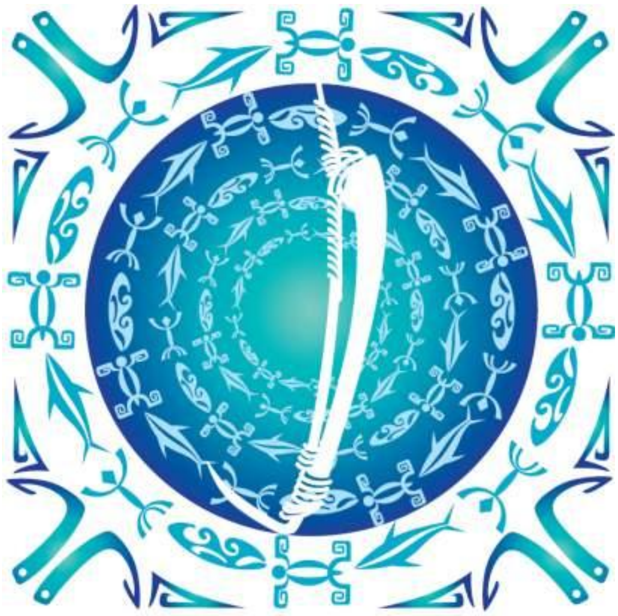
SciCOFish

SCIENTIFIC SUPPORT FOR THE MANAGEMENT OF COASTAL AND OCEANIC FISHERIES IN THE PACIFIC ISLANDS REGION

Status report: Reef and nearshore fisheries and aquaculture 2013



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SUMMARY

This report addresses the status of reef fisheries for finfish and invertebrates, nearshore fisheries for pelagic fish including tuna, fisheries for demersal fish including deepwater snappers and aquaculture.

Strong 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 populations in Pacific islands. However, much of the additional seafood required will need to come from nearshore pelagic fish, tuna in particular, as well as aquaculture

Climate change will have varying effects on countries and different fisheries. It is essential to develop the necessary monitoring tools and implement long-term national and regional monitoring programmes for climate change as soon as possible – the longer the time-series, the greater the power to detect change and provide information needed for adaptive management.

SPC data suggests that many reef fisheries based on finish and invertebrates are exposed to unsustainable fishing and sound management is urgently needed to maintain catches on a sustainable basis.

Giant clams have been fished to local extinction in several areas. Trochus exports have declined markedly and at least some of this decline has been due to uncontrolled fishing as well 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 of all commercial fisheries, that on sea cucumbers, has suffered from over-fishing.

The status of several other invertebrates, including lobsters, crabs, and octopuses, is generally not known. Even though these species are important in subsistence fisheries and local markets, there are very few catch statistics.

In the face of depleted stocks, SPC is assisting many countries with the development and imposition of management measures including size limits and short harvest seasons. In valuable and threatened invertebrate stocks, some countries have taken the bold move to close their fisheries to allow stocks to rebuild. But these ‘moratoria’ or resting periods 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 as 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. Export of aquarium fish and invertebrates (including corals) from Pacific Island countries and territories started in the 1970s. It has since expanded to become an important source of income and employment for a number of communities in the region. And again management must ensure that best practices are followed to avoid damage to fragile reef ecosystems.

Live coral exports from the Pacific region peaked in 2006 and have been in decline since. This may be linked to the economic downturn and also the culturing of some corals within importing nations.

Nearshore fisheries include those for pelagic and demersal species. Commercial tuna fisheries are believed to have some potential for further growth in the Pacific Island share in the catching and processing sectors. At present over 30% of the total tuna catch is caught within the EEZs of Pacific Island countries and territories.

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 runners. In some countries, the catch of non-tuna species is higher than that for tuna.

Many member countries have been benefiting from FADs over the last 25 years. Tuna catch rates (kg per hour) from trolling around FADs are often three times the catch rates of tunas taken when chasing tuna and trolling in open water and around reefs. Nearshore pelagics and the use of FADs are also important for the slowly expanding game-fishing operations in the Pacific. 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 squids with a mean weight of 18 kg, have been encouraging and there is potential to develop fisheries in some countries.

Deepwater snapper fishing was the subject of an SPC international workshop in 2011. The gathering recognised a need for well designed biological studies of deepwater demersal fish species across the Pacific Islands region to gain a full understanding of the demography 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 this species has a wider distribution than previously thought. These finds 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 systems introduced to the region in the early 1950s by SPC have only become established within 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 from oversupply and poor market prices while Cook Island pearl production was affected by market value, water quality and other environmental problems. By 2010, the value of aquaculture in the region had reduced to about USD 100 million.

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

Key commodities identified as 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 amongst the most suitable species to help meet the food security needs.

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

There is much interest from Pacific countries 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 stock 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 larger scale experimental releases and post release monitoring.

Knowledge of gender roles and their changes are an important input to effective fisheries management, as it allows interventions to be tailored to the needs and abilities of specific target groups of fishers. Although the general dominance of men still persists in fishers who exclusively target finfish, the opposite is true for fishers who exclusively target invertebrates, which remains a women's domain.

In 2011, studies on the participation of women in fisheries science and management indicated that women only represent 18% of the total number of staff working in the fisheries science and management sector in government fisheries, environmental institutions and environmental NGOs. In contrast, the number of women employed in administrative and clerical roles in government fisheries divisions exceeds 60%. SPC's FAME Division strongly believes that all fisheries careers are equally acceptable to women as to men and focuses on "breaking down the barriers" to help women moving into the fisheries area if they so choose.

The need for more reliable catch information and sensible management is now more important than ever if our fisheries are to be more resilient to the future effects of climate change and increasing fishing pressure.

1. Introduction

This report addresses the status of reef fisheries for finfish and invertebrates, nearshore fisheries for pelagic fish including tuna, deeper water fisheries for demersal fish including snappers, and aquaculture.

Although commercial tuna fisheries contribute greatly to revenue and national economic development, coastal fisheries are important in securing national food security and rural incomes. In terms of benefits through import substitution and livelihoods, it is likely that oceanic fisheries and coastal fisheries are approximately equally important 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 islands will need to come from nearshore pelagic fish, tuna in particular, as well as aquaculture (Bell et al. 2011). Careful 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 by growing populations (Fig. 1).

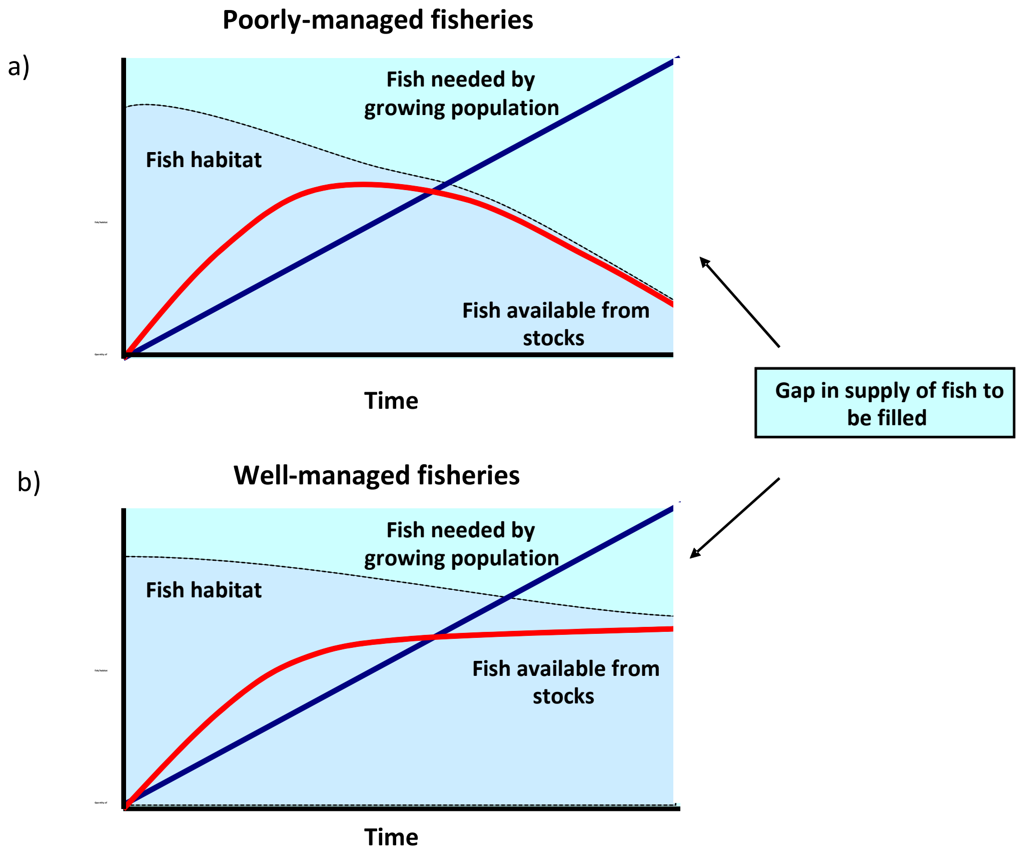


Figure 1. In a poorly managed fishery (graph a) fish stocks and catches (red line) will decrease and marine habitats (blue area) will deteriorate over time. In a well-managed fishery (graph b) fish stocks and catches will remain at a sustainable level. Well-managed fisheries will minimise the gap between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

SPC is involved in providing support on several fronts, including the following:

- 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 sports fishing.

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

Collection of data

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 appears to be three types of situations, however, where good estimates are available:

- Countries that have a dedicated on-going 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) for small-scale fisheries production purposes.

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

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

The national household income and expenditure surveys (HIES) provide a reliable and regular way of collecting the 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 the data to be recorded, stored and analysed easily.

Data on the abundance and size frequency of tuna and other large pelagic fish caught by nearshore fisheries, including catches made around inshore fish aggregating devices (FADs), can be collected using the SPC-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 the data with appropriate supervision. The TUFART database has been set up to manage and report on the data. Training, equipment (calipers and pocket-sized identification guides) are available from SPC.

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

Table 1. Preliminary estimates of annual catches in tonnes and as percentage of total catch for the three main categories of coastal fisheries in Pacific Island countries and territories (PICTs). 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 in 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 2011).

	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[ag]	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 & Futuna	718	74.7	106[a]	11	137	14.3	961
Total	**86,007**	**55.6**	**42,938**	**27.8**	**25777**	**16.7**	**154,722**

a = Nearshore pelagic fishery dominated by non-tuna species; b = nearshore pelagic fishery comprised equally of non-tuna and tuna species; c = nearshore pelagic fishery dominated by tuna; d = includes deep-water snappers; e = includes mangrove crabs and spiny lobsters sold on local market; f = includes hundreds of tonnes of penaeid shrimps; g = includes 800 t of baitfish; h = includes 700 t of deep-water snappers.

Climate change

Dedicated sampling programmes are also needed to monitor the effects of climate change on demersal fish and invertebrates as well as their supporting habitats. These programmes require an experimental design where the effects of other stressors such as pollution or fishing pressure are either removed or controlled for, such as comparisons between 'impact' (e.g. fished) and 'control' (e.g. unfished) areas. For fish habitats, simple methods for collecting remotely-sensed data and ground-truthing this information have a role to play; measures of changes in coral cover, species composition and topographic complexity will also be 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 CFP is currently finalising a survey manual and database software to support the collection and storage of market and creel survey data, while SPC's existing Reef Fisheries Integrated Database (RFID) is designed to facilitate storage of fisheries-independent survey information such as UVC data.

It is essential to develop the necessary monitoring tools and implement long-term national and regional monitoring programmes for climate change as soon as possible – the longer the time-series, the greater the power to detect change and provide information needed for adaptive management.

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 (1) catches, and catch values, of the three basic categories of coastal fisheries described above; and (2) 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 cases of ciguatera in each country should also be reported and 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 of the United Nations (FAO). FAO (2012) noted that 18 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, essentially in waters from 0-50m depth. These are the main food-fisheries of the Pacific and the basis of the main non-tuna exports – they often include non-perishable invertebrate commodities like trochus shell and bêche-de-mer (dried sea cucumber) but also finfish, including high-value fish and invertebrates exported alive for food and aquarists. Pacific Island reef fisheries are commercialized to different extents in different countries but they are mainly artisanal and subsistence fisheries, without the full-time involvement of professional fishers.

Fishing pressure on reef fisheries

Socioeconomic data obtained under the Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish) project assessed the degree to which Pacific Island countries are dependent on coastal, and particularly reef and lagoon, resources, for food, income and livelihood. The degree of exploitation is a proxy to estimate impact – fishing pressure – and knowledge on the kind of dependence allowing identification of which possible alternatives may be needed to reduce current fishing pressure. Analysis of the regional dataset has revealed the strongest correlation for finfish fishing pressure between the total number of people and catch rate density (Fig. 2).

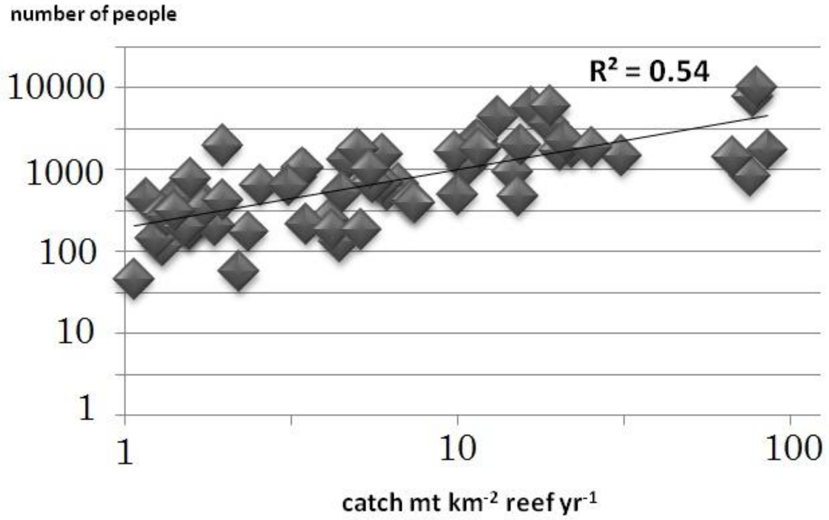


Figure 2. Regression between population and finfish catches across PICTs.

Fishing pressure and its possible impact vary between countries and sites due to a number of different factors but the more people, the more pressure on reef and lagoon resources.

Fishing pressure is a function of extraction for food (subsistence), for social obligations (non-market exchange, gifts) and income (sale). PICTs are quoted as having the highest seafood consumption rate worldwide but there are significant differences amongst sites and countries studied. At the regional scale, annual per capita consumption of finfish (edible parts only), invertebrates (edible meat only) and canned fish (net weight of fish meat only) was found to vary between 16–139 kg, 2–16 kg, and 2–25 kg respectively (PROCfish data). Averaging the sum of per capita consumption of all seafood categories per each site studied, on average seafood covers between 5–25% of the total annual energy needs of an average adult Pacific Island person. The highest seafood consumption patterns were in Micronesian and lowest in Melanesian countries. Overall, finfish is the most important source everywhere; however, invertebrates and canned fish play an important role in certain countries and regions.

Income dependency from fisheries is another important determinant of fishing pressure. Again, the dependency of households earning first or second income from this sector was found to vary substantially across all 63 sites in 17 countries studied, i.e. between 10-93%.

The combined effects of seafood needs, income dependency on fisheries, and the degree of diversification of household income are important information for fisheries management planning as they allow identification of the most urgent needs for intervention if fishing pressure must be reduced. Communities that already have a much higher income diversification and hence access to alternative income opportunities, offer a much greater potential for restrictive fisheries regulations compared to communities that predominantly rely on fisheries with no access to other alternatives.

Effective fisheries management also needs to take into account target groups for adjusting interventions to their needs and capacities. Countries and sites studied comprise a wide range of tenure, reaching from the open access system often referred to as being subject to the tragedy of the commons (Hardin, 1968) to customary tenure with clear and strict regulations concerning target species, temporal or periodic closures, etc. Different tenure systems have often been quoted as having a major impact on resource exploitation; however, differences between sites studied did not generally show this. On the other hand, significant differences were found in gender participation and its 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 population density and a set of socioeconomic variables that cover income, financial and other aspects. Catch data extrapolated from fisher surveys suggest that the degree of both, finfish and invertebrate exploitation levels are positively correlated. Hence, half of all sites studied appear to be exposed to unsustainable fishing on both finfish and invertebrate populations. Findings also pinpoint that cultural differences and gender participation are crucial to successful fisheries management.

Status of reef finfish fisheries

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

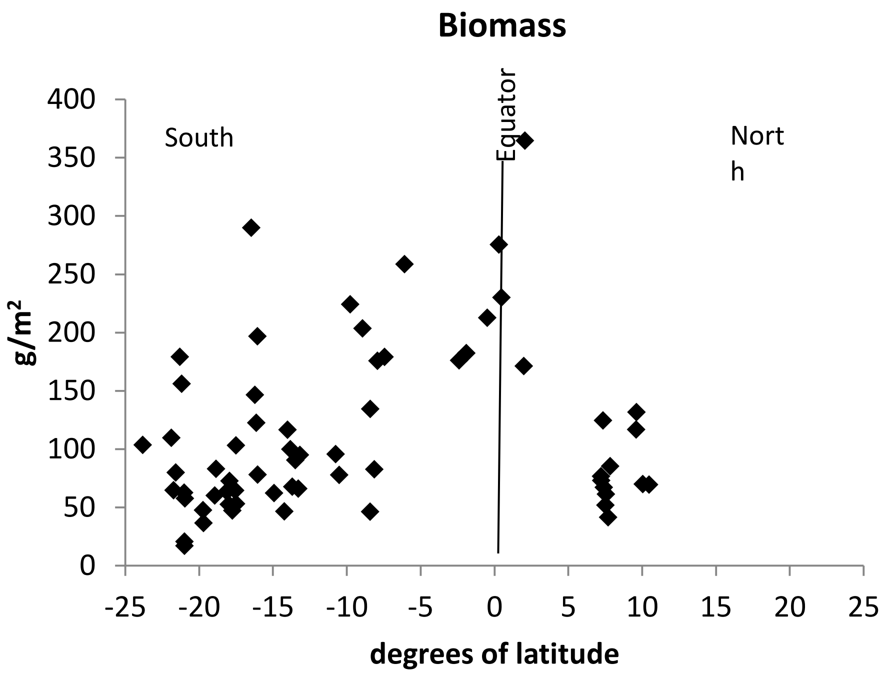


Figure 3. Average biomass of reef fish (g per square metre) plotted against latitude of site.

The regional analysis also revealed a decrease of biodiversity with increasing distance from a centre of biodiversity in the area north of Papua New Guinea (Fig. 4), as expected under ecological theory. However, the decrease is not linear and not without a high variability. This variability is likely to be due to the impact of fishing.

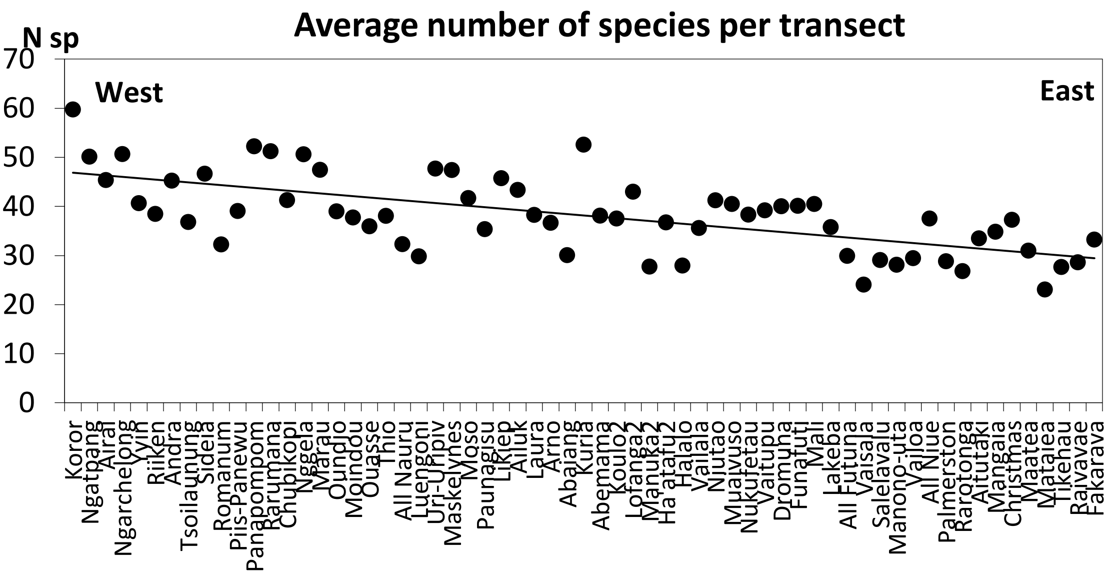
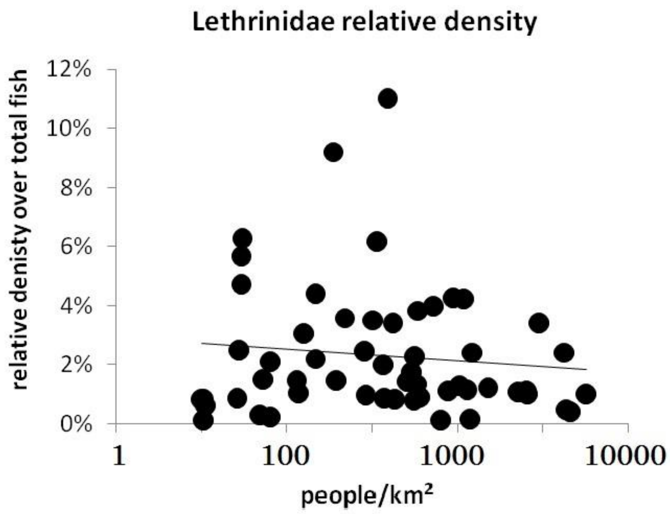


Figure 4. Biodiversity of commercial finfish from west to east.

Without an indication of what constitutes a "healthy fish condition" and "normal" community structure at different sites due to their varying conditions and productivity, and without reference of time changes it is difficult to say anything absolute about the status of the system as a whole. However, analyses strongly suggest a high influence of fishing on the state of finfish resources. Most sites appeared to be impacted by different levels of fishing. Total numbers, and especially average size and biomass of fish, were major indicators of an increasing level of fishing.

As expected, the relative density of carnivorous groups, such as emperors (Lethrinidae), decreased with increasing fishing pressure. However, some herbivorous groups, such as surgeonfishes (Acanthuridae), increased with increasing fishing pressure (Fig. 5). This is probably a response from a group of opportunistic species that responds to a decrease of predators. These changes were uncovered after extracting variations due to environmental characteristics (geographical position, type of island, type of reef, composition of substrate, etc), therefore they are mostly due to pure fishing impact.



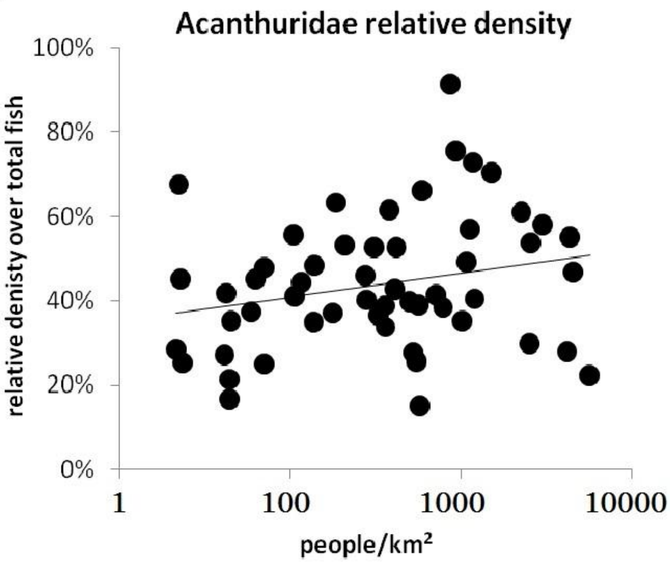


Figure 5. (TOP) relative density of emperors over total commercial fish against number of people per square kilometre of reef. (BOTTOM): relative density of surgeonfishes over the commercial fish against number of people per square kilometre of reef.

Considering that people density is strongly correlated with fishing intensity, there is a strong reduction in the mean size of piscivorous fish (Serranidae and Lutjanidae) with increasing fishing pressure (Fig. 6).

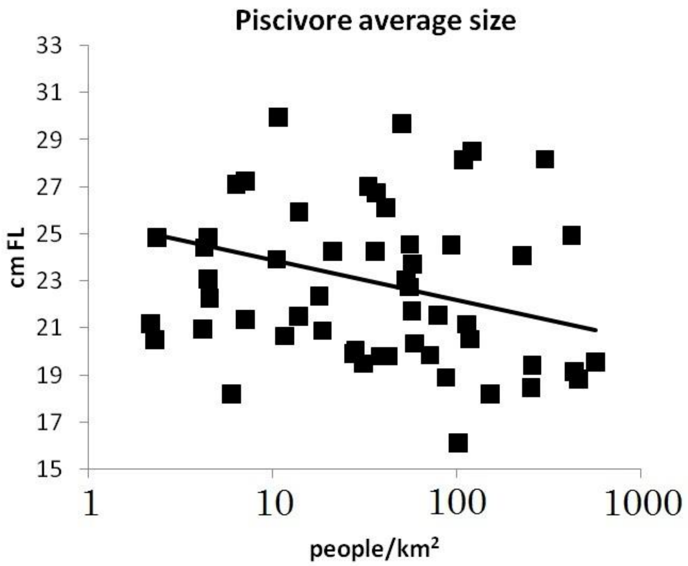


Figure 6. Mean fork length of piscivores (Serranidae, Lutjanidae) against number of people per square kilometre (used as a proxy for fishing pressure).

In terms of the health of reef food fisheries and their supporting ecosystems, one indicator that has been suggested for general use in other parts of the world is the proportion of herbivorous fish to carnivorous fish. A high proportion of carnivores is usually an indicator of good reef ecosystem health. Some Pacific Islands however might 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 be due to differences in fish targeting – some Pacific Island societies having more of a preference for herbivores such as parrotfish. But mostly the differences in such proportions are due to environmental differences: for example high volcanic islands appeared to have higher proportion of herbivores compared to carnivores. Nonetheless, this ratio was useful in the regional assessment as it turned out to be a significant signal of fishing intensity when environmental variability was extracted by the calculations.

The data analysed showed that density, sizes and consequently biomass of fish decreased with increasing fishing intensity; similarly, the higher the fishing intensity, the more the relative importance of herbivores over carnivores and the stronger the dominance of small-sized surgeonfishes.

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 (bêche-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 Region, 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, where other opportunities to generate income can be difficult to find. Declines in the sustainability of sea cucumber and MOP fisheries are thus of widespread concern. As well as reducing foreign exchange earnings, damage to invertebrate export fisheries also contributes to outer-island depopulation and urban drift.

Giant clams

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

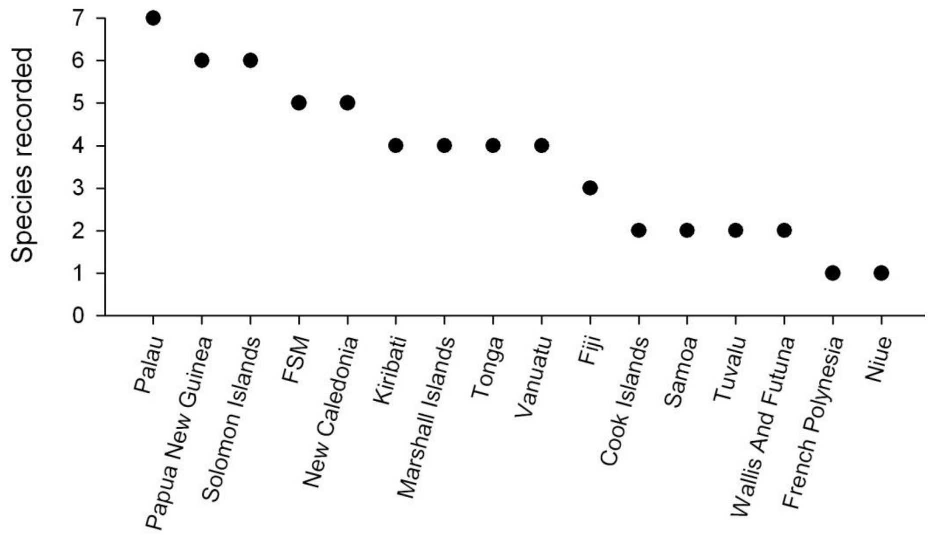


Figure 7. Number of giant clam species recorded in recent SPC surveys by country.

The smaller, commoner clam species are found at most sites, while larger species like *Tridacna gigas* and *T. derasa* are rare. In the case of the largest giant clam, *T. gigas*, individuals were only recorded at 39% of survey sites within their geographical and ecological range, despite dead shells being commonly noted onshore at many more sites. In Kiribati, Solomon Islands and Marshall 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 which incorporates both density and size information, is not always a useful measure for invertebrates, as unlike in fish, 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, it is noticeable that there is considerable variation across countries (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.

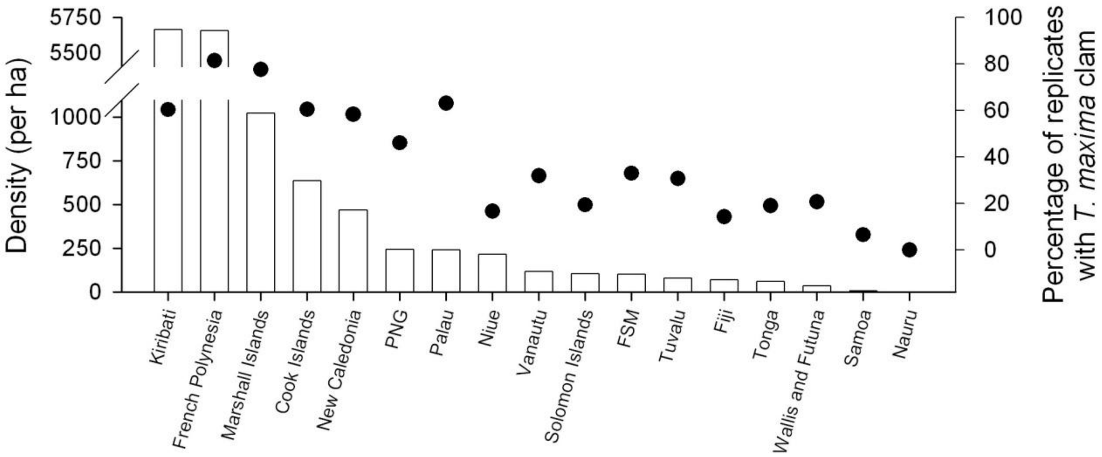


Figure 8. Density of T. maxima clams by country (bars, left axis) and 'coverage' of T. maxima clams (points, right axis).

Trochus and other gastropods

Pacific Island mother-of-pearl (MOP) fisheries are mainly 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 4,000 shells per person per day 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 French Polynesia, Cook Islands, Federated States of Micronesia, Marshall Islands and, recently, Tonga and Samoa.

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 per hectare. Minimum size limits of 3 inch (75mm) are imposed in some countries and some countries have implemented minimum and maximum size limits.

A model example of the management of a trochus fishery

Trochus harvests in Aitutaki in the Cook Islands are announced after an underwater visual assessment has been completed by Fisheries Department staff. A total allowable catch (TAC) is set at between 30–40% of the biomass of trochus within the 80–110mm size window. The TAC is divided amongst the 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. Stocks of trochus remain healthy in Aitutaki.

In 2001, Aitutaki trochus shell reached a value of NZ$8500 per tonne and fishers harvested 37 tonnes (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 NZ$4370 per tonne and about 19 tonnes of shells were collected at a value to fishers of almost NZ$83000; in comparison fishers could receive NZ$8 per kg (NZ$8000 per tonne) for gilled, gutted and iced tuna.

Results from PROCFish/C surveys indicate that, at most sites, trochus were harvested throughout the year (mean of 33 trips per year) 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 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 Palau, Cook Islands and Wallis. By surveying the fishery, and examining recordings from past harvests, preliminary calculations suggest that fishers should fish in 3–4 year rotations and harvest 180 shell per hectare per year.

The Coastal Fisheries Program has very few recent country data on exports of mother-of-pearl. Green snails are found throughout the western Pacific and there have been some introductions to the east (eg Tonga). The species has been heavily exploited in almost all countries where it exists and stock levels have declined to very low levels. Some countries have taken firm action to allow stocks to rebuild – 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 US$50 million during peak production years. Sea cucumbers are not used as local food in most islands but are exported to Asian markets, mainly Hong Kong, China 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 led to the depletion of resources across the Pacific.

Of the 60 commercial sea cucumber species exploited worldwide, 35 species are present in the Pacific Islands region. The Western Pacific Islands of Melanesia, Palau, FSM and Tonga have a higher diversity than the rest of the Pacific (Fig. 9). The thick walled varieties such as the white teatfish (*Holothuria fuscogilva*), black teatfish (*H. whitmaei*), and stonefish (*Actinopyga miliaris*), tend to be slower growers, are present in lower densities, are reef dwellers and can be found down to 30m (white teatfish somewhat deeper). Sea cucumbers spawn throughout the year with peak activity in the warmer months.

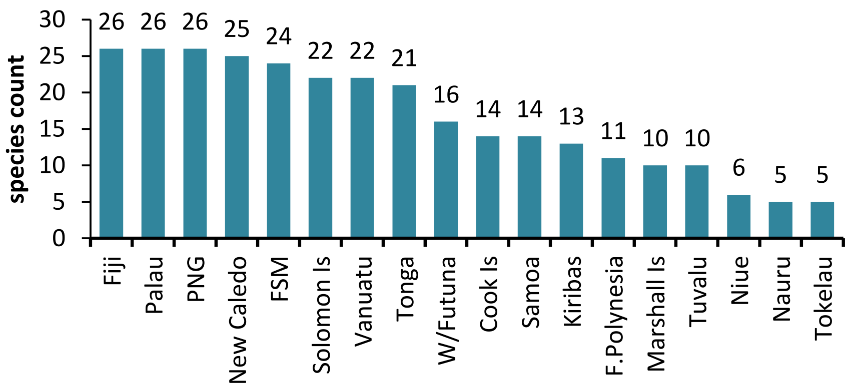


Figure 9. Commercial sea cucumber species recorded by PICs and territories.

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 invest in power boats, use of underwater breathing apparatus (SCUBA and hookah) diving gear, drag nets, "bombs" (lines with lead weights and hooks) or spear fishing, and night fishing using torchlight. UBA fishing has been the main cause of over-fishing of white teatfish and has been outlawed in most Island countries. 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. Products are salted, boiled, dried several times to reach final product stage. These dried products are consolidated in-country by specialist bêche-de-mer traders for exports. Quality has been a long standing problem contributing around 20–30% loss of the product value. Monitoring and control systems and training are needed to improve quality.

Product prices vary greatly by product type, by distance to market and from different processors and down the product chain. Boom production in the 1980s peaked in the 1990s and has declined since that time. Figure 10 shows the combined exports of beche-de-mer (expressed in tonnes, dried weight) for five countries included in an SPC study over the period 1971 to 2012 (Carleton 2013). The graphic has been overlain with a polynomial trendline reflecting the broad changes in export across this time series. In the broadest of terms, the recent evolution of the fisheries has been low-level exploitation through the 1970's, steady growth of exploitation in the 1980s reaching a peak in the early 1990s. Harvests dropped off after this but a secondary, lower level, peak was reached in the mid-2000s. Concerns about widespread over-fishing of stocks resulted in the subsequent closure of fisheries in the Solomon Islands, Vanuatu and PNG (the Tongan fishery was closed from 1997). In the late 2000s, with most fisheries subject to moratorium, regional production is being provided by Fiji and Tonga only – and in both these countries stocks are now thought to be over-exploited and reduced fishing pressure will be required in future years to allow for stock recovery.

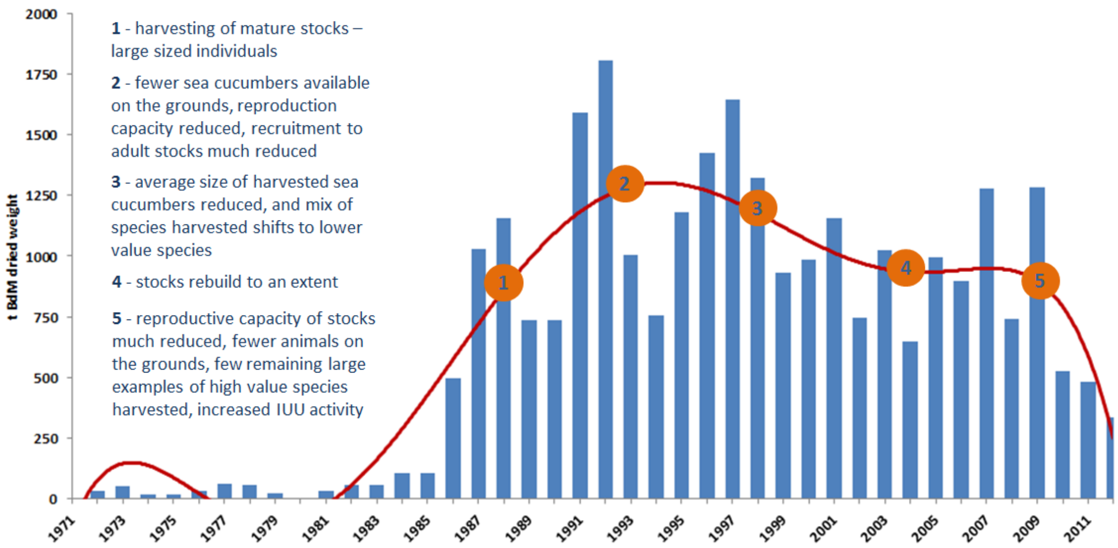


Figure 10. The combined exports of beche-de-mer (expressed in tonnes, dried weight) for the five countries under study over the period 1971 to 2012 (from Carlton 2013).

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

Areas of prolonged fishing without any form of management not only results in low abundance but loss of mature adults 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 do not have 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 the countries is being addressed. Successful management policies depend on strong enforcement but this is often under-resourced compared with those in offshore fisheries in most countries.

Table 2. 15 year average of beche-de-mer exports per country, by species, 1998 to 2012 – expressed in tonnes of dried product; plus estimated current purchase value (from Carleton 2013).

	15 year av. exports - t dried					value at current purchase prices - US$M				
	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
Deepw. blackfish	-	1	0	-	-	$0.00	$0.01	$0.00	$0.00	$0.00
Deepw 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 trunkf.	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	$0.66
average unit value of exports - US$/kg dried						$23/kg	$15/kg	$14/kg	$12/kg	$12/kg

Other invertebrates

There are very few catch statistics on other invertebrates even though they may be important in subsistence fisheries and local markets. These species include lobsters, crabs, and octopuses.

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 Pacific islands 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, banning the taking of egg-bearing females, and banning the use of underwater breathing apparatus.

Several species of crabs are caught and sold at local markets and the mangrove crab is 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), banning the taking of female crabs, banning the taking of berried female crabs, and banning the use of certain fishing methods such as gill nets and spears. Traps are one of the best ways of catching mangrove crabs as they do not damage the caught crabs which can therefore be released if they are females or are too small.

Octopuses are fished locally throughout Pacific islands using a variety of fishing methods including the use of lures, baited lines, traps and spears as well as 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, its density can reach 33,750 individuals per ha, or 3.4 individuals per m^2 at main fishing locations.

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.

The species targeted cause particular management concerns because their stocks are relatively fragile. The most sought-after fish are found in two families – **Serranids (groupers)**: *Plectropomus areolatus, Plectropomus leopardus, Cromileptes altivelis, Epinephelus fuscoguttatus, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus coioides*, **Labrids (wrasses)**: *Cheilinus undulatus* (this species, the humphead wrasse, is now red listed under CITES as an endangered species).

The decrease in the number of active exporting countries is a result of the improved awareness of the public and fisheries departments of the consequences of the trade, especially in trying to meet the minimum quantities, which may be up to 30 t of fish per shipment, required by buyers.

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 socio-economic 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.

Export of aquarium fish and invertebrates (including corals) from Pacific Island countries and territories started in the 1970s. It 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, Yeeting 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 to traditional fishery products (Lovell, McLardy 2008;Wabnitz, Taylor et al. 2003). In Tonga, the trade was ranked as the country's second highest income earner in 2008.

The trade currently operates out of 12 countries: Fiji, Papua New Guinea, Solomon Islands, Vanuatu, New Caledonia, French Polynesia, Marshall Islands, Tonga, Cook Islands, Federated States of Micronesia, Kiribati, and Palau. Commodities include coral reef fish, hard and soft corals, giant clams, live rock and a number of reef invertebrates (e.g., sea stars, crabs, shrimp etc).

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

The Convention on Trade in Endangered Species of Wild Fauna and Flora (CITES) provides a means to both monitor and regulate the trade in species listed. In the case of marine ornamentals and coral rock, more than 2,000 species of hard corals and all species of giant clams are listed under Appendix II. Parties to CITES, which include Fiji (1997), Vanuatu (1989), Palau (2004), Papua New Guinea (1975), Samoa (2004), Solomon Islands (2007), all overseas territories, and the main importers of marine ornamentals (i.e., USA and EU member countries) are required to submit trade figures annually in accordance with CITES guidelines (CITES 2011). Analysis of importers' data from the CITIES Trade Database (managed by UNEP 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 region peaked in 2006 and declined since (Fig. 11).

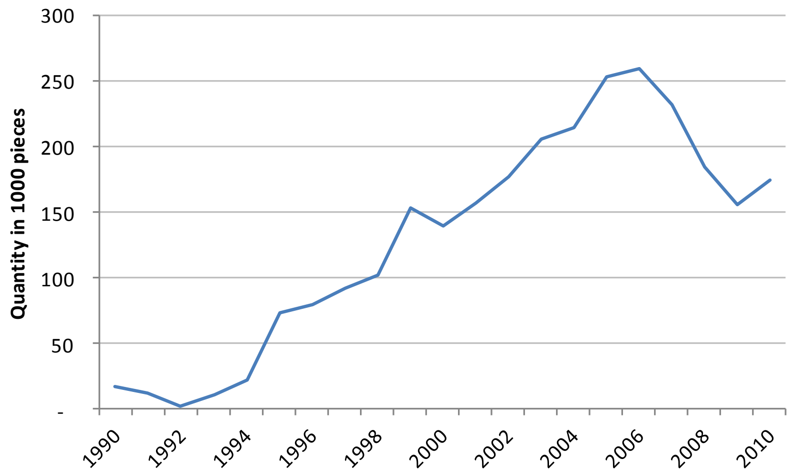


Figure 11. Direct trade from the Pacific region between 1990 and 2010 in live pieces of coral.

The decline post-2006 may, in part, be linked to (i) the economic downturn, in which people spent less on goods not considered essential and (ii) 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).

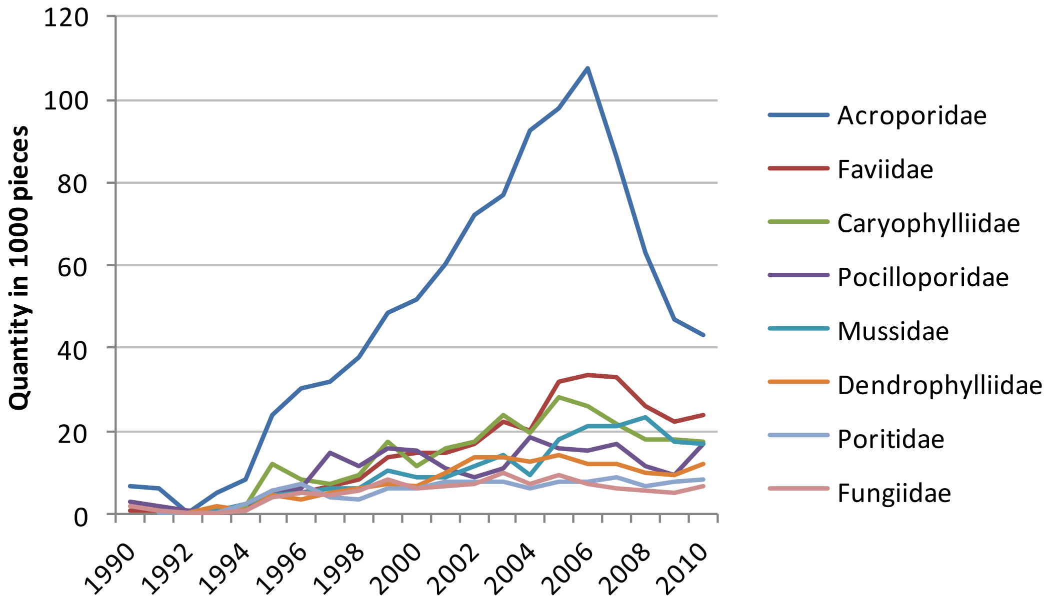


Figure 12. Trend in main coral families traded as live pieces for the marine ornamental trade.

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, the Solomon Islands, and Tonga capturing over the years analyzed 52%, 23% and 22% of the trade respectively. The United States 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 the Federated States of Micronesia and 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 3cm 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 2180t 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 following suit one year later. The United States was by far the leading importer of coral rock from the region, accounting for 93% by weight of the market over the period 1990–2010.

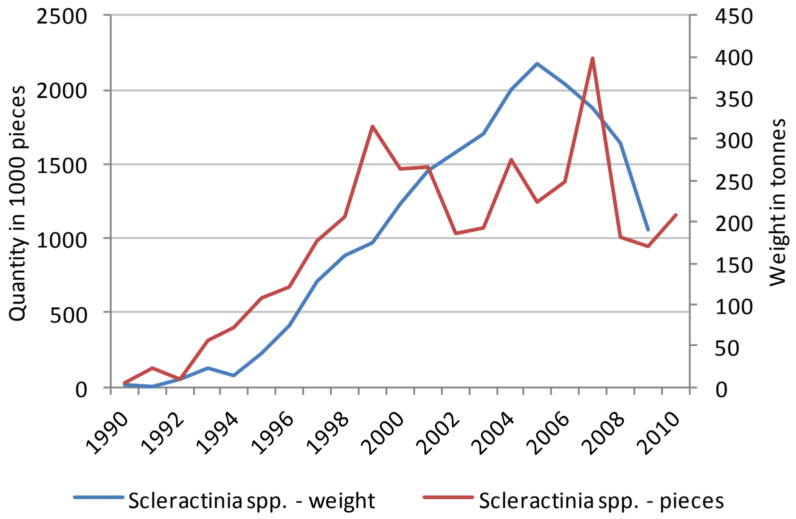


Figure 13: Direct trade in coral rock (*Scleractinia* spp.) by weight and number of pieces between 1990 and 2010.

The proportion of maricultured coral rock showed an increasing trend, from hardly any cultured coral rock in 2007, to 8% in 2008, 18% in 2009, and 23% in 2010. This is an encouraging trend as 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, Tuwai 2005).

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 importers' data, most specimens were traded in 2007. As noted above, the United States 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 decline registered subsequent to 2007 may in part be due to an increase in the use of artificial substrata.

Overall, 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 Pacific Island countries actively involved in the trade to further strengthen capacity in CITES requirements, nomenclature, species identification and enforcement of existing management rules.

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 Solomon Islands, Marshall Islands, Tonga, FSM, and Vanuatu contributed 83% of all clams to the marine live ornamental trade between 1990 and 2010.

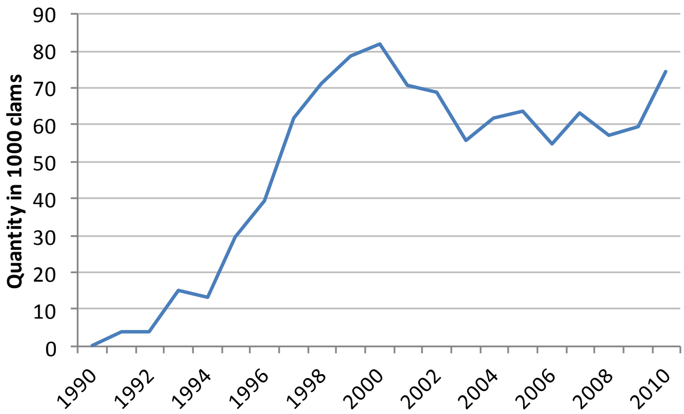


Figure 14. Number of giant clams in trade from PICTs between 1990 and 2010.

The United States, accounting for 68% of all imports, was the leading importer of giant clams from the Pacific region followed by Germany, France and the United Kingdom.

A particularly interesting trend is the decline, starting in 2000, of the collection of wild specimens for marine ornamental purposes and a significant increase in the contribution of cultured clam to the trade, with a sharp rise observed in 2010 (Fig. 15). Solomon Islands, Tonga, Vanuatu, Fiji, FSM, Marshall Islands and Palau accounted for 97% of wild exports; while Marshall Islands, Solomon Islands, FSM, Tonga, Cook Islands, Vanuatu and Fiji accounted for 94% of cultured clams traded. Aquaculture provides the means to more specifically regulate trade supply and also presents a more sustainable image to importing nations by reducing its footprint on reef environments

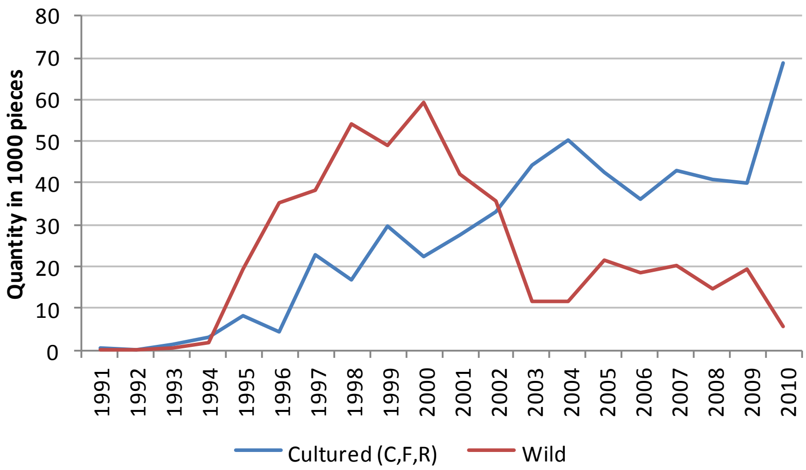


Figure 15. Direct trade in cultured and wild giant clam individuals from PICTS from 1990 to 2010.

Trade in the number of *Tridacna crocea* exported have declined over the time frame considered 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*, ~25% for *T. derasa*, while *T. crocea* averaged 20% for wild collection compared to 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, Braga et al. 2012).

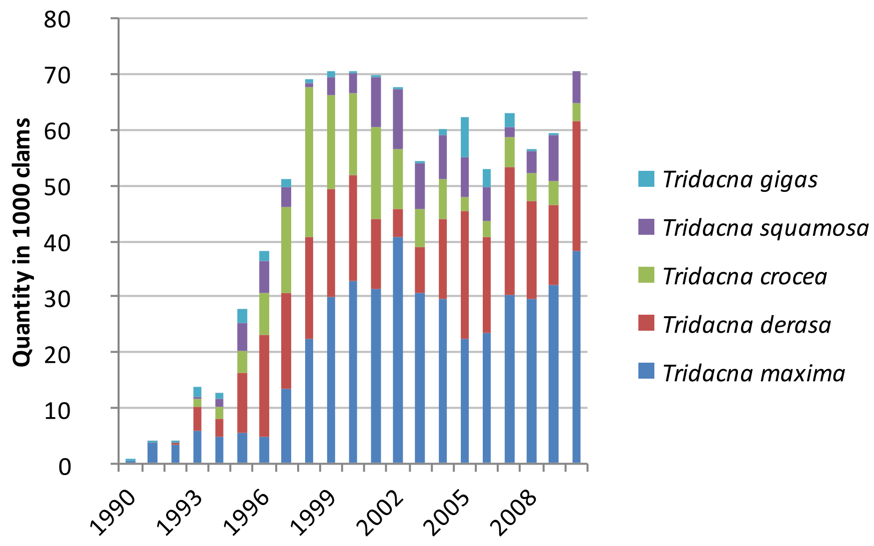


Figure 16. Number of individual species of giant clams exported as live marine ornamentals from 1990 to 2010.

Marine ornamental fish

No centralised mechanism exists to record and monitor the trade in marine ornamental fish, therefore precluding a region-wide analysis. However, in collaboration with local Fisheries Departments, SPC has been developing, and a number of countries successfully trialling, a database system, which allows for Fisheries Departments to monitor exports from licensed companies. The database can be customised to meet the 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, slated to be trialled in at least three more, with a view to eventually be implemented region wide. The system could also help track and monitor trade in invertebrate species besides coral and giant clams (e.g., echinoderms, crustaceans), which constitutes a small but diverse fishery.

General considerations relating to the aquarium trade

General considerations relating to the aquarium trade include positive and negative impacts to ecosystems and societies.

At a time when climate change and other anthropogenic impacts are threatening reef habitats, the species they support and the people that rely on them for their livelihoods, the onus is on those involved at all levels of the trade in marine ornamentals, including exporting countries, to ensure in demonstrable fashion that it is sustainable in the long term. To that end, regular collection of trade data, monitoring of target species abundance and reef health, development and enforcement of management plans, are some of the key requirements. Vanuatu, Tonga, PNG, Kiribati, Marshall Islands, Cook Islands and Kosrae have, or are in the process of developing, management plans.

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, Tlusty et al. 2012). Such actions need to be extended and local capacity strengthened.

As aquarists grow more conscious of the potential environmental impacts of the trade on resources, an increasing number of hobbyists are looking to stock their aquarium with 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 petrol prices and consequently freight rates worldwide. Incentives should therefore be placed on continuing to (i) implement measures that promote the sustainable collection of wild species; and (ii) where aquaculture alternatives exist, promote socio-economically viable mariculture initiatives at the community scale. 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 the right-sized specimens, focusing on species that are known to do well in aquaria, spreading fishing effort over a vast area, maintaining species adequately prior to shipping and packing them appropriately) the trade can cause minimum impacts on reef fish populations and surrounding environment, and has the potential to provide a sustainable livelihood for communities where income opportunities are few. Although global efforts to eco-label aquarium fishery products, including from Pacific islands 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 by all. The standards are to achieve the following goals: (i) the promotion of sustainable fishery practices, (ii) the fostering of good fishing and handling practices prior to export, and (iii) the promotion of good packing practices at export. These sets of practices are currently being written up so that they can be distributed regionally to further promote their implementation. In addition, to encourage the adoption of best practices by the industry, SPC has been and will continue working closely with governments and the private sector, to build capacity locally and train collectors in proper catching, handling, storing and shipping techniques.

Just like 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 on the market place, rather than actual supply. In other words, keeping a commodity as 'rare' will increase the likelihood that its price stays 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, greatly putting health and lives at risk. In summary, there must be sufficient balance of licenses (or operators) in a country or region such that the economic benefits of the trade are suitably widespread, however limited enough for incumbent operators to remain sufficiently 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 Pacific Island countries and territories 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 (SST), 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 (Tables 5.3 in Hoegh-Guldberg et al. 2011, and 6.5 in Waycott et al. 2011).

Coastal fish and invertebrate species are likely to be sensitive to changes in SST 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 which 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

Bottom-dwelling fish are expected to have a low vulnerability to the combined direct and indirect effects of climate change by 2035 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.

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 the EEZ. These are usually pelagic fisheries (fishing from 0–500 m depth) and tuna is 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 from 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. Hence there is a comparatively good knowledge of the status of regional tuna stocks that nearshore fisheries rely upon. 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 tuna 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 – not so much in expansion of the total catch as expansion of the Pacific Island share in the catching and processing sectors.

The catch composition based on total catches in the Pacific Ocean is skipjack *(Katsuwonus pelamis)* 63%, yellowfin *(Thunnus albacares)* 24%, bigeye *(Thunnus obesus)* 8%, and albacore *(Thunnus alalunga)* 5%. The status of these four main tuna stocks in the western and central Pacific Ocean are regularly assessed by the SPC's Oceanic Fisheries Programme, and the reports can be found at (http://www.spc.int/oceanfish/Html/SAM/StockAss.htm). In addition, the 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), which is the regional fisheries management organisation for the tuna and other highly migratory fish stocks of the Western and Central Pacific Ocean.

Tuna are highly migratory species, which are found throughout the EEZs of PICTs. The industrial purse seine fishery, and to a certain extent the longline fishery (larger vessels from distant water fishing nations – DWFN), fall outside the scope of this coastal fisheries report. However, there is an overlap of tuna fishing activities with domestic longline vessels and small-scale tuna boats fishing in association with fish aggregating devices (FADs), trolling close to the reef, and trolling tuna schools usually within 10 nm of the reef. Trolling and mid-water handlining from small-scale vessels is covered in more detail in the next section, as a mix of other nearshore pelagics is also taken in the catch. The annual catches of tuna from within the EEZs of PICTs are shown in Figure 17.

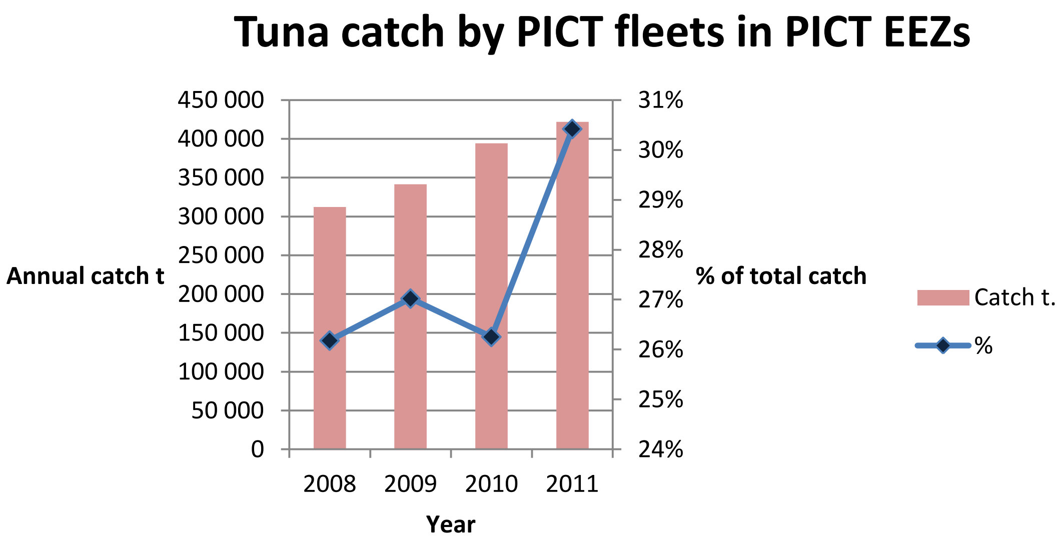


Figure 17. Tuna annual catches (t), shown as a histogram, from within the EEZs of PICTs. The percentage of the total tuna catch is shown as a line (from SPC, OFP database).

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. The industrial tuna fishing companies in Papua New Guinea and the Solomons have ongoing FAD programmes for their fleets, and they allow small-scale fishers to use them. To further utilise the FADs in Papua New Guinea, pump-boats have been brought in from the Philippines to handline for tunas around the FADs. Tuna catch rates (kg per hour) from trolling around FADs are often three times the catch rates of tunas taken when chasing tuna and trolling in open water and around reefs. The range of types of FADs is shown in Figure 18.

There is also one significant small-scale tuna fishery in the Pacific that does not use FADs; the troll and pole fishery from South Tarawa in Kiribati, where around 200 outboard-powered skiffs fish on a daily basis (weather permitting) for tunas. FADs are starting to be used in this fishery which catches over 1500 t annually and all sold locally. Many countries, especially in Polynesia, rely on catching tuna from small outboard-powered boats and canoes to supplement their overall fish consumption needs.

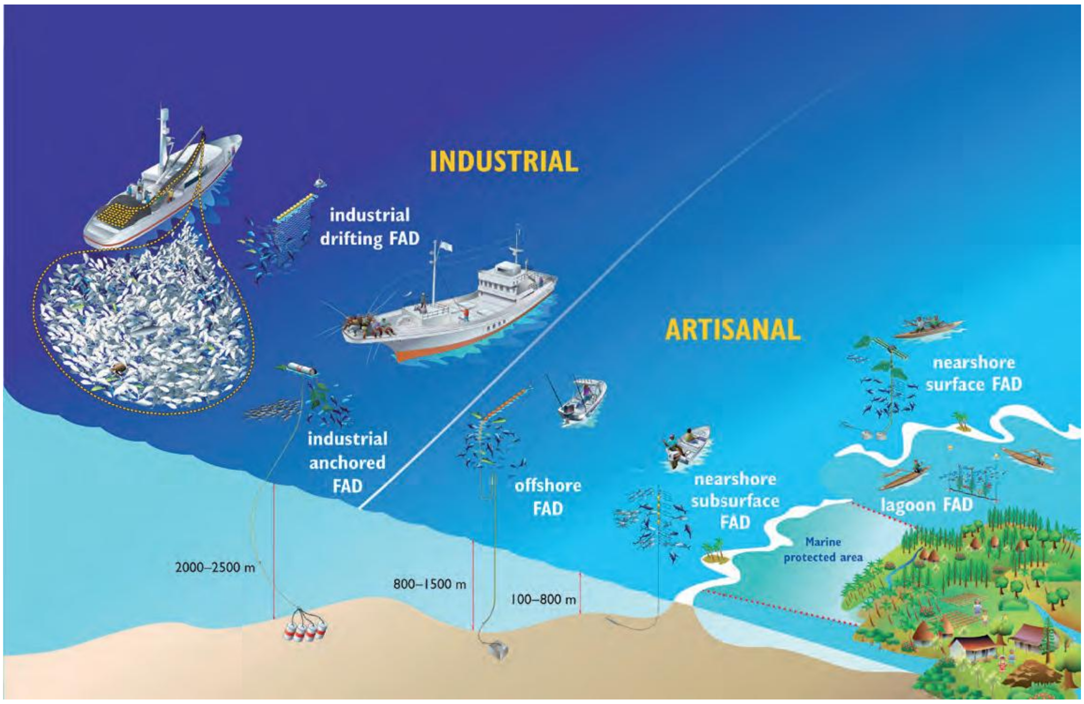


Figure 18. FAD types, users, location and typical depths in the Pacific.

Status of other nearshore pelagic fisheries

The nearshore fishery for non-tuna pelagic fish is primarily a surface troll fishery outside the reef and around fish aggregating devices (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 west of the region.

Trolling is carried out in all PICTs, with thousands of small outboard-powered dinghies and skiffs, as well as some motorised outrigger canoes involved. 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 such vessels/canoes fishing for both subsistence needs and livelihoods. Catches vary considerably from country to country, although data is poor in most PICTs where there are limited or no data collection systems in place. In some countries, the catch of non-tuna species is higher than that for tuna.

Nearshore pelagics and the use of FADs are also important for the slowly expanding gamefishing operations in the Pacific. Most PICTs now have charter fishing operations taking 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 an increasing number of recreational fishers chasing these species.

Very little is known about the stocks of non-tuna pelagics, although through the work of the new WCPFC, some of these species, such as some marlin species and possibly wahoo, will be targeted for stock assessment work in the future. Currently, there are no management plans for these species.

There are a range of other fishing activities targeting pelagic species in PICTs, some are traditional, while others are using new technologies, and these include:

- Scoop-netting of flyingfish at night with 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 allow the chasing of flyingfish, and battery-powered spotlights are mounted on bike helmets to make the spotting easier. Little is known on the number of flyingfish species being targeted, and the status of these stocks.

- Baitfishing in lagoons and in passageways at night using light attraction and a Bukiami net targeting sardines, pilchards and anchovies, plus many other species, is a method practiced by commercial tuna pole-and-line vessels. The number of countries using this method has dwindled over the last 25 years.

- There is a 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-backed 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, in conjunction with the New Caledonia Merchant Navy and Sea Fishery Department (SMMPM), carried out some exploratory fishing trials for diamond-back squids in waters off New Caledonia. This resource has been commercially exploited in Okinawa (Japan) since the late 1980s with catches 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 also to identify a possible alternative for nearshore commercial fishers in New Caledonia. The trials consisted of eight fishing days, setting 20 vertical drifting lines 500 m long, each fitted with four jigs, with the fishing undertaken in depths of 1500 to 2000 m. The results far exceeded SPC's hopes, as no less than 70 squid, amounting to a total weight of 785 kg (average weight 11.2 kg) were caught. Two species of commercially exploitable 'giant' squid therefore occur in New Caledonia and apparently in major quantities: the diamond squid (*Thysanoteuthis rhombus*), or 'sei-icko', as it is known 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 another species, the purple flying squid (*Ommastrephes bartramii*), smaller in size and with lower commercial value (35 specimens caught, average weight 4.6 kg).

  Even if the price paid for diamond squid to Japanese fishers appears not high enough to consider exporting it from the Pacific Islands to Japan, it does seem quite feasible to develop this resource as part of efforts to diversify coastal fishing, by targeting local markets and restaurants. Contrary to most cephalopods, the diamond squids are present in male/female pairs. This therefore is a fragile resource liable to shrink rapidly if overfished. The development of a management plan for this resource would therefore be required before beginning commercial exploitation of diamond squid.

- Small pelagic fish, such as sardines, mackerels, scads and anchovies, are a plentiful and rich protein source, which remains relatively underexploited in the Western and Central Pacific Ocean. Diverting fishing effort from large predators, reef fish and invertebrates to more robust stocks, such as small pelagic fish, has the potential to rejuvenate the 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 (Dalzel, 1990). As with any fishery, increasing effort must be done with caution and yields must be maintained within sustainable levels.

  As reported by Sokimi (2012), SPC, in conjunction with the Pacific Islands Forum Fisheries Agency (FFA) and the Marshall Islands Marine Resource Authority (MIMRA), is researching the potential of an Indonesian adopted fishing technology in the Pacific. This fishing technique is operated from an anchored platform, called a 'Bagan' in Indonesia. 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 is available at this stage to estimate catch rates, however, albeit in small quantity, the catch from the initial fishing trials sold quickly for US $1.50/lbs on the local market, which is indicative that there is demand for small pelagic fish in Majuro. If successful, this project will provide an alternative source of food and income from a sustainable fish resource, which 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.

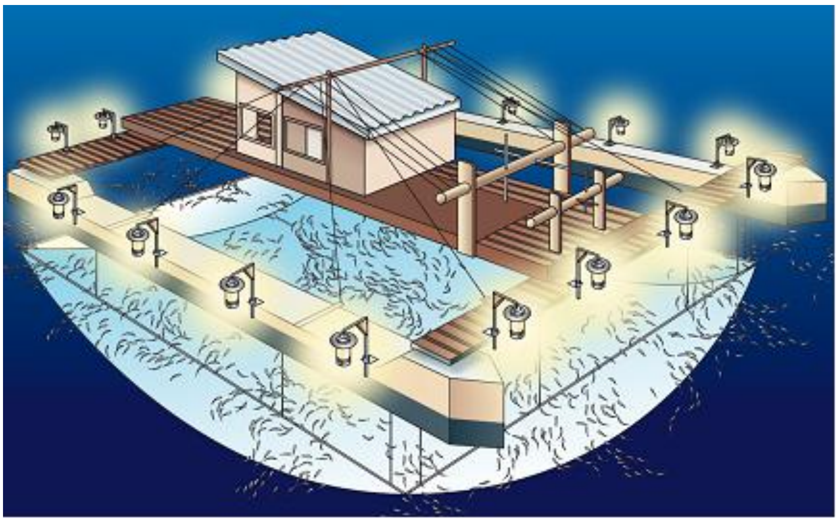


Figure 19. A typical bagan, a floating platform, that uses lights to aggregate fish and lift-net to capture them.

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. When the large projected differences in abundance of tuna between the west and the east, and the greater projected decreases in productivity of zooplankton in the west are combined with the average proportions of tuna and non-tuna species in the catch, there are substantial differences in projected abundances 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.

Despite the projected decreases in availability of nearshore pelagic fish in the west, countries located there should be in a position to substantially increase catches of tuna by nearshore pelagic fisheries in the years ahead because there should still be ample tuna 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 tuna 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 between 100 and 400 m depths, on the outer reef slope and on seamounts. 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 fishes.

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 (MSY) for each country based on an annual harvest of 10–30% of the virgin biomass. As 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 Papua New Guinea, Fiji and French Polynesia, had a much larger virgin biomass (Table 3). Since these preliminary MSY 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)
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
Northern Marianas	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 & Futuna	10–30
Samoa	19–57
Total	**2313–6719**

Source: Dalzell & Preston, 1992

The 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 Papua New Guinea 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 that started in the 1980s and continues today. However, the fishery, which is based on fishing the many seamounts within the Tonga 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 programs in place for the deepwater snapper fishery. The three US territories (Guam, CNMI and American Samoa), have had management plans in place since August 1986 and these 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 been updated or revised since. A management plan was drafted in 1995 for the Tuvalu deepwater snapper fishery although 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 their 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, 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 demography of harvested species.

Preliminary data indicate that many species associated with deepwater demersal fisheries in the Pacific Island region have extended lifespans (> 20 years), are generally slow-growing and late to mature, making them vulnerable to overfishing. Based on the recommendations of the workshop, 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 region. 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 to those from the 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 OFP 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 international waters between Tonga and NZ, 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 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, and these include:

- Deepwater shrimp fishing trials were conducted in many PICTs in the 1980s, with catches in 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 is available on these trials, the catches taken, and little is known on the stock status of these species.

- The trapping of deepwater crabs in depths of 500–700 m has occurred in Vanuatu, Palau, Tonga and the Cook Islands. Little is known about the fishery or the status of deep-water 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.

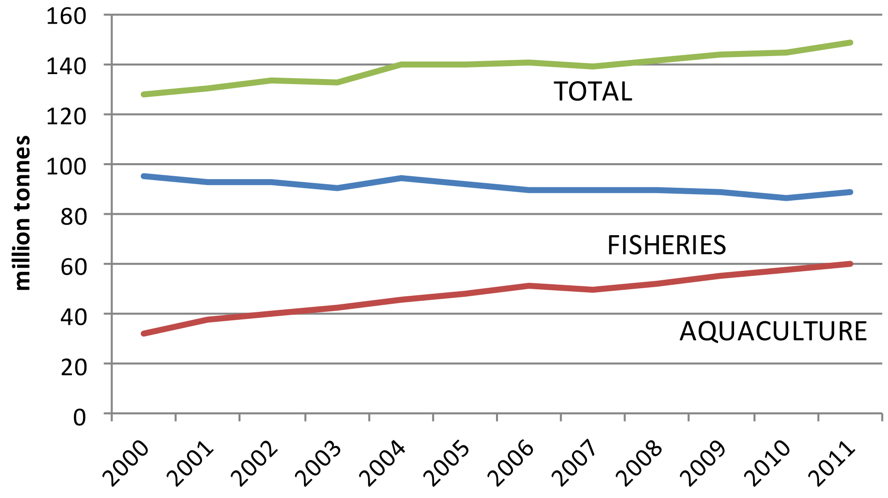


Figure 20. Production in millions of tonnes from fisheries and aquaculture (FAO data).

Aquaculture in the Pacific

Aquaculture systems introduced to the region in early 1950s by SPC have only become established within the past few decades. Today, aquaculture in the Pacific is becoming increasingly more widespread and is quite diverse for such a relatively small terrestrial area.

Like many primary development sectors in the Pacific, aquaculture is often constrained by the remoteness of the region, distance to markets, lack of basic infrastructure, institutional capacity, social/cultural values and marketing. Models which are technically feasible in one place cannot simply be transposed into another and many Pacific Island countries 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 percent of the total value from aquaculture. New Caledonia, Fiji Islands and the Cook Islands make up almost all of the remaining total value of production. The key commodities produced by these countries are cultured pearls and marine shrimp, which are high value and 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, production in aquaculture from the region has dropped significantly as a result of a decline in pearl production. By 2010, the value of aquaculture in the region had reduced to about USD 100 million.

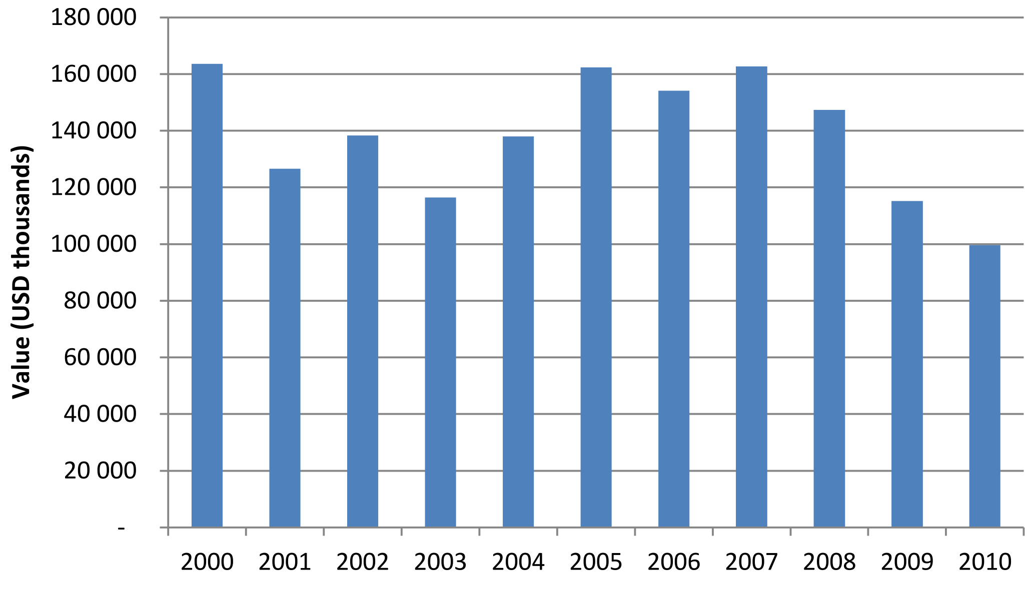


Figure 21. Value of aquaculture in Pacific islands by year, from pearl, shrimp, milkfish, finfish and seaweed production (Source FAO FishSTAT, 2012).

The most valuable commodity produced in the Pacific has until 2008 has traditionally been cultured pearls. However, pearl production from the two main pearl producing countries of French Polynesia and Cook Islands has declined from over USD 140 million in 2007 to about USD 85 million in 2010

(Fig. 22). The collapse in value of pearl from French Polynesia was mainly due to oversupply and poor market prices and in Cook Islands related to disease, environmental problems and market value (Hambrey, 2011).

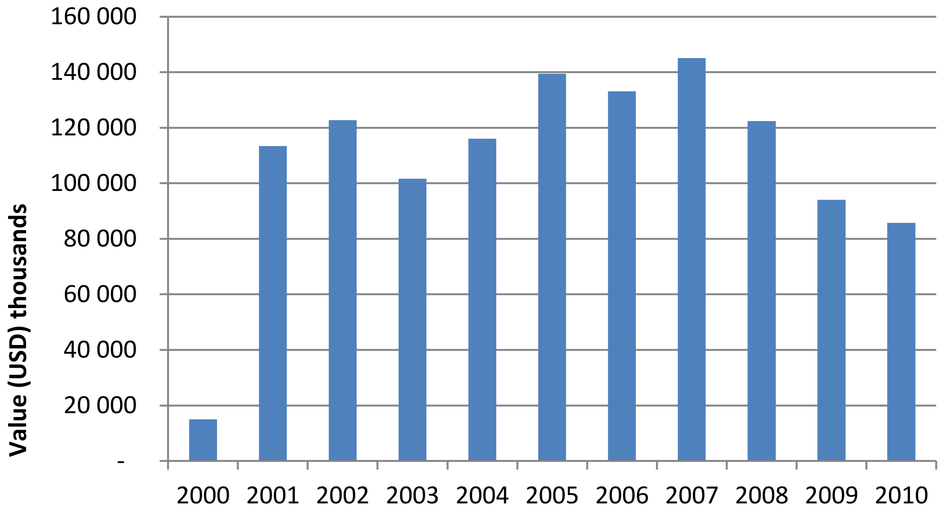


Figure 22. Value of pearl production from major pearl producing countries (Source FAO data).

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

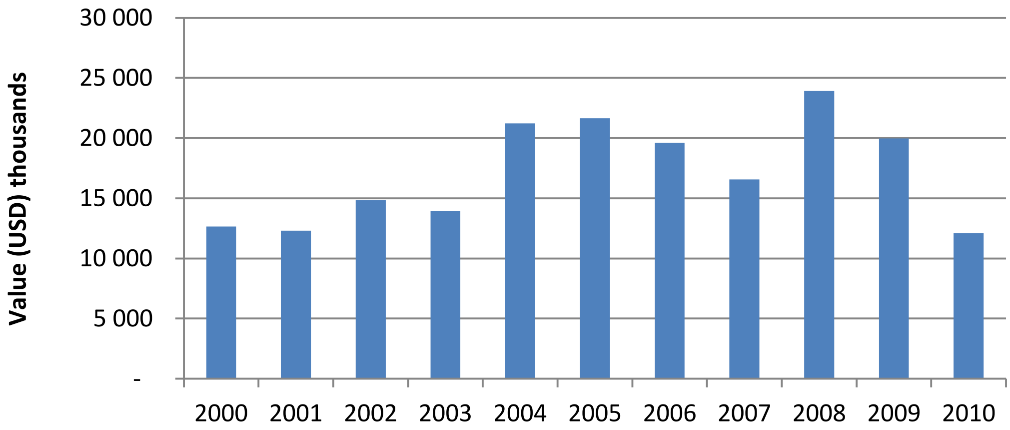


Figure 23. Value of Shrimp production from New Caledonia and French Polynesia (Source FAO data).

The contribution of other species and countries to aquaculture can be best seen by removing shrimp and pearl from New Caledonia and French Polynesia respectively from the data (Fig. 24). Pacific oyster in New Caledonia has the highest value (US$700,000) followed by tilapia production in several countries including Papua New Guinea, Fiji and Vanuatu. Seaweed production is increasing, mainly in Solomon Islands and Fiji.

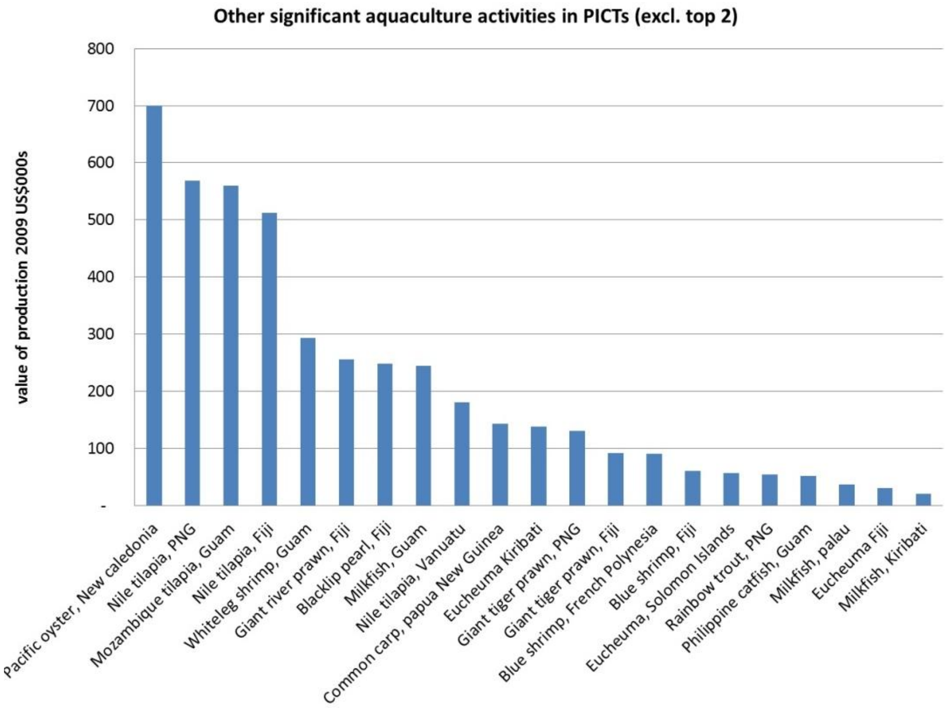


Figure 24. Value of cultured species in Pacific island countries in 2009 excluding shrimps and pearl production from New Caledonia and French Polynesia (from Hambrey, 2011).

Role of aquaculture in livelihoods and food security

The population in the Pacific is expected to grow by almost 50% by the year 2030. The two major focal areas where aquaculture can assist society to meet this challenge is through the provision of livelihoods such as in household cash and through improving food security to ensure a ready access to fish protein and good nutrition.

Key commodities (Fig. 25) which have been identified as 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. Most of these commodities in the past were focused on export markets, but the region is also facing increasing urbanization which has now created an expanded domestic market.

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

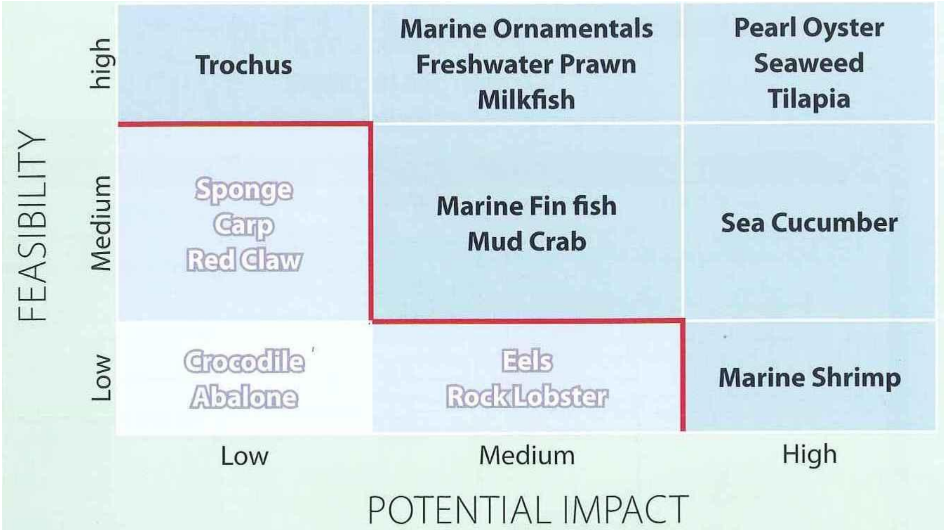


Figure 25. SPC Aquaculture Commodity Priorities (SPC Regional Aquaculture Action Plan 2007).

Opportunities for the culture of marine ornamentals especially giant clam and coral culture targeting the aquarium trade industry appears promising especially for locations that are accessible to international airports.

In addition to the high production in New Caledonia, other countries presently producing shrimp in the region and targeting domestic markets include Northern Mariana Islands with 25 t yr^{-1}, Guam with 10 t yr^{-1} and French Polynesia with 50 t yr^{-1} (Patrois, 2010). The last named has a high domestic demand for 600 t yr^{-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 yr^{-1} but sourcing sufficient number of broodstock from the wild remains a challenge for the operation.

Freshwater (*Macrobrachium*) prawns are relatively easy to grow in ponds and highly marketable. It is thought that satellite prawn farms in rural areas could supply larger central operations similar to the chicken grower 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 have been developed. There is a high interest from Pacific countries in adopting aquaculture techniques to restore their wild sea cucumber fishery. However it is unclear to what extent aquaculture can contribute to the restocking of depleted wild stock or form the basis of profitable sea ranching or pond farming systems. 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 industry. Although farming of seaweed is simple and ideal for coastal villagers the costs of shipping large quantities makes it only marginally profitable. The major producing country for seaweed in the region in 2010 was Solomon Islands with 8,000 t followed by Kiribati with 4,700 t. A major seaweed processor has now been established in Fiji. A hardier strain of seaweed which is more tolerant to heat is recently been sourced by Fiji from Indonesia and it is likely that seaweed production will increase in the region in the coming years.

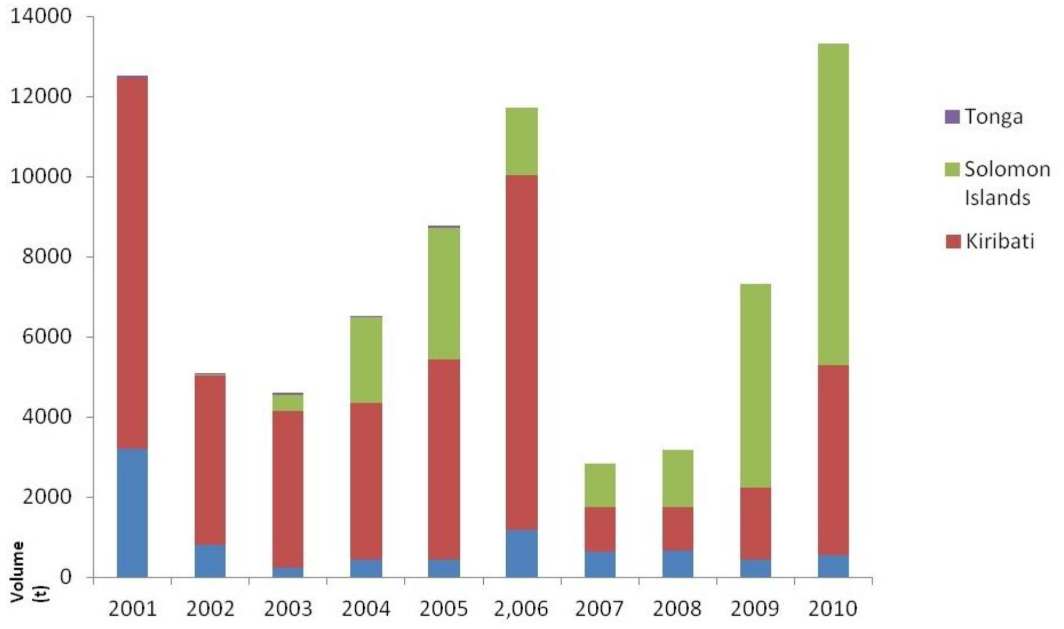


Figure 26: Weight (t) of *Kappaphycus* seaweed farmed in the Pacific region (FAO data 2012).

In order to maintain the current rate of fish consumption per capita against the growing population, it is expected that an additional 100,000 t of fish will be required. This 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 amongst the most suitable species to help meet the food security needs.

Nile tilapia being easy to farm can provide a protein source for the poor. It can also supply high value markets and is amongst the top five fish species sold in the United States. Nile tilapia has been sold in municipal markets in Fiji for many years and more recently has proved popular in countries such as Vanuatu and the Cook Islands. In inland areas it has prospects for artisanal farming and many of the estimated 10–15,000 fish farmers in Papua New Guinea are likely to benefit.

The SPC Aquaculture Action Plan

As a regional bloc, the SPC Members at the SPC/FAO Regional Aquaculture Scoping Mission in Nadi in October 2011, reviewed the existing SPC Aquaculture Action Plan 2007. The 2007 Plan strategy set the regional focus on aquaculture based on prioritizing commodities for livelihood and for food security in the region as well as identifying important cross-cutting issues surrounding the sector. It was agreed that prioritizing commodities be best left for countries to decide while for a new regional strategy, focus should be on program 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 its role to play in helping to preserve the unique biodiversity that sustains our fishing traditions and ethno-biodiversity. Aquaculture must also take a more holistic “ecosystems approach” so that it does not cause an imbalance to the natural ecology and affect other 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 the 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 livelihoods (pearl oysters, shrimp, seaweed), and the lesser cultured commodities (giant clams and other marine ornamentals, marine fish, sea cucumbers and trochus), are expected to be more vulnerable to climate change. They will be exposed to 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 temperature. However, potential longer-term negative impacts include greater risk of temperature-related diseases and problems in drying out ponds 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 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 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 livelihoods 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.

5. Roles of women and men in fisheries

Knowledge of gender roles and their changes are an important input to effective fisheries management, as it 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 study (2002 – 2009).The general dominance of fishermen still persists (Fig. 27) and this is particularly visible in regard to participation of fishers who exclusively target finfish. The opposite is true for fishers who exclusively target invertebrates which remains a women's domain.

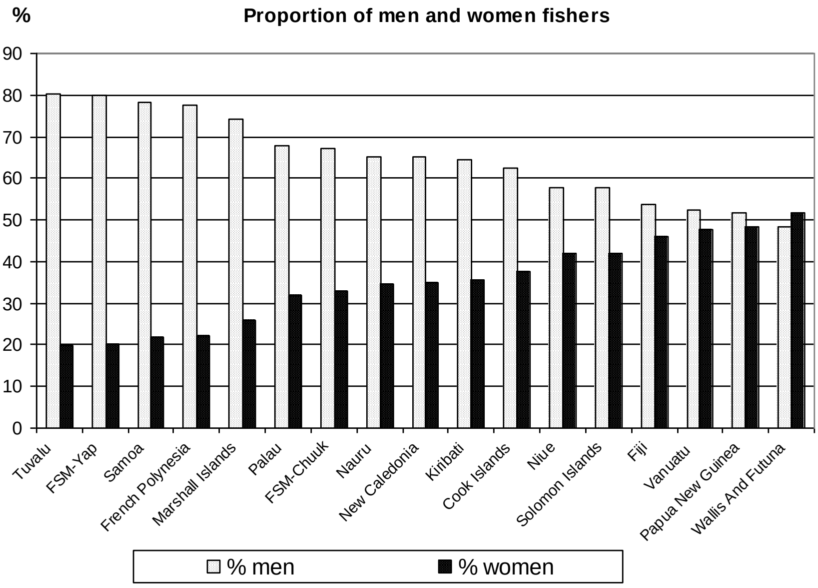


Figure 27. Proportion of men and women fishers by country.

If we compare the participation of men and women targeting finfish and invertebrates (not necessarily at the same time), three groups emerge in the figure below. Fiji, Papua New Guinea, Solomon Islands, Niue, Wallis and Futuna, and Palau, where the ratio between men and women fishers is comparable; New Caledonia, Vanuatu, Nauru, Cook Islands, and perhaps Samoa, where women's participation is significantly less than men's; and finally Yap, Kiribati, Tuvalu, Marshall Islands and French Polynesia with either no or very little participation of women in fishing activities.

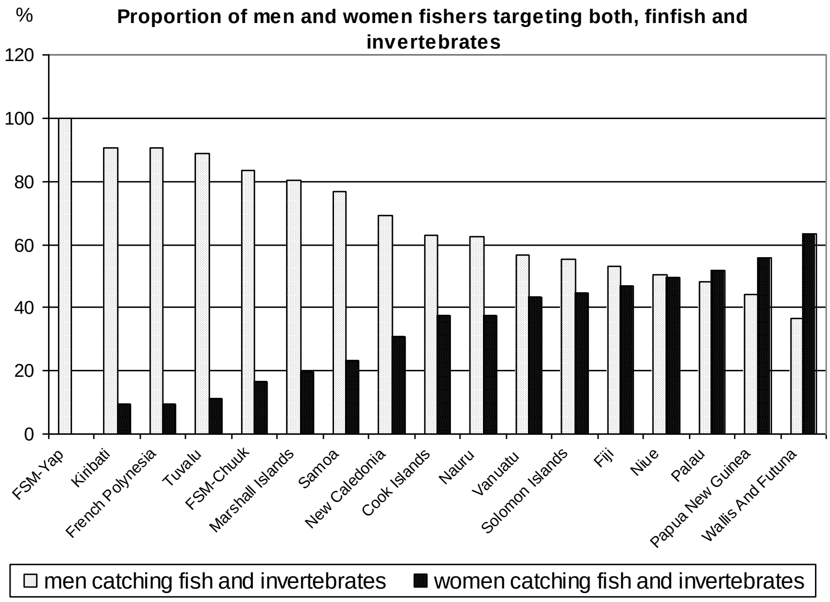


Figure 28. Participation (%) of men and women fishers who target both finfish and invertebrates.

Role of women and men in fisheries management

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

The study reveals that women only represent 18% of the total number of staff working in the fisheries science and management sector in government fisheries, environmental institutions and environmental NGOs. In contrast, the number of women employed in administrative and clerical roles in government fisheries divisions exceeds 60% (Fig. 29).

SPC's FAME Division strongly believes that all fisheries careers are equally acceptable to women as to men and focuses on "breaking down the barriers" to help women moving into the fisheries area if they so choose. For its own recruitment procedures, SPC provides equal employment opportunities for all positions.

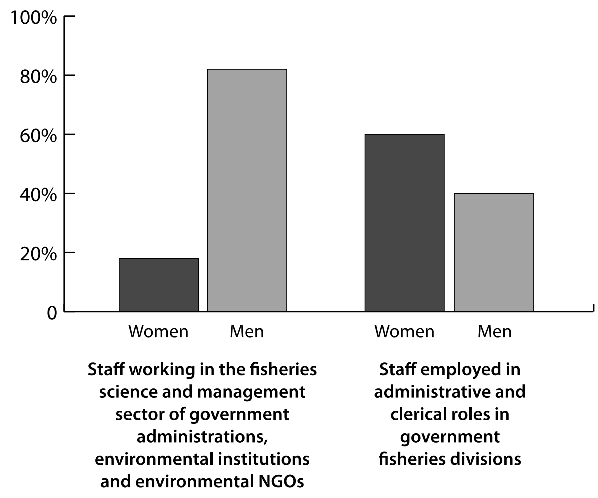


Figure 29. Percentage of men and women employed in fisheries science and management compared with the percentage employed in administrative and clerical roles in government fisheries divisions.

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