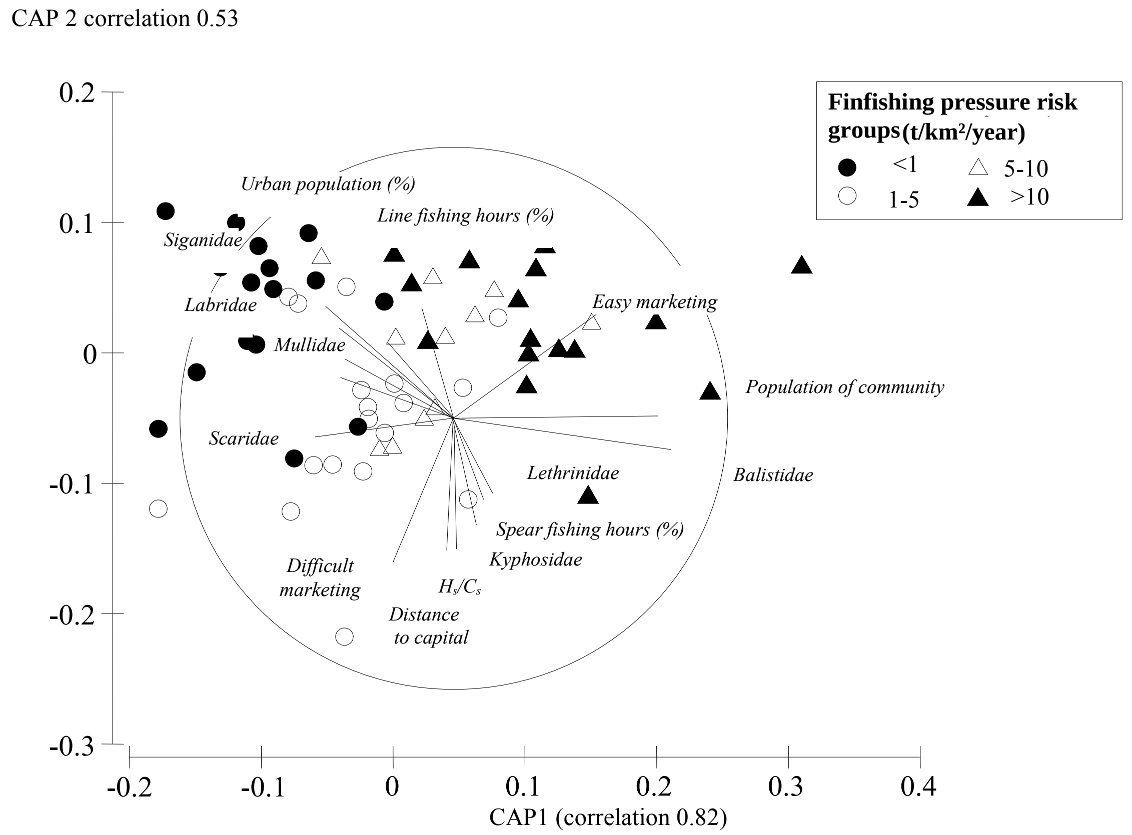

Figure A4.3.9: Canonical analysis of principal coordinates (CAP) of catch rates (t/km^2 reef/year), and socioeconomic, fishery and resource variables, using finfish fishing pressure risk groups as a factor.

Exploring the superimposed vectors (Spearman R^2 >0.3) shows that high catch rates are most strongly associated with: large populations in the community, easy marketing, close distance to capitals, and a relatively low H_s/C_s ratio. The opposite group of sites studied, i.e. those with low catch rates and rather small populations in their communities are most strongly associated with high habitat diversity, and have higher average biomass of Siganidae, Labridae, Mullidae and Scaridae. They are more closely linked to a higher proportion of line-fishing and a lower proportion of spearfishing hours.

However, we did not find any significant interaction between the two factors, island type and finfish fishing pressure risk group, as tested for using a crossed design in PERMANOVA. Results are highly significant for island type (P <0.002) and finfish fishing pressure risk groups (P <0.002), but there is no significant interaction between the two factors (P = 0.45). This indicates that neither island type nor finfish fishing pressure risk depend on each other, but that they each have a strong effect on their own.

4.4 Surveys

SURVEY FOR COLLECTION OF BASELINE INFORMATION ON SEA CUCUMBERS AND TROCHUS STUSTAINABLE MANAGEMENT IN SHEFA PROVINCE, VANUATU: *CONSUMPTION*

Name of surveyor: ____

1. Date ___________ 2. Village: ___________________________

3. Name of Respondents: ____

4. Gender: ☐ female ☐ male 5. Age: ☐

Sea cucumber & trochus consumption:

5. a) Do you and your family eat sea cucumbers? Yes No ☐ ☐

   b) Do you and your family eat trochus? Yes No ☐ ☐

6. If yes, for how many people do you regularly prepare a meal of:

   a) sea cucumbers? ☐ this number includes how many adults? ☐

   b) trochus? ☐ this number includes how many adults? ☐

   (adult = children aged 15 years and above)

7. a) Do you eat sea cucumbers throughout the year, or only during certain months?

   throughout the year: ☐

   certain months only: from months __________ to month ____________

   b) Do you eat trochus throughout the year, or only during certain months?

   throughout the year: ☐

   certain months only: from months __________ to month ____________

8. a) In the months that you eat usually sea cucumbers, how often would you prepare a meal for the people/family you regularly share your meal with?

   No of days/**week** ☐ **or:**

   Once every **2 weeks** ☐ **or:**

   No of times/**month** ☐ **or:**

   No of times/**year** ☐

b) In the months that you eat usually sea cucumbers, how often would you prepare a meal for the people/family you regularly share your meal with?

No of days/**week** ☐ **or:**

Once every **2 weeks** ☐ **or:**

No of times/**month** ☐ **or:**

No of times/**year** ☐

9. a) How many sea cumbers does your household (the people who eat regularly together every time) consume in a day?

No of bottles	***Size of bottle***
	285 ml
	500 ml
	750 ml
	1 l
	Other, specify:

b) How many trochus does your household (the people who eat regularly together every time) consume in a day?

Number of animals	***Diameter with shell***	***Diameter meat only***

10. a) Where do you get the sea cucumbers from? Please indicate which is the most important source. If you have more than one source: 1= most important, 2 = second most important, 3 = least important.

Somebody in my household fishes them ☐

We receive them as a gift ☐

We buy them ☐ where? ____________________

b) Where do you get the trochus from? Please indicate which is the most important source. If you have more than one source: 1 = most important, 2 = second most important, 3 = least important.

Somebody in my household fishes them ☐

We receive them as a gift ☐

We buy them ☐ where? ___________________

Thank you?

SURVEY FOR COLLECTION OF BASELINE INFORMATION ON SEA CUCUMBERS AND TROCHUS SUSSTAINABLE MANAGEMENT IN SHEFA PROVINCE, VANUATU: *FISHER SURVEY*

1. Date ___________ 2. Village: ______________________________

3. Name of respondent: ____

4. Gender: female: ☐ male: ☐ 5. Age: ☐

General issues of fishery and alternatives:

6. Do people in your village fish for sea cucumbers: Yes ☐ No ☐

7. Do they fish in your area (fishing ground?) Yes ☐ No ☐

8. If no, where do they fish? ____

9. Do you fish for sea cucumbers? Yes ☐ No ☐

10. Do you fish for:
Home consumption: ☐
Giving away (no money paid for): ☐
For sale: ☐

11. What other fisheries do you do and what reason for?

	For home consumption	For giving to friends	For selling
Trochus			
Giant clams			
Octopus			
Lobster			
Fish			
Others (specify)			

12. If you compare all the different fisheries that you earn money from, which one do you think is the most important, the second most important, the third most important, etc. fishery for you?

Fishery	***Rank***
Trochus	
Giant clams	
Octopus	
Lobster	
Fish	
Others (specify)	

13. What other income sources and how important are they as compared to income that you earn from all ofyour fishing activities?

Source of Income	***Rank***
Fishing	
Agriculture	
Salary	
Business	
Handicraft	
Social payments, remittances, pension, retirement schemes etc.	

<u>Sea cucumber fishing:</u>

2. How do you collect sea cucumbers?

Free diving: ☐ using Scuba: ☐

Gleaning by wading in shallow water: ☐

3. On which reefs do you mostly fish sea cucumbers?

Coastal reef: ☐ Lagoon reef: ☐ Barrier reef: ☐ Passes or deep water: ☐

mangroves & seagrass: ☐ others: ☐ where?______________________ .

The catch

5. Which species and sizes of sea cucumbers do you mostly collect?

Species	No.	Size (cm)	You find these sea cucumbers:		
			easily/lots of	sometimes	hard/rarely
H. scabra (Sanfis)					
*H. coluber (*Snakefis)					
H. edulis (Pinkfis)					
H. atra (Lolifis)					
H. whitmaei (Blaktit)					
H. fuscogilva (Waettit)					
H. fuscopunctata (Elephantfis)					
A. echinites (Deep wota redfis)					
A. spinea (Long blakfis)					
A. miliaris (Blakfis)					
A. palauensis (Rif loli)					
A. mauritiana (Sedredfis					
A. lecanora (Waet ass)					
S. chloronotus (Grinfis)					
S. herrmanni (Karrifis)					
*S. horrens (*Pintafis)					
T. ananas (Paenapolfis)					
T. anax (Ambafis)					
B. argus (Tigerfis)					
B. similis (Chalkfis)					
P. graeffei (Flaoafis)					

<u>Fishing effort:</u>

You fish: the whole year? Yes ☐ No ☐

during a season Yes ☐ No ☐

<u>If you fish the **whole year:**</u>

How many days usually do you fish in a: week? ☐

month? ☐

How long does the fishing trip usually take? Hours: ☐

<u>If you fish during **a season** only:</u>

Do you go fishing sea cucumbers longer than a day? Yes ☐ No ☐

If **yes**, how many days per fishing campaign? Days: ☐

And how many hours do you usually spent collecting per day during such a fishing campaign?

Hours: ☐

If no, how many days do you usually fish in this period?

Days: ☐

And how many hours do you usually spent collecting per day?

Hours: ☐

For all sea cucumber fishers regardless whether they fish throughout the year or seasonal:

How do you get to the fishing site?

Walking: ☐ Car: ☐ Own boat: ☐ Someone else's boat: ☐

If someone else's boat, do you pay them for taking you there?

Yes ☐ No ☐

On a normal day, how many people would you fish sea cucumbers with? _____ . people

During the past year, what weight of sea cucumbers would **you** normally catch?
(if he/she fishes in a group needs to specify how many fishers are accountable for the catch figures given)

On average? __________ kg per day __________ kg per trip

And on a bad day/trip? __________ kg per day __________ kg per trip

And on a very good day/trip? __________ kg per day __________ kg per trip

This is the catch that you yourself make in a day or trip? Yes ☐ No ☐

If no, please tell how many fishers are usually involved for that catch? ☐

(Optional: add-in a break-down by species or species groups)

<u>**Processing of sea cucumber:**</u>

Do you gut the sea cucumbers? Yes ☐ No ☐

If yes, when? Immediately ☐ After returning to land ☐

Do you boil the sea cucumbers you collect Yes ☐ No ☐

Do you salt them? Yes ☐ No ☐

Do you boil and dry them?

All the time ☐ Most of the time ☐ Only sometimes ☐ Never ☐

Sale:

Who do you normally sell the sea cucumbers to? ________________________________.

____

Do you get different prices for different species? Yes ☐ No ☐

Do you get different prices for different sizes or quality? Yes ☐ No ☐

Do the buyers reject small sea cucumbers?

Always ☐ Sometimes ☐ Never ☐

What price per kg do you get for the main species you collect?

Species	Minimum Vatu/kg	Maximum Vatu/kg

Are those prices for dried, salted, or fresh product? Dried ☐ Salted ☐ Fresh ☐

Does the person you sell to ask you to collect certain species? Yes ☐ No ☐

If yes, which species? ____.

____

____.

Do you sometimes sell to a different buyer? Yes ☐ No ☐

Appendix 4: Socioeconomic assessment data and analysis methods

Fishing history:

For how many years have you been fishing sea cucumbers? _____________ years.

Did you used to catch more per day? Yes ☐ No ☐

If yes, what weight of sea cucumbers could you catch on *a good day*? ___________ kg

What was the *average* weight of sea cucumbers you used to catch per day? ___________ kg

How many years ago was that? _____________years

Did you collect the same species that you collect now, or were you fishing different species then?

Same ☐ Different ☐

If different, which sea cucumbers would you collect (more) in the past?

____

____

____

____

In the past, were you fishing different areas? Yes ☐ No ☐

(Optional: define locations, establish the distances travelled, perhaps problem with ownerships, any factor that may have supported/or limited access to BDM/trochus in the past, currently and in the future)

What do you think about the status of sea cucumber stocks in your fishing area?

Increasing	
Stay about the same	
Getting less	
Almost nothing left	

Why do you think so? ____.

Management:

Are you aware of the fishing regulations for sea cucumbers in your Province? Yes ☐ No ☐

If yes, what regulations are you aware of? ______________________________.

Do you think there should be regulations to fishing sea cucumbers? Yes ☐ No ☐

What fishery regulations do you think would be good for the sea cucumber fishery here?

- ☐ Size limits: Fresh: ☐ Dried: ☐
- ☐ Reserves or No-Take Zones
- ☐ Seasons or ban fishing for part of year
- ☐ Rotational closures (e.g. allow fishing on each reef every 4 years)
- ☐ Restrict number of fishers
- ☐ Prohibit fishing of some species
- ☐ Annual quota (total wt that can be fished in a province)
- ☐ Limit the gear used e.g. no SCUBA
- ☐ Limit the size of boat that can be used
- ☐ Prohibit night fishing
- ☐ Moratorium (ban) on fishing
- ☐ Others: ______________________________.

Who do you think should enforce the regulations?

National Government: ☐ Province: ☐ Community: ☐

Family: ☐ Fishers: ☐

Do you think the current regulations are good? Yes ☐ No ☐

If no, why not? ______________________________.

Do you think the current regulations are respected by most fishers? Yes ☐ No ☐

If no, what regulations are being infringed: ______________________________ .

THANK YOU!

4.5 Gender roles and socioeconomic drivers for artisanal coastal fisheries in Pacific Island countries and territories - a cross-cultural and regional analysis

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Abstract

Pacific Island countries and territories depend greatly on their marine resources. These resources are subject to overexploitation and disturbance resulting from anthropogenic causes and climate change, rendering economies and people increasingly vulnerable. Successful planning and implementation of holistic small-scale artisanal fisheries and coastal resource management strategies depend on a sound understanding of the nature of the region's fishery production systems, including gender roles, shifts in access to resources and opportunities in the surrounding social, cultural and institutional context. We addressed the lack of a region-wide, gender-disaggregated subsistence and small-scale artisanal fisheries analysis at the community level by providing insight into contemporary differences and similarities between fishermen and fisherwomen in finfish fisheries and invertebrate harvesting across 17 Pacific Island countries and territories. Identification of major socioeconomic drivers that determine the extent to which men and women are dependent on wild-caught marine resources revealed a better understanding of current gender roles in coastal subsistence and artisanal fisheries. Using results obtained we appraised gender-related vulnerabilities, comparing the three major cultural groups (Melanesia, Micronesia and Polynesia) in terms of their needs and limitations as entry-points for successful fisheries management strategies.

Finfish fishing was found to be the major food and income source and is principally accounted for by men. While women's finfish catch mostly contributes to home consumption, changes are visible as Melanesian fisherwomen engage substantially in finfish fishing for food and income. We found that regionally and within cultural groups total harvesting time and total annual catch of major invertebrate species groups are generally equally shared by men and women. Today, the major gender difference in invertebrate fisheries is the fact that women do not participate in free-diving fishing activities, resulting in gender-biased access to, participation in and benefit from commercial export fisheries. Main socioeconomic drivers found to determine fishers' productivity vary in their importance between cultural groups but include a combination of demographic, economic and financial factors, and access to alternative income sources. Major differences emerge according to gender role. Women are mostly affected by community-based or even household-based factors as their main contribution aims at subsistence needs, while men's commercial finfish and invertebrate production, matched with their subsistence contribution, are associated with an interaction of socioeconomic factors at the national and the community level. We argue that the substantial changes observed in Melanesian women's significant engagement in finfish fishing are a response to the combined effects of a rigorous economic environment and favorable cultural conditions.

Keywords: gender; artisanal fisheries; socioeconomic drivers; fisheries management; South Pacific

Introduction

Pacific Island countries and territories (PICTs) preside over one of the largest arrays of marine habitats and coastal biodiversity in the world, including an exclusive economic zone (EEZ) covering more than 30 million km^2. By comparison the total land surface scattered over approximately 30,000 islands is only about 551,483 km^2. With such a small land area, there are limited alternatives for agricultural production and the people of the region depend on marine resources for food, livelihood and economic development (World Bank 2000a, Dalzell and Schug 2002, SPC 2002, Ram-Bidesi 2008).

The contribution of subsistence and small-scale artisanal coastal fisheries in PICTs falls mostly under the informal sector, and non-monetised as well as a large proportion of monetised values of many activities and transactions do not enter into the national cash economy accounting (Gillett and Lightfoot 2001). The rising dilemma of declining fishery productivity due to overfishing, habitat destruction, pollution and possibly the effects of climate change, and an increasing demand for food and income due to the region's projected population growth (from an estimated 9.7 million people in mid 2009 to approximately 14 million people by 2030) (Bell *et al.* 2009), has changed the political tide. In response, regional strategies are in place that give priority to enhancing and stimulating economic growth via sustainable development and good governance (Pacific Islands Forum Secretariat, 2007a), with high priority on coastal marine resources (Pacific Islands Forum Secretariat, 2007b), and regional mechanisms to harmonise national policies and activities that address the long-term sustainability of coastal fisheries resources and maintenance of healthy marine ecosystems (Secretariat of the Pacific Community 2008). Leaders in PICTs have recognised that fisheries management is about managing people rather than fish stocks. In response the ecosystem approach to fisheries (EAF) has been adopted and, along with community-based fisheries management (CBFM), is being promoted region-wide to reach one of the major goals of the Apia Policy: 'to ensure the optimal and sustainable use of coastal fisheries and their ecosystems by Pacific Island communities'.

The sustainable development agenda also called for the integration of gender equity and justice into economy and environment policy and sustainable resource management (Ram-Bidesi 2008), and global strategies (United Nations 1992, 2002, United Nations Population and Information Network 1994) are being adapted to meet the context of PICTs. The Pacific Regional Gender and Development Partners Cooperation Framework, spearheaded by the Secretariat of the Pacific Community (SPC), is a mechanism for enhancing agency coordination and collaboration based on the Revised Pacific Platform for Action (2004) and the Pacific Plan (Pacific Islands Forum Secretariat 2007a) in which PICTs committed to national action to promote the advancement of women. However, large differentials still exist between women's and men's access to resources, higher education, and economic and political participation, severely handicapping whole societies and economies in achieving economic and development goals (Secretariat of the Pacific Community 2005, Clark and Rodrigues 2009, Nelson 2008).

Successful planning and implementation of holistic small-scale artisanal and coastal resource management strategies depend on understanding small-scale fishery production systems (Kronen 2003, Hilborn 2007), allowing the identification of appropriate entry points for development interventions or policy support (Allison and Ellis 2001). Fishery production systems include men and women. Without a complete understanding of gender roles, changes in gender roles in response to shifts in access to resources and opportunities, and shifting norms and events in the social and institutional context (Ellis 2000a), the goal of ensuring sustainable livelihoods and coastal fisheries management is unlikely to be achieved (Bennett 2005).

Gender in coastal fisheries has been discussed frequently with the goal of enhancing understanding of women's roles and their needs, strategies and contributions to food security and income (Bennett 2005, Williams 2001, Matthews 1991, Kronen and Vunisea 2005). Women's diverse and dynamic roles and contributions in the region's subsistence and artisanal fishery sector are undervalued or unrecognised (Williams 2009a). Various sets of indicators or checklists that have been devised to measure the core role of women in developing countries, such as the World Bank indicators (2003a), the Gender-related Development Index (GDI) and Gender Empowerment Measure (GEM) (UNDP 2003), the United Nations Food and Agriculture Organization (FAO) checklist on women in fishing communities (1988), or the cross-disciplinary examination of gender in inland fisheries (Seki and Sen 1994) are considered too broad in scale and too generalised to provide information on women's activities at the community level (Omoto 2004). Quantitative and gender-disaggregated data is considered essential to understand how men and women interact with the resource (Bennett 2005) and participate in the various dimensions of wild-caught fisheries and aquaculture (Williams 2009b), and to formulate and monitor natural resource policies (FAO 2007).

This paper addresses the lack of a region-wide, gender-disaggregated subsistence and small-scale artisanal fisheries analysis at the community level. Based on gender-disaggregated fishery data collected in 63 communities across 17 PICTs, we give the first ever regional overview of commonalities and differences in the participation of fishermen and fisherwomen in finfish fishing and invertebrate fisheries for subsistence and income purposes and in their fishing strategies, fishing techniques, productivity, resource exploitation levels, and marketing of catch. We further analyse relations between gender and dependency on finfish and invertebrate resources and socioeconomic factors at the national and community scales and between the three cultural groups: Melanesia, Micronesia and Polynesia. It is the overall objective of this study to characterise current roles of men and women in coastal subsistence and artisanal fisheries, to reveal socioeconomic drivers that determine the extent to which men and women are dependent on wild-caught marine resources, and to appraise gender-related vulnerabilities according to their needs and limitations as entry-points for successful fisheries management strategies.

Data and methods

Data collected from 5186 fishers, including 2663 finfish fishers (2212 fishermen, 451 fisherwomen) and 2523 invertebrate fishers (1221 invertebrate fisherwomen, 1302 invertebrate fishermen) in 63 communities within 17 PICTs were analysed using average figures for each community for the gender and culture groups. Data were further classified into two major fisheries: finfish fisheries and invertebrate harvesting. We further distinguish between fishers practicing only finfish fishing, or only invertebrate harvesting, and those who may do both, but not necessarily combined in one fishing trip. For finfish fisheries, three major habitats were distinguished, i.e. the sheltered coastal reef (including mangroves where applicable), the lagoon (including back reef) and the outer reef (including passages). For invertebrate fisheries, gleaning and free-diving activities were compared. Within gleaning activities, distinction was made between targeting soft-benthos (mainly seagrass), intertidal (mainly sandy areas), mangrove, and reef-top habitats. For free-diving activities we distinguished between bêche-de-mer, lobster, trochus and other target species groups. The group of other target species basically represents free-diving harvesting of clams, Lambis lambis, and also trochus, lobster and octopus as possible but not regular species. Invertebrate fisheries data were also organised and compared by target species group, including clams (Tridacna sp., Hippopus sp.), crustaceans (excluding lobster), bivalves (excluding clams), gastropods (excluding commercial trochus), bêche-de-mer (for commercial export, not as a possible target species during gleaning activities for numerous species), lobster (mainly Panulirus sp., to a minor extent Parribacus sp.), octopus and trochus (commercial, not as a possible by-product of gleaning).

Data were collected using standardised fully structured closed questionnaire surveys (Kronen *et al.* 2007). Respondents were selected by stratified random sampling to obtain a comparative sample representing the proportion of gender participation in any finfish fisheries and invertebrate fisheries operating at the subsistence and/or commercial levels in each of the communities studied. All snapshot surveying took place between mid-2003 and 2008. The sample design allowed us to extrapolate survey data to estimate total impact in relation to the total population size per site. Sites were selected for their representativeness at the country level as fishery dependent rural coastal communities with access to important habitats and fisheries. A site is defined as the ensemble of a village or villages and the fishing ground that they own or use.

The 17 PICTs included in the survey fall into three major cultural groups: Melanesia, with five PICTs (Fiji Islands, New Caledonia, Papua New Guinea, Solomon Islands, Vanuatu) represented by a total of 21 sites studied; Micronesia, with five PICTs (Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau) with a total of 17 sites studied; and Polynesia, including seven PICTs (Cook Islands, French Polynesia, Niue, Samoa, Tonga, Tuvalu, Wallis and Futuna) with a total of 25 sites studied.

For finfish fisheries analysis, total annual finfish fishing hours, total annual catch, and both parameters disaggregated as total annual finfish fishing hours and total annual catch by habitat, were used for impact assessment. Overall average catch per unit effort (CPUE) and by habitat was used as a productivity measure. CPUE is defined as the catch (kg) per hour of fishing trip, i.e. from starting to landing point. The analysis of fishing strategies included time preference for finfish fishing (notably night fishing), the regular use of boat transport, frequency of finfish fishing trips (times/week), average duration of fishing trips, and the use of finfish fishing techniques. A total of nine major finfish fishing techniques emerged from the survey data and were distinguished. Speardiving encompasses any free-diving activity that uses artisanal or modern spearguns. Handlining is fishing with a single line held in the hands, using bait fish or lures, and may be performed from the shore or from boats. Gillnets include a range of different mesh sizes. Fishing rods include artisanal bamboo rods as well as modern cast rods. Handheld spearing uses artisanal spears that may be employed while walking or from boats. Castnets, also called throw nets, are nets with small weights distributed around their edges. Bottom fishing is commonly done from boats by using a weight tied to the end of a line and a hook about 2–3 cm above it. Methods grouped as others may be represented by one or a combination of traditional, mostly low-cost tools, such as bush knives, artisanal bows and arrows, small home-made scoop nets, traditional fish poisoning (use of the poisonous root from Derris sp.) (Kronen 2002a, Merlin 2002), and in rare cases artisanal fish fences and fish traps.

Total annual hours spent gleaning or free-diving; the total annual fishing times spent collecting in soft benthos, mangroves, intertidal areas, and reeftops; the total annual fishing times spent harvesting bêche-de-mer, lobster, trochus and others; and the total catch (wet weight) by invertebrate species group were used to analyse impact for invertebrate fisheries. In addition, average reported clam and Lambis lambis catch sizes were used to compare possible impact of gleaning and free-diving activities on the two resources. Productivity was measured in terms of average catch (wet weight) per invertebrate fishing trip.

The variables selected to investigate invertebrate fisheries strategies were time preferences for invertebrate harvesting, the use of boat transport, and frequency and average duration of invertebrate fishing trips for gleaning.

T-tests and single factor, one-way analysis of variance (ANOVA) were used to test for differences between two or more independent groups, and linear regressions for analysing relationships between two variables. Data was, where necessary log (X+1) transformed. For multivariate analysis a forward selection model, using R^2 in redundancy analysis (RDA) in CANOCO 4.5 (Ter Braak and Smilauer 2002) was employed to select the most important demographic and socioeconomic variables at national and community scales that explain regional variation found in finfish and invertebrate catch rates. At the national scale these variables were: population density, the percentage of urban population, dependency ratio (age group of 15–59 years), gross migration and the per capita export–import balance (0 to negative values). At the community scale these variables were selected and input into the model: total number of boats, average household size, percentage of households in the community receiving remittances, percentage of adults in the community with primary and secondary education, average household expenditure and per capita invertebrate consumption. Gender relations aiming at identifying socioeconomic drivers by gender-specific annual catch rates of finfish and invertebrate species groups were determined from Euclidean-based distance matrices with canonical analysis of principal coordinates (CAP) (Anderson and Willis 2003) applying 9999 permutations in PERMANOVA+ for PRIMER (Anderson *et al.* 2008). Data were normalised. Spearman correlations of individual variables with canonical axis 1 were used for interpretation and shown in graphs if absolute correlation was >0.20. Distinction of cultural groups was tested for by PERMANOVA (permutation 9999) in main and pair-wise tests.

Results

Participation of women and men

Each community selected for survey was classified as a coastal fishery dependent community and each community surveyed had participation of both women and men in at least some of the fisheries compared. Participation of both gender groups varies between fisheries, countries and cultural groups. If one compares the number of communities where men and women participate in any of the three possible major fishery types (exclusive finfish fishing, exclusive invertebrate fishing, and both finfish fishing and invertebrate fishing), women are usually less engaged in exclusive finfish fishing, and more engaged in exclusive invertebrate fishing. The relationship between men's and women's participation in any of the three fishery types by cultural groups is comparable, with the exemption of Melanesia, where women are engaged in finfish fishing and invertebrate collection in each community studied (Table1).

Table 1: Percentages of sites having gender participation in any of the fishery groups

	Melanesia (n=24)		Micronesia (n=17)		Polynesia (n=22)	
Fishery	men	women	men	women	men	women
exclusive finfish fishing	92	50	100	41	100	55
exclusive invertebrate fishing	38	88	35	88	36	91
finfish fishing & invertebrate fishing	100	100	100	65	100	77

Significant variation exists in the percentage of fishers in each of the three major fishery types at the regional level and between cultural groups. Micronesian and Polynesian communities have the highest proportions of exclusive fishers, with men targeting finfish and women targeting invertebrates. Most men and women in Melanesian communities are less specialised but engage in both finfish fishing and invertebrate collection, with no significant gender differences (Table 2).

Table 2: T-test analysis comparing participation (% of fishers) in major fishery groups by gender and culture

Cultural group	Fishery group	P
Regional	Exclusive finfish fishers	<0.0001
	Exclusive invertebrate fishers	<0.0001
	Finfish and invertebrate fishers	<0.0001
Melanesia	Exclusive finfish fishers	<0.0001
	Exclusive invertebrate fishers	<0.0001
	Finfish and invertebrate fishers	n.s.
Micronesia	Exclusive finfish fishers	<0.0001
	Exclusive invertebrate fishers	<0.0001
	Finfish and invertebrate fishers	<0.001
Polynesia	Exclusive finfish fishers	<0.0001
	Exclusive invertebrate fishers	<0.0001
	Finfish and invertebrate fishers	<0.0001

To further refine gender differences in finfish fisheries and invertebrate harvesting, total hours fished by women and men, split into finfish fishing, gleaning and diving time, were compared. Fishermen across all cultural groups account for most of the total finfish fishing hours (Figure 1). In Micronesian and Polynesian communities, fisherwomen contribute little to the total time fished, with 9.5% and 10.9% respectively. By comparison, finfish fishing time accounted for by Melanesian fisherwomen is substantial (35.1%). Time invested by both gender groups for the harvesting of invertebrates, including both gleaning and diving, is comparable across cultural groups (Figure 2). However, statistically significantly differences exist between the total gleaning time (mostly accounted for by women) and the total diving time (explained by men) (Table 3).

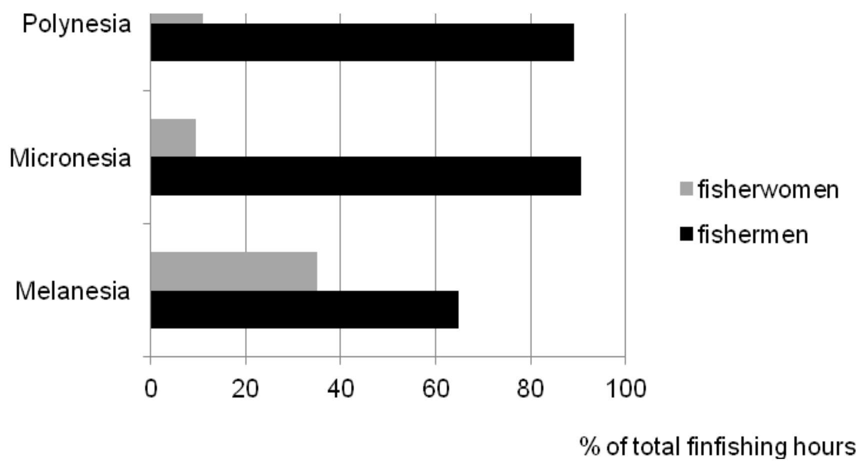

Figure 1: Percentage of total finfish fishing hours accounted for by fishermen and fisherwomen across all cultural groups in PICTs

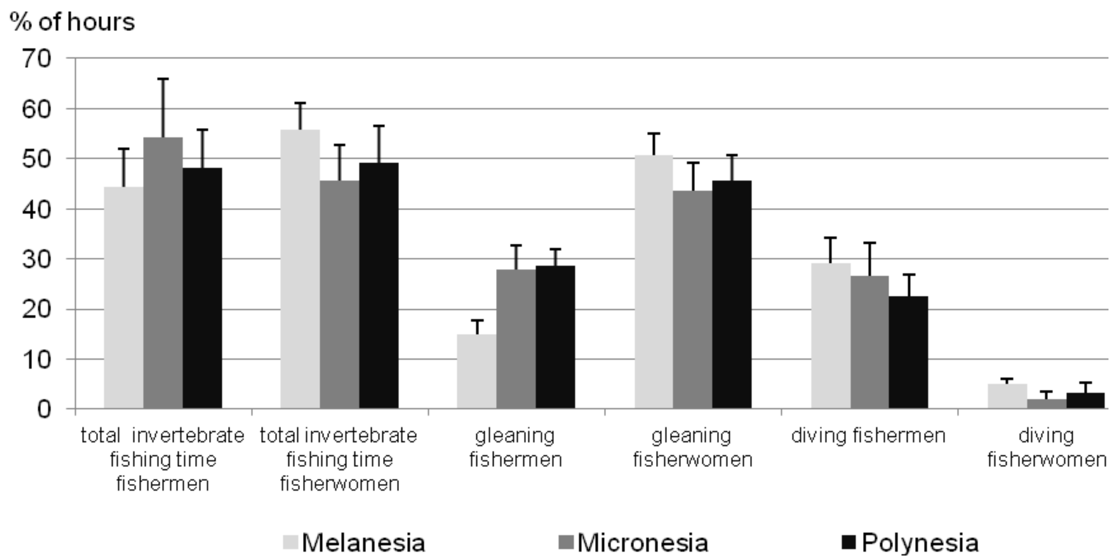

Figure 2: Average proportions (%) of total fishing time spent for invertebrate collection and of total gleaning and free-diving time by gender and cultural groups

Table 3: Differences in time spent collecting invertebrates (% of total hours) for gleaning and free-diving, by gender and cultural group (T-test)

Cultural group	Collection activity	P
Regional	Gleaning Free-diving	<0.0001 <0.0001
Melanesia	Gleaning Free-diving	<0.0001 <0.0001
Micronesia	Gleaning Free-diving	<0.05 <0.001
Polynesia	Gleaning Free-diving	<0.01 <0.0005

Substantial differences were also found for major habitats targeted for finfish fishing between gender and cultural groups (Figure 3). Time spent fishing by Melanesian fishermen decreases with increasing distance from shore. However, Micronesian and Polynesian fishermen spent most time in the lagoon area, dividing the remainder of their time more or less equally between sheltered coastal and outer-reef areas. Melanesian fisherwomen spent most of their finfish fishing time closest to shore, while Micronesian and Polynesian fisherwomen slightly favor the lagoon habitat. Fisherwomen across all cultural groups spent very little time finfish fishing at the outer reef, with marginal proportions of 1% and 3% respectively for Melanesian and Micronesian fisherwomen, and 15% for Polynesian fisherwomen.

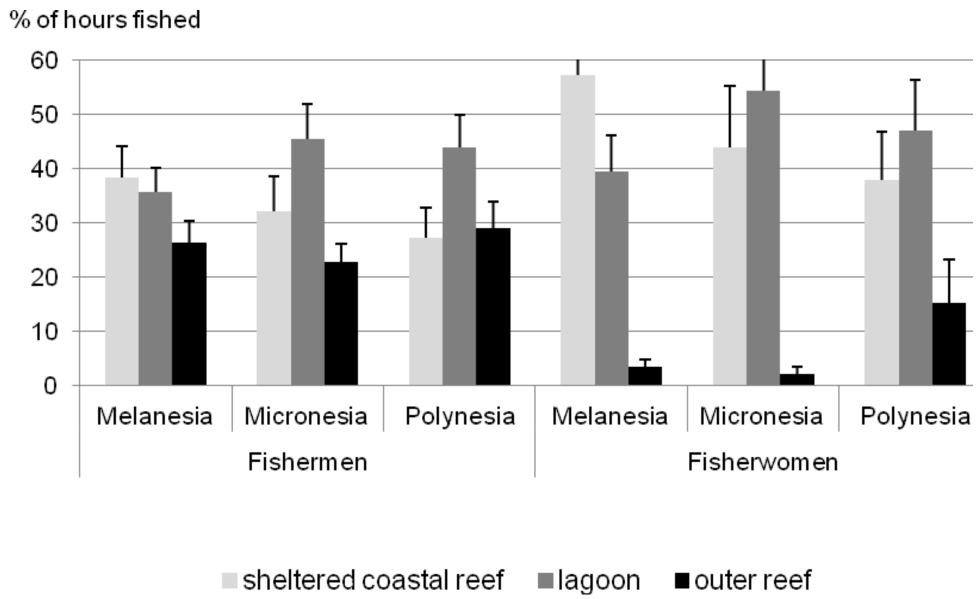

Figure 3: Percentage of hours spent finfish fishing in the three different habitats by fishermen (left) and fisherwomen (right) (fishermen hours = 100%, n=63; fisherwomen hours = 100%, n=52)

Gender preferences of habitats targeted for finfish fishing, measured by the proportional fishing time per habitat, are statistically highly significant at the regional scale, and for all habitats in the case of Micronesia and Polynesia (Table 4). In the case of Melanesian communities studied, no significant differences were found between the proportion of finfish fishing time by gender group in sheltered coastal reef and lagoon habitats.

Table 4: T-test analysis comparing the per cent of finfish fishing time spent in the three different habitats by gender and across cultural groups

Cultural group	Habitat	P
Regional	Sheltered coastal reef	<0.001
	Lagoon	<0.0001
	Outer reef	<0.0001
Melanesia	Sheltered coastal reef	n/a
	Lagoon	n/a
	Outer reef	<0.0001
Micronesia	Sheltered coastal reef	<0.01
	Lagoon	<0.05
	Outer reef	<0.0001
Polynesia	Sheltered coastal reef	<0.05
	Lagoon	<0.01
	Outer reef	<0.0001

Significant differences also exist when comparing the contribution in proportional fishing time by gender and cultural group for different invertebrate fisheries (Table 5). Certain fisheries were not exploited in some of the sites studied due to the lack of the supporting habitat (soft benthos, intertidal), or due to regulations such as temporary or permanent closure of the fishery (bêche-de-mer, trochus, in some cases lobster). Therefore, total sample size (n) per fishery and cultural group vary. We have already observed that fisherwomen are dominant in gleaning, and fishermen in free-diving invertebrate collection. Thus it is no surprise that most fishing time spent in soft-benthos and intertidal habitats is accounted for by fisherwomen. Also, Melanesian fisherwomen accounted for most of the time spent on mangrove and reef-top gleaning activities as compared to their male counterparts. However, on average the proportion of time spent in these two fisheries is gender balanced in Micronesian and Polynesian communities. Conclusions are supported by the highly significant gender differences found in the proportion for each invertebrate fishery compared, with little or no significant distinction between fishermen and fisherwomen pursuing any of the gleaning fisheries in Micronesian and Polynesian communities (Table 6).

Free-diving fisheries, in particular lobster and trochus, but also other target species that are collected by free-diving (clams, Lambis lambis), are a domain of fishermen and are hardly exploited by fisherwomen of any cultural background. Experiences during the field survey have shown that all community members participate in the commercial bêche-de-mer fishery when it is open. However, in the case of Melanesian countries with the least regulations on the bêche-de-mer fishery, bêche-de-mer resources are widely depleted and remaining target stocks are mainly found at greater depth, requiring free-diving. For bêche-de-mer, depletion of the resource therefore explains fishermen's dominance. The same factor applied in the two communities in Micronesia where bêche-de-mer fishing was practiced during the field survey. The Micronesian or other communities that harvest certain bêche-de-mer species mainly for home consumption are mainly accounted for under soft benthos as bêche-de-mer are part of a range of invertebrates targeted during one fishing trip.

Table 5: Percentage of fishing times spent by gender group for invertebrate fisheries across three cultural groups (n = total number of communities applicable per fishery and cultural group)

	Melanesia			Micronesia			Polynesia		
	fishermen	fisherwomen	n	fishermen	fisherwomen	n	fishermen	fisherwomen	n
Soft benthos	16.9	83.1	16	40.6	59.4	12	43.8	56.2	12
mangrove	25.9	74.1	18	43.1	56.9	6	47.8	52.2	6
intertidal	18.2	81.8	19	28.9	71.1	10	14.6	85.4	11
reeftop	20.5	79.5	24	50.0	50.0	14	48.2	51.8	22
BdM	78.1	21.9	11	100.0	0.0	2	42.1	57.9	1
lobster	100.0	0.0	17	100.0	0.0	10	100.0	0.0	15
trochus	100.0	0.0	19	100.0	0.0	2	100.0	0.0	2
other	86.3	13.7	18	90.7	9.3	10	93.3	6.7	16
Standard error									
soft benthos	6.0	6.0	16	7.1	7.1	12	10.3	10.3	12
mangrove	5.5	5.5	18	18.7	18.7	6	18.8	18.8	6
intertidal	6.1	6.1	19	11.2	11.2	10	5.9	5.9	11
reeftop	4.2	4.2	24	8.4	8.4	14	6.0	6.0	22
BdM	6.1	6.1	11	0.0	0.0	2	n/a	n/a	1
lobster	0.0	n/a	17	0.0	n/a	10	0.0	n/a	15
trochus	0.0	n/a	19	0.0	n/a	2	0.0	n/a	2
other	3.5	3.5	18	6.0	6.0	10	4.5	4.5	16

Table 6: T-test analysis comparing time spent collecting invertebrates (% of total hours) by fishery, gender and culture

Cultural group	Fishery	P
Regional	Soft benthos	<0.0001
	Mangrove	<0.001
	Intertidal	<0.0001
	Reeftop	<0.0001
	Bêche-de-mer	<0.001
Melanesia	Soft benthos	<0.0001
	Mangrove	<0.0001
	Intertidal	<0.0001
	Reeftop	<0.0001
Micronesia	Soft benthos	n.s.
	Mangrove	n.s.
	Intertidal	<0.05
	Reeftop	n.s.
Polynesia	Soft benthos	n.s.
	Mangrove	n.s.
	Intertidal	<0.001
	Reeftop	n.s.

Fishing strategies

Generally, statistically significant differences were found for finfish fishing strategies, while little, if any, variation exists between gender groups concerning invertebrate gleaning strategies. These results underline where gender differences in fishing strategies must be recognised by fisheries management, as fishermen and fisherwomen have different requirements, experience different limitations, and may, as a consequence, exert different impacts on the resource.

In the case of finfish fisheries, fishermen are differentiated from fisherwomen by their preference for fishing at night, their much higher proportion of regular use of boat transport, their higher frequency of fishing trips and the longer average duration of each of their fishing trips (Table 7). This observation applies at the regional level. At the level of cultural groups, trends were confirmed for Polynesia. However, Melanesian fisherwomen were found to use boat transport as regularly and to fish as frequently as their male counterparts. Also, the duration of an average fishing trip was comparable for Micronesian fishermen and fisherwomen.

Table 7: T-Test analysis comparing finfish fishing strategies for fishermen and fisherwomen at the regional scale and within each cultural group

Cultural group	Strategic item	P
Regional	Preference for fishing at night	<0.0001
	Proportion always using boat transport	<0.05
	Frequency of fishing trips (times/week)	<0.05
	Duration of fishing trip (hours)	<0.001
Melanesia	Preference for fishing at night	<0.001
	Proportion always using boat transport	n.s.
	Frequency of fishing trips (times/week)	n.s.
	Duration of fishing trip (hours)	<0.0001
Micronesia	Preference for fishing at night	<0.05
	Proportion always using boat transport	<0.0001
	Frequency of fishing trips (times/week)	<0.0001
	Duration of fishing trip (hours)	n.s.
Polynesia	Preference for fishing at night	<0.001
	Proportion always using boat transport	<0.0001
	Frequency of fishing trips (times/week)	<0.0001
	Duration of fishing trip (hours)	<0.05

Invertebrate gleaning fisheries that have participation of fishermen and fisherwoman – including soft-benthos, intertidal, mangrove and reef-top habitats – did not reveal any major significant differences between gender and cultural groups. Generally, a weak relationship was found between men's and women's gleaning in terms of total hours spent gleaning in a year (ANOVA, $F=4.74$, $P<0.05$), with women fishing on average more hours than men, and the preference of women to walk rather than use boat transport (ANOVA, $F=7.61$, $P<0.01$). However, when investigating such possible gender differences within cultural groups, no significant variation between fishermen and fisherwoman was found for Micronesia and Polynesia. This is also largely true for Melanesian fishers, except that Melanesian women spent significantly more time fishing in a year as compared to their male counterparts (ANOVA, $F=6.25$, $P<0.01$).

Fishing techniques

Reef fisheries in PICTs include a variety of techniques, and a combination of techniques may be used during one fishing trip. Results suggested that major gender differences do not necessarily exist in the use of any of the nine major finfish fishing techniques that emerged from our survey results, but there are differences in the degree to which they are employed by the two gender groups. In 80–100% of the sites studied (n=63), fishermen use speardiving and handlines. The other techniques listed are employed in about 50–60% of sites. In the case of fisherwomen (n=52), handlines are employed at most sites (77%), gillnets are used less often (54%) and the other techniques are used at 17–33% of all sites where women are engaged in finfish fisheries. Comparison of the degree to which various techniques are used by cultural groups (Figure 4) showed little differences in the widespread use of speardiving, handlines and gillnets for fishermen. For fishermen, the use of handheld spearing is much more common in Melanesia, fishing rods and artisanal traditional techniques ('others') are mostly employed in Polynesia, and Micronesian fishermen show more use of castnets and bottom fishing than fishermen from other cultures. Melanesian and Micronesian fisherwomen mostly use handlines, while among Polynesian fisherwomen fishing rods are more common

(Figure 5). Among Polynesian and Micronesian fisherwomen, not unlike fishermen in both cultural groups, the use of artisanal traditional fishing techniques ('other') is common.

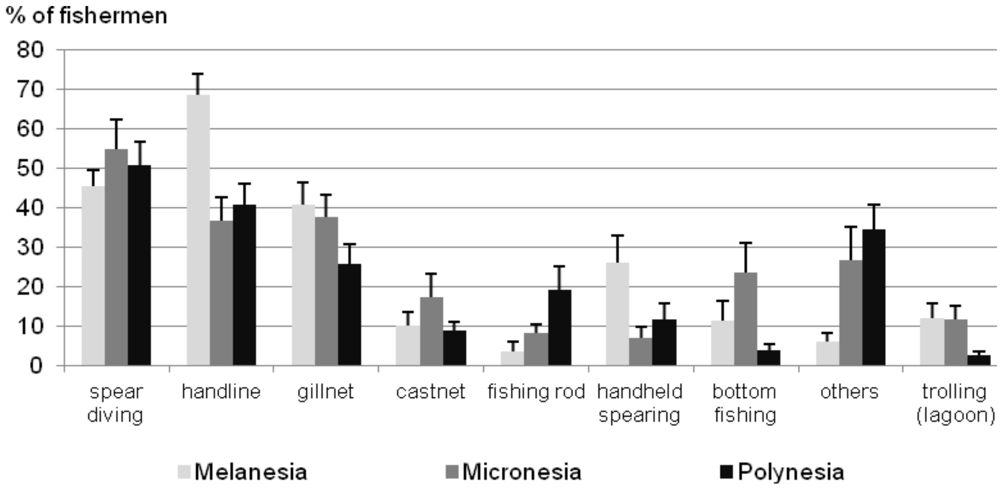

Figure 4: Percentage of fishermen using the nine fishing techniques on average across all sites studied per cultural group (Melanesia n= 24, Micronesia n=17, Polynesia n=22)

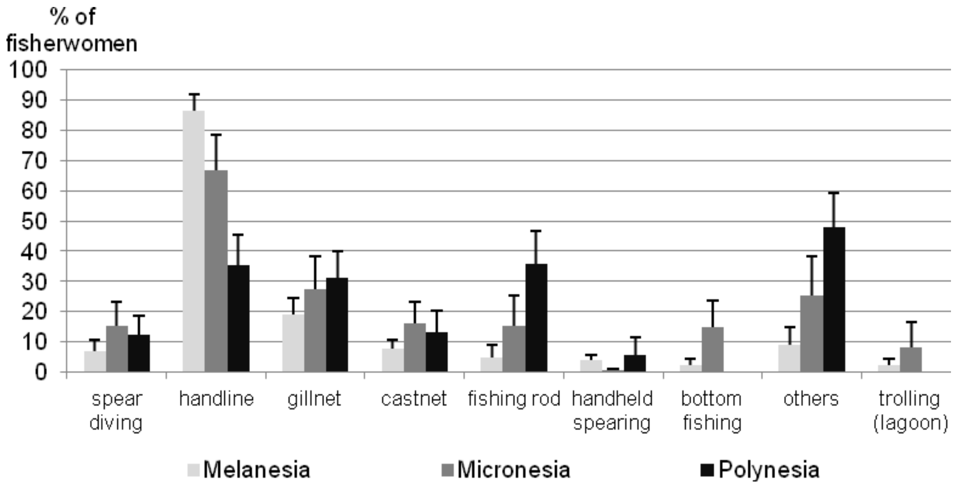

Figure 5: Percentage of fisherwomen using the nine finfish fishing techniques on average across all sites studied per cultural group (Melanesia n= 23, Micronesia n=12, Polynesia n=17)

Productivity

Given the major gender differences found regarding average fishing trip duration, habitats targeted, and fishing techniques used, we also expected to find major differences in finfish fishing productivity. Indeed, statistically significant differentiation exists at the regional scale if we compare total average annual catch (kg/fisher/year) and CPUE, and average annual catch and CPUE for sheltered coastal reef and lagoon fishing (Table 8). However, pair-wise comparisons between fishermen's and fisherwomen's productivity at the level of cultural groups suggest that the regional picture is mainly determined by the performance of Melanesian fishing communities. No gender differences were found for any of the productivity parameters for Micronesian communities. Differences are not generally significant for Polynesian fishers; however, there is evidence of increased productivity of fishermen in terms of average annual catches and CPUE when comparing gender groups at the habitat level.

Table 8: T-test analysis comparing finfish fishing productivity by using fishermen's and fisherwomen's average catch rates and CPUEs at the regional scale, and within each cultural group

Cultural group	Finfish productivity	P
Regional	Annual catch (kg/fisher/year)	<0.05
	Annual catch from sheltered coastal reef (kg/fisher)	<0.05
	Annual catch from lagoon (kg/fisher)	<0.001
	CPUE (kg/hour of fishing trip)	n.s.
	CPUE sheltered coastal reef (kg/hour of fishing trip)	<0.001
	CPUE lagoon (kg/hour of fishing trip)	<0.001
Melanesia	Annual catch (kg/fisher/year)	<0.0001
	Annual catch from sheltered coastal reef (kg/fisher)	<0.001
	Annual catch from lagoon (kg/fisher)	<0.001
	CPUE (kg/hour of fishing trip)	<0.0001
	CPUE sheltered coastal reef (kg/hour of fishing trip)	<0.001
	CPUE lagoon (kg/hour of fishing trip)	<0.01
Micronesia	Annual catch (kg/fisher/year)	n.s.
	Annual catch from sheltered coastal reef (kg/fisher)	n.s.
	Annual catch from lagoon (kg/fisher)	n.s.
	CPUE (kg/hour of fishing trip)	n.s.
	CPUE sheltered coastal reef (kg/hour of fishing trip)	n.s.
	CPUE lagoon (kg/hour of fishing trip)	n.s.
Polynesia	Annual catch (kg/fisher/year)	n.s.
	Annual catch from sheltered coastal reef (kg/fisher)	<0.05
	Annual catch from lagoon (kg/fisher)	<0.05
	CPUE (kg/hour of fishing trip)	n.s.
	CPUE sheltered coastal reef (kg/hour of fishing trip)	<0.01
	CPUE lagoon (kg/hour of fishing trip)	<0.05

Gender comparison of productivity in invertebrate fisheries was restricted to fisheries pursued by both gender groups, excluding free-diving activities. Productivity was measured in terms of average catch weight (wet weight) per fishing trip. In contrast with our findings for finfish fisheries, no significant gender difference was found at the regional scale or between or within cultural groups when comparing the average catch (wet weight) per fishing trip between fishermen and fisherwomen for any of the invertebrate fisheries shared by both.

Impact

Fishermen exert the most impact (total annual catch) on finfish resources as shown by linear regression results between total finfish fishing hours accounted for by men (R^2=0.84) as compared to women (R^2=0.34). Gender differences in total annual finfish catch are statistically significantly different within each cultural group, Melanesia included (Table 9). And despite the general belief to the contrary, the same was found to be true for invertebrate catches. Our results showed that generally, total annual invertebrate catches are accounted for by gleaning hours invested by both fisherwomen and fishermen (Table 9). Women's dominance shows at the regional scale in higher regression coefficients obtained for fisherwomen's gleaning time and total catch of clams, crustaceans, bivalves and gastropods, while fishermen's gleaning time has stronger influence on commercial bêche-de-mer and (with their diving time) lobster catches.

Gender comparison of total annual catches between and within cultural groups using ANOVA (Table 10) confirms significant differences for finfish catches, but not for total annual catches of most invertebrate species groups. Significant gender differences were only found for bivalves (ANOVA, $F=10.76$, $P<0.001$) between cultural groups. However, this difference is mainly due to Melanesian fisherwomen and fishermen (ANOVA, $F=12.30$, $P<0.001$), as no significant gender differences in bivalve catches exist in Micronesia and Polynesia.

Table 9: Linear regression on total annual catch kg (wet weight) between total fishing hours accounted for by fishermen and fisherwomen at the regional scale (data Log (X+1) transformed; n = total number of sites that practice fishery)

Regional	n	Total annual catch (kg wet weight)	Total hours fished	R^2	P
All fishers	63	Finfish (total)	Finfish fishing (total)	0.81	<0.0001
Fisherwomen	63	Finfish (total)	Finfish fishing (total)	0.07	<0.05
	51[1]	Finfish (total)	Finfish fishing (total)	0.34	<0.0001
Fishermen	63	Finfish (total)	Finfish fishing (total)	0.84	<0.0001
All fishers	58	Finfish (SCR)[2)]	Finfish fishing (SCR)	0.83	<0.0001
Fisherwomen	44	Finfish (SCR)[2)]	Finfish fishing (SCR)	0.45	<0.0001
Fishermen	55	Finfish (SCR)[2)]	Finfish fishing (SCR)	0.89	<0.0001
All fishers	53	Finfish (Lagoon)	Finfish fishing (Lagoon)	0.91	<0.0001
Fisherwomen	38	Finfish (Lagoon)	Finfish fishing (Lagoon)	0.62	<0.0001
Fishermen	42	Finfish (Lagoon)	Finfish fishing (Lagoon)	0.91	<0.0001
All fishers	59	Finfish (OR)[2]	Finfish fishing (OR)	0.78	<0.0001
Fisherwomen	14	Finfish (OR)[2]	Finfish fishing (OR)	0.67	<0.001
Fishermen	59	Finfish (OR)[2]	Finfish fishing (OR)	0.78	<0.0001
All fishers	59	Clams	Gleaning	0.35	<0.0001
Fisherwomen	59	Clams	Gleaning	0.26	<0.0001
Fishermen	59	Clams	Gleaning	0.21	<0.001
All fishers	44	Crustaceans	Gleaning	0.51	<0.0001
Fisherwomen	44	Crustaceans	Gleaning	0.47	<0.0001
Fishermen	44	Crustaceans	Gleaning	0.40	<0.0001
All fishers	47	Bivalves	Gleaning	0.38	<0.0001
Fisherwomen	47	Bivalves	Gleaning	0.43	<0.0001
Fishermen	47	Bivalves	Gleaning	0.24	<0.001
All fishers	57	Gastropods	Gleaning	0.27	<0.0001
Fisherwomen	57	Gastropods	Gleaning	0.20	<0.001
Fishermen	57	Gastropods	Gleaning	0.16	<0.01
All fishers	14	Bêche-de-mer	Bêche-de-mer fishery	0.89	<0.0001
Fisherwomen	14	Bêche-de-mer	Bêche-de-mer fishery	0.62	<0.0001
Fishermen	14	Bêche-de-mer	Bêche-de-mer fishery	0.88	<0.0001
All fishers	48	Lobster	Diving	0.82	<0.0001
Fisherwomen	48	Lobster	Diving	0.17	<0.01
Fishermen	48	Lobster	Diving	0.81	<0.0001
All fishers	48	Lobster	Gleaning	0.79	<0.0001
Fisherwomen	48	Lobster	Gleaning	0.82	<0.0001
Fishermen	48	Lobster	Gleaning	0.02	n.s.

Considering sites only with women participating in finfish fisheries

SCR = sheltered coastal reef (including mangroves); OR = outer reef (including passages)

Table 10: ANOVA (one-way, single factor) of total annual finfish catches by fishermen and fisherwomen at the regional scale and within cultural groups

Scale	F	P
Regional	35.26	<0.0001
Melanesia	47.86	<0.0001
Micronesia	21.60	<0.0001
Polynesia	12.04	<0.001

Marketing

Comparison (ANOVA) of proportions of women's and men's finfish fishing for subsistence, gift and sale revealed statistically significant gender differences in subsistence and commercial finfish fishing (Table 11). At the regional scale, a higher proportion of fisherwomen than fishermen catch finfish for subsistence or home consumption, while the opposite applies for commercial finfish fishing (Figure 6). There is no significant gender difference in the proportion of finfish catch for non-monetary distribution (gift) between family or community members, highlighting the importance of cultural traditions and social institutions in PICTs' coastal communities.

Table 11: Comparison of the proportion of fisherwomen and fishermen catching finfish for gift, subsistence, and commercial purposes (ANOVA; total n = 63)

Purpose of finfish fishing	F-statistic	P
Gift (non-monetary distribution)	0.07	n.s.
Subsistence	8.03	<0.005
Sale	52.76	<0.0001

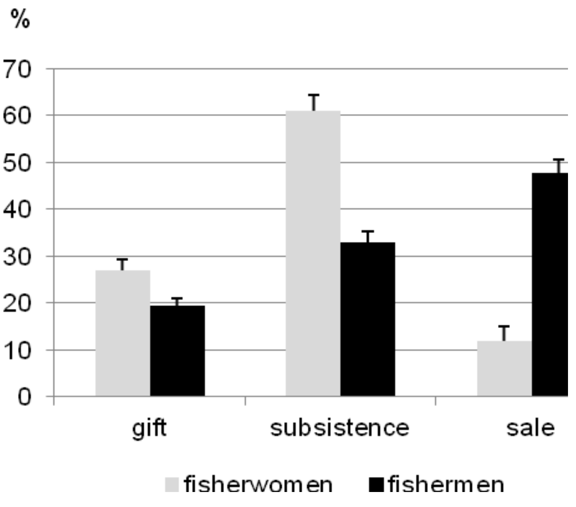

Figure 6: Proportions of fishermen's and fisherwomen's catch for non-monetary distribution (gift), subsistence (household) and commercial (sale) use

Within cultural groups, statistically significant gender differences are less pronounced, with a higher proportion of women catching finfish for home consumption (P<0.06) in Melanesia, and a higher proportion of men pursuing commercial finfish fishing in Melanesian (P<0.03) and Polynesian (P<0.001) communities only (Table 12).

Table 12: T-test analysis comparing the proportion of fisherwomen and fishermen catching finfish for gift, subsistence, and commercial purposes by cultural group

	Gift (non-monetary distribution)	Subsistence	Sale
Purpose of finfish fishing	P	P	P
Melanesia	n.s.	<0.06	<0.03
Micronesia	n.s.	n.s.	n.s.
Polynesia	n.s.	n.s.	<0.001

Today, invertebrate resources serve both as a source for protein and nutrition for coastal communities and as source of income. Income from invertebrate catches may be generated by selling raw or processed target species at the local market, or selling catch via agents and middlemen for export. Usually, target species for home and local consumption do not compete with export target species. This is also true for the trochus fishery, where shells are collected for export sales and meat is often consumed locally. Based on the information obtained from all invertebrate fishers interviewed, we distinguished between invertebrate fishermen and fisherwomen selling catch from gleaning serving the local market, and those targeting mainly commercial fisheries for export. First, we found that eight, or about 13% of all communities studied are not engaged in any marketing of invertebrate catch. The highest percentages of these communities were found in Micronesian and Polynesian PICTs. Percentages of the total numbers of fishers by gender and by gleaning or commercial fishery marketing activity shows that fisherwomen do most marketing of catch from gleaning, while fishermen do most marketing of commercial catch but are also to a great extent involved in marketing of catch from their gleaning fisheries (Table 13). Strongest differences between gender groups exist in Melanesia, with a clear dominance of fisherwomen in the marketing of gleaning and fishermen in the marketing of commercial fishery catch. The proportions of invertebrate marketing fishers in the other cultural groups, be it for local or for export markets, are much smaller or negligible.

Table 13: Participation in marketing of invertebrate catch from gleaning and commercial fishery activities by gender in per cent of total invertebrate fishermen and fisherwomen

Culture		Marketing catch from gleaning (SE)	Marketing catch from commercial fisheries (SE)
Melanesia	Fisherwomen	27.99 (±6.29)	6.43 (± 1.97)
	Fishermen	12.31 (±3.54)	47.10 (±14.41)
Micronesia	Fisherwomen	6.65 (±3.30)	0
	Fishermen	8.42 (±5.31)	2.13 (± 1.13)
Polynesia	Fisherwomen	7.40 (±2.04)	0.34 (± 0.34)
	Fishermen	8.36 (±3.07)	2.91 (± 0.90)

Socioeconomic drivers and vulnerability

Based on gender differences and similarities found for finfish and invertebrate catches and their marketing between and within cultural groups, gender-specific multivariate analysis was performed to identify major drivers between cultural groups – and possibly between genders – determining current exploitation. We used the most important socioeconomic and geographic variables from our dataset determined by a forward model selection approach in

RDA, total annual finfish and invertebrate catches (wet weight by species groups) against cultural effects (Melanesia, Micronesia, Polynesia), first for fishermen (Figure 7), than for fisherwomen (Figure 8). In all cases canonical analysis (CAP) yielded highly significant canonical test statistics ($P=0.0001$ for all tests, using 9999 permutations). The first two canonical axes in each plot reveal a clear pattern where sites in each cultural group are closely clustered together. For both analyses, cultural groupings proved to be highly statistically significant under general (PERMANOVA $P<0.0001$) and under pair-wise tests (PERMANOVA, $P<0.01–0.0001$). We next considered the correlations of all individual variables with canonical axis 1 with an absolute correlation >0.20, i.e. any positive correlation with axis 1 indicates increasing values and a negative correlation indicates decreasing values.

Comparison between fishermen's and fisherwomen's plots shows that there is a joint set of main drivers that determine current artisanal and subsistence catch in each cultural group for both fishermen and fisherwomen. Women's fishing is mostly driven by socioeconomic factors at the community level, while men's fishing activities are not only closely associated with socioeconomic factors at the community but also at the national scale. Gender differences result mainly from higher finfish fishing catch and higher commercial engagement in finfish fishing and invertebrate collection accounted for by men. We can therefore conclude that the size of finfish and invertebrate catch for income is largely determined by the interaction between the overall socioeconomic conditions at the national and community levels, while subsistence and complementary income from finfish fishing and invertebrate harvesting are mostly driven by factors at the community level. In other words, fishermen's commercial activities are more influenced to socioeconomic factors at the national scale, while fishermen's and fisherwomen's subsistence and complementary income activities are more influenced to the socioeconomic conditions at the community, or even household level.

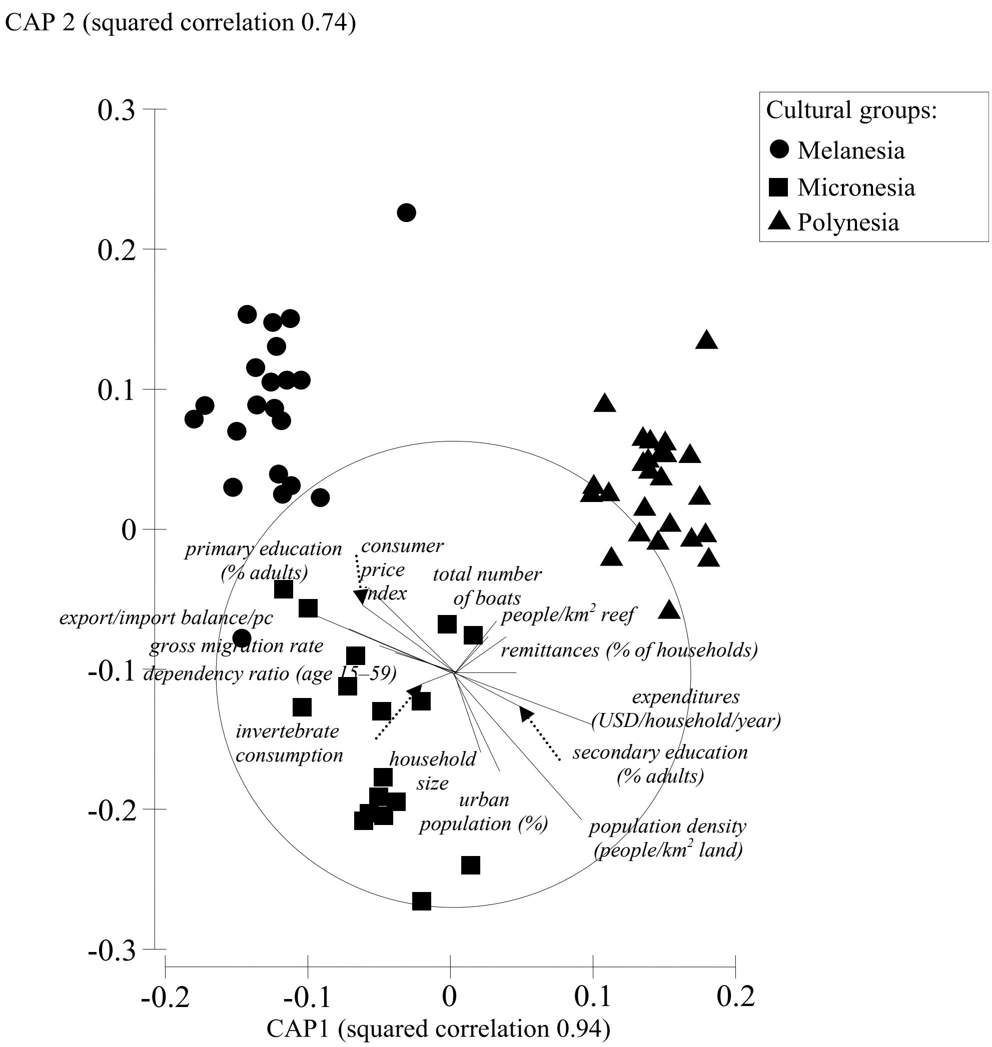

Figure 7: Socioeconomic drivers associated with the size of fishermen's total annual finfish catch (kg/year) and invertebrate catch (by species groups; kg wet weight/year) using culture as a factor, canonical analysis of principal coordinates

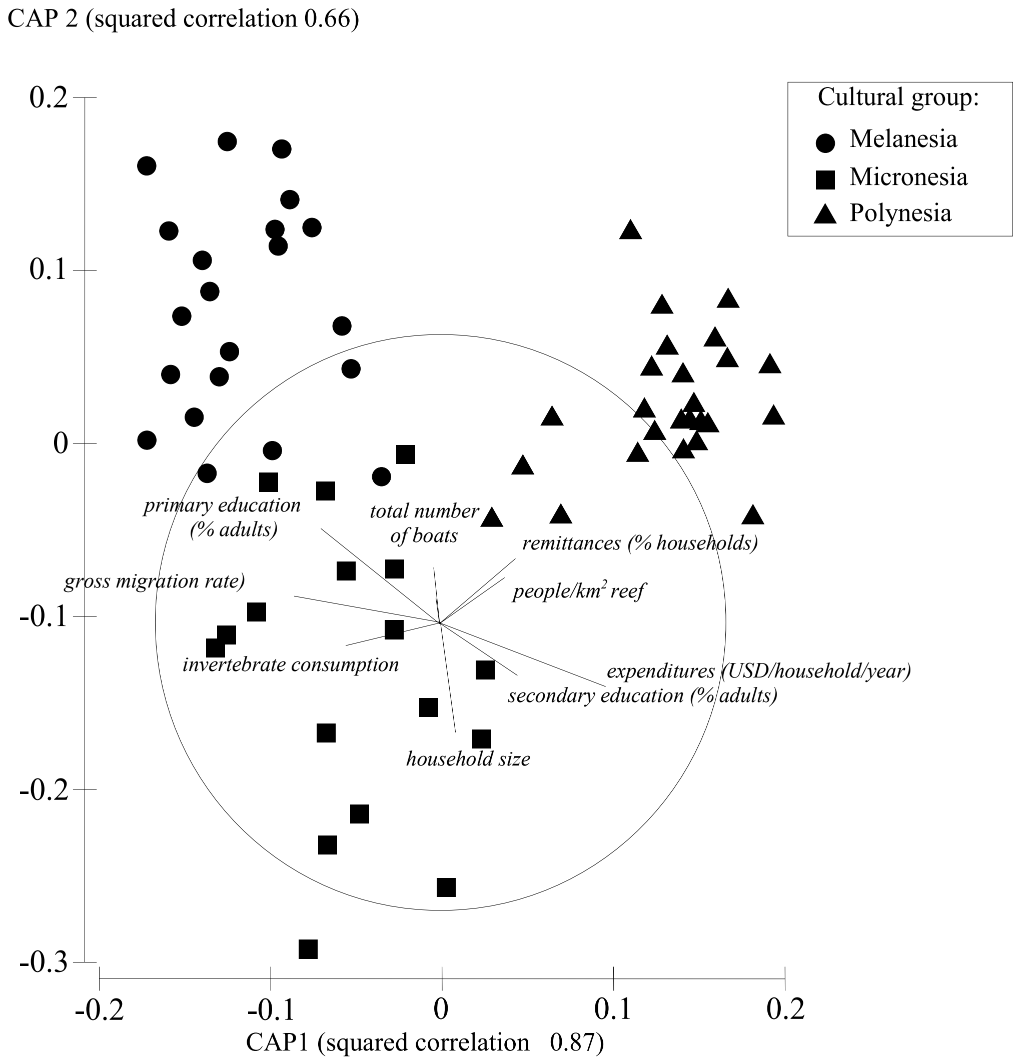

Figure 8: Socioeconomic drivers associated with the size of fisherwomen's total annual finfish catch (kg/year) and invertebrate catch (by species groups; kg wet weight/year) using culture as a factor, canonical analysis of principal coordinates

Main drivers that determine the size of artisanal fisheries are dependent on demographic and financial factors, and access to alternative income sources. In the case of Melanesian fishermen's engagement in artisanal fisheries and particularly finfish fishing, it is determined by a high consumer price index, a high negative per capita export–import balance, a high dependency rate (age 15–59 years) and a tendency to a high gross migration rate characterising relatively poor economic conditions at the national scale, coupled with limited access to alternative income sources suggested by a high percentage of adults with primary education only at the community level. Melanesian women's fisheries are characterised by low educational and low household expenditure levels suggesting a high dependency on marine resources because access to alternative and cash income is limited.

Men's fishing in Polynesian fishing communities is mainly driven by high population pressure on the available reef area and a high number of boats, while Polynesian fisherwomen are driven by high population pressure but also by a high dependency on remittances, suggesting that the more fisherwomen cannot cover living cost from local income, the more active they are in fishing.

Micronesian fishing communities are the most diverse in terms of drivers determining fishermen's and fisherwomen's activities. Artisanal fishing, particular finfish fishing done by men in rural coastal communities, is driven by a high urban population at the national scale, suggesting that urban populations have other income sources than fisheries, as well as large average household size underpinning the persistence of traditional lifestyle in the rural context. Fisherwomen's activities basically increase with larger average household size and higher per capita invertebrate consumption.

Discussion

Our survey results have made visible women's share in the small-scale artisanal fisheries in PICTs and do not leave any doubt that fishing in PICTs' coastal communities is important for women and men (Ram 1993, Lambeth 2000; Kronen 2002b, Kronen 2008, Kronen and Bender 2007, Williams *et al.* 2002, Bennett 2005). Analysing gender-determined fisheries production in the socioeconomic context at national and community levels further to a comparison of gender-disaggregated data regarding fishing strategies, techniques used, productivity, impact and marketing, has revealed how much fishermen's and fisherwomen's activities differ in their resource dependency, exploitation strategies and vulnerability, and how these differences apply for each of the cultural groups.

Reviewing men's and women's participation in coastal subsistence and artisanal fisheries in PICTs confirms both changes in and persistence of traditionally defined gender roles. Both women and men play particular roles in finfish fishing and invertebrate collection, and these roles vary between cultural groups (Clausen 2008). Gender-related specialisation in fisheries follows the principal commonalities of local knowledge systems pertaining to coastal marine environments and resources identified by Ruddle (1993, 1994), including the conclusion that skills and tasks are age- and gender-specific and are taught by members of the appropriate sex (Omoto 2004, Kronen 2004a). For example, Melanesian fishing communities have the highest percentage of fishermen and fisherwomen who target finfish and invertebrates, while Micronesian and Polynesian communities have the highest proportion of fishermen targeting exclusively finfish and fisherwomen specialised in invertebrate harvesting. Historically, western Melanesia had some of the most egalitarian societies of the world (Crocombe 2001); this may be an explanation for why Melanesian communities developed a higher participation of women in finfish fisheries, which is otherwise traditionally defined as a man's domain (Bataille-Benguigui 1988).

Pacific Island societies have a strong history of defined customary roles with a clear division of labour between women and men (Vunisea 2007), and men were traditionally the providers for the family. These roles are visible in our regional comparison. Finfish fishing is the major food and income source and finfish fishing is principally accounted for by men in terms of fishing time, total catch and commercial catch. Women, on the other hand, contribute most of the finfish for home consumption. However, there are also indications of change. Melanesian fisherwomen, in contrast with Micronesian and Polynesian fisherwomen, contribute substantially to both total finfish fishing time and total catch, which is mostly, but not exclusively, for subsistence purposes. In Micronesia there are no gender differences in the proportional use of finfish catch for any purpose, and in Polynesian fishing communities differences are limited to the higher proportion of commercial finfish caught by men. These results confirm earlier reports from the Gulf of Papua New Guinea (Melanesia), and American Samoa (Polynesia), where women accounted for 25–50% and 32%, respectively, of the total finfish yield (Chapman 1987). Despite the general belief that invertebrate collection is mainly a women's chore (Booth 1990, Tonga *et al.* 2000, Matthews 2002), we found that at the regional scale, and within cultural groups, total harvesting time for invertebrates is generally equally shared by men and women, and so are total annual catches for most invertebrate species groups. Today, the fact that Pacific women do not participate in free-diving fishing activities constitutes the major gender difference in invertebrate fisheries, and results in gender-biased access to and participation in commercial export fisheries. Over the past decades, resource decline of bêche-de-mer (Uthike and Conand 2005, Conand 2004, Polon 2004, Kinch 2002), trochus (Bettencourt 1995, Traffic Network 1995), and lobster (Adams and Dalzell 1993) has taken place in most PICTs due to export-oriented overfishing (Vuki *et al.* 2000). Remaining stocks are typically found at greater depth and distance from shore and are no longer available by gleaning but only by free-diving collection.

With the introduction and increasing influence of modern market economies (Middlebrock *et al.* 2006, Barnett 2007), modernisation, education and exposure to Western cultures, gender barriers should break down (Vunisea 2007). However, it is argued that strong traditional forces guiding the social values and norms in PICTs continue to result in a high degree of conservativeness (Ram-Bidesi 1995, Nelson 2008), particularly attributed to women. Women are therefore most restrained in exploring new avenues, for example in fisheries. This argument may explain why traditional taboos have apparently been overcome with regard to men's recognised engagement in invertebrate gleaning, but may still be enforced with regard to Pacific women's engagement in free-diving fisheries and the unbound use of motor boats, impeding their access to and possible benefit from high value and alternative fisheries as well as increased finfish fishing opportunities.

Gender-disaggregated data has revealed both similarities and dissimilarities in gender roles in subsistence and artisanal fisheries in PICTs, notably in terms of men's and women's contributions to total annual production of finfish and invertebrates. Results provide gender-specific fishery characteristics necessary to identify target groups in coastal fisheries, and their capacities, objectives and limitations, which need to be considered for effective fisheries management. Complementing this information with gender relations analysis has identified socioeconomic drivers at the national and community levels that determine fishers' productivity and consequently the vulnerability of gender groups to external factors and processes shaped by the broader society and hence beyond their influence (Sunderlin 1994, Andrew *et al.* 2007). Main drivers include a combination of demographic and financial factors, and access to alternative income sources. Major differences that emerged suggest that women, mainly responsible for subsistence and complementary household income, are mostly affected by community-based or even household-based factors. Men's commercial finfish and invertebrate production, matched with their subsistence contribution, are associated with an interaction of socioeconomic factors at the national and community scales. Main drivers between cultural groups may vary; however, they all point in the same direction. Overall demographic pressure or population pressure on reef resources, coupled with limited access to alternative income sources – indicated by lack of education or high dependency on external finances (remittances), and difficulties meeting living cost, determine small-scale fisheries production and the dependency of men and women in PICT coastal fishing communities. Indicators for the overall economic situation applying to PICTs in cultural groups magnify the dependency on commercial fisheries in response to high living cost, low productivity (negative export-import balances) and migratory tendencies (education, labor).

Traditionally, fishing was considered a dangerous activity (Schoeffel 1995) and the time spent at sea, which was often at night, did not allow women to tend to their family chores. In

Polynesia, catching fish and large marine mammals is not only seen as men's work, but is traditionally also a part of the masculine gender identity (Malm 2009). Recent economic development, particularly increasing cash-based living cost, has not only prompted adaptive changes in fishers' behaviour (Matthews *et al.* 1998; Kronen, Sauni, and Veitayaki 2006; Teh *et al.* 2009) but has also demanded that women engage in finfish fishing, or/and intensify invertebrate collection to contribute to subsistence and basic cash needs of the family. Matthews (1991) stated that 11% of the households in Kiribati (Micronesia) rely completely on shellfish collected by women and children for their protein supply. In other places, for instance Tuvalu (Lambeth, 2000), shellfish and crab collection by women has been replaced by increased finfish catches accounted for by fishermen. However, it is still practiced during extended periods of bad weather when men are unable to fish. An example that illustrates that fishing in PICTs is not purely a necessity (Cinner *et al.* 2008) but is also an integral component of lifestyle, and a fall-back position in times of need. Shellfish collection for handicrafts has become a source of revenue for households in isolated (Tiraa-Passfield 1996) as well as in touristic areas, contributing in some places substantially to household income (Kronen, Tardy, *et al.* 2008; Kronen, Friedman, *et al.* 2008).

Fisherwomen in PICTs have adapted to cope with double responsibilities, i.e. they continue to be housewife and caretaker for the family but are now also responsible for contributing to the household's economy (Agilar and Castaneda 2000, Levine *et al.* 2001, Williams *et al.* 2002, CGIAR News 2002, Lambeth *et al.* 2002, Tindall and Holvoet 2008, Zein 2008). Women's role in managing the household's food and cash needs is intensified in communities subject to high labour migration overseas, rendering women dependent on the frequency and amount of remittances received, and often requiring a high commitment to cope on their own. Taking into account the amplified role of women in PICT fishing communities, it is to no surprise that fisherwomen have to cut down and plan their fishing time with a focus on meeting the ad hoc fish demand of the family's daily meals, and consequently prefer more easily accessible habitats closer to shore, fishing during day-time, use of low-cost fishing techniques (handlines, fishing rods) and not using boat transport to save time or cost for fuel. The major difference that men provide most of the income and women mainly contribute to subsistence needs also explains differences in gender productivity. Women's fishery production is scaled to meet the immediate needs, while men's fishery production aims to maximise production and revenues. Subsistence and small complementary income needs are met with the least cost investment, while commercial fisheries demand higher investment and more effective fishing techniques to increase choice and access to fishing grounds, target species, and markets and to increase productivity. These circumstances elucidate gender differences found in the use of boat transport, choice of habitats targeted and use of fishing techniques.

Small-scale subsistence and artisanal fisheries in PICTs are of an opportunistic nature as they have adapted in the past to the available resources, market conditions, and more efficient fishing techniques (Kronen, Sauni, Magron, *et al.* 2006). Comparison of gender and cultural groups shows that gender roles change as a function of socioeconomic drivers (Delgado *et al.* 2003, Cochrane and Doulman 2005), including demographic pressure and the urgency to acquire cash income (Turner *et al.* 2007, Teh *et al.* 2009, Ram-Bidesi 2009, Zann and Zann 2008). Melanesian fishing communities are most challenged by meeting living costs (as indicated by national and community socioeconomic drivers), having limited access to alternative income opportunities due to their generally low adult educational level and an overall economic situation that has been fostering overseas migration. A rigorous economic environment and favourable cultural conditions may be the major reasons that gender differences regarding fishing strategies and performance in Melanesian fishing communities are smallest and women are significantly engaged in fishing for food and contributing to household income.

Polynesian fishing communities have weakest associations with socioeconomic drivers at the national scale, suggesting that fishing households or fishing communities are less advantaged as compared to the general socioeconomic environment. Polynesian fishing households are not only more dependent on coastal fisheries resources and vulnerable to economic changes related to coastal fisheries production, but are also more dependent on external finance, i.e. remittances (Kronen 2004b).

Micronesian fishing communities show the greatest amplitude in relation to numerous drivers, and we can distinguish two major sub-groups. One of these sub-groups is closely linked to Melanesian fishing communities. However, although drivers are comparable, the relationship between catch and socioeconomic conditions is much weaker. The second Micronesian sub-group, in contrast to Polynesian fishing communities, seems to be represented by a rather traditional rural lifestyle as indicated by larger household sizes and high invertebrate consumption, determining a dependency on coastal marine resources, which differentiates this sub-group from the high percentage of urban population at the national level. We found that in Micronesia, traditionally defined gender roles largely persist. Taking into account that low adult educational level (limiting access to alternative income opportunities), and unfavourable economic conditions only apply for a few Micronesian sites, we argue that in Micronesian fishing communities, demographic and economic urgency are generally not significant enough to trigger significant changes in gender roles. Therefore, Micronesian fisherwomen continue to contribute substantially to the family's food supply with invertebrates and to occasionally sell them at the market if income is needed (Kronen and Tafileichig 2008).

Lack of alternative income sources beyond the fisheries sector or difficulty in accessing them are determining factors for dependency and vulnerability. Inadequate knowledge and skills hinder access to alternative employment niches, especially outside the primary sector (Barrett *et al.* 2001, Dercon 1998, Brugère *et al.* 2008). Educational marginalisation faced by fishing communities is considered one of the key aspects preventing diversification of livelihoods and reduction of vulnerability (FAO 2006). The issue of low educational levels among adults applies particularly to Melanesia as well as to some of the Micronesian communities studied and to fishery dependent households in Polynesia, rendering the communities, fishermen and fisherwomen concerned more vulnerable.

Using the degree to which gender roles in coastal fisheries have changed toward equity as a measure for adaptive capacity of fishing communities – which is crucial to building resilience and reducing vulnerability – Melanesian fishing communities, and notably Melanesian fisherwomen, may be the most adaptable. Nevertheless, societal values and traditional taboos may yet delay the adaptive process. Women's focus on invertebrate collection and easily accessible fishing grounds, coupled with limited time budgets due to their numerous household, family and social chores, restrictions on their participation in free-diving, and fewer opportunities for independent use of motorised boat transport limit fisherwomen's opportunities to improve productivity and income.

As a rule, fishers are vulnerable to the consequences of any changes in the aquatic resource they depend on. However, the question is to what extent fishers can cope with future changes

(Folke *et al.* 2004, Walker *et al.* 2004), and to what extent the adaptive capacity may vary between gender and cultural groups in PICTs. The predicted population growth in the Pacific region (SPC Statistics and Demography Programme 2007), urbanisation and possible impacts of climate change (World Bank 2009) that may reinforce the impacts from other human disturbances (Rose 2004, Brander 2008, Cheung *et al.* 2009), including over-fishing, changes or destruction of habitat and ecosystems (Bunce *et al.* 2008, Pinnegar and Engelhard 2008, Newton *et al.* 2007), are likely to accelerate resource decline and reduce catches (Friedlander and DeMartini 2002). As a result, the risk and vulnerability of fishers and communities that depend on fisheries will increase (Whittingham *et al.* 2003, Allison *et al.* 2009), in particular those communities where fish and other living marine resources are the only renewable resource and thus the primary income source for economic security (Zeller *et al.* 2007).

Current fisheries management in PICTs is a challenging task that requires effectively combining social, economic and ecological objectives to ensure livelihoods of coastal communities, achieve sustainable marine resource use, and restore ecosystems and fisheries in decline (Jennings 2007). This challenge is increased by environmental problems related to economic development outside the fishery sector (Bennett 2005), and the effects of climate change (Clark *et al.* 2001, McClanahan *et al.* 2006, 2009). A widened approach is required, including alternative resource use and income opportunities (Cunningham 1993) at the local and national levels (World Bank 2000b, Dixon *et al.* 2001, Ruddle 2008). The importance of taking a gendered view for effective resource management (Tietze 1995, Diamond *et al.* 2003, Bennett 2005) has been emphasised by the World Summit on Sustainable Development (United Nations 2002), and in more detail by the FAO's gender policies for responsible fisheries (2007), which call for gender-disaggregated data complemented by gender relations analysis to make possible effective formulation of fisheries management policies. Our analysis has aimed at contributing to filling the gap in gender-disaggregated quantitative and qualitative fisheries data for the PICTs' small-scale artisanal fisheries sector, to identify drivers that determine men's and women's current fishery production and their vulnerability at the regional level and within cultural groups. Results suggest that effective planning should take into consideration the following:

Combining coastal fisheries management with diversification of livelihoods of communities and households, to increase cash income and lessen dependency and pressure on wild-caught marine resources. This objective may require adaptive capacity assessments to tailor specific development programmes to the available resources and the communities' and households' capabilities, and to apply a gender lens beyond fisheries to tailor strategies to men's and women's contributions to the household's food and income security and their possibilities and limitations in exploring alternatives.

Gender equity in access to improvements in quality of life and income, including capital, equipment, technology, transport, credit, training, employment and education (Kinch and Bagita 2003, Vincent 2007), and equity in decision-making regarding resource use and use of household assets and income. Gender equity does not necessarily have to conflict with existing social institutions and cultural traditions, as demonstrated by successful credit schemes and fisheries processing and marketing projects for women.

The implications of livelihood diversification programmes on gender participation and responsibilities. Fisherwomen are a vulnerable group in terms of the risk of becoming over-burdened as the responsibilities imposed by gender defined roles may be maintained within traditional and cultural value systems. In response to economic stress, fisherwomen have already expanded their traditional roles to increasingly contribute to household cash income (particularly in Melanesia), while maintaining their traditional services for the well-being of their families and social institutions within communities.

Including fisherwomen in training necessary to redirect fishing pressure from near-shore to off-shore resources, including fishing at fish aggregating devices (FADs) and the outer reef.

Including fisherwomen as equal stakeholders in restocking and monitoring programmes for commercial or high-value invertebrate species, particularly bêche-de-mer and giant clams, to ensure their participation in the fisheries and their benefit from revenues.

Although community fisheries management addresses the entire community, more attention should be given to women's fisheries issues that are often invisible (Vunisea 2008). Habitats and fisheries important for women's gleaning and finfish fishing activities, particular fishing grounds that are close to shore and easy to access, should be included in protective management areas, or considered for pulse fishing, without jeopardising women's contribution to food supply of families and small household income.

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4.6 Terminology and definitions

Socioeconomic terminology and definitions

Fisheries and fishing includes all wild-caught marine finfish and invertebrates. We distinguish between *finfish* and *invertebrates* to specify which fishery and catch we are looking at. The term *fish* is used to include both *finfish* and *invertebrates,* or all living marine animals relevant to our study. We focus on finfish that are targeted for human consumption and that are associated with coral-reef, lagoon, soft-benthos (seagrass), mangrove and coastal habitats, and include passages and outer-reef habitats with a higher pelagic influence. Therefore, certain pelagic fish, particularly tuna, may be included in our reported fish catches, although we exclude catch reported using any pelagic fishery techniques, i.e. trolling or longlining.

The term *invertebrate fishery* includes two major groups, distinguished by harvesting techniques. (1) The opportunistic collection of or foraging for multispecies within one particular habitat or across a variety of habitats in one fishing trip. We term this fishing as ‘gleaning’. Gleaning is mostly done by walking (although boats may be used to reach the fishing grounds) at low tide when reeftops, intertidal areas, mangroves or mud flats are exposed. Gleaning does not require any specialised tools except sticks, iron spikes, knives and baskets, bags or plastic containers to bring home the catch. (2) The targeted collection of certain species, usually a commercial, export-oriented fishery, such as bêche-de-mer, trochus, lobster. Due to ecological characteristics and/or resource decline, remaining stocks are found at greater depth and require free-diving. Free-diving for species associated with reef or soft-benthos, such as giant clams, *Lambis lambis*, and others, may be done as a multi-target species activity or as a by-product of free-diving to spear finfish.

The term *subsistence fishery* in the stricter sense, i.e. satisfying the family’s consumption needs only, is characterised by no involvement in the money economy. Traditionally, subsistence fishery included, and continues to include, the non-monetary exchange of catch among family and community members. Today, the subsistence fishery further includes the circumstantial or regular selling of catch to contribute to the immediate cash needs of the family or to cover cash needs that may arise at certain times or occasions only (school fees, social obligations). However, income derived from the subsistence fishery does not constitute the main income of the household. Due to economic pressure, women are increasingly engaged in contributing cash income rather than food, but women’s monetary contributions are often not acknowledged publicly and often accounted for as ‘subsistence’. The non-commercial exchange of marine catch is also termed ‘gift’.

The *per capita finfish, invertebrate and canned fish* consumption figures in our analysis are age–gender corrected average annual per capita consumption figures. For finfish and invertebrate per capita consumption, correction factors are applied for reported consumption frequency and for edible proportions of the total specimen consumed. Details of how these consumption figures have been calculated are described in the manual by Kronen *et al.* (2007).

Commercial fisheries aim to provide a major part of, if not the main revenue for the household. Commercial fishing may include various activities, finfish fishing, and invertebrate collection, and it may aim at selling catch at the village level, regional markets or via agents and middlemen for export. While in the framework of our study finfish is rarely exported, certain invertebrates, i.e. bêche-de-mer, trochus shells and some of the lobsters, may be exported to overseas markets. We therefore refer to *export fisheries*, if invertebrates are mainly harvested for overseas markets.

None of the coastal fisheries included in our programme are *'industrialised fisheries*'. This term describes a highly efficient approach to maximise catch from pelagic species by minimising production cost. We suggest using the term 'industrial fisheries' to distinguish between national commercial small-scale artisanal fisheries and highly efficient and productive large-scale fisheries serving export for pelagic fish species.

Artisanal fishery includes small-scale commercial and subsistence fishing and the practices used, particularly for coastal or island ethnic groups using traditional techniques such as rods, tackle, arrows and harpoons, throw nets and drag nets, today also including gillnets, modern spear guns, deep-bottom lines, traditional (one-man paddle) canoes and today also small motorised boats. This fishery usually involves short fishing trips, close to shore, targeting a wide range of fish and invertebrates, using small amounts of capital and energy. It does not include sports fishing. It is usually subject to a lack or inadequacy of cool chains and processing facilities; it mainly serves to satisfy home consumption and national markets.

Small-scale fishery describes typically a traditional, artisanal and/or subsistence kind of fishery that embarks upon fishing activities that have been passed on from generation to generation, and that serves mainly livelihood and food-security purposes. This term is used synonymously with 'artisanal fishery'.

The term *livelihood* means 'the financial means whereby one lives' or in relation to resource 'the available source of wealth, which may include a new or reserve supply that can be drawn upon when needed'. In the wider socioeconomic term we propose the definition used by UK's Department for International Development (DFID – http://www;dfid.gov.uk/research/rurallivelihoods.asp):

'A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.'

The *livelihoods approach* originates in the development of deeper understandings of the dimensions of poverty, such as the sustainable human development approach adopted by UNDP (UNDP 1990). The *Sustainable Livelihoods Approach (SLA)* was developed to address poverty, to build on strengths, and create links among community level (micro), level of service provision (meso) and the policy level (macro).

Sustainable development is a term often applied and often defined differently. Overall it means a development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED 1987).

The *sustainability of activities* that provide for human wellbeing depends on the maintenance of environmental functions (capacity of natural processes to provide goods and services for human needs), which themselves, directly and indirectly, contribute to human welfare.

An *ecosystems-based approach* aims at sustainable development giving emphasis to maintain stability and resilience of the ecosystem, and recognising the interdependencies of human economies with their environment. It requires scientific understanding of ecosystem functioning and change (FAO 1999).

Resilience is the capacity of a system to absorb disturbance and yet still retain essentially the same function, structure identity, and feedbacks. Resilience is required to absorb change.

Adaptability is the capacity of people in a social-ecological system to manage resilience through collective action. Adaptability is required to reinforce and sustain desired social-ecological states.

Transformability is the capacity of people in a social-ecological system to create a fundamentally new social-ecological system (SES) when ecological, political, social or economic conditions make the existing system vulnerable. Transformability is required in order to move into a more desired social-ecological trajectory.

Diversification is the process by which a household increases the diversity (i.e. number) of its income-generating activities (Ellis 2000b).

Diversification is considered as a household strategy to manage risk, used to secure income and consumption needs whilst minimising the risk of failing to do so, which could be part of an adaptation or accumulation process. The objective is to establish a portfolio of income-generating activities that have a low covariate risk among them. Migration and mobility are the geographical components of diversification. Specialisation is not antagonistic to diversification (i.e. specialisation on high-value target species); however, it does not mean substitution, i.e. shifting (exclusive) dependency from one income source to another.

A *risk-aversion strategy* aims at avoiding risk unless adequately compensation is available. Risk is defined as the perceived uncertainty. If two investments have the same expected return, the one with lower risk will be preferred. A riskier investment has to have a higher expected return in order to provide an incentive for a risk-averse investor to select it.

Demographic and economic terms used at national scale

Price elasticity is the commonly used term for *price elasticity of demand*. It measures the rate of response of quantity demanded due to a price change. Low elasticity applies if changes in price do not change the demand; a high elasticity occurs when change in price significantly changes the demand.

Population density is used as a proxy to fishing pressure in our study and refers to the total number of people in a *community studied* per appropriated available km^2 reef or fishing ground. *Population density* if referred to at the *national scale* means the total number of people in the country's population per km^2 of total land surface of the country.

Gross migration is the sum of the in-migration and out-migration for a geographic area over time. Gross migration is a measure of the total movement or turnover of population.

Dependency ratio is the proportion of the population (people aged <16 years and >64 years) that depends on the people of working age (16–64 years). Countries that have a high dependency ratio have more people who are not of working age, and fewer who are working and paying taxes. The higher the dependency rate, the higher the proportion of people who need looking after.

Gross Domestic Product (GDP) is a basic measure of a country's economic performance; it is the market value of all final goods and services made within the borders of a nation in a year. Per capita GDP is the GPD divided by the number of people and used as a measure for the country's living standard.

The *Consumer Price Index (CPI)* is an inflationary indicator that measures the change in the cost of a fixed basket of products and services, including housing, electricity, food, and transportation. CPI is also called the cost-of-living index.

In demographics and ecology, *Population growth rate (PGR)* or *growth rate* is the fractional rate at which the number of individuals in a population increases. Specifically, PGR ordinarily refers to the change in population over a unit time period, often expressed as a percentage of the number of individuals in the population at the beginning of that period.

The *urban population* is the percentage of the country's population considered to live in an urban area. An urban area is characterised by higher population density in comparison to areas surrounding it. Urban areas may be cities, towns or conurbations, but the term is not commonly extended to rural settlements such as villages and hamlets. Urban areas are created and further developed by the process of urbanisation. Measuring the extent of an urban area helps in analysing population density and urban sprawl, and in determining urban and rural populations.

Indicators – Definition and use

An *indicator* reflects the wellbeing of, or problems related to, the resource and human components of the system, and progress (or lack of it) towards the objective of sustainable development (in relation to societal goals and objectives). Geographical 'units' should be selected for which indicators will be reported: e.g. individual fisheries, or sub-national regions, or fish families, etc.

Ideally, indicators for each component should be developed by:

i) identifying objectives relative to the component;
ii) specifying a 'model' (either conceptual or numerical) of our scientific understanding of how the component functions; and
iii) determining the variables from the model that indicate performance relative to the objectives and for which information is available or can easily be collected and indicators constructed.

To make use of indicators, temporal or spatial changes are compared. It is necessary to specify reference values (or reference points) that are either targets (indicating desirable states of the system and good performance) or thresholds to be avoided. These reference levels may be derived empirically by considering past performance of the system (e.g. fisheries are likely to 'crash' when less than 30 per cent of the spawning biomass is left) or derived from mathematical models that indicate how the system should be expected to perform (FAO 1999).

Fisheries terminology and definitions

Fishing pressure is defined as annual catch per km^2 of reef (or occasionally as per total fishing ground, thus including lagoon surfaces with soft-benthos habitat). Annual catch may be expressed in tonnes (t) (usually used for finfish catch), or in numbers (nos) (often used for invertebrate catches). Distinction is made between reported and extrapolated catches. Reported catches record the information gathered from the survey respondents. Extrapolated catches are calculated by multiplying the sample data by a factor that applies to the total population of the community concerned.

Catch in socioeconomic fishery survey analysis is calculated in weight (kg or tons), using the reported average fish size length–weight relationship from ReefBase. Weights for invertebrates are an assumed average wet weight, further distinguished into edible and non-edible proportions for major invertebrate families and species reported in our surveys. Weight details for invertebrates are provided in Annex XI of the manual by Kronen *et al.* (2007).

Habitats, as perceived and targeted by fishers, distinguish (a) the sheltered coastal reef, which also includes mangrove habitats and intertidal flats; (b) the lagoon, comprising the total lagoon area with soft-benthos and reef habitats and also including the back-reef; and (c) the outer reef, which includes passages. Because fishers refer to and fish in the entire habitat area, no distinction is made between soft-benthos and reef habitats. Therefore, the surface areas used in the socioeconomic survey may exceed those used in the finfish resource surveys. This applies in particular to lagoon surface areas.

The total reef area referred to in the socioeconomic analysis and results is the sum of sheltered coastal reef and outer reef, both defined according to fishers' perceptions, and the lagoon reef area as defined by the finfish resource surveys, thus including the back-reef.

The total fishing ground area is the sum of all habitat surface areas defined according to fishers' perception.

Productivity in socioeconomic fishery terms means the production of fish or invertebrates i.e. catch. The more a fisher catches per unit of time, the higher his/her productivity. The *catch per unit effort (CPUE)* is a classical instrument to measure fishery productivity and to monitor fishing impact. However, in the context of coastal small-scale artisanal and subsistence fisheries in PICTs, CPUE must be used with great care, bearing in mind a number of particularities. Firstly, fishing is often not performed with a revenue-maximising approach but rather fulfills a combination of lifestyle, subsistence and income needs. The duration of a fishing trip may vary considerably and is often determined by non-catch-related factors. We use CPUE to calculate the amount (kg) of fish caught per hour of fishing trip. The fishing trip duration includes the time from take off to landing and, when possible, excludes longer break times during a fishing trip that serve purposes other than fishing. However, fishing in order to maximise income increasingly occurs in areas where households depend on fisheries, particularly finfish fisheries, for primary income and, in particular, if motorised boat transport is required to reach promising fishing grounds. While time may not be the decisive factor, fuel consumption represents a major operation cost. Hence, the less fuel is consumed and the more fish is caught, the better the revenue.

CPUE may be used for habitats targeted, or for fishing techniques used.

Reef productivity is the annual production in biomass that a certain reef area produces. There are no accurate contemporary or historical reef productivity figures available for all of the 63 communities and their appropriated fishing grounds studied. Documented and published estimates and field survey data vary considerably due to the sites studied, times when surveys were conducted, and survey methodology. For socioeconomic analysis, we used global reviews of documented reef-productivity figures in combination with a review on the available, published reef productivity data in PICTs, taking into account the factor of human footprint (impact from previous fishing), to model different scenarios represented by the current reef productivity and the current catch rates as determined by our study.

In total, eight major *finfish fishing techniques* emerged from the survey data: (1) speardiving encompasses any free-diving activity that uses an artisanal or modern speargun; (2) handlining is fishing with a single line held in the hands, using baitfish or lures, and may be performed from the shore or from boats; (3) gillnets include a range of different mesh sizes; (4) fishing rods include artisanal bamboo rods as well as modern cast rods; (5) handheld spearing uses artisanal spears while walking or from boats; (6) castnets, also called throw nets, are nets with small weights distributed around their edges; (7) bottom fishing is commonly done from boats by using a weight tied to the end of a line and a hook about 2–3 cm above it; and (8) methods grouped as ‘others’ may use one or a combination of traditional, mostly low-cost tools, such as bush knives, artisanal bows and arrows, small home-made scoop nets, traditional fish poison (the poisonous root from *Derris* sp.) (Kronen 2002, Merlin 2002) and, in rare cases, artisanal fish fences and fish traps. We have further condensed the fishing-technique data into three major groups: (1) line-fishing, including handlining, fishing rods and bottom fishing; (2) spear fishing, including speardiving and handheld spearing (the latter is a minor contribution); (3) gillnetting, including castnetting (the latter is a minor contribution); and (4) others, as defined above.

In total, 24 *finfish families* were distinguished in socioeconomic fishery surveys if recorded in more than one community surveyed. All other (rather anecdotal) records are grouped under ‘others’. These 24 fish families are: Acanthuridae, Albulidae, Balistidae, Belonidae, Caesionidae, Carangidae, Chanidae, Cirrhitidae, Exocoetidae, Gerreidae, Hemiramphidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mugilidae, Mullidae, Platycephalidae, Priacanthidae, Scaridae, Serranidae, Siganidae, and Sphyraenidae.

Eleven fish families were recorded by both the finfish resource and socioeconomic fishery surveys, and can, therefore, be used for joint analysis of both datasets. These were: Acanthuridae, Balistidae, Holocentridae, Kyphosidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Scaridae, Serranidae and Siganidae.

However, additional finfish families as reported by fisheries are important for socioeconomic analysis, in particular Carangidae (when caught as a ‘by-catch’ of coastal reef fisheries and not targeted using oceanic fishing techniques) and Mugilidae, but also Belonidae, Caesionidae, Chanidae, Gerreidae, Priacanthidae and Sphyraenidae are used if not comparing finfish parameters between both datasets.

For socioeconomic fishery analysis, the *diet group and diet group composition* of catch was determined by classifying finfish families generally as follows:

Herbivores	Carnivores	Piscivores	Zooplankton-feeders
Acanthuridae	Balistidae	Belonidae	Caesionidae
Chanidae	Gerreidae	Carangidae	Holocentridae
Kyphosidae	Labridae	Lutjanidae	Priacanthidae
Scaridae	Lethrinidae	Serranidae	
Siganidae	Mugilidae	Sphyraenidae	
	Mullidae		
All herbivores	***All carnivores***		

To distinguish therefore the herbivore/carnivore ratio in the socioeconomic fishery analysis from the ratio in the finfish resource survey data, the abbreviation H_s/C_s is used for catch data.