Status report:

Pacific Islands reef and nearshore fisheries and aquaculture

2013

SPC
Secretariat of the Pacific Community
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Status report: Pacific Islands reef and nearshore fisheries and aquaculture

2013

Compiled by members of the SciCOFish Project team

Secretariat of the Pacific Community (SPC) Noumea, New Caledonia, 2013

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Abbreviations

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
cm	centimetre(s)
EEZ	exclusive economic zone(s)
FADs	fish aggregating device(s)
FAO	Food and Agricultural Organization of the United Nations
FFA	Pacific Islands Forum Fisheries Agency
FSM	Federated States of Micronesia
g	gram(s)
ha	hectare
HIES	household income and expenditure surveys
i.e.	that is
kg	kilogram(s)
km	kilometre(s)
km^2	square kilometre(s)
lbs	pound(s)
m	metre(s)
m^2	square metre(s)
mm	millimetre(s)
MOP	mother-of-pearl
NZD	New Zealand dollar(s)
PICTs	Pacific Island countries and territories
PNG	Papua New Guinea
PROCFish/C	Pacific Regional Oceanic and Coastal Fisheries development Project (coastal component)
S	south
scuba	self-contained underwater breathing apparatus
SPC	Secretariat of the Pacific Community
t	tonne(s)
UNEP	United Nations Environment Programme
USD	United States dollar(s)
UVC	underwater visual census
WCPFC	Western and Central Pacific Fisheries Commission
yr	year(s)

Image: Colette Wabnitz

Summary

This report discusses the status of Pacific Island reef fisheries for finfish and invertebrates, nearshore fisheries for pelagic fish (e.g. tunas), fisheries for demersal fish (e.g. deepwater snappers), and aquaculture.

Effective fisheries management is needed to maximise the yields of demersal fish and invertebrates, and reduce the size of the 'food gap' between available seafood and that required to meet the needs of growing human populations in the Pacific Islands region. However, much of the additional seafood required will need to come from nearshore pelagic fish (tunas in particular) and aquaculture.

Climate change will have varying effects on Pacific Island countries and fisheries. It is essential to develop monitoring tools and implement long-term national and regional monitoring programmes for climate change. This should be done as soon as possible, because the ability to detect change and provide information for adaptive management increases with the duration of the monitoring programme.

Data from the Secretariat of the Pacific Community (SPC) suggest that many reef fisheries that are based on finfish and invertebrates are exposed to unsustainable fishing, and that sound management is urgently needed to maintain catches at a sustainable level.

Reef fisheries

Reef fisheries, which covers inshore finfish and invertebrates resources, provide the daily protein for most Pacific island people and have been the basis for food security and small-scale livelihoods. However, these resources are finite and the current levels of fishing in many locations are unsustainable, so effective management arrangements need to be implemented to control the harvest of there resources.

Giant clams have been fished to local extinction in several areas. Trochus exports have declined markedly, and some of this decline has been due to uncontrolled fishing and low international prices for the commodity. Green snails have been heavily exploited in almost all countries where they exist and many stock are at very low levels. One of the oldest commercial fisheries, that on sea cucumbers, has suffered from overfishing.

The status of several other invertebrates, including lobsters, crabs and octopuses, is generally not known. Although these species constitute an important part of subsistence fisheries and local markets, there are very few catch statistics on them.

In the face of depleted stocks, SPC is assisting many Pacific Island countries and territories (PICTs) with developing and imposing management measures, including size limits and short harvest seasons. With valuable and threatened invertebrate stocks, some countries have taken the bold move to close their fisheries in order to allow stocks to rebuild. These 'moratoria' (or resting periods), however, must be long enough to ensure full recovery. Many invertebrate species with limited movement require a large number of individuals to be in close proximity to each other for reproduction to be successful.

The live reef food fish trade has declined because more authorities have become aware of the implications and consequences of the trade, especially in trying to meet the large minimum quantities required by buyers. Exports of aquarium fish and invertebrates (including corals) from PICTs began in the 1970s, and has expanded to become an important source of income and employment for a number of communities in the region. To ensure these fisheries can provide sustainable livelihoods, management must ensure that best practices are followed to avoid damage to fragile

reef ecosystems, including through improved, standardised collection methods and monitoring of country-level data.

Live coral exports from the Pacific Islands region peaked in 2006 and have declined since then. This may be linked to the economic downturn, and the increase in culturing of some corals within importing nations.

Nearshore fisheries

Nearshore fisheries include those for pelagic and demersal species. There is some potential to increase the Pacific Islands' share of commercial tuna catching and processing activities. At present, over 30% of the total tuna catch is caught within the exclusive economic zones (EEZs) of PICTs.

Domestic longline vessels and small-scale boats, which fish near fish aggregating devices (FADs) and troll close to the reefs, also target species such as wahoo, mahi mahi and rainbow runner. In some countries, the catch of non-tuna species is higher than that of tunas.

Many member countries have benefited from FADs over the last 25 years. Tuna catch rates (expressed in kg hr^{-1}) from trolling around FADs are often three times the tuna catch rates when chasing tunas and trolling in open water and around reefs. Nearshore pelagic species and the use of FADs are also important for Pacific gamefishing operations, which are slowly expanding. Many countries now have charter fishing operations taking paying passengers to fish for marlin, wahoo, mahi mahi and tunas.

There is a growing interest in fishing for squid in the region and SPC has been involved in exploratory fishing trials for 'giant' squids. Catches of large squids, including diamond-back squids with a mean weight of 18 kg, have been encouraging and there is potential to develop squid fisheries in some countries.

Deepwater snapper fishing was the subject of an SPC international workshop in 2011, which recognised the need for well-designed biological studies of deepwater demersal fish species across the Pacific Islands region in order to gain a full understanding of the population distribution of harvested species. Most species have extended lifespans (> 20 years), are generally slow-growing and late to mature, making them vulnerable to overfishing.

Data obtained during SPC's surveys on the deepwater snapper project revealed sizeable stocks of bluenose and blue warehou on the seamounts of southern Tonga and in international waters between Tonga and New Zealand. Catches of bluenose as far north as 19°S have been reported in Fiji waters, suggesting that this species has a wider distribution than previously thought. These findings suggest that there may be some potential for the development of these fisheries in this region and other locations at similar latitudes such as Fiji and New Caledonia.

Other surveys have been conducted for deepwater species including caridean shrimps, alfonsino and deepwater crabs. However, the economics of fishing in deep water and the lack of knowledge of the stocks make commercial fishing unpromising.

Aquaculture

Aquaculture systems were introduced to the region in the early 1950s by SPC, but have only become well established during the past few decades. However, since 2007, production from the region has dropped significantly as a result of the collapse in the value of pearl production from both French Polynesia and Cook Islands. This decline was related to a reduction in value of pearl from French Polynesia, mainly as a result of oversupply and poor market prices, while Cook Islands' pearl production was affected by market value, water quality and other environmental problems.

By 2010, the value of aquaculture in the region had been reduced to about USD 100 million.

Excluding production of shrimp from New Caledonia and pearls from French Polynesia, Pacific oysters in New Caledonia have the highest value, followed by tilapia production in several countries, including Fiji, Papua New Guinea and Vanuatu. Seaweed production is increasing, mainly in Fiji and Solomon Islands.

The key commodities that were identified in the SPC's Aquaculture Action Plan 2007 as being the most feasible and having the greatest potential are cultured pearl, seaweed, giant clams and coral farming (for the ornamental trade), marine shrimp, tilapia, freshwater prawn, sea cucumber, and marine finfish. Species such as tilapia and milkfish, which have well established fish farming methods, are among the most suitable species to help meet the food security needs.

Pearl farming continues in countries such as the Federated States of Micronesia and Fiji where smaller and more specialist producers target local tourism and local industry. New research is underway in neighbouring countries such as Tonga to produce round pearls from other pearl oyster species, such as the winged pearl oyster.

There is much interest from PICTs in adopting aquaculture techniques to restore stocks of sea cucumbers. Although techniques to breed the valuable sandfish species have been developed, it is unclear to what extent aquaculture can contribute to the restocking of depleted wild stocks or form the basis of profitable sea ranching or pond farming systems. One of the key challenges is to demonstrate the effectiveness of sea cucumber restocking and sea ranching through large-scale experimental releases and post-release monitoring.

Roles of women and men in fisheries

Knowledge of gender roles and their changes are an important input to effective fisheries management because it allows interventions to be tailored to the needs and abilities of specific target groups of fishers. Long-standing gender patterns continue, with men predominating among fishers who exclusively target finfish, and women predominating among fishers who exclusively target invertebrates.

In 2011, studies on the participation of women in fisheries science and management indicated that women account for only 18% of the total staff working in fisheries science and management in government fisheries, environmental institutions, and environmental non-governmental organisations. In contrast, women account for more than 60% of administrative and clerical staff in government fisheries divisions. SPC's Fisheries, Aquaculture and Marine Ecosystems Division strongly believes that all fisheries careers should be equally accessible to both women and men, and focuses on 'breaking down the barriers' to help women gain work in fisheries should they so choose to do so.

The need for reliable catch information and sensible management is more important than ever given the dual impacts of climate change and increasing fishing pressure.


Image: Colette Wabnitz

1. Introduction

This report discusses the status of reef fisheries for finfish and invertebrates, nearshore fisheries for pelagic fish (e.g. tunas), deeper water fisheries for demersal fish (e.g. snappers), and aquaculture.

Although commercial tuna fisheries contribute greatly to revenue and national economic development, coastal fisheries are essential for ensuring national food security and rural incomes. In terms of economic benefits, through import substitution and livelihood support, it is likely that oceanic and coastal fisheries are of (approximately) equal importance in many island countries.

Coastal habitats such as coral reefs, mangroves, seagrass beds and intertidal flats have a limited capacity to produce fish and invertebrates. Therefore, much of the additional seafood required to meet the nutritional needs of growing populations in Pacific Island countries and territories (PICTs) must come from nearshore pelagic fish, especially tunas, and aquaculture (Bell et al. 2011a). Careful management is needed to maximise the yields of demersal fish and invertebrates (SPC 2011, 2012, 2013), and reduce the size of the 'food gap' between available seafood and that required by growing human populations (Fig. 1).

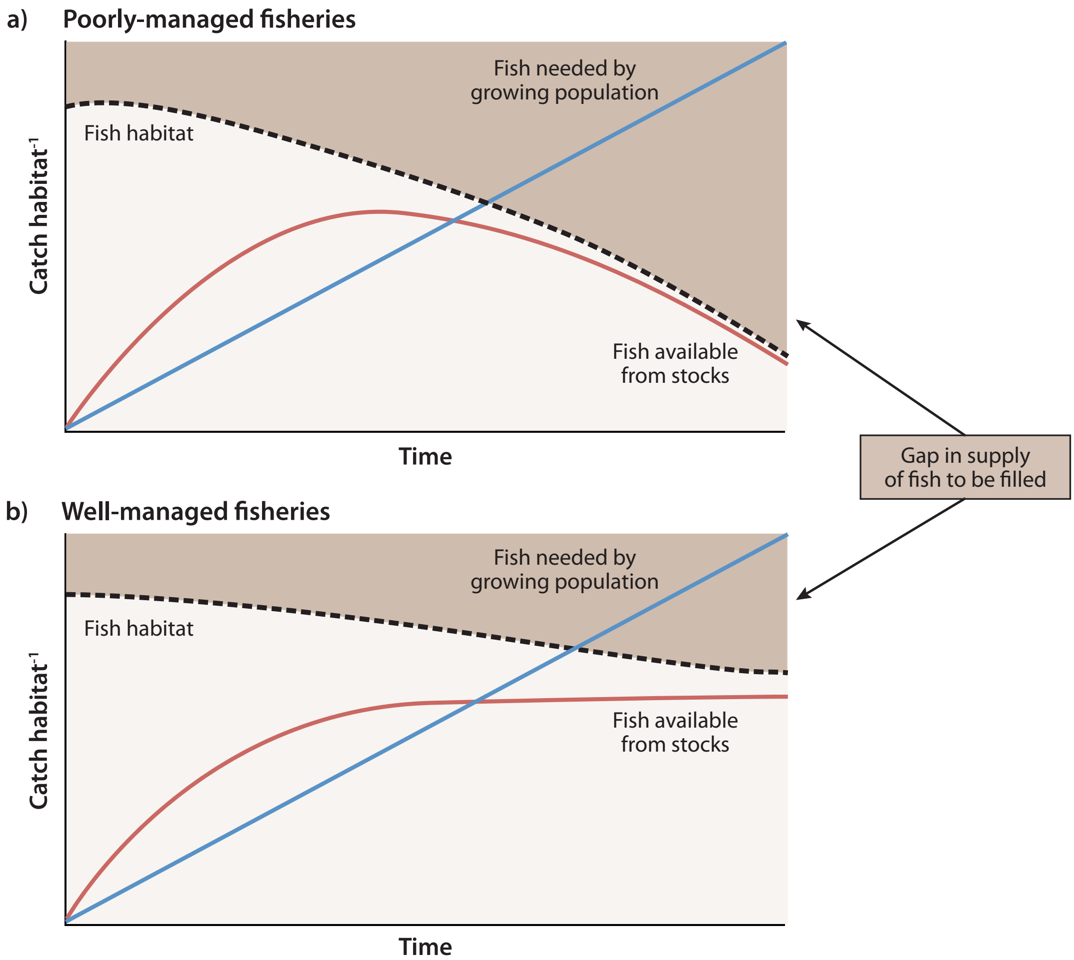

Figure 1. In a poorly managed fishery (graph a), fish stocks and catches (red line) decrease, and marine habitats (brown area) deteriorate over time. In a well-managed fishery (graph b), fish stocks and catches remain at a sustainable level. Well-managed fisheries minimise the gap between seafood required by rapidly growing human populations and sustainable harvests of demersal fish and invertebrates (SPC 2008; Bell et al. 2011).

The Secretariat of the Pacific Community (SPC) is involved in providing support to PICTs for coastal and nearshore fisheries, and aquaculture by:

- developing a regional approach to aquatic biosecurity with a focus on introduced species for aquaculture;
- assessing the economic viability of projects and small-scale commercial activities;
- supporting new and improved data collection systems;
- developing technical and policy foundations for aquaculture and mariculture;
- supporting effective fisheries management involving traditional governance, local knowledge, community-based management and ecosystem approaches;
- providing support for strong management actions in some coastal export fisheries, including national bans on exports and short fishing seasons, to effectively promote stock recovery;
- developing a framework for regional coastal export fisheries management and marketing coordination;
- assisting with the sustainable development of the aquarium live fish trade;
- establishing pilot sites to detect the effects of climate change over time;
- increasing the domestic catch from commercial tuna fisheries and developing artisanal tuna fishing including that from coastal fish aggregating devices (FADs);
- assisting competent authorities in meeting requirements for the export of fisheries products;
- assisting with the development of tuna fishers' associations to contribute to the management of their fisheries; and
- promoting non-extractive activities such as sportsfishing.

Fisheries managers require reliable, up-to-date information on the status of fisheries resources and the ecosystems that support them in order to determine the success of measures and policies to 1) maintain catches of demersal fish and invertebrates, and 2) increase catches of nearshore pelagic fish.

The management and conservation of these fisheries benefit greatly from regional communication and cooperation, access to shared regional support services, and by comparing experiences directly in gatherings such as the SPC Heads of Fisheries meetings. Information contained in this status report comes from national fisheries authorities, SPC in-country activities, and SPC data collection systems.

Data collection

In most Pacific Island countries, there is an extremely weak factual basis for the estimates of coastal commercial and coastal subsistence catches (Gillett 2009). There are three situations, however, in which good estimates are available:

- Countries that have a dedicated ongoing national fisheries statistical system supported for many years by an overseas agency.
- Countries that have carried out an intensive, well-planned survey of fisheries to obtain an accurate 'snapshot'.
- Countries that use a household income and expenditure survey (HIES) to measure small-scale fisheries production.

At a minimum, basic information on total catches is needed for three broad categories of species: 1) demersal (bottom-dwelling) fish associated with coral reefs and other coastal habitats; 2) nearshore pelagic fish, including tunas; and 3) invertebrates collected from coastal habitats. Information should also be provided on the proportion of fish caught by subsistence and commercial (artisanal) fishing in each category. Catch estimates for these categories (given in Table 1) are an example of the information required. Where possible, data should be collected on the composition and size structure of indicator species within each category.

Table 1. Preliminary estimates of annual catches in tonnes and as a percentage of total catch for the three main categories of coastal fisheries in Pacific Island countries and territories. Based on catches for 2007 reported by Gillett (2009) and calculated using the method described by Pratchett et al. (2011). A breakdown of the catches for each of the three categories into subsistence and commercial catches is available at (http://cdn.spc.int/climate-change/fisheries/assessment/chapters/12-supp-tables.pdf) (Source: Bell et al. 2011b). PNG = Papua New Guinea; FSM = Federated States of Micronesia; CNMI = Commonwealth of the Northern Mariana Islands.

	Demersal fish		Nearshore pelagic fish		Invertebrates		Total catch
	Tonnes	%	Tonnes	%	Tonnes	%	Tonnes
Melanesia							
Fiji	17,450[d]	64.9	5270[a]	19.6	4180	15.5	26,900
New Caledonia	2670	55.1	560[a]	11.5	1620[e]	33.4	4850
PNG	14,520	40.7	13,760[a]	38.5	7420[f]	20.7	35,700
Solomon Islands	8925	48.9	5750[a,g]	31.5	3575	19.6	18,250
Vanuatu	1730	51.4	753[a]	22.4	885	26.3	3368
Micronesia							
FSM	6290	49.9	3560[b]	28.3	2750	21.8	12,600
Guam	33	28.9	77[b]	67.5	4	3.5	114
Kiribati	15,075	72.8	4250[c]	20.5	1375	6.7	20,700
Marshall Islands	2417	64.5	1080[a]	28.8	253	6.8	3750
Nauru	310	47.7	310[c]	47.7	30	4.6	650
Palau	950	44.9	680[a]	32.2	485	22.9	2115
CNMI	260	57.6	161[a]	35.7	20	4.4	451
Polynesia							
American Samoa	92	59.4	47[a]	30.3	16	10.3	155
Cook Islands	146	36.5	240[c]	60	14	3.5	400
French Polynesia	3666	53.3	2582[c]	37.5	634	9.2	6882
Niue	62	41.3	75[a]	50	13	8.7	150
Pitcairn Islands	10	83.3	1[a]	8.3	1	8.3	12
Samoa	4419	51.2	2550[b]	29.6	1655	19.2	8624
Tokelau	182	48.5	150[c]	40	43	11.5	375
Tonga	5245[h]	80.7	650[c]	10	605	9.3	6500
Tuvalu	837	68.9	326[b]	26.8	52	4.3	1215
Wallis and Futuna	718	74.7	106[a]	11	137	14.3	961
Total	**86,007**	**55.6**	**42,938**	**27.8**	**25,777**	**16.7**	**154,722**

a = Nearshore pelagic fishery dominated by non-tuna species; b = nearshore pelagic fishery comprising equal amounts of non-tuna and tuna species; c = nearshore pelagic fishery dominated by tunas; d = includes deepwater snappers; e = includes mangrove crabs and spiny lobsters sold at local market; f = includes hundreds of tonnes of penaeid shrimps; g = includes 800 t of baitfish; h = includes 700 t of deepwater snappers.

Information on fishing effort (the amount of fishing conducted) is more difficult to collect but allows the calculation of catch rates and the quantity of fish caught per unit of time spent fishing. Catch rates are important indicators of the 'health' of a fishery, and declining catch rates may indicate that more or different management measures are required.

A national HIES provides a reliable and regular way of collecting basic information on subsistence and commercial catches of the three categories of coastal fisheries, provided the HIES has been modified to include suitable questions (Bell et al. 2008).

Data on the abundance and size frequency of demersal fish and invertebrates can be obtained by sampling catches at central markets using methods that allow data to be easily recorded, stored and analysed.

Data on the abundance and size frequency of tunas and other large pelagic fish caught by near-shore fisheries, including catches made around inshore fish aggregating devices (FADs), can be collected using the SPC-Pacific Islands Forum Fisheries Agency (FFA) Regional Data Forms. These forms can be used to collect data on catch and effort, vessel activity, biological indicators, and economics. This information is best collected at the point of unloading, but it is also possible for fishers to record data, given appropriate supervision. The Tuna Fisheries Artisanal Data Management System (TUF-ART) database has been set up to manage and report on data. Training and equipment (calipers and pocket-sized identification guides) are available from SPC.

The system used to monitor catches of tunas and other large pelagic species can also be used to record catches of deepwater snappers and other demersal species.

Climate change

Dedicated sampling programmes are needed to monitor the effects of climate change on demersal fish and invertebrates and their supporting habitats. These programmes require an experimental design that controls for or removes the effects of other stressors, such as pollution or fishing pressure; this can be achieved, for example, through comparisons between 'impacted' (e.g. fished) and 'control' (e.g. unfished) areas. For fish habitats, requirements include simple methods for collecting remotely-sensed data and ground-truthing this information; measurement of changes in coral cover, species composition and topographic complexity is also needed, because of their importance in determining the abundance of demersal fish and invertebrates. Fish and invertebrate resources should be assessed using both fishery-dependent methods (e.g. market and creel surveys) and fishery-independent methods (e.g. underwater visual census [UVC] methodologies). SPC's Coastal Fisheries Programme is finalising a survey manual and database software to support the collection and storage of market and creel survey data, and SPC's existing Reef Fisheries Integrated Database is designed to facilitate storage of fisheries-independent survey information such as UVC data.

It is essential to develop monitoring tools and implement long-term national and regional monitoring programmes for climate change. This should be done as soon as possible because the ability to detect change and provide information for adaptive management increases with the duration of the monitoring programme.

Monitoring and reporting

A uniform system is needed for PICTs to record key information on coastal fisheries and aquaculture production. This system should provide for reporting catches and catch values for the three basic categories of coastal fisheries described above; and key information on aquaculture, including quantities or volumes of the main aquaculture commodities produced, number of farm units, number and gender-balance of people employed part and full-time, and export value. The number of ciguatera cases in each country should also be reported (a data collection form is available from SPC).

This system should also be designed to make it easier for countries to provide the information required by the Food and Agriculture Organization (FAO) of the United Nations. FAO (2012) noted that 18 out of 23 countries in Oceania did not report adequate catch data in 2009.

2. Reef fisheries

Reef fisheries refer to those based on organisms associated with tropical coral reefs and lagoons, in waters from 0–50 m in depth. These are the main food-fisheries in the Pacific and the basis of the main non-tuna exports, often including non-perishable invertebrate commodities such as trochus shell and beche-de-mer (dried sea cucumber), but also finfish, including high-value fish and invertebrates exported live for food and aquarists. The degree of commercialisation of Pacific Island reef fisheries varies across the region, but these are primarily artisanal and subsistence-focused, and do not involve full-time, professional fishers.

Fishing pressure on reef fisheries

Socioeconomic data obtained under the Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish) assessed the degree to which PICTs are dependent on coastal (particularly reef and lagoon) resources for food, income and livelihood. The degree of exploitation is a proxy to estimate resource impacts (i.e. fishing pressure) and dependence (the degree to which a community is dependent on a fishery), simplifying the identification of possible alternatives that could be used to reduce fishing pressure. Analysis of the regional dataset has revealed that finfish fishing pressure is strongly correlated with (human) population size (Fig. 2).

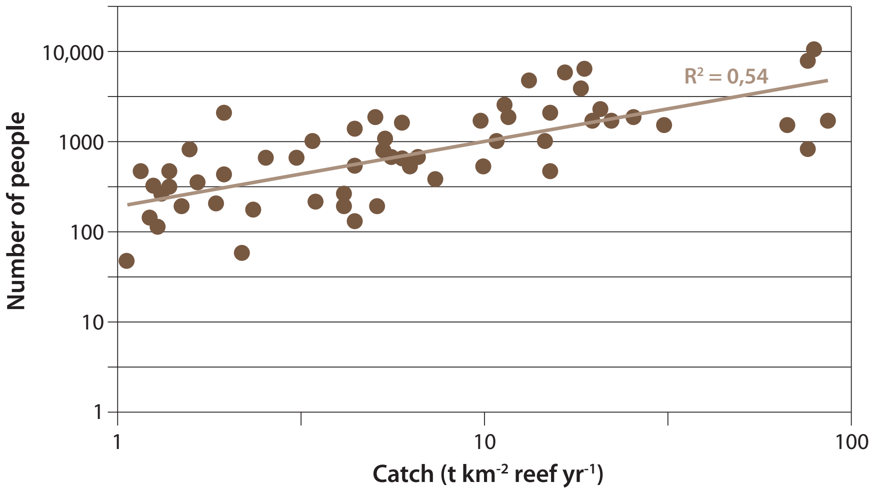

Figure 2. Regression between population and finfish catches across PICTs.

Fishing pressure and its possible impact on fisheries varies among countries and sites because of a number of different factors, but in general, the pressure on reef and lagoon resources increases with larger human populations.

Fishing pressure is the sum of activities undertaken for food harvesting (subsistence fishing), social obligations (fishing to obtain non-market exchange and gifts) and income (fishing for sale). PICTs have the highest seafood consumption rate in the world but there are significant differences among sites and countries. Regionally, annual per capita seafood consumption varies between 16 kg and 139 kg for finfish (edible parts only), 2 kg and 16 kg for invertebrates (edible meat only) and 2 kg and 25 kg for canned fish (net weight of fish meat only) (PROCfish data). Averaging the sum of per capita consumption of all seafood categories for each site studied indicates that seafood provides 5–25% of the total annual energy needs of an average adult Pacific Islander. Seafood consumption patterns are highest in Micronesian countries, and lowest in Melanesian countries. Overall, finfish constitutes the most important seafood consumed throughout the Pacific, although invertebrates and canned fish are also important in certain countries and regions.

The degree of dependency on income from fisheries is another important determinant of fishing pressure. The proportion of households whose primary or secondary source of income is derived from fishing varies substantially across all 63 sites in the 17 countries studied (i.e. between 10% and 93%).

The dependency of communities on seafood and income derived from fisheries, and the degree to which household income is diversified directly impacts fisheries management planning, and can indicate which interventions are preferred if fishing pressure must be reduced. Communities with significant income diversification (and access to alternative income opportunities) are better able to cope with restrictive fisheries regulations than communities that rely predominantly on fisheries for income, with no access to other alternatives.

Effective fisheries management needs to adjust interventions according to the needs and capacities of target groups. There are a wide range of tenure systems in place across the countries and sites that have been studied, ranging from the open access system — often referred to as the 'tragedy of the commons' (Hardin 1968) — to customary tenure with clear and strict regulations concerning target species, and temporal or periodic closures. Different tenure systems are often regarded as having a major impact on resource exploitation, but this was not reflected in differences between the sites studied. On the other hand, significant differences were found in participation by gender, and the associated contribution to fishing pressure (see Section 5).

The PROCFish/C results, mainly based on socioeconomic surveys, corroborate other findings regarding the existing high exploitation rate of reef and lagoon resources, including finfish and invertebrates in PICTs. Results demonstrated that fishing pressure is closely associated with human population density and various socioeconomic variables (including income and financial status). Catch data extrapolated from fisher surveys suggest that the levels of finfish and invertebrate exploitation are positively correlated, with half of all sites studied apparently exposed to unsustainable fishing of both finfish and invertebrate populations. Findings also suggest successful fisheries management must address cultural differences and gender participation.


Image: Pierre Boblin

Status of reef finfish fisheries

The preliminary regional analysis of PROCFish/C data suggests that the average standing biomass of commercial reef fish across the Pacific Islands region is currently about 100 grams of fish per square metre (or 100 t km^{-2}) of reef but this figure is highly variable by site, ranging from more than 360 g m^{-2} to less than 20 g m^{-2}. Biomass is highest near the equator (Fig. 3) and decreases with distance to the north or south in both the northern and southern hemispheres. Changes with longitude are much more irregular.

The regional analysis also revealed decreasing biodiversity with increasing distance from the area north of Papua New Guinea (PNG) (Fig. 4), as expected under ecological theory. However, the decrease is nonlinear and highly variable, probably as a result of fishing impacts.

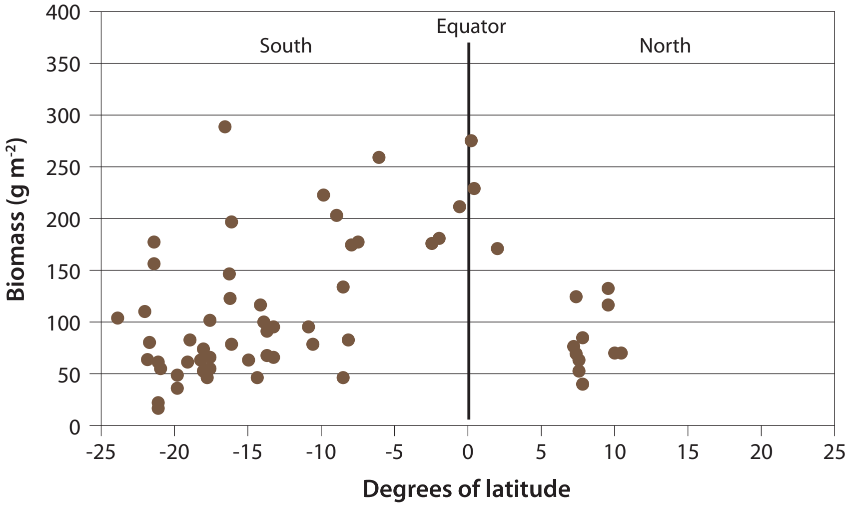

Figure 3. Average biomass of reef fish (g m^{-2}) by latitude of site.

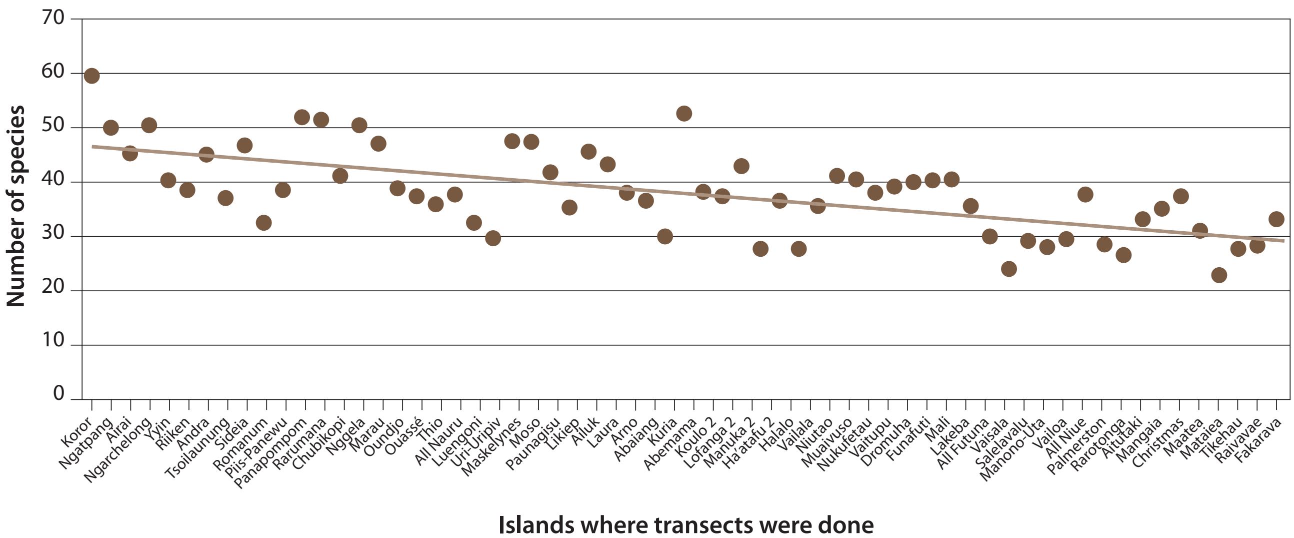

Figure 4. Biodiversity of commercial finfish from west to east across the Pacific.

Analysis of the regional status of reef finfish is complicated by 1) the lack of a clear indication of what constitutes a 'healthy fish condition' and 'normal' community structure at different sites, which have naturally varying conditions and productivity levels; and 2) changes over time. However, analyses strongly suggest that fishing is significantly impacting finfish resources, with most sites apparently impacted by different fishing levels. Total finfish numbers, and especially average size and biomass of fish, were major indicators of increasing fishing levels.

As expected, the relative density of carnivorous fish such as emperors (Lethrinidae) decreased with increasing fishing pressure. However, some herbivorous fish, such as surgeonfish (Acanthuridae), increased with increasing fishing pressure (Fig. 5), probably reflecting a response by a group of opportunistic species to a decrease in predator levels. These changes were apparent after removing variations due to environmental characteristics (e.g. geographical position, type of island, type of reef, composition of substrate), and therefore result primarily from fishing impact.

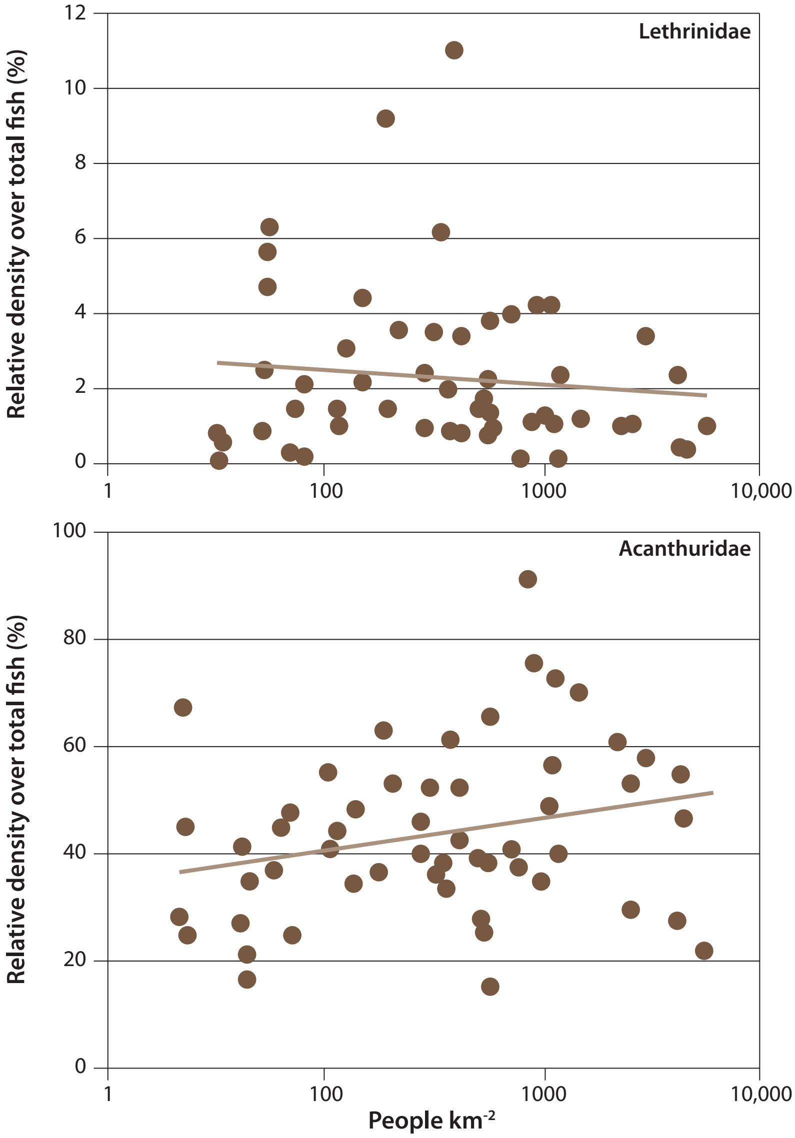

Figure 5. Top: Relative density of emperors over total commercial fish against number of people per square kilometre of reef. Bottom: Relative density of surgeonfish over the commercial fish against number of people per square kilometre of reef.

Human population density is strongly correlated with (and used as a proxy for) fishing intensity, and data suggest a strong reduction in the mean size of piscivorous fish (e.g. Serranidae and Lutjanidae) with increasing fishing pressure (Fig. 6).

The proportion of herbivorous fish to carnivorous fish has been suggested as an indicator in other parts of the world to measure the health of reef food-fisheries and their supporting ecosystems (i.e. a high proportion of carnivores is usually an indicator of good reef ecosystem health). Some Pacific Islands, however, have low fishing pressure but high proportions of herbivores to carnivores, and some islands with apparently high fishing pressure have low proportions of herbivores. Differences in these proportions could result from the types of fish being targeted; some Pacific Island societies, for example, prefer herbivores, such as parrotfish, over carnivores. But the differences in these proportions result primarily from environmental differences; for example, high volcanic islands appear to have a higher proportion of herbivores than carnivores. Nonetheless, this ratio was useful in the regional assessment as it provides a significant indicator of fishing intensity when environmental variability was removed.

The data analysed indicate that density, size and consequently biomass of fish decreased with increasing fishing intensity; similarly, increasing fishing intensity heightened the relative importance of herbivores over carnivores, and the dominance of small-sized surgeonfish.

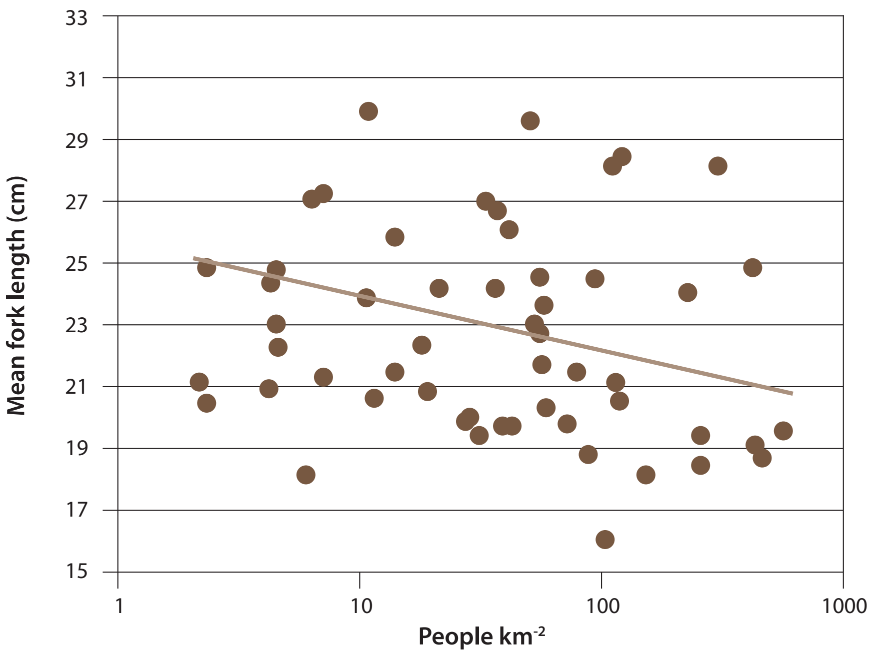

Figure 6 Mean fork length of piscivores (e.g. Serranidae, Lutjanidae) in cm against the number of humans per square kilometre (used as a proxy for fishing pressure).

Status of invertebrate fisheries

Invertebrate export fisheries in the Pacific have a history dating back to before European settlement. These fisheries are primarily based on the sale of sea cucumbers (beche-de-mer), trochus and pearl oysters (mother-of-pearl shell, or MOP) and, more recently, the export of dead coral products and live molluscs, crustaceans and corals for the ornamental trade.

In the western Pacific, most of these fisheries have exhibited boom-and-bust cycles throughout their history. Increased demand from Asian markets and elevated export prices since the 1980s has been the catalyst for increased and more sustained fishing, and at many localities, high-value species have been depleted and are now being replaced by previously unfished species of lower value.

Invertebrate export fisheries have the potential to provide income (derived from foreign currency) directly to remote village economies with few other income-generating opportunities. Declines in the sustainability of sea cucumber and MOP fisheries are thus of widespread concern. In addition to reducing foreign exchange earnings, damage to invertebrate export fisheries also contributes to outer-island depopulation and urban drift.

Giant clams

As is true of fish, the number of invertebrate species, including giant clams, increases with the environmental complexity of the area studied, and decreases in a cline from west to east across the Pacific (Fig. 7).

The smaller, more common clam species are found at most sites, while larger species, such as *Tridacna gigas* and *T. derasa*, are rare. In the case of the largest giant clam, *T. gigas*, individuals were recorded at only 39% of survey sites within their geographical and ecological range, despite dead shells being commonly noted onshore at many more sites. In Kiribati, Marshall Islands and Solomon Islands, *T. gigas* was only present at one of the four sites surveyed in each country, with two of these countries being represented in the database by a single individual clam.

More targeted assessments provide a clearer picture of stocks in specific shallow reef locations. Biomass, a measure that incorporates both density and size information, is not always a useful measure for invertebrates; invertebrate target species are often partly made of shell, which complicates the comparison of weight measures between the large range of invertebrate body forms.

Unlike fish, however, the density and size of samples can be reliably measured and re-measured in known locations, as many important invertebrate stocks are relatively sessile. If one examines the density of elongate giant clam (*T. maxima*) across countries in the Pacific, the considerable variation across countries is clearly evident (Fig. 8). Results from atoll lagoon systems in the eastern Pacific (where larvae of clams are entrained) will need to be compared with related systems, and considered differently to results from more 'open' lagoon systems that are characteristic of reef systems in Melanesia.


Image: Ian Bertram

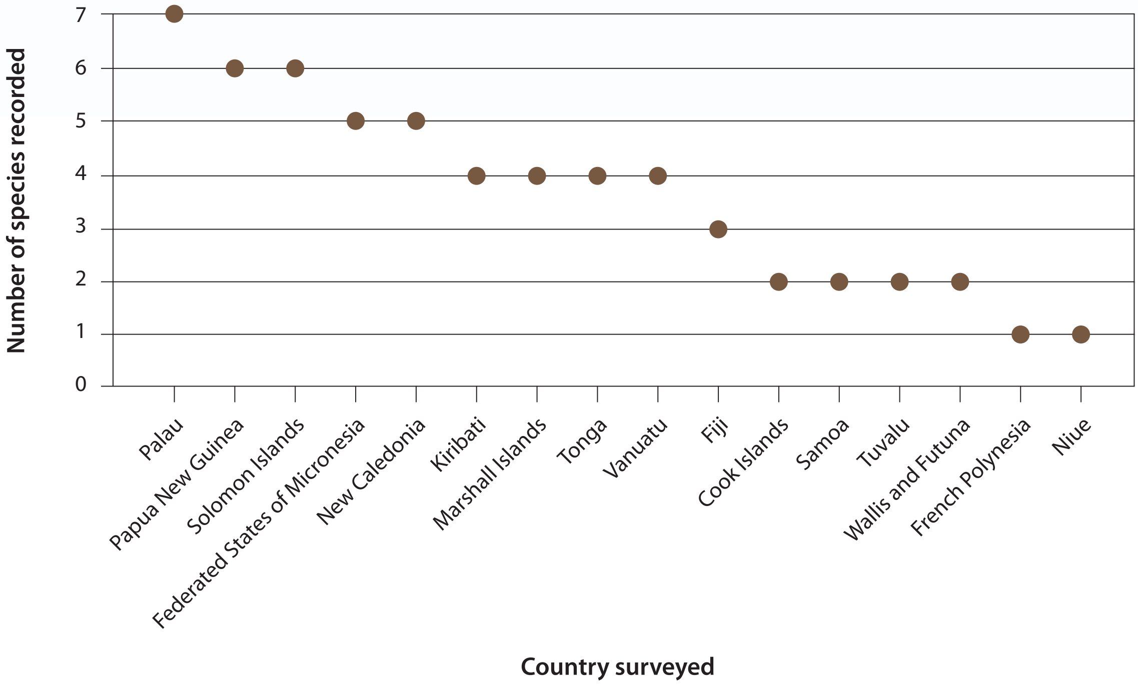

Figure 7. Number of giant clam species recorded in recent SPC surveys by country.

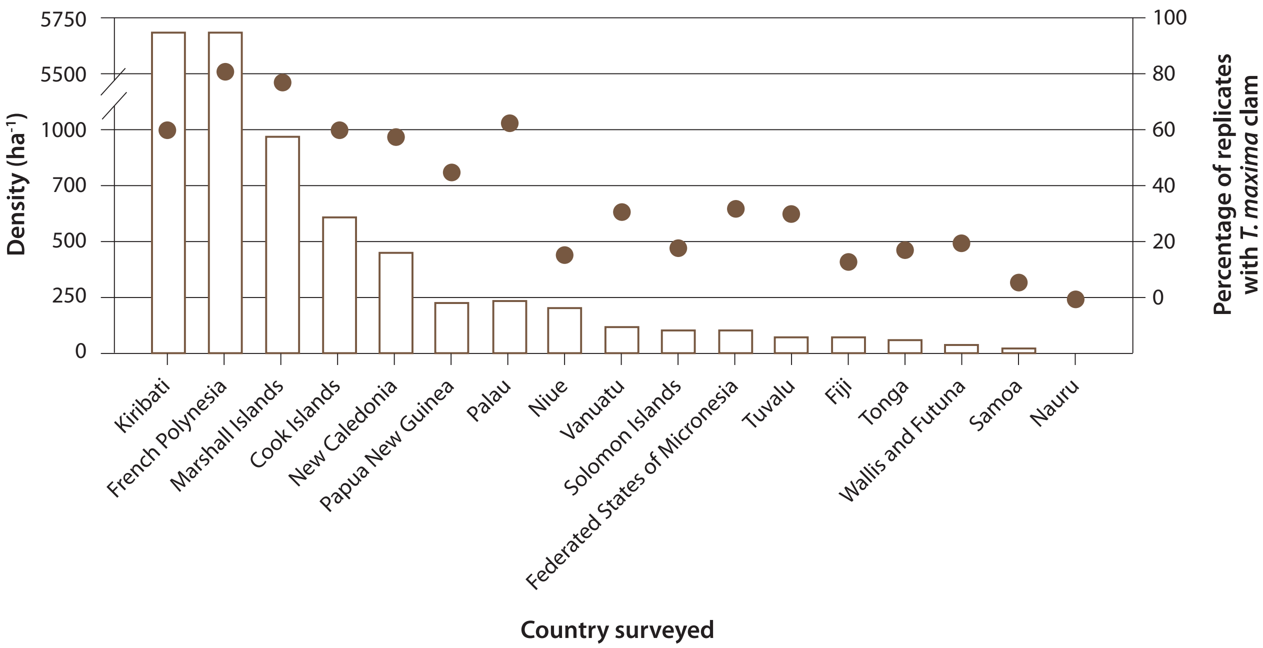

Figure 8. Density of *Tridacna maxima* clams by country (bars, left axis) and 'coverage' of *T. maxima* clams (points, right axis).

Trochus and other gastropods

Pacific Island MOP fisheries mainly target trochus, but also include pearl oysters and other nacre species.

In the early 1900s, records show large harvests of commercial topshell, *Tectus* (*Trochus*) *niloticus*, being taken from virgin fisheries in the Pacific; catch rates of 4000 shells person^{-1} day^{-1} were known. Similar large harvests of pearl shell from atoll lagoons in the eastern Pacific have also been documented, although many pearl oyster beds never recovered and today most pearl shell reaching the markets is a by-product of spat collection technology and pearl farming.

Trochus have been subjected to over 150 transplantations within islands, between islands and between countries since the 1920s. Introductions have been made to areas where stocks have been depleted and to new areas where the species has not naturally existed. Introduction of wild adult trochus has resulted in new fisheries in Cook Islands, Federated States of Micronesia (FSM), French Polynesia, Marshall Islands and, recently, Samoa and Tonga.

Trochus exports have declined markedly and this may be primarily due to low international prices for the commodity. Some countries declare short harvest seasons when stock levels are greater than 500–600 trochus ha^{-1}. Size limits imposed by some countries include a minimum size of 3 inches (75 mm); some countries have minimum and maximum size limits.

A model example of the management of a trochus fishery

Trochus harvests in Aitutaki, Cook Islands are announced after an underwater visual assessment has been completed by Fisheries Department staff. A total allowable catch is set at between 30% and 40% of the biomass of trochus within the 80–110 mm size window. Total allowable catch is divided among community households. A harvest may last for a few weeks, generally toward the end of the year. Families collect, boil, clean and dry trochus shell ready for inspection and grading by the Fisheries Department and Island Council. During grading, undersize and oversize shell may be confiscated. Trochus stocks remain healthy in Aitutaki (Bertram and Story 2011).

In 2001, Aitutaki trochus shell reached a value of NZD 8500 t^{-1} and fishers harvested 37 t. After 2001, prices to fishers dropped and expanding tourism provided alternative employment. Consequently, trochus were not harvested again until 2011, when the value per tonne was NZD 4370 t^{-1} and about 19 t of shells were collected at a value to fishers of almost NZD 83,000; in comparison, fishers could receive NZD 8 kg^{-1} (NZD 8000 t^{-1}) for gilled, gutted and iced tunas.

Results from PROCFish/C surveys indicate that, at most sites, trochus were harvested throughout the year (mean of 33 trips year^{-1}), with fishers taking many small catches (mean of 17 trochus harvested per trip), and slowly depleting stocks to levels where spawning success was compromised.

Interestingly, despite the large number of depleted sites, small pockets of trochus were present in aggregations at a high enough density to provide a source for successful reproduction and stock recovery if management controls could be implemented. Trochus need to be in close proximity to each other for reproduction (to induce broadcast spawning and ensure successful fertilisation of gametes) and this will not occur effectively when they are fished to low densities.

To allow stocks and therefore fishery productivity to rebuild, closures of underperforming (and declining) fisheries needs to be implemented, and in some cases trochus need to be aggregated to kick-start a return to productivity.

In order to develop a model to describe productivity from well-managed fisheries, SPC examined past harvests from trochus fisheries in Cook Islands, Palau and Wallis and Futuna. By surveying the fishery and examining past harvest records, preliminary calculations suggest that fishers should fish in three- to four-year rotations and harvest 180 shells ha^{-1} year^{-1}.

SPC has very few recent country data on exports of MOP. Green snails are found throughout the western Pacific, with some introductions to the east (e.g. Tonga). The species has been heavily exploited in almost all the countries where it exists, and stock levels have declined to very low levels. Some countries have taken firm action to allow stocks to rebuild; for example, Vanuatu has declared a moratorium on the harvest, sale and export of green snail.

Sea cucumbers (beche-de-mer)

The beche-de-mer trade in the Pacific is the oldest commercial fishery still active today, and has been valued at over USD 50 million during peak production years. Sea cucumbers are not used as local food in most islands but are exported to Asian markets (mainly China, Hong Kong and Singapore), and are second in value only to the significantly larger tuna trade.

The sale of beche-de-mer is an important source of income for many coastal communities, but years of continued intensive fishing, rising market demand and lack of effective management by authorities have resulted in depletion of beche-de-mer resources across the Pacific.

Of the 60 commercial sea cucumber species exploited worldwide, 35 species are present in the Pacific Islands region. Diversity is highest in the western Pacific (FSM, Palau and Tonga) and decreases to the east (Fig. 9). Thick-walled varieties — such as the white teatfish (*Holothuria fuscogilva*), black teatfish (*H. whitmaei*), and stonefish (*Actinopyga miliaris*) — tend to grow more slowly, are present at lower densities than the soft bodied, fast growing species, are reef dwellers, and can be found down to depths of 30 m (white teatfish somewhat deeper). Sea cucumbers spawn throughout the year, with peak activity in the warmer months.

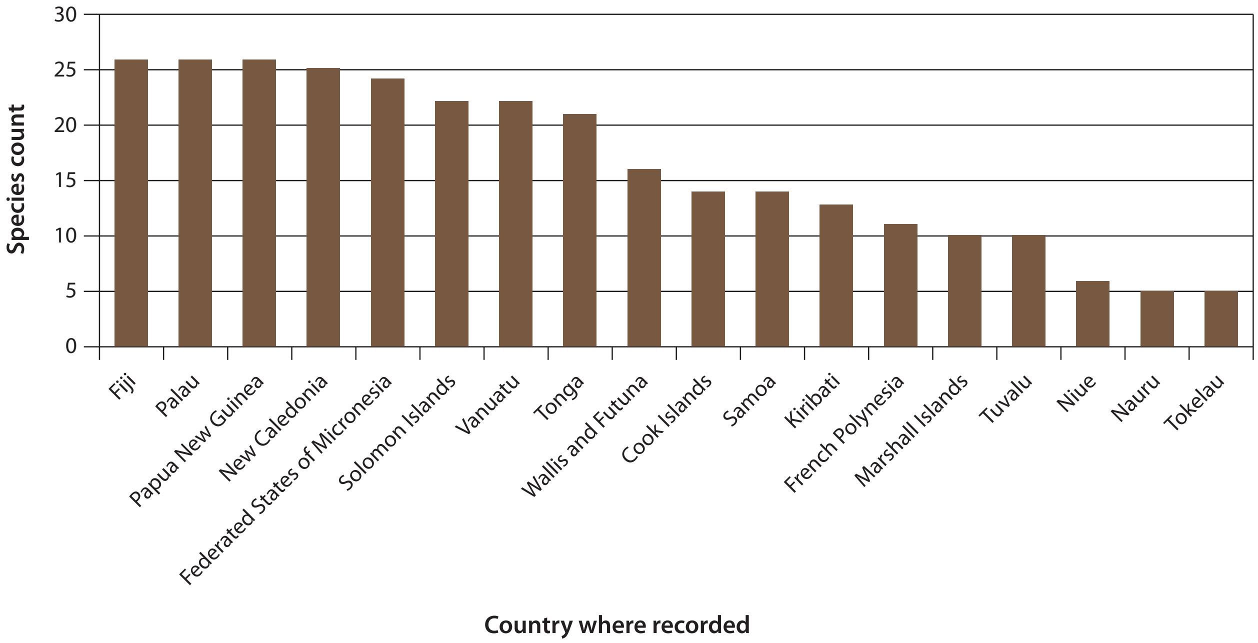

Figure 9. Commercial sea cucumber species recorded in PICTs.

Sea cucumber fisheries most typically follow a boom and bust pattern of exploitation. They are harvested traditionally by gleaning and snorkelling in shallower waters. Commercialisation of the fishery has induced fishers, processors and exporters to 1) invest in power boats; 2) use some kind of underwater breathing apparatus (scuba and hookah) diving gear; use drag nets and 'bombs' (lines with lead weights and hooks); or do spear fishing and night fishing using a torch (flashlight). Underwater breathing apparatus fishing has been the main cause of overfishing of white teatfish and has been outlawed in most PICTs. However, illegal fishing is known to be a problem in several places.

Fishing and processing varies from simple household or individual fisher operations to large-scale operators using transport ships and electric driers. Sea cucumbers are salted, boiled and dried several times to produce the final product, which is consolidated in-country by specialist beche-de-mer traders for export. Quality has been a long-standing problem, contributing to a 20–30% loss of product value. Monitoring and control systems and training are needed to improve quality.

Prices vary greatly by product type and distance to market, among processors, and by the point on the product chain. Production was high in the 1980s, peaked in the 1990s, and has declined since then. Figure 10 shows the combined exports of beche-de-mer (expressed in tonnes, dried weight) for five countries included in an SPC study covering 1971–2012 (Carleton 2013). The numbered polynomial trendline reflects the broad changes in exports across the time series. In the broadest of terms, there was low-level exploitation of sea cucumbers throughout the 1970s, and steady growth of exploitation in the 1980s, reaching a peak in the early 1990s. Harvests subsequently declined, but a secondary, lower, peak was reached in 2003–2005. Concerns about widespread overfishing of stocks resulted in the subsequent closure of fisheries in PNG, Solomon Islands and Vanuatu (the Tongan fishery was closed from 1997). In recent years, with most fisheries subject to a moratorium, regional production is being provided by just Fiji and Tonga; stocks in both countries are thought to be over-exploited and reduced fishing pressure will be required in future years to allow for stock recovery.

Peak production is not a very good indication of production capacity and a 15-year average (Table 2) is more representative. The table presents an indication of the general scale of production across the last 15 years, a typical breakdown of species composition and prices typically paid by in-country traders for finished dried product (Carleton 2013).

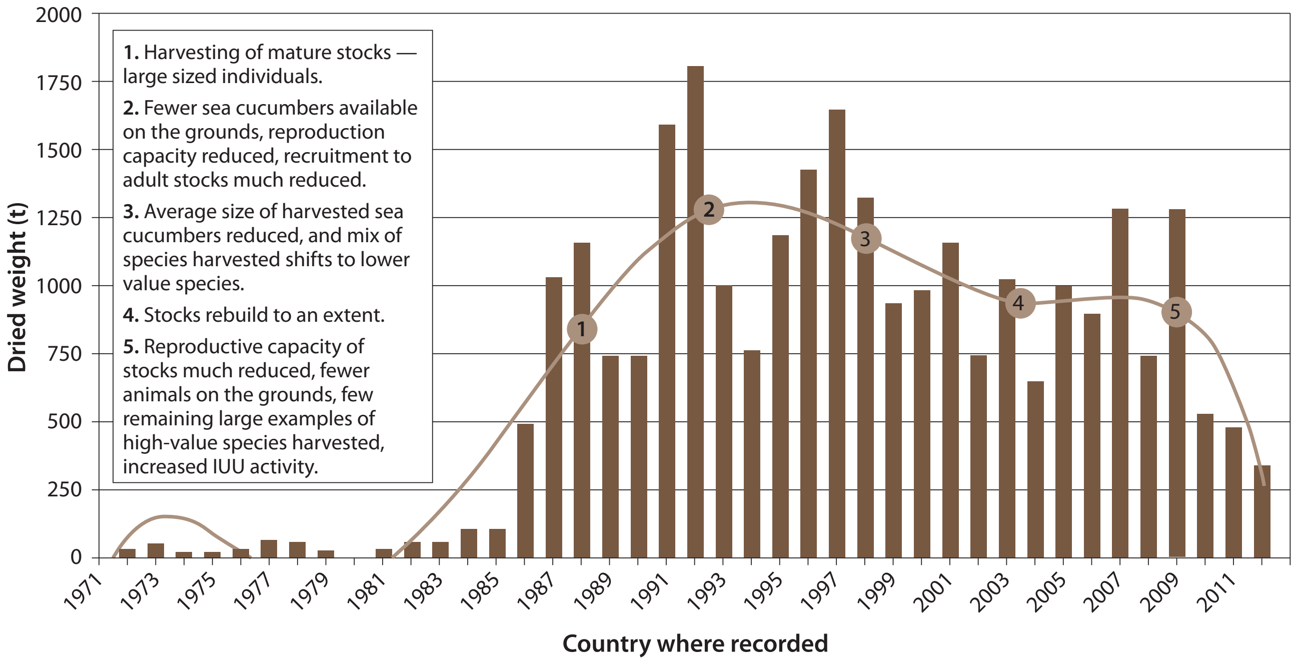

Figure 10. The combined exports of beche-de-mer (expressed in t, dried weight) for the five countries under study (Fiji, PNG, Solomon Islands, Tonga and Vanuatu) over the period 1971–2012 (from Carlton 2013).

Table 2. A 15-year average of beche-de-mer exports per country, by species, 1998–2012 (expressed in tonnes of dried product), plus estimated current purchase value (from Carleton 2013).
PNG = Papua New Guinea; SOL = Solomon Islands; VAN = Vanuatu; FIJI = Fiji; TON = Tonga.

	15 year average exports – t dried					Value at current purchase prices – USDM				
	PNG	SOL	VAN	FIJ	TON	PNG	SOL	VAN	FIJ	TON
Sandfish	75	1	1	-	0	3.59	0.03	0.03	0.00	0.01
White teatfish	96	30	1	22	4	4.31	1.37	0.06	0.98	0.17
Golden sandfish	-	-	-	-	-	0.00	0.00	0.00	0.00	0.00
Black teatfish	11	5	1	8	2	0.27	0.11	0.02	0.20	0.04
Greenfish	10	0	1	5	1	0.24	0.01	0.02	0.13	0.02
Prickly redfish	23	0	0	6	1	0.48	0.01	0.00	0.13	0.02
Deepwater blackfish	-	1	0	-	-	0.00	0.01	0.00	0.00	0.00
Deepwater redfish	0	3	0	3	0	0.00	0.07	0.00	0.06	0.00
Surf redfish	23	-	3	6	6	0.41	0.00	0.05	0.10	0.10
Blackfish	8	4	0	10	1	0.07	0.03	0.00	0.10	0.01
Curryfish	36	4	-	14	1	0.34	0.03	0.00	0.13	0.01
Stonefish	-	4	-	5	3	0.00	0.04	0.00	0.05	0.03
Tigerfish	34	5	1	25	5	0.32	0.05	0.00	0.23	0.05
Snakefish	10	9	1	44	10	0.07	0.06	0.01	0.32	0.07
Peanutfish	-	5	-	-	0	0.00	0.03	0.00	0.00	0.00
Chalkfish	21	8	-	14	2	0.13	0.05	0.00	0.09	0.01
Flowerfish	2	-	0	0	0	0.01	0.00	0.00	0.00	0.00
Brown sandfish	36	23	4	19	4	0.24	0.15	0.02	0.13	0.03
Amberfish	22	6	0	16	2	0.15	0.04	0.00	0.11	0.01
Lollyfish	32	45	4	66	10	0.17	0.24	0.02	0.34	0.05
Elephant trunkfish	21	7	0	8	2	0.11	0.04	0.00	0.04	0.01
Pinkfish	8	5	0	3	0	0.02	0.01	0.00	0.01	0.00
Total	**467**	**164**	**18**	**274**	**54**	**10.94**	**2.38**	**0.26**	**3.15**	**0.66**
Average unit value of exports — USD kg^{-1} dried						23.00	15.00	14.00	12.00	12.00

Prolonged fishing in areas in the absence of any form of management has resulted in both low abundance and loss of mature adult stocks and reproductive potential. Some countries have taken the bold move to close their fisheries but these 'moratoria' (or resting periods) must be long enough to ensure full recovery. Many countries lack strong fishery management policies.

SPC is currently assisting countries with their national sea cucumber policies. Measures include moratoria, restricted fishing seasons, minimum harvest sizes, size limits and gear restrictions. In addition, ensuring the right of local citizens to participate in the industry, providing avenues for value adding and price improvements, and options for providing resource rent to countries is being addressed. Successful management policies depend on strong enforcement, but this is typically under-resourced in most countries compared with offshore fisheries.

Other invertebrates

There are very few catch statistics on other invertebrates, such as lobsters, crabs, and octopuses, although they may be important in subsistence fisheries and local markets.

Lobsters are often caught by hand or by free diving at night with underwater lights, and are sold at local markets. Many large-scale operations to catch lobsters in the Pacific have failed because the main species are generally present in low abundance and, except for the Hawaiian spiny lobster, do not enter traps or pots readily. Management measures include minimum size limits on various species, bans on taking egg-bearing females, and bans on using underwater breathing apparatus.

Several species of crabs are caught and sold at local markets, with the mangrove crab being the most valuable. Mangrove crabs are caught by hand, sometimes with the aid of a hooked stick to remove crabs from their burrows, and by spears, nets, dillies and baited traps. Measures applicable to all fishing for mangrove crabs include the application of minimum size limits (often between 120 mm and 150 mm shell width), bans on taking female crabs, bans on taking berried female crabs, and bans on using certain fishing methods such as gill nets and spears. Traps are one of the best ways to catch mangrove crabs as they do not damage the trapped crabs, which can be released if they are females or are undersized.

Octopuses are fished locally throughout the Pacific using a variety of fishing methods, including lures, baited lines, traps and spears, and by hand. Some fishing methods result in considerable destruction of corals as the octopuses are removed from their nests. It appears that no fisheries management regulations have been applied to octopuses, even though their numbers have decreased on many reefs.

The sea hare, *Dollabella auricularia*, is harvested and sold at local market; its mature egg masses and flesh are eaten raw or cooked. A wide range of sea urchins are used, and the collector urchin *Tripneustes gratilla* is a common species. In Fiji, *T. gratilla* can reach densities of 33,750 individuals ha^{-1}, or 3.4 individuals m^{-2} at main fishing locations.

Image: Colette Wabnitz

Status of live reef export fisheries

Live reef food fish trade

The demand for live reef fish for restaurants in Hong Kong and southern China resulted in large exports from PICTs during the late 1990s, but this trade has dwindled, although the trade still operates at a low scale from a few countries.

The species targeted cause particular management concerns because their stocks are relatively fragile. The most sought-after fish are found in two families: 1) serranids (groupers): *Plectropomus areolatus*, *P. leopardus*, *Cromileptes altivelis*, *Epinephelus fuscoguttatus*, *E. polyphekadion*, *E. lanceolatus*, *E. coioides*; and 2) labrids (wrasses): *Cheilinus undulatus* (this species, the humphead wrasse, is now listed as endangered on the International Union for Conservation of Nature Red List, as well as being listed since 2004 in Appendix II of Convention on Trade in Endangered Species of Wild Fauna and Flora [CITES]).

The decrease in the number of active exporting countries is a result of improved awareness of the public and fisheries departments of the consequences of the trade, especially in trying to meet the buyers' minimum required quantities, which may be up to 30 t of fish per shipment.

Some initiatives are planned for grouper aquaculture in some countries with the goal of exporting plate-sized animals to supply the live reef food fish industry in Southeast Asia, based on local stocks or imported broodstock. However, economic assessments are required to determine if such initiatives will provide long-term socioeconomic benefits and be viable after initial project support is no longer available. Moreover, the potential environmental consequences of supplying food for growing fish that are to be exported should be examined.

Live reef ornamentals for the aquarium trade

This section covers the live marine ornamentals trade only; the curio trade (e.g. dead corals) represents an important trade segment for some countries in the region, but is not covered in this report.

Exports of aquarium fish and invertebrates (including corals) from PICTs started in the 1970s, and has since expanded to become an important source of income and employment for a number of communities in the region. For example, in Fiji, the trade employs around 600 people (Teitelbaum et al. 2010) and Fijian communities that derive a livelihood from the aquarium trade tend to have a higher median income from this harvest when compared with traditional fishery products (Lovell and McLardy 2008; Wabnitz et al. 2003). In Tonga, the trade was ranked as the country's second highest income earner in 2008.

At the time of writing this report, the aquarium trade operates out of 12 countries: Cook Islands, Fiji, French Polynesia, FSM, Kiribati, Marshall Islands, New Caledonia, Palau, PNG, Solomon Islands, Tonga and Vanuatu. Commodities include coral reef fish, hard and soft corals, giant clams, live rock and a number of small reef invertebrates (e.g. sea stars, crabs, shrimp).

Analysis of CITES data for corals, coral rock and giant clams

CITES provides a means to both monitor and regulate the trade in listed species. In the case of marine ornamentals and coral rock, more than 2000 species of hard corals and all species of giant clams are listed under Appendix II of CITES. Parties to CITES, which include Fiji (1997), Vanuatu (1989), Palau (2004), PNG (1975), Samoa (2004), Solomon Islands (2007), all overseas territories, and the main importers of marine ornamentals (i.e. US and European Union [EU] member countries) are required to submit trade figures annually in accordance with CITES guidelines (CITES 2011). Analysis of importers' data from the CITES Trade Database (managed by the United Nations Environment Programme World Conservation Monitoring Centre) provides an understanding of patterns in the trade of corals, coral rock and giant clams.

Live coral recorded in pieces

Live corals in the trade are typically transported in water. They vary in size and are identifiable to the level of species or genus (CITES 2008). Trade reports submitted by importers from 1990–2010 indicate that live coral exports from the Pacific Islands region peaked in 2006 and have declined since then (Fig. 11).

The post-2006 decline may be linked in part to the economic downturn, in which people spend less on goods not considered essential, and to the increasing contribution of corals in trade within importing nations (i.e. hobbyists sourcing corals from among their peers through so called 'fragging' or from local facilities successfully culturing corals). This latter point seems to be underlined by the dramatic and significant decline in corals in the family Acroporidae, which are some of the easiest to culture (Fig. 12).

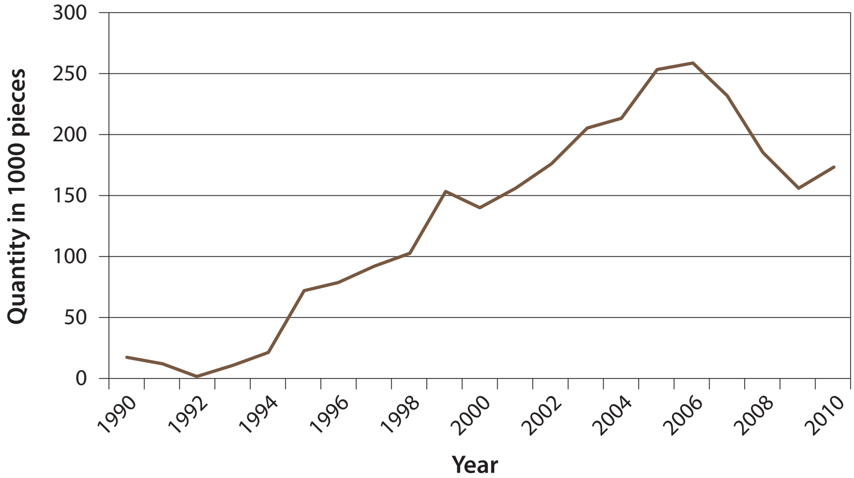

Figure 11. Direct trade from the Pacific region between 1990 and 2010 in live pieces of coral.

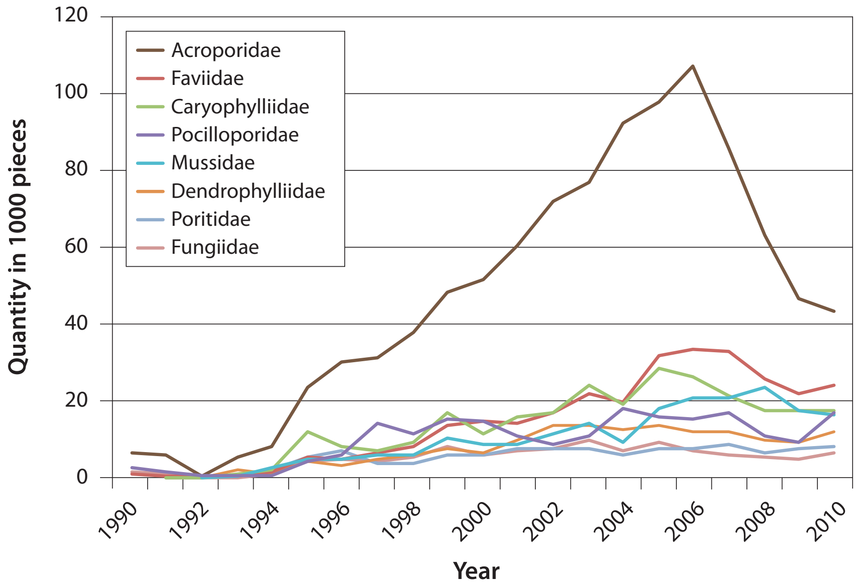

Figure 12. Trend in main coral families traded as live pieces for the marine ornamental trade.

Twenty genera, out of a total of 92, made up 86% of the trade from the region, with *Acropora* accounting for 30% of total trade in live coral. The largest exporters were Fiji (capturing 52% of the trade over the years analysed), the Solomon Islands (23%) and Tonga (22%). The US was the leading importer (83% of all trade records) followed by the United Kingdom, Singapore and Germany.

Most of the trade focused on specimens collected from the wild, with cultured corals amounting to a maximum of 6% of traded specimens in 2009 and 2010. Most cultured specimens were exported from FSM and the Marshall Islands. The most commonly cultured corals were species of the genus *Acropora*, followed by *Euphyllia*, *Montipora* and *Goniopora*. Aquaculture is likely to continue contributing to the marine ornamental trade providing a sustainable income for local communities and a sustainable source of corals for aquarists. However, a large number of species will be sourced from the wild for years to come as they do not lend themselves to culture, generally due to slow growth and poor survival.

Coral rock traded as *Scleractinia* by weight

According to its CITES definition, coral rock is hard consolidated material greater than 3 cm in diameter, formed of dead coral fragments and other sedimentary rocks, and that is characteristically covered in coralline algae (CITES 2008). Hobbyists purchase coral rock to use as architectural features and for its properties as biological filter and water chemistry stabiliser. Trade in coral rock (also commonly traded as live rock and substrate), peaked in 2005 at 2180 t, dipping to 863 t in 2010 (Fig. 13). Fiji and Tonga exported the majority of coral rock from the region (75% and 18%, respectively). The Marshall Islands stopped exporting coral rock in 2007, with Tonga stopping exports in 2008. The US was by far the leading importer of coral rock from the region, accounting for 93% (by weight) of the market during 1990–2010.

The proportion of coral rock that is maricultured has increased from a very low level in 2007, to 8% in 2008, 18% in 2009, and 23% in 2010. This is an encouraging trend because the large-scale removal of live rock impacts the reef framework with potential detrimental long-term consequences, including increased erosion and reduced productivity and biodiversity (Why and Tuwai 2005).

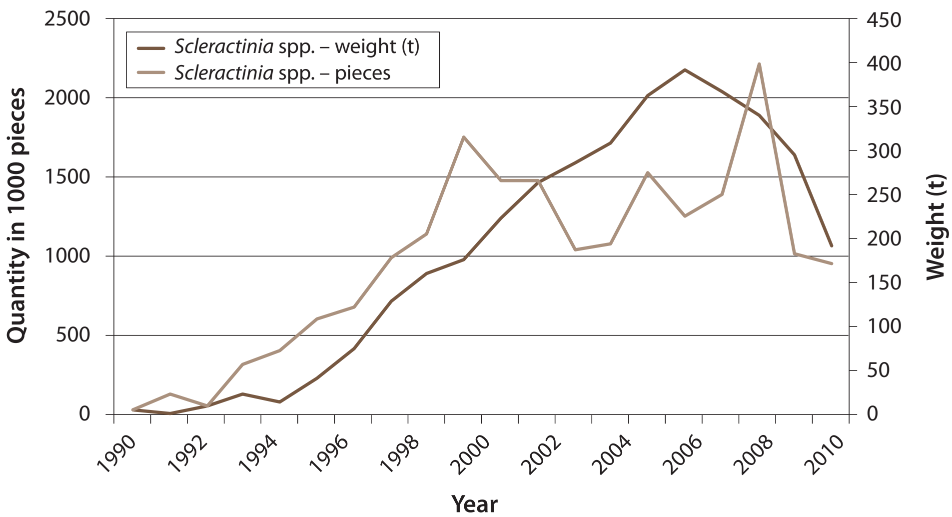

Figure 13. Direct trade in coral rock (*Scleractinia* spp.) by weight and number of pieces between 1990 and 2010.

Coral rock recorded as *Scleractinia* by pieces

Coral rock, used as substrate of soft corals for example, and other non-CITES listed organisms are typically recorded by number and as *Scleractinia* spp. (CITES 2008). Based on data from importers, the number of specimens traded peaked in 2007. As noted above, the US was the leading importer, accounting for 90% of all trade from the region; Fiji (56%), Tonga (25%) and the Solomon Islands (12%) dominated exports of coral rock pieces. The post-2007 decline may be caused in part by an increase in the use of artificial substrata.

Giant clams

Based on importers' data, the number of giant clams traded peaked in 2000, with trade stabilising at around 60,000 specimens thereafter, and registering a significant increase in 2010 (Fig. 14). Contributions from individual PICTs have fluctuated over time but overall, the FSM, Marshall Islands, Solomon Islands, Tonga and Vanuatu (all combined) contributed 83% of all giant clams to the marine live ornamental trade between 1990 and 2010.

The United States (US) was the leading importer (68%) of giant clams from the Pacific Islands region followed by Germany, France and the United Kingdom.

A particularly interesting trend is the decline, starting in 2000, in the collection of wild specimens for marine ornamental purposes and a significant increase in the contribution of cultured clams to the trade, with a sharp rise observed in 2010 (Fig. 15). Fiji, FSM, Marshall Islands, Palau, Solomon Islands, Tonga and Vanuatu (all combined) accounted for 97% of wild exports; while Cook Islands, Fiji, FSM, Marshall Islands, Solomon Islands, Tonga and Vanuatu (all combined) accounted for 94% of cultured clams traded. Aquaculture provides a means to more specifically regulate the supply, and is more sustainable, with a reduced impact on reef environments; this can also be important from a marketing standpoint.

The number of *Tridacna crocea* exported has declined over the last two decades, with a concomitant increase in *T. derasa* and *T. maxima* (Fig. 16). The overall proportions of individual species contributing to total numbers of wild and cultured clams is similar for the two most-traded species: ~40% for *T. maxima* and ~25% for *T. derasa*, while *T. crocea* averaged 20% for wild collection compared with 11% from captive rearing environments. The latter may be due to *T. crocea* being less attractive as a farmed species, despite being in high demand in the aquarium trade, because it is the hardest to breed in captivity and generally has slow growth and low survival (e.g. Mies et al. 2012).

Marine ornamental fish

There is no centralised mechanism to record and monitor the trade in marine ornamental fish, precluding a regional analysis. However, in collaboration with local fisheries departments, SPC has been developing a database system that allows fisheries departments to monitor exports from licensed companies. The database can be customised to meet a country's needs, but at a minimum includes species, quantities traded, date of export, origin and destination. The system is currently being used and/or tested in three countries, and is slated to be trialled in at least three more, with a view to eventually being implemented across the region. The system could also help track and monitor trade in invertebrate species other than coral and giant clams (e.g. echinoderms, crustaceans), which constitutes a small but diverse fishery.

General considerations relating to the aquarium trade

Climate change and other anthropogenic impacts are threatening reef habitats, the species they support and the people that rely on them for their livelihoods. In this context, participants at all levels of the trade in marine ornamentals, including exporting countries, have a responsibility to ensure the

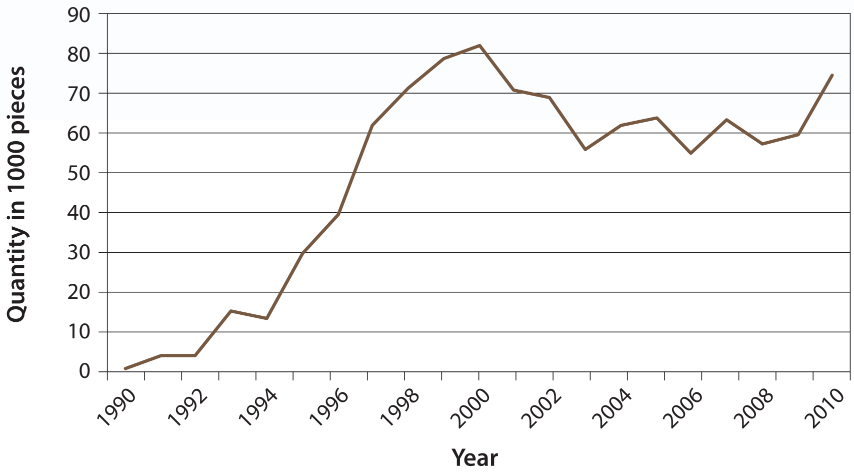

Figure 14. Number of giant clams in trade from PICTs between 1990 and 2010.

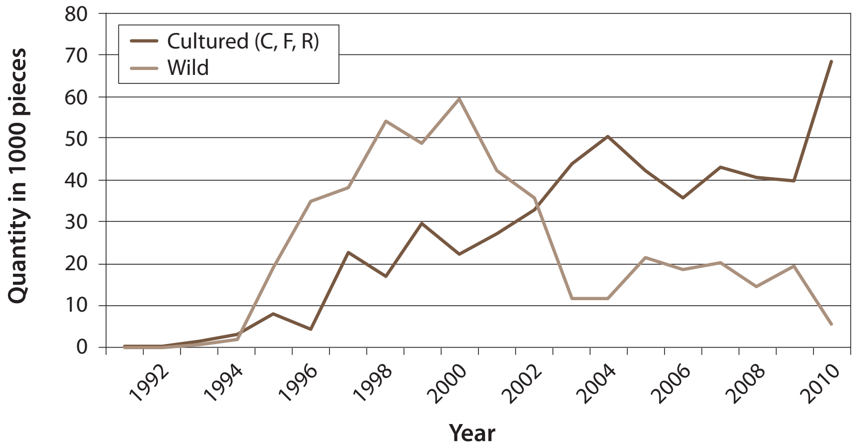

Figure 15. Direct trade in cultured — understood to include all specimens as cultured (C), farmed (F) or reared (R) under CITES — and wild giant clam individuals from PICTs from 1990 to 2010.

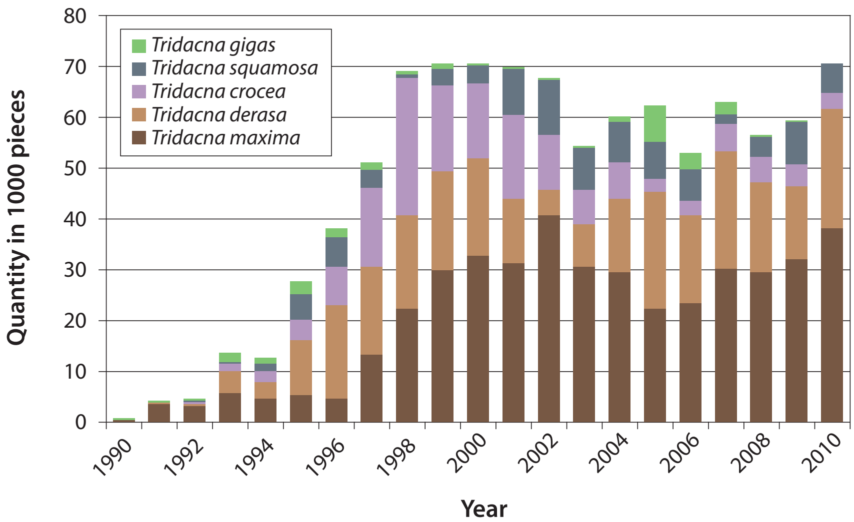

Figure 16. Number of individual species of giant clams exported as live marine ornamentals (1990–2010).

trade is sustainable in the long term, and to clearly demonstrate this. Key requirements include regular collection of trade data, monitoring of the abundance of target species abundance and reef health, and development and enforcement of management plans. Cook Islands, Federated States of Micronesia (Kosrae), French Polynesia, Kiribati, Marshall Islands, PNG, Solomon Islands, Tonga and Vanuatu have, or are in the process of developing, management plans and/or trade-specific legislation.

The database developments mentioned above, together with existing management plans and regulations to guide and provide control measures for these fisheries represent significant steps taken by national governments to attempt to effectively monitor and regulate the trade, as well as sustainably develop this fishery. They also illustrate the region's willingness and desire to respond to international calls for greater transparency in the trade (Rhyne et al. 2012). Such actions need to be extended and local capacity strengthened.

However, a significant number of inconsistencies in reporting and regular seizures of shipments as revealed by the analysis of CITES importers' data highlight the need for all exporting PICTs actively involved in the trade to further strengthen capacity in CITES requirements, nomenclature, species identification and enforcement of existing management rules.

As aquarists grow more conscious of the potential environmental impacts of the trade on resources, an increasing number of hobbyists are seeking to use aquacultured products. This trend may encourage production within importing countries, potentially threatening the small communities that have historically supplied the trade. This risk is all the more tangible with increasing fuel prices and consequently freight rates worldwide. Incentives should, therefore, be placed on continuing to implement measures that promote the sustainable collection of wild species; and promote socioeconomically viable mariculture initiatives at the community scale where aquaculture alternatives exist. This would also ensure that aquarium fisheries align with the Convention on Biological Diversity (Secretariat of the Convention on Biological Diversity 2005).

When operating according to best practices (e.g. respecting diving rules, collecting specimens of proper size, focusing on species that are known to do well in aquaria, spreading fishing effort over a vast area, and maintaining species adequately prior to shipping and packing them appropriately) the trade can have a minimal impact on reef fish populations and the surrounding environment, and has the potential to provide a sustainable livelihood for communities with few other income opportunities. Although global efforts to eco-label aquarium fishery products, including from the Pacific Islands region, have failed, SPC has been working on a set of core standard best practices that can be effectively and efficiently applied at the local scale. The guidelines seek to achieve the following goals: 1) the promotion of sustainable fishery practices, 2) the fostering of good fishing and handling practices prior to export, and 3) the promotion of good packing practices at export. These best practices are currently being assembled and will be distributed regionally to promote their implementation. In addition, to encourage the adoption of best practices by the industry, SPC has been and will continue to work closely with governments and the private sector to build capacity locally and train collectors in proper catching, handling, storing and shipping techniques.

As is true of all traded goods, marine ornamental prices are largely subject to supply and demand interactions. Prices obtained for a given commodity (e.g. flame angelfish, giant clam) are generally dictated by 'perceived' abundance in the market place, rather than actual supply. In other words, maintaining the relative scarcity of a commodity will increase the likelihood that its price remains high/stable, that revenues generated can cover costs, and that those involved in the trade derive a good livelihood from it. With a number of countries indicating an interest to enter the trade and/or the number of applicants for aquarium fisheries licenses in existing countries on the increase, it is therefore necessary to consider the potential impact that new entrants to the trade may have on supply and thus price. Should specific commodities become or be perceived as abundant, prices will fall, curtailing revenue for those employed by the trade. This in turn may lead to fishers collecting more fish to cover costs (or more specifically, overheads), and/or diving longer and/or at greater depths to maximise revenue, endangering health and lives. In summary, the number of licenses (or operators) in a country or region must be controlled, with a sufficient number of licenses issued to ensure that the economic benefits of the trade are suitably widespread, while ensuring incumbent operators can remain profitable in an already competitive market.

Climate change: Vulnerability of bottom-dwelling fish and invertebrates

Shallow-water, bottom-dwelling fish and invertebrate species, which are estimated to comprise ~70% of the coastal fisheries catch for all PICTs combined, are expected to be vulnerable to both the direct and indirect effects of climate change (Pratchett et al. 2011). The direct effects will be due to changes in atmospheric conditions (Table 2.6 in Lough et al. 2011), sea surface temperature, ocean acidification, ocean currents, nutrient supply and sea level (Table 3.2 in Ganachaud et al. 2011). The indirect effects will occur through changes to the habitats that support coastal fish and invertebrates — coral reefs, seagrasses, mangroves and intertidal flats (Table 5.3 in Hoegh-Guldberg et al. 2011, Table 6.5 in Waycott et al. 2011).

Coastal fish and invertebrate species are likely to be sensitive to changes in sea surface temperature because temperature regulates their metabolism and development, and influences their activity and distribution. In particular, when the optimum temperature threshold of a species is exceeded, increased metabolic rate and oxygen demand may interfere with reproduction, recruitment and growth. The projected decreases in aragonite (calcium carbonate) saturation levels resulting from ocean acidification are expected to affect the ability of molluscs to construct their shells. The main potential impact of ocean acidification is expected to be greater predation on molluscs with thinner shells. However, the sensory ability of larval and postlarval fish can also be impaired by the reduced pH of sea water. This can reduce the ability of fish larvae to navigate to reefs, distinguish beneficial settlement sites and detect and avoid predators, resulting in lower rates of recruitment. Changes in ocean currents can also affect the dispersal of larvae and their ability to find suitable settlement habitats. Variation in the supply of nutrients required to support the food webs of coastal ecosystems due to altered currents can also be expected to affect the replenishment potential of coastal fish and invertebrate species. Rises in sea level are likely to have few significant effects, except on those invertebrate species that depend on intertidal soft substrata.

The projected alterations to habitats are expected to have the greatest effects on coastal fish and invertebrates, which are likely to be highly sensitive to changes in the quality of the food and shelter they obtain from coral reefs, seagrasses, mangroves and intertidal flats. The potential impacts include reduced diversity and abundance of fish and invertebrates as their food resources decline, and increased rates of mortality due to greater predation as structurally complex habitat is lost. Specialist fish species that depend directly on live coral for food and shelter are likely to experience greater impacts than generalist species, such as the carnivorous snappers (Lutjanidae) and emperors (Lethrinidae), which already use a range of habitats. The proportions of herbivorous parrotfish (Scaridae), surgeonfish (Acanthuridae), and rabbitfish (Siganidae) are expected to increase as the percentage cover of live corals declines and the cover of macroalgae increases.

Future catches of bottom-dwelling fish and invertebrates

The vulnerability of bottom-dwelling fish to the combined direct and indirect effects of climate change by 2035 is expected to be low, and any such effects will be difficult to separate from those due to fishing pressure and habitat loss due to local stressors. However, the vulnerability of bottom-dwelling fish is expected to increase to moderate by 2050 and to high by 2100. Overall, the production of these fish is estimated to decrease by < 5% by 2035, 20% by 2050 and by 20–50% by 2100 (Pratchett et al. 2011). Invertebrates are estimated to have little or low vulnerability to climate change by 2035, increasing to low to moderate by 2050 and moderate to high by 2100. Decreases in productivity of the invertebrates are expected to be 5–10% by 2050 and 10–20% by 2100.

Image: Lindsay Chapman

3. Nearshore fisheries

Nearshore fisheries include those based on organisms in the water-column or on the ocean floor outside lagoons and outer reefs, within territorial waters and exclusive economic zones. These are usually pelagic fisheries (fishing from 0–500 m depth), with tunas being the major component of the catch. They also include deep-bottom, deep-slope and offshore seamount fisheries (such as deepwater snapper, deepwater crabs and shrimp) caught in depths of 100–1000 m. These fisheries are usually fully commercial and carried out by Pacific Island companies, professional fishers, or tourist gamefishing operations, but also include artisanal and subsistence nearshore fisheries, particularly around atolls.

Major components of the nearshore fishery catch are highly-migratory tuna stocks, which are also fished by comparatively well-observed and reported industrial fleets. Consequently, knowledge of the status of regional tuna stocks that nearshore fisheries rely upon is comparatively good. There is also some information on the status of other pelagic species such as marlin, shark and leatherback turtle. However, little is known about just how much tunas and other nearshore pelagic fish are caught by non-commercial Pacific Island fishers, and in many countries deepwater snapper landings and effort are not consistently recorded.

Status of nearshore tuna fisheries

Tuna fisheries are a major contributor to revenue and national economic development and still have considerable potential for further development, primarily as an expansion of the Pacific Island share of the catching and processing sectors, rather than through expansion of the total catch.

The composition of the total Pacific Ocean catch is: skipjack (*Katsuwonus pelamis*) 63%, yellowfin (*Thunnus albacares*) 24%, bigeye (*Thunnus obesus*) 8%, and albacore (*Thunnus alalunga*) 5%. The status of the four main tuna stocks in the western and central Pacific Ocean is regularly assessed by SPC's Oceanic Fisheries Programme, and the reports can be found at (http://www.spc.int/oceanfish/Html/SAM/StockAss.htm). In addition, the Pacific Islands Forum Fisheries Agency (FFA) produces reports on the economic status of industrial tuna fisheries, and these can be found at (http://www.ffa.int/node/862). This information includes the wider deliberations of the Western and Central Pacific Fisheries Commission (WCPFC), the regional fisheries management organisation that addresses tunas and other highly migratory fish stocks in the western and central Pacific Ocean.

Tunas are highly migratory species, and are found throughout the EEZs of PICTs. Some tuna fishing activities — the industrial purse-seine fishery, and to a certain extent the longline fishery (larger vessels from distant water fishing nations) — fall outside the scope of this coastal fisheries report. However, tunas are also targeted by domestic longline vessels and smaller boats that target tunas by fishing in association with fish aggregating devices (FADs), trolling close to reefs, and trolling for tuna schools that occur within 10 nautical miles of reefs. Trolling and mid-water handlining from small-scale vessels is covered in more detail in the following section (Status of Other Nearshore Pelagic Fisheries), because a mix of other nearshore pelagic species is also caught. The annual catches of tunas from within the EEZs of PICTs are shown in Figure 17.

Anchored fish aggregating devices (FADs) are an important component of small-scale tuna fishing operations, and most SPC island member countries have used them over the last 25 years. Industrial tuna fishing companies in PNG and Solomons Islands have ongoing FAD programmes for their fleets, and also allow small-scale fishers to use them. To further utilise the FADs in PNG, pumpboats from the Philippines are used to handline for tunas around the FADs. Tuna catch rates (kg hr^{-1}) from trolling around FADs are often three times the catch rates of tunas taken when chasing tunas and trolling in open water and around reefs. The types of FADs are shown in Figure 18.

The troll-and-pole fishery from South Tarawa in Kiribati is a significant small-scale tuna fishery that historically did not use FADs; about 200 outboard-powered skiffs fish for tunas on a daily basis (weather permitting). However, FADs are starting to be used in this fishery, which catches over 1500 t annually for local sale. Many countries, especially in Polynesia, rely on tunas caught from small outboard-powered boats and canoes to supplement their overall fish consumption needs.

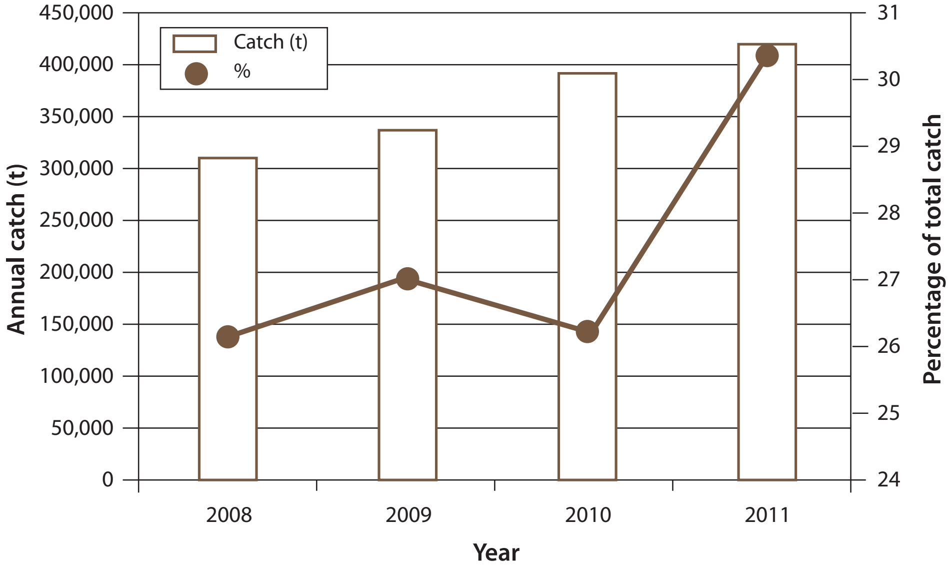

Figure 17. Tuna annual catches (t) — shown as a histogram — from within the EEZs of PICTs. The percentage of the total tuna catch is shown as a line (from SPC, Oceanic Fisheries Programme database).

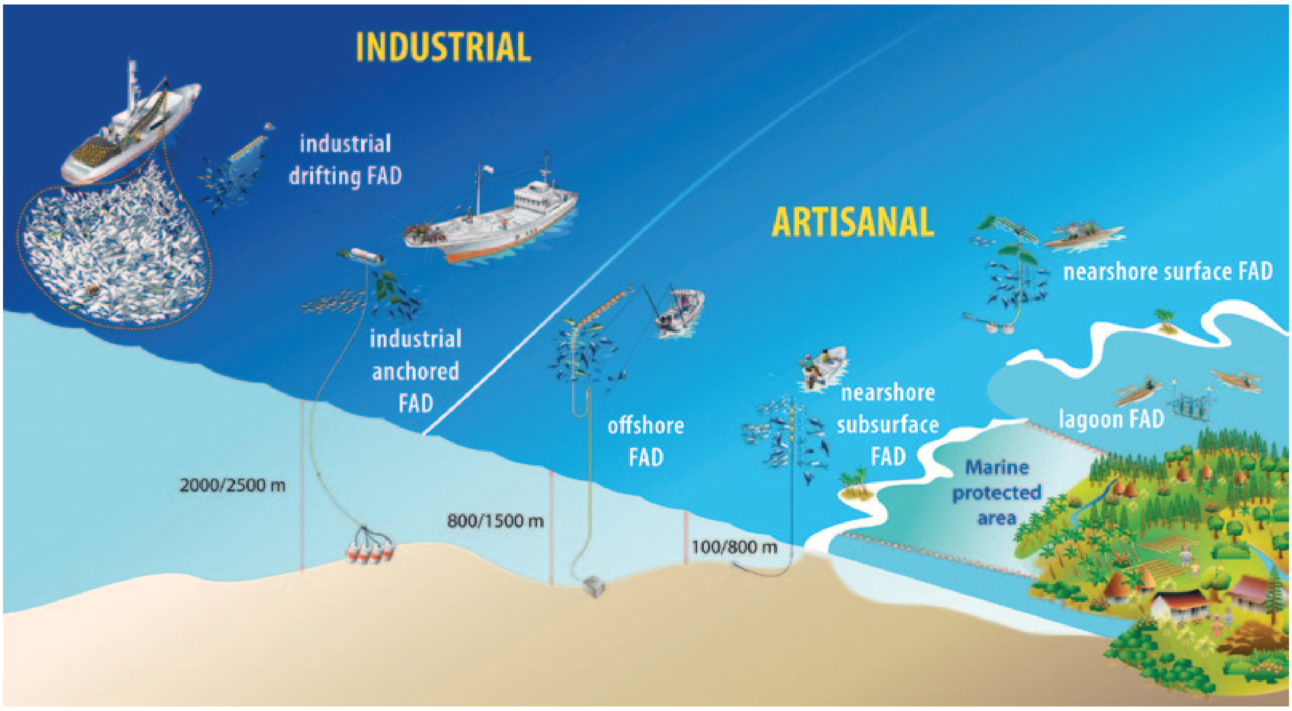

Figure 18. FAD types, users, location and typical depths in the Pacific.

Status of other nearshore pelagic fisheries

The nearshore fishery for pelagic fish other than tunas is primarily a surface troll fishery outside the reef and around FADs, where the target species are wahoo (*Acanthocybium solandri*), mahi mahi (*Coryphaena hippurus*), marlins (*Makaira* spp. and *Tetrapturus* spp.), sailfish (*Istiophorus platypterus*), barracudas (*Sphyraena* spp.) and rainbow runner (*Elagatis bipinnulata*). Spanish mackerel (*Scomberomorus commerson*) is targeted where it occurs (in the western Pacific).

Trolling is carried out in all PICTs with thousands of small outboard-powered dinghies and skiffs and some motorised outrigger canoes. Some of these vessels also use mid-water fishing techniques, such as vertical longlines, drop-stone and palu-ahi (mid-water handlining), both around FADs and in 'tuna holes'. Paddling and sailing outrigger canoes are also increasingly used for mid-water handlining, both around nearshore FADs and in tuna holes close to the reef. This fishery contributes significantly to food security in Nauru and some outer islands in Micronesia. The Cook Islands and French Polynesia each have over 300 small vessels and/or canoes that fish to meet both subsistence needs and livelihoods. Catches vary considerably from country to country, although data are poor in most PICTs, which have limited or no data collection systems in place. In some countries, the catch of non-tuna species is higher than that of tuna.

Nearshore pelagic species and the use of FADs are also important for the region's slowly expanding gamefishing operations. Most PICTs now have charter fishing operations that take paying passengers to fish for marlin, wahoo, mahi mahi and tunas. In many cases, data from gamefishing operations are available, but there is no information on the catches from the increasing number of recreational fishers that target these species.

Very little is known about the stocks of non-tuna pelagic fish, although WCPFC is targeting some of these species (such as some marlin species, and possibly wahoo) for future stock assessments. There are currently no management plans for these species.

There are a range of other fishing activities that target pelagic species in PICTs, using both traditional and new technologies. These include:

- Scoop-netting of flyingfish at night using light attraction is widely practiced in Polynesian countries and territories, with many small-scale vessels involved. In the Cook Islands and French Polynesia, boats have been specifically designed with forward-mounted steering to facilitate the chasing of flyingfish, and battery-powered spotlights are mounted on bike helmets to simplify spotting. Little is known about the number of flyingfish species being targeted, and the status of these stocks.
- Baitfishing for sardines, pilchards and anchovies, and many other species is practiced at night in lagoons and passageways using light attraction and a buki-ami net by commercial tuna pole-and-line vessels. The number of countries using this method has dwindled over the last 25 years.
- There is growing interest in fishing for squid in the region, and the main techniques used are squid jigs attached to droplines or jigging machines. Both techniques are practiced at night and use light attraction. Some trials have taken place in the past in different PICTs, and Palau had one vessel fishing for large diamond-back squid in the late 1990s. Little is known about the potential for squid fishing in the region or about the status of squid stocks.

  In August 2012, SPC and the New Caledonia Merchant Navy and Sea Fishery Department carried out exploratory fishing trials for diamond-back squid in waters off New Caledonia. This resource has been commercially exploited in Okinawa (Japan) since the late 1980s, with catches increasing from 15 t in 1989 to more than 2000 t today.

The aim of the fishing trials was to confirm the presence of commercially viable 'giant' squid stocks and to identify a possible alternative for nearshore commercial fishers in New Caledonia. The trials were carried out over eight fishing days, and involved setting 20 vertical drifting lines 500 m long, each fitted with four jigs, with the fishing undertaken in depths of 1500–2000 m. The results far exceeded SPC's expectations: 70 squid totalling 785 kg in weight (average weight 11.2 kg). Two species of commercially exploitable 'giant' squid occur in New Caledonia, and apparently in major quantities: the diamond-back squid (*Thysanoteuthis rhombus*), known as 'sei-icko' in Okinawa, where it is exported to the main islands of Japan to be consumed raw as sashimi or sushi (35 specimens caught, with an average weight of 18 kg); and the purple flying squid (*Ommastrephes bartramii*), which is smaller, with a lower commercial value (35 specimens caught, average weight 4.6 kg).

Although the price paid in Japan for diamond-back squid may be too low to make exports from the Pacific Islands to Japan feasible, this resource could be developed by targeting local markets and restaurants, as part of efforts to diversify coastal fishing. Contrary to most cephalopods, diamond-back squids are present in male/female pairs. This is a fragile resource that is likely to shrink rapidly if overfished. The development of a management plan for this resource would therefore be required before beginning commercial exploitation of diamond-back squid.

- Small pelagic fish — such as sardines, mackerels, scads and anchovies — are plentiful and a rich protein source, and remain relatively underexploited in the western and central Pacific Ocean. Diverting fishing effort from large predator fish, reef fish and invertebrates to more robust stocks, such as small pelagic fish, has the potential to rejuvenate overexploited marine resources while continuing to supply the Pacific's growing population with protein. Increasing fishing effort on small pelagic fish is deemed sustainable given the biological nature of these fish — they grow rapidly, have short life spans and high mortality rates (Dalzell 1990). As with any fishery, an increase in effort must be undertaken with caution and yields must be maintained within sustainable levels.

  As reported by Sokimi (2012), SPC, in conjunction with FFA and the Marshall Islands Marine Resource Authority, is researching the potential of adopting the Indonesian fishing technology in the Pacific, where fishing takes place from an anchored platform, called a *bagan*. Fish are attracted to the platform by bright overhead and/or underwater lights and when sufficient numbers of fish have aggregated underneath the *bagan*, a bag net is lifted and closed between the *bagan* hulls, entrapping the fish (Fig. 19).

  Insufficient data are currently available to estimate catch rates, but the catch from the initial fishing trials (albeit a small quantity) sold quickly for USD 1.50 lbs^{-1} (USD 3.30 kg^{-1}) on the local market, which indicates that demand for small pelagic fish exists in Majuro. If successful, this project will provide an alternative source of food and income from a sustainable fish resource that is not currently exploited in the Marshall Islands. It is planned that the fish will be consumed fresh and in value-added form (salted, dried, smoked) on the local market. A similar *bagan* fishing trial project was launched in March 2013, in collaboration with the National Fisheries College in Kavieng, Papua New Guinea. The Kavieng project is trialling a different type of fishing platform supported by large plastic drums.

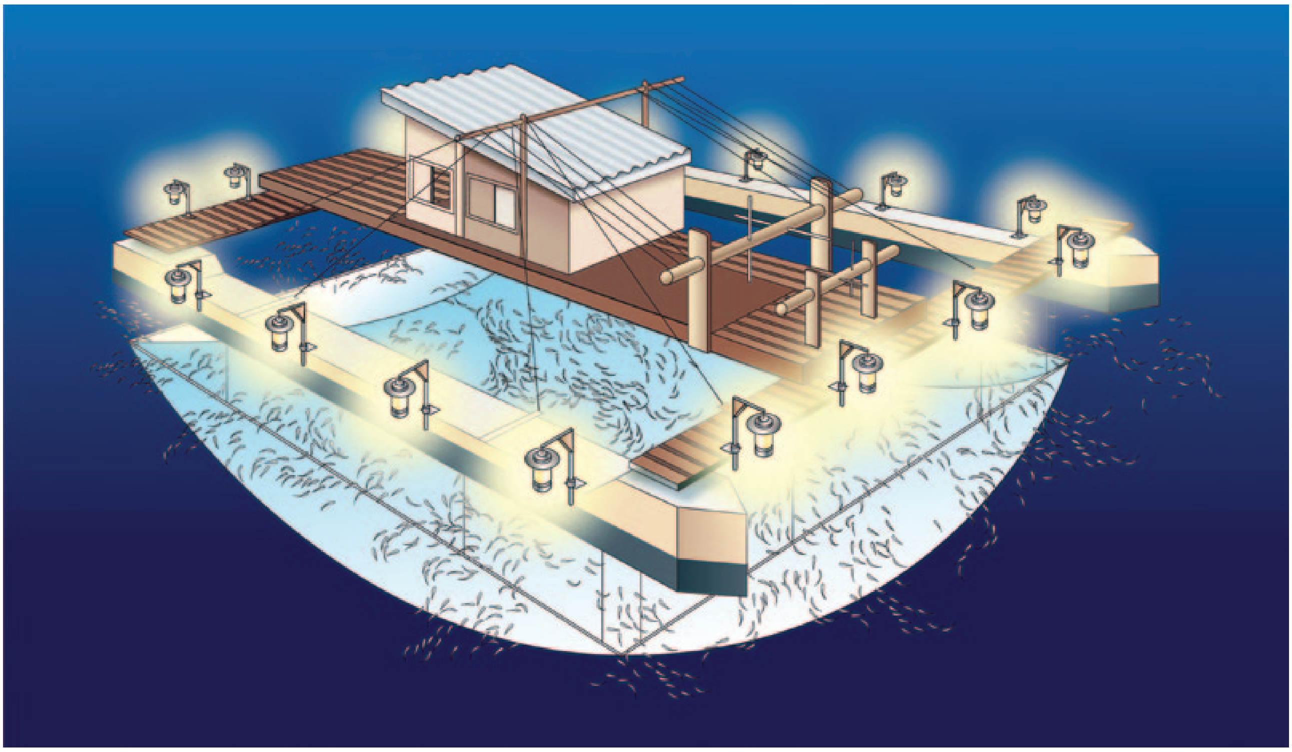

Figure 19. A typical *bagan*, a floating platform, that uses lights to aggregate fish and a lift net to capture them.

Climate change: Vulnerability of nearshore pelagic fisheries

Preliminary estimates of the effects of climate change on the future availability of nearshore pelagic fish, which are estimated to comprise ~30% of the coastal fisheries catch across the region, have been made based on 1) preliminary modelling for skipjack tuna (Lehodey et al. 2011), and 2) projections for zooplankton (Le Borgne et al. 2011) in the food webs of other (non-tuna) species (e.g. Spanish mackerel and small pelagic fish). There are large projected differences in tuna abundance between the western and eastern Pacific, and a greater projected decrease in zooplankton productivity in the western Pacific. When combined with the average proportions of tuna and non-tuna species in the catch, the result is a substantial difference in the projected abundance of nearshore pelagic fish in the two parts of the region (Table 9.8 in Pratchett et al. 2011). In the west, the overall catch is projected to decrease by 2100, whereas it is likely to increase in the east by 15–20% in 2035, and 10–20% in 2100.

Although the availability of nearshore pelagic fish in the western Pacific is expected to decline, countries in that part of the region should be able to substantially increase catches of tunas by nearshore pelagic fisheries in coming years because there should still be ample numbers of tunas for the coastal fishery (Lehodey et al. 2011). It is also possible that the increased runoff from major rivers may increase the productivity of phytoplankton and zooplankton in coastal areas within the archipelagic waters of PNG, improving the environmental conditions for tunas and other large and small pelagic fish (Bell et al. 2011).

Key messages from a recent SPC workshop included the projection that catches of skipjack tuna are expected to increase in the eastern Pacific due to climate change, whereas catches of bigeye tuna are likely to decline across the region.

Status of fisheries for deepwater snappers and other demersal species

The deepwater snapper fishery is based on fishing on outer reef slopes and on seamounts, in depths of 100–400 m. The main families being targeted are the deepwater lutjanids (primarily of the genera *Etelis* and *Pristipomoides*, but also *Aphareus* and *Paracaesio*), shallower water lutjanids (*Aprion* and *Lutjanus*), lethrinids (*Gymnocranius*, *Lethrinus* and *Wattsia*), and serranids (*Cephalopholis*, *Epinephelus*, *Saloptia* and *Variola*). A range of other species are also taken, including gempylids (*Ruvettus* and *Promethichthys*) and other bony fish.

Deepwater snapper fishing activities were promoted in the late 1970s and 1980s, with SPC conducting 50 projects in 19 of its member countries during this period. These activities were conducted to test the viability of catching deepwater snapper species using simple low-cost handreels, understand the species composition, and introduce local fishers to the fishing gear and fishing methods. A regional assessment in 1992 of the data that had been collected resulted in estimates of virgin biomass and estimated maximum sustainable yield for each country based on an annual harvest of 10–30% of the virgin biomass. Because the length of the 100 fathom (180 m) isobath was used in the calculation, PICTs such as Nauru, Pitcairn and Guam, with limited areas had a very small virgin biomass while those with a large area such as Fiji, French Polynesia and PNG had a much larger virgin biomass (Table 3). Since these preliminary maximum sustainable yield estimates, no further assessments have been attempted.

Table 3. Rough estimates of sustainable yield per annum for deepwater snapper fisheries.

Country/Territory	Yield range (t yr^{-1})
American Samoa	17–50
Palau	16–49
Cook Islands	41–124
Federated States of Micronesia	145–435
Fiji	409–1230
French Polynesia	343–1028
Guam	9
Kiribati	73–219
Marshall Islands	111–332
Nauru	0.25–0.75
New Caledonia	109–327
Niue	7–21
Commonwealth of the Northern Mariana Islands	99
Papua New Guinea	488–1464
Pitcairn	1.1–1.3
Solomon Islands	171–513
Tokelau	10–30
Tonga	113–338
Tuvalu	22–67
Vanuatu	98–294
Wallis and Futuna	10–30
Samoa	19–57
Total	**2313–6719**

Deepwater snapper stocks are considered vulnerable to fishing due to their high longevity, late maturity and slow growth. As such, the chance of localised stock depletion is likely to be high unless fishing effort is spread over a large portion of the available fishing area.

Development of the deepwater snapper fishery in PICTs has been sporadic, with fishing for these species being done on an ad hoc basis from small-scale vessels working close to their home port. Targeting of these species occurs in Guam (up to 20 small-scale vessels when weather permits), New Caledonia (8–10 full-time vessels), Northern Mariana Islands (5 vessels over 15 m), Tonga (23 licensed vessels in 2005) and Vanuatu (over 100 small-scale vessels). In PNG and the Solomon Islands, the targeting of deepwater snappers has been promoted through specific projects, but has not developed further.

In Samoa, deepwater snappers were targeted in the late 1980s and early 1990s with fishers reporting a decline in stocks from 1992 to 1994, when fishing effort turned to the tuna fishery. With declines in the tuna fishery in the early 2000s, some fishing effort has switched back to the deepwater snappers. Tonga has the most consistent deepwater snapper fishery, which started in the 1980s and continues today. However, the fishery, which is based on fishing the many seamounts within Tonga's EEZ, is reporting a decrease in the size of fish and volume of catch, particularly around the Haapai island group, raising concerns about the sustainability of current fishing rates.

Very few PICTs have management plans or regular data collection programmes in place for the deepwater snapper fishery. The three US territories — American Samoa, Commonwealth of the Northern Mariana Islands and Guam — have had management plans in place since August 1986 that are reviewed regularly. Tonga finalised its management plan for deepwater snappers and groupers in 2008. In 1987, Fiji put management guidelines in place, although they have not

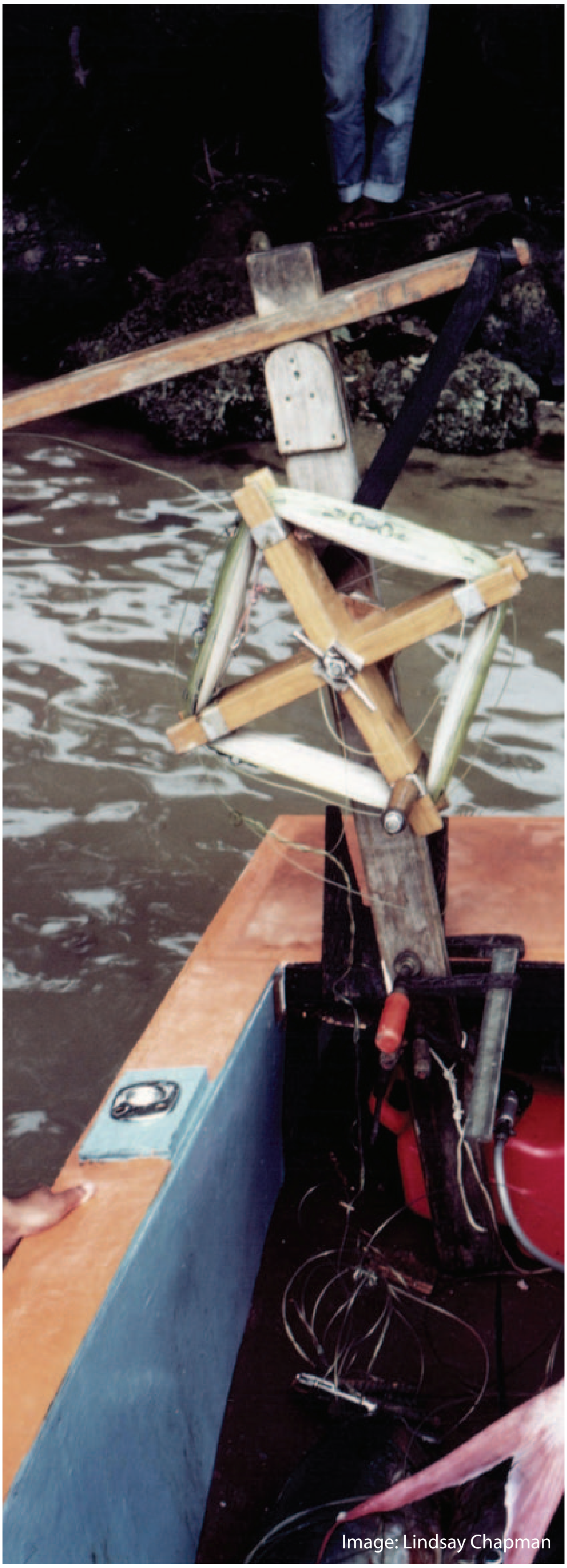

Image: Lindsay Chapman

been updated or revised since then. A management plan was drafted in 1995 for the Tuvalu deepwater snapper fishery, but minimal fishing has been recorded. At least two provinces in PNG have produced draft management plans. There has also been some concern expressed in New Caledonia about the state of the country's deepwater snapper fishery, with the fisheries department developing management arrangements in 2008. Seven PICTs have regular data collection systems in place that target or include deepwater demersal fish catches, landing and/or effort data: American Samoa, French Polynesia, Guam, New Caledonia, Commonwealth of the Northern Mariana Islands, Samoa and Tonga.

In July 2011, SPC hosted an international workshop to review the current status of information for deepwater snapper and other deepwater demersal fisheries in the Pacific Islands region. A clear outcome of the workshop was a recognised need for well-designed biological studies of deepwater demersal fish species across the Pacific Islands region to gain a full understanding of the population distribution of harvested species.

Preliminary data indicate that many species associated with deepwater demersal fisheries in the Pacific Islands region have extended life spans (greater than 20 years), and are generally slow growing and late to mature, making them vulnerable to overfishing. Based on the workshop recommendations, SPC is currently implementing two biological sampling strategies to obtain much-required information on catch composition and age, growth rates, mortality estimates, maturity schedules and stock structure of deepwater snapper and other deepwater demersal fish in the Pacific. The first approach is to conduct dedicated research cruises in several countries on remote seamounts that have received little historical fishing pressure. Biological samples from these cruises will be used to provide an estimate of what the biology of relatively unexploited populations looks like. The second approach is to collect biological samples from fishers after they land their catch in port. These samples can then be compared with those from unexploited populations. This will help fisheries managers set target reference points for management. Results of this study will be presented in future reports.

Data obtained by SPC's Oceanic Fisheries Programme during surveys for the deepwater snapper project suggest that sizeable stocks of bluenose, *Hyperoglyphe antarctica*, and blue warehou, *Seriolella brama*, exist on the seamounts of southern Tonga and in international waters between Tonga and New Zealand, indicating some potential for the development of these fisheries in this region and other locations at similar latitudes such as Fiji and New Caledonia. Catches of bluenose as far north as 19°S have been reported in Fiji waters, suggesting that this species has a wider distribution than previously thought.

Other deepwater bottom fishing activities

Over the last 25 to 30 years, a range of other fishing activities have been trialled for deepwater species.

- Deepwater shrimp fishing trials were conducted in many PICTs in the 1980s, with catches for the most part too low to be economically viable. Additionally, these stocks were assessed as being very fragile.
- Deepwater trawling trials have been conducted in the search for alfonsino (*Beryx* spp.) and other commercial species in Fiji, New Caledonia and Tonga. Although some commercial species were taken during the trials, they were not in commercial quantities to warrant further fishing. No real data are available on these trials, and/or the catches taken, and little is known about the stock status of these species.
- The trapping of deepwater crabs in depths of 500–700 m has occurred in Cook Islands, Palau, Tonga and Vanuatu. Little is known about the fishery or the status of deepwater crab stocks.

4. Aquaculture

Aquaculture in the present context includes marine aquaculture (or mariculture) and freshwater aquaculture (usually in ponds).

Global aquaculture

On a global basis, aquaculture is one of the fastest growing food sectors. Production from wild-caught fish and other seafood is decreasing and that from aquaculture is increasing (Fig. 20). By 2020, production is predicted to increase by 16% to 70 million tonnes, whereas fisheries will remain close to its present level of about 90 million tonnes.

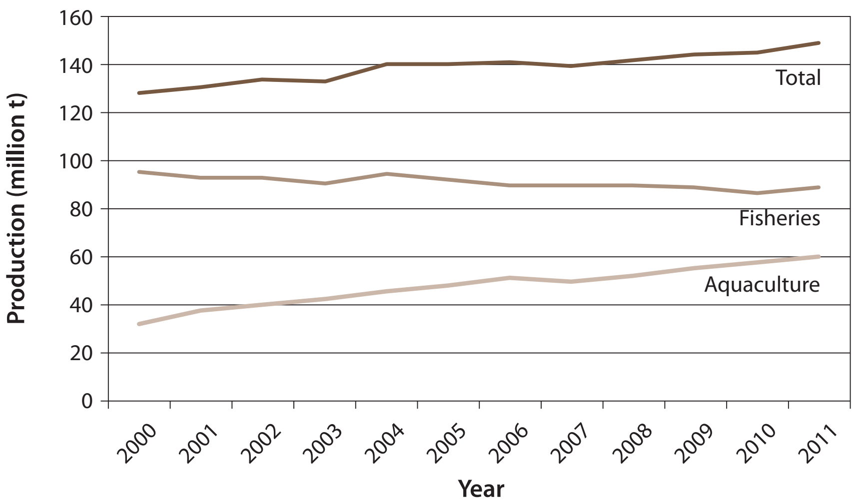

Figure 20. Production in millions of tonnes from fisheries and aquaculture (FAO 2012).

Aquaculture in the Pacific

Aquaculture systems were introduced to the Pacific Islands region in the early 1950s by SPC, but have only become well established during the past few decades. Today, aquaculture in the Pacific is becoming increasingly more widespread and is quite diverse given the region's relatively small terrestrial area.

Like many primary development sectors in the Pacific, aquaculture is often constrained by the region's remoteness, distance to markets, lack of basic infrastructure, institutional capacity, social and/or cultural values and by marketing challenges. Models that are technically feasible in one location cannot be simply transposed to another, and many PICTs have spent years of trial and error in applied development and research.

Annual value and volume of aquaculture production in the Pacific

French Polynesia accounts for almost 76% of the region's total aquaculture production value, with Cook Islands, Fiji and New Caledonia making up almost all of the remaining production (Fig. 21). The key commodities produced by these countries are cultured pearls and marine shrimp, which are high-value, low-volume commodities suitable for export to lucrative overseas markets.

The most valuable commodity produced in the Pacific has been cultured pearls, accounting for 98% of the total value of production in the region (Ponia 2010). Since 2007, the value of regional aquaculture has dropped significantly as a result of a decline in pearl production. By 2010, the value of aquaculture in the region had declined to about USD 100 million, from a high of USD 160 million in 2007 (Fig. 21).

Pearl production from the two main pearl-producing countries — Cook Islands and French Polynesia — has declined from over USD 140 million in 2007 to about USD 85 million in 2010 (Fig. 22). The collapse in value of pearls from French Polynesia was mainly a result of oversupply and poor market prices, while in the Cook Islands production was affected by disease, environmental problems and market value (Hambrey 2011).

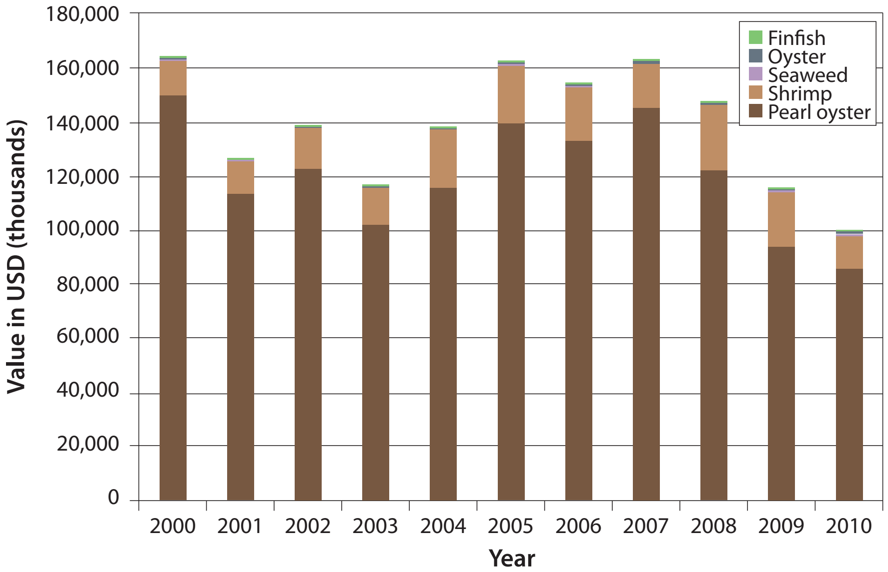

Figure 21. Value of aquaculture in Pacific Islands by year, from pearl, shrimp, oysters, finfish and seaweed production (Source: FAO 2012).

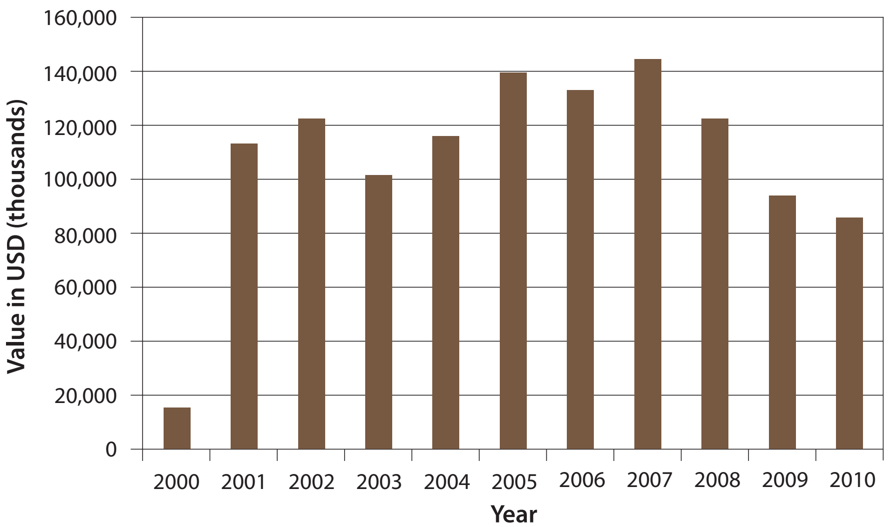

Figure 22. Value of pearl production from French Polynesia and Cook Islands (Source FAO 2012).

Shrimp production remains the second-most valuable aquaculture commodity in the Pacific Islands region. Data collected mainly from French Polynesia and New Caledonia showed an increase in the value of shrimp production from USD 16.5 million in 2007 to just under USD 24 million in 2008, with a subsequent decline to USD 12 million in 2010 (Fig. 23). In New Caledonia, the entire production cycle of the shrimp industry is being reviewed.

If New Caledonia's shrimp production and French Polynesia's pearl production are removed from the data (Fig. 24), the dominant aquaculture products in the region are Pacific oyster in New Caledonia (with a value of USD 700,000) followed by tilapia production in several countries, including Fiji, PNG and Vanuatu. Seaweed production is increasing, mainly in Fiji and the Solomon Islands.

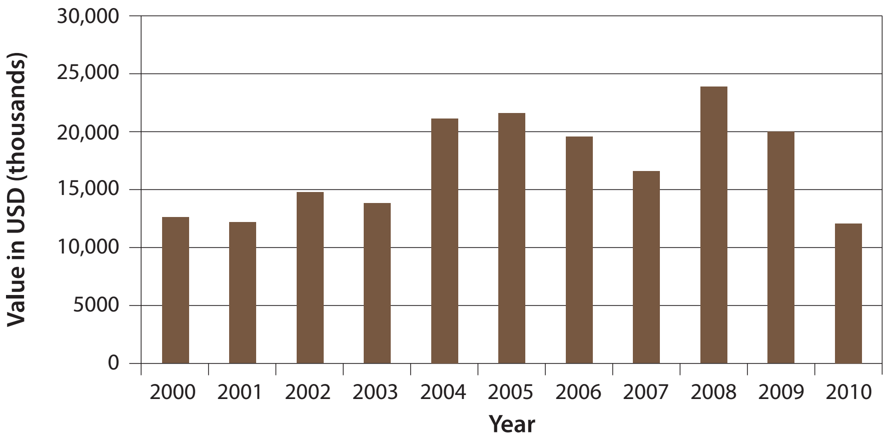

Figure 23. Value of Shrimp production from New Caledonia and French Polynesia (Source FAO 2012).

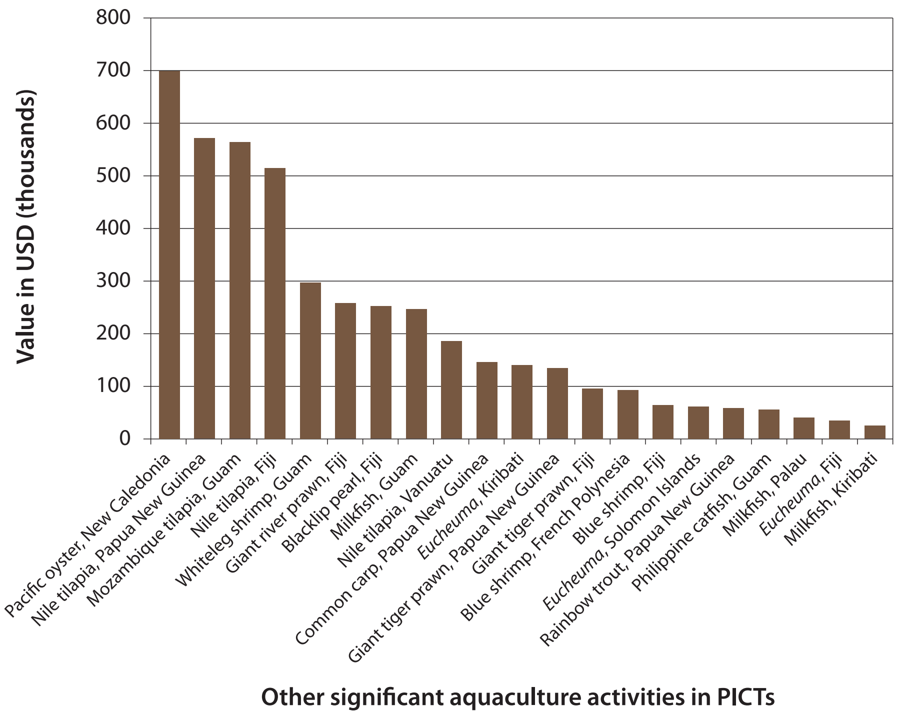

Figure 24. Value of cultured species in PICTs in 2009, excluding shrimp and pearl production from French Polynesia and New Caledonia (from Hambrey 2011).

Role of aquaculture in livelihoods and food security

The population in the Pacific is expected to grow by almost 50% by the year 2030 (SPC 2008). The primary ways in which aquaculture can assist society to meet this challenge is by providing households with cash to support livelihoods, and by ensuring ready access to fish protein and good nutrition, thereby improving food security.

The key commodities (Fig. 25) that have been identified as being the most feasible and with the greatest potential for aquaculture production are cultured pearl, seaweed, giant clams and coral farming for the ornamental trade, marine shrimp, tilapia, freshwater prawn, sea cucumber, and marine finfish. In the past, production of these commodities was primarily for export markets, but the region's increasing urbanisation has created an expanded domestic market.

FEASIBILITY	POTENTIAL IMPACT: Low	POTENTIAL IMPACT: Medium	POTENTIAL IMPACT: High
High	Trochus	Marine ornementals Freshwater prawns Milkfish	Pearl oyster Seaweed Tilapia
Medium	Sponge Carp Red claw	Marine finfish Mud crab	Sea cucumber
Low	Crocodile Abalone	Eels Rock lobster	Marine shrimp

Figure 25. SPC aquaculture commodity priorities (SPC 2007).

Pearl farming continues in countries such as Fiji and FSM, where smaller, specialist producers target local tourism and industry. New research is underway in neighbouring countries such Tonga to produce round pearls from other pearl oyster species such as winged pearl oyster (*Pteria penguin*),while PNG is undertaking pearl culture baseline studies.

Opportunities for the culture of marine ornamentals — especially giant clams and coral culture targeting the aquarium trade industry — appears promising, especially for locations that are accessible to international airports. However, the market for these commodities will be limited.

In addition to the high production in New Caledonia, other countries presently producing shrimp in the region and targeting domestic markets include Guam (10 t year^{-1}), French Polynesia (50 t year^{-1}) and the Northern Mariana Islands (25 t year^{-1}) (Patrois 2010); French Polynesia has high domestic demand for 600 t year^{-1}. High importation of frozen shrimp into Vanuatu has affected the potential to supply the domestic market. PNG has initiated farming of black tiger prawns with a production capacity of 80 t year^{-1}, but sourcing sufficient broodstock from the wild remains a challenge.

Freshwater (*Macrobrachium*) prawns are relatively easy to grow in ponds and are highly marketable. It is thought that satellite prawn farms in rural areas could supply larger, central operations, similar to the chicken industry in Fiji.

Sea cucumber stocks are in danger throughout the Pacific because of their high value, and their sedentary nature have made them vulnerable to overfishing. Techniques to breed the valuable sandfish species (*Holothuria scabra*) have been developed. PICTs are very interested in adopting aquaculture techniques to restore their wild sea cucumber fishery, but the extent to which aquaculture can contribute to the restocking of depleted wild stocks or form the basis of profitable sea ranching or pond farming systems is unclear. The capacity to produce juvenile sandfish in a hatchery for ocean nursery pen culture on a pilot commercial scale has been achieved, and the leading countries in research are New Caledonia, FSM and Palau, followed by Solomon Islands, Fiji and Kiribati. One of the key challenges is to demonstrate the effectiveness of sea cucumber restocking and sea ranching through larger-scale experimental releases and post-release monitoring.

Kappaphycus seaweed is farmed for its carrageenan extract, which is an important ingredient in the food and pharmaceutical industries. Although seaweed farming is simple and ideal for coastal villagers, the costs of shipping large quantities makes it only marginally profitable. The major seaweed producing country in the region in 2010 was Solomon Islands (8000 t), followed by Kiribati (4700 t) (Fig. 26). A major seaweed processor has now been established in Fiji. A hardier strain of seaweed that is more tolerant to heat has recently been sourced by Fiji from Indonesia, and it is likely that seaweed production will increase in the region in the coming years.

Given the region's growing population, maintaining the current rate of fish consumption per capita will require an additional 100,000 t of fish. The need will be greatest in rural inland areas, where fish consumption rates are already limited by poor access to coastal fisheries. Melanesian countries will face the largest increase in rural inland populations. Commodities such as tilapia and milkfish, which have well-established fish farming methods, are among the most suitable species to help meet the region's food security needs.

Nile tilapia are easy to farm and can provide a protein source for the poor; they can also supply high-value markets, being one of the top five fish species sold in the US. Nile tilapia has been sold in municipal markets in Fiji for many years and has more recently proven to be popular in countries such as the Cook Islands and Vanuatu. In inland areas it has prospects for artisanal farming, and many of the estimated 10,000–15,000 fish farmers in PNG are likely to benefit.

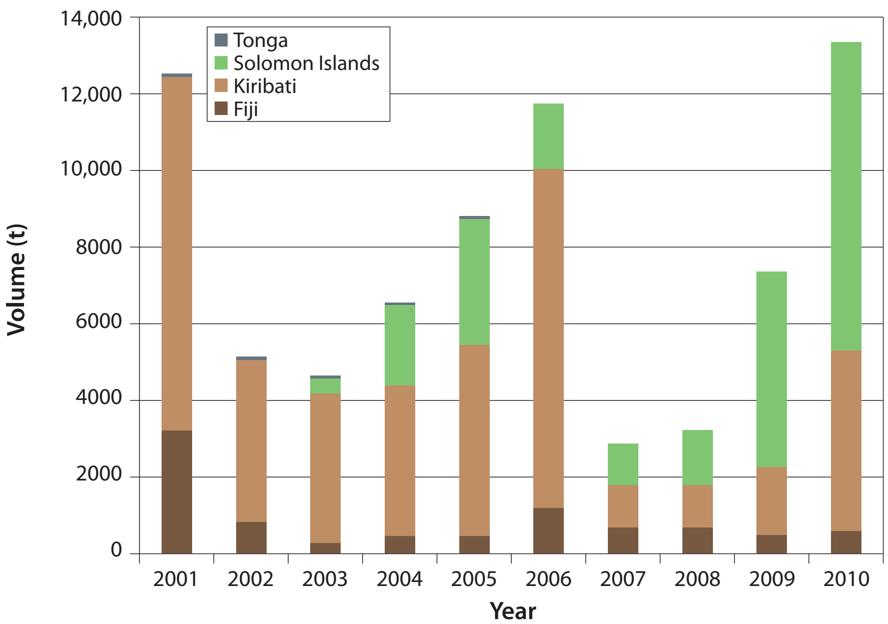

Figure 26. Volume (t) of *Kappaphycus* seaweed farmed in the Pacific Islands region (FAO 2012).

SPC Aquaculture Action Plan

At the SPC/FAO Regional Aquaculture Scoping Mission in Nadi, Fiji in October 2011, SPC members reviewed the existing SPC Aquaculture Action Plan 2007. The 2007 Plan set the regional focus on aquaculture, based on prioritising commodities for livelihood and food security in the region, as well as identifying important cross-cutting issues affecting the sector. It was agreed that prioritising commodities should be done on a country-by-country basis, and that the focus of a new regional strategy should be on programme areas. The revised SPC Regional Aquaculture Strategy will focus on the programme areas and outcomes shown in Table 4.

Table 4. Proposed programmes and outcomes of the SPC Regional Aquaculture Strategy.

Programme	Outcome
Aquatic biosecurity	Production and transfer aquatic organisms with minimum biosecurity risks
Capacity building	Improved capacity at all levels among PICTs to develop aquaculture and manage strategic and technical issues
Feasibility assessment	Commercial and non-commercial aquaculture that is economically, socially and environmentally viable, with sustained and stable production
Statistics and data	Improved aquaculture policy and decision-making through the provision of knowledge of the status, contributions and trends in the aquaculture sector
Markets and trade	Increased trade (domestic and export) in Pacific aquaculture products
Technology transfer and improvement	Improve production efficiency through adoption of appropriate, proven technology

Cross-cutting issues included in all of the six programme areas include gender, capacity building, climate change and environmental sustainability, governance and research issues.

Putting in place the proper strategic institutional frameworks and business climate will require forward planning and policies for sustainable aquaculture and proper economic and marketing analyses. Aquaculture has a role to play in helping to preserve the unique biodiversity that sustains the region's fishing traditions and ethno-biodiversity. Aquaculture must also take a more holistic ecosystem approach to ensure that activities do not negatively impact the natural environment or human users. The transfer and production of aquatic organisms must be done with minimal risks to existing organisms and environments.

Climate change: Projected effects on aquaculture

The species used to produce aquaculture commodities are potentially vulnerable to changes in surface climate, the ocean and coastal habitats. The main aquaculture commodities for food security (Nile tilapia, carp and milkfish) are expected to be exposed to projected increases in water temperature and rainfall (Pickering et al. 2011). Low-lying ponds near the coast are also expected to be exposed to sea-level rise and possibly more intense cyclones. Enterprises and households farming these species will be sensitive to these changes because temperature regulates fish growth and reproduction and rainfall influences water temperature and water exchange (and its effect on dissolved oxygen levels) in ponds. On balance, however, aquaculture operations for tilapia, carp and milkfish are expected to benefit from the projected increases in temperature and rainfall as growth rates increase and the more locations become suitable for pond aquaculture. Nevertheless, care will be needed to build ponds where they are not prone to flooding or to inundation or damage from sea-level rise or storm surge.

The main aquaculture commodities for livelihood support (pearl oysters, shrimp, seaweed), and lesser-cultured commodities (giant clams and other marine ornamentals, marine fish, sea cucumbers and trochus), are expected to be more vulnerable to climate change. These will be exposed to a variety of changes — increases in sea surface temperatures, ocean acidification, decreases in salinity due to changing rainfall patterns, sea-level rise, and possibly more intense cyclones — and are sensitive to such changes in various ways (Pickering et al. 2011). Increases in sea surface temperature and rainfall will make pearl oysters more susceptible to disease and parasites, and warmer sea surface temperatures are likely to affect survival of spat, nacre deposition and pearl quality. The effects of sea-level rise and more intense cyclones also increase the exposure of pearl farm infrastructures to damage.

In the shorter term, shrimp farming may benefit from higher growth rates and improved yields due to increasing temperatures. However, potential longer-term negative impacts include greater risk of temperature-related diseases and problems with ponds drying between production cycles as sea level rises.

Production of giant clams and cultured corals is likely to become more difficult as increasing sea surface temperatures and ocean acidification make conditions more hostile for their growth and survival. In some locations, sea-level rise could reduce the potential impact on giant clams and coral by improving water exchange and nutrient supply to nutrient-poor sites.

The sensitivity of hatchery-based marine fish aquaculture to higher sea surface temperature is expected to be low because these operations will rely mainly on controlled facilities to maintain broodstock and rear juveniles. Sensitivity of marine fish that are grown out in sea cages to increases in sea surface temperature should be similar to the responses of bottom-dwelling fish associated with coastal habitats.

For sea cucumbers, higher temperatures, reduced salinity and ocean acidification, and degraded seagrass habitats are likely to increase the mortality of hatchery-reared juveniles released in the wild. Sea cucumbers grown in ponds will be at greater risk from the increased likelihood of stratification caused by higher temperatures and rainfall. Where such problems occur, ponds will need to be modified to maximise mixing. Sea-level rise and increased rainfall are likely to reduce the availability of habitat for juvenile trochus, limiting the areas suitable for trochus restocking programmes.

Seaweed (*Kappaphycus alvarezii*) farming operations are expected to be adversely affected by increased stress to plants from higher sea surface temperatures and reduced salinity, resulting in crop losses due to increased incidence of outbreaks of epiphytic filamentous algae and tissue necrosis. Lower salinities are also likely to reduce the number of sites where seaweed can be grown. More intense cyclones would increase the risk of damage to the equipment used to grow seaweed in Fiji.

The combined effects of climate change on species and infrastructure indicate that 1) existing and planned aquaculture activities to produce tilapia, carp and milkfish in freshwater ponds for food security are likely to be favoured by climate change; and 2) mariculture enterprises producing commodities for livelihood support in coastal waters are likely to encounter production problems (Table 11.5 in Pickering et al. 2011). The benefits for freshwater aquaculture are expected to be apparent by 2035, provided that the changing climate does not limit access to the fishmeal needed to formulate appropriate diets for tilapia, carp and milkfish.

Although most mariculture commodities are expected to become progressively more vulnerable to climate change, this does not necessarily mean that there will be reductions in productivity in the future. Rather, the efficiency of enterprises is likely to be affected. Total production of coastal aquaculture commodities could still increase if aquaculture operations remain viable and more enterprises are launched.

Image: Lindsay Chapman

5. Role of women and men in fisheries

Knowledge of gender roles and their changes are an important input to effective fisheries management, and allows interventions to be tailored to the needs and abilities of specific target groups of fishers.

Role of women and men in coastal fishing

No new study of the respective roles of men and women in coastal capture fisheries has been made since the PROCFish/C study (2002–2009). The general predominance of men in fishing continues (Fig. 27); this is particularly apparent among fishers who exclusively target finfish, while women predominate among fishers who exclusively target invertebrates.

If we compare the participation of men and women targeting finfish and invertebrates (not necessarily at the same time), three groups emerge (Fig 28): 1) in Fiji, Niue, Palau, PNG, Solomon Islands, and Wallis and Futuna the ratio of fishermen and fisherwomen is comparable; 2) in Cook Islands, Nauru, New Caledonia, Vanuatu and perhaps Samoa, women's participation is significantly less than men's; and 3) in French Polynesia, Kiribati, Marshall Islands, Tuvalu and Yap there is either no or very little participation by women in fishing activities.

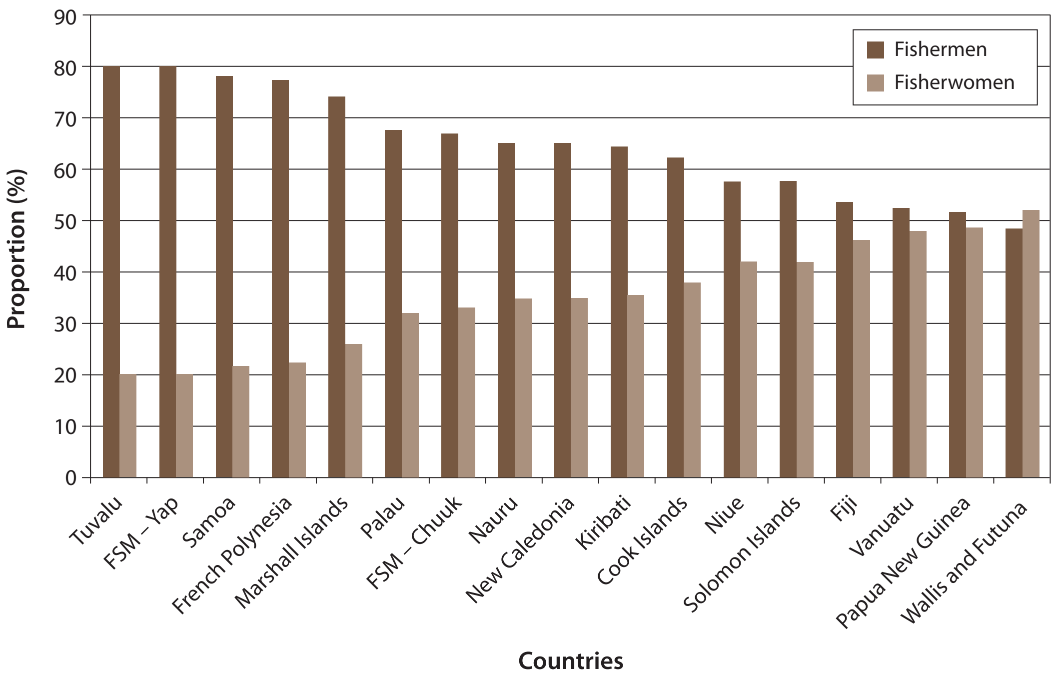

Figure 27. Proportion of fishermen and fisherwomen by country.

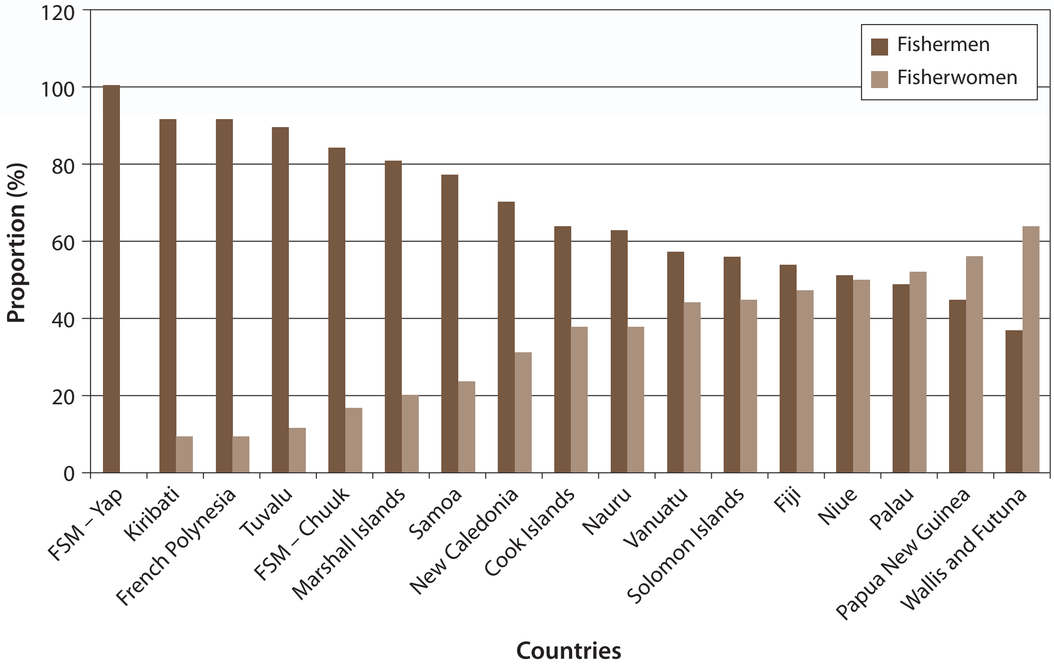

Figure 28. Participation (%) of fishermen and fisherwomen who target both finfish and invertebrates.

Image: Valérie Allain

Role of women and men in fisheries management

In 2011, the participation of women in fisheries science and management was studied in three countries: Solomon Islands, Marshall Islands and Tonga (Tuara and Passfield 2011). The findings are estimated to be broadly representative of the situation in the Pacific Islands region.

The study reveals that women account for just 18% of the total number of staff working in fisheries science and management in government fisheries, environmental institutions and environmental non-governmental organisations. In contrast, women account for more than 60% of administrative and clerical staff employed in government fisheries divisions (Fig. 29).

SPC's Fisheries, Aquaculture and Marine Ecosystem Division strongly believes that all fisheries careers should be equally accessible to both women and men, and focuses on 'breaking down the barriers' to help women gain work in fisheries should they so choose. In its own recruitment procedures, SPC provides equal employment opportunities for all positions.

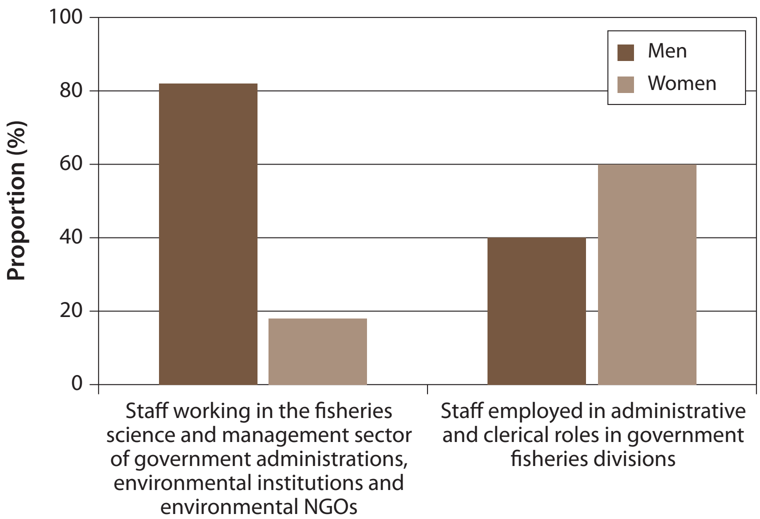

Figure 29. Percentage of men and women employed in fisheries science and management compared with the percentage employed in administrative and clerical roles in government fisheries divisions.

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