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In this issue

Editorial

Two of the three feature articles in this issue relate to coastal marine resource assessments, and they, not surprisingly, ring alarm bells.

In Fiji, Jeremy Prince and colleagues assessed the spawning potential of 29 reef fish species using a new technique called the length-based spawning potential ratio (p. 28). The methodology involves community members who are trained to measure fish length and assess fish maturity stages. The training gives them a glimpse of the science 'hiding' behind management decisions. With a better understanding of why stocks need to be managed, community members should better accept regulations when these are put in place. And, regulations will be needed, as the researchers' findings show that many of the stocks studied are in crisis.

In Pohnpei, Federated States of Micronesia, Andrew Halford, Pauline Bosserelle and their research team have collected data on mangrove crab stocks (p. 42). They found a resource clearly in need of a new management plan but note that the real challenge will be its effective implementation.

Considerable effort has been made to develop coastal fisheries management plans in the Pacific Islands region, but lack of enforcement capacity has made their implementation difficult. Transferring some of the enforcement responsibility to communities could help but, as noted in the first article of this issue (p. 2): '... it is difficult for community members to monitor each other'. Placing more emphasis on education and awareness, to ensure that resource users understand the need for regulations, is one of many ways to address the lack of enforcement capacity.

Aymeric Desurmont, *Fisheries Information Specialist, SPC*

Selling fish by the roadside, Tarawa, Kiribati. (image: Johann Bell)

FAME
Fisheries Aquaculture and Marine Ecosystems Division

Scaling up Tonga special management areas through community-to-community exchange

A special management area (SMA) is a locally managed marine protected area. In the Kingdom of Tonga, The Fisheries Management Act (2002) enables communities to set up SMAs to control fishing activities and create resource management rights for areas adjacent to their village. These communities take the leading role in managing their coastal fisheries resources with assistance from the Fisheries Division. To enhance Tonga's SMA programme, which is designed to implement SMAs throughout the country, the Ministry of Fisheries organised a three-day national workshop in Neiafu, Vavau with the support of partner organisations.[1,2]

Hon Semisi Tauelangi Fakahau, Minister of Agriculture, Forestry, Food and Fisheries (front row, fourth from left), with representatives from the Government of Tonga. He was honored by communities and partner organisations for his presence and active involvement during the three-day meeting. (image: Céline Muron, SPC)

A workshop to share knowledge and experiences

The workshop took place in Neiafu, Vava'u, from 30 April to 2 May 2019, and broughttogether around 150 participants from existing SMA communities, interested communities, and relevant stakeholders from government, non-governmental organisations, and funding partners.

One of the key objectives of the workshop was to provide local communities with a chance to share lessons learned in implementing an SMA and broader fisheries management measures.

Establishing SMAs

Fishing in the Kingdom of Tonga has historically been open access, with all Tongans having equal access to coastal fishery resources. Open access fishing encourages he harvesting of as much as possible, as fast as possible and, therefore, often leads to a lack of fishers' involvement in marine resources and habitat management (Petelo et al. 1995). In Tonga, it

[1] The national SMA workshop, organised by Tonga's Ministry of Fisheries, was supported by the following partner organisations: Food and Agriculture Organization of the United Nations (FAO); the Italian Ministry for the Environment and Sea; Mainstreaming of Rural Development Innovation (MORDI); the Pacific Community under the Pacific-European Union Marine Partnership programme; the Vava'u Environmental Protection Association; and the WAITT Institute.

[2] The PEUMP (Pacific-European Union Marine Partnership) programme is funded by the European Union and the Government of Sweden. For more information: https://fame1.spc.int/fr/projets/peump

has triggered increasing concerns over the depletion of local fisheries resources, degraded marine habitats, and an absence of adequate actions to address climate change consequences. In the mid-1990s, it was considered that coastal communities in Tonga should be granted legal powers to manage fisheries in their nearby coastal areas. As a result, in 2002, Tonga's Fisheries Management Act was amended to allow local communities to manage their nearby marine areas through the establishment of SMAs, and thus the Ministry of Fisheries launched the SMA programme. Four years after the amendment of the Fisheries Act, the first SMA was established at 'O'ua in the Ha'apai group. To date, 40 SMAs have been established throughout Tonga.

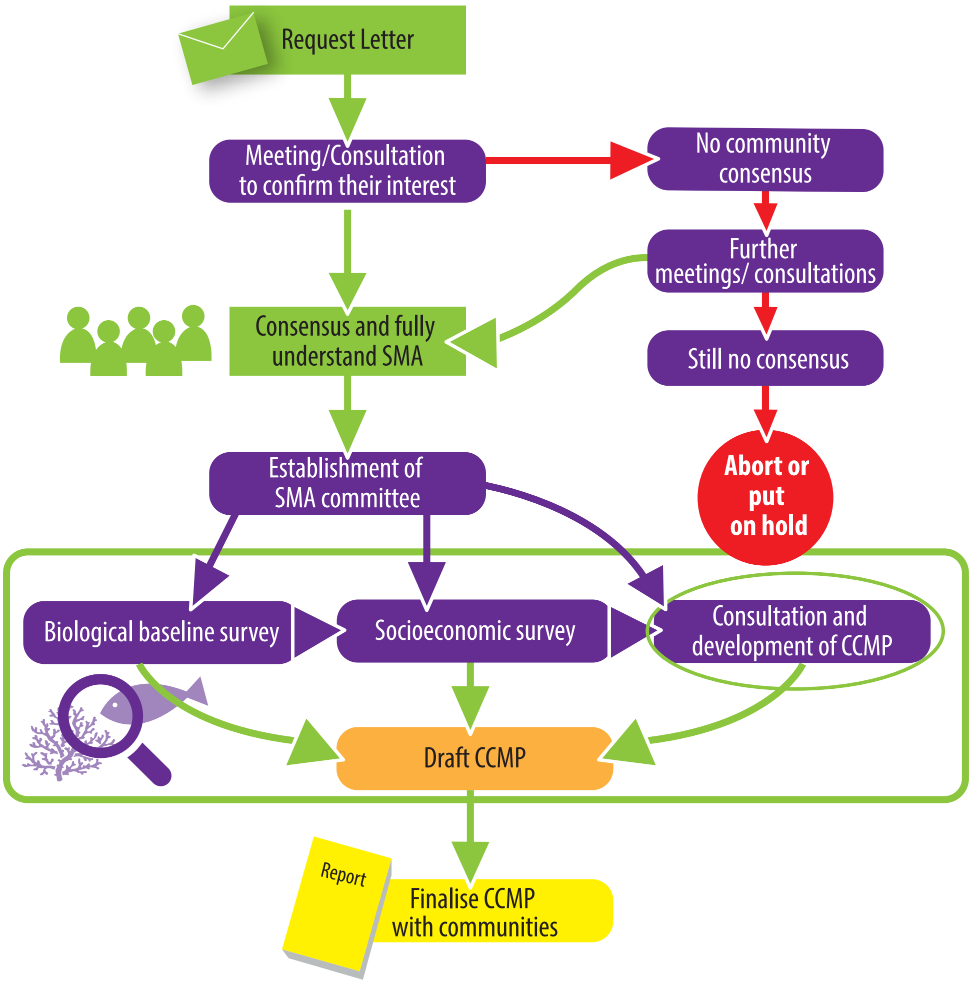
SMA process

Communities interested in establishing an SMA need to submit a formal request to the Ministry of Fisheries, which then assesses whether there is a large consensus within the community about the issue. If the establishment of an SMA is granted, the Ministry of Fisheries will assist the community in developing a management plan.

Why are SMAs unique?

As with other community-based management tools in the Pacific Islands region, SMAs aim mainly at restricting access to fishing grounds for varying periods, setting up catch sizes and quotas, and regulating fishing methods. What makes SMAs unique in the region is that they are only open to registered community members; and, if there is a reserve area within an SMA, then the reserve is closed to everybody, including registered community members. SMA committees can seize equipment and report breaches to the government, which will, in turn, prosecute.

Table 1 describes the roles and responsibilities of the various stakeholders involved in SMAs governance.



Process followed to set up an SMA and develop a coastal community management plan (CCMP).

Table 1. Governance of a special management area as a community-based management tool.[3]

Lead stakeholder	Role of government	Management committee (name/composition/role)	Legal framework
Communities	**Assessment** of community interest **Technical support** - Facilitate management planning process - Assess resources (baseline surveys and monitoring) - Provide regulatory and legal advice **Seek funding** for community	**Name:** Coastal community management committee (CCMC) **Composition:** - Chairperson (elected by the community) - Town officer- District officer - 2 representatives among fishers - 2 representatives among women - 2 representatives among youth - 1 representative from the Ministry of Fisheries **Role:** - Develop a participatory management plan - Assist with its implementation - Maintain registers of fishers and vessels allowed to fish in SMA - Enforcement	SMAs are established by the 2002 Fisheries Act. Local rules are legalized (similar process to the one used for Samoan by-laws) since the 2009 Fisheries Coastal Communities Regulations.

General fishing conditions for SMAs

In Tonga, the following conditions apply to fishing in an SMA:

- Only fishers and fishing vessels listed in the fishers register and fishing vessel register of an SMA are authorised to fish in that SMA. Any other person or vessel owner not listed on either register may apply for a fishing permit from the SMA Coastal Community Management Committee.
- No person shall harvest any marine organism for the aquarium industry – this includes hard corals, soft corals, small invertebrates and aquarium fish.

The following priority needs were highlighted during the workshop:

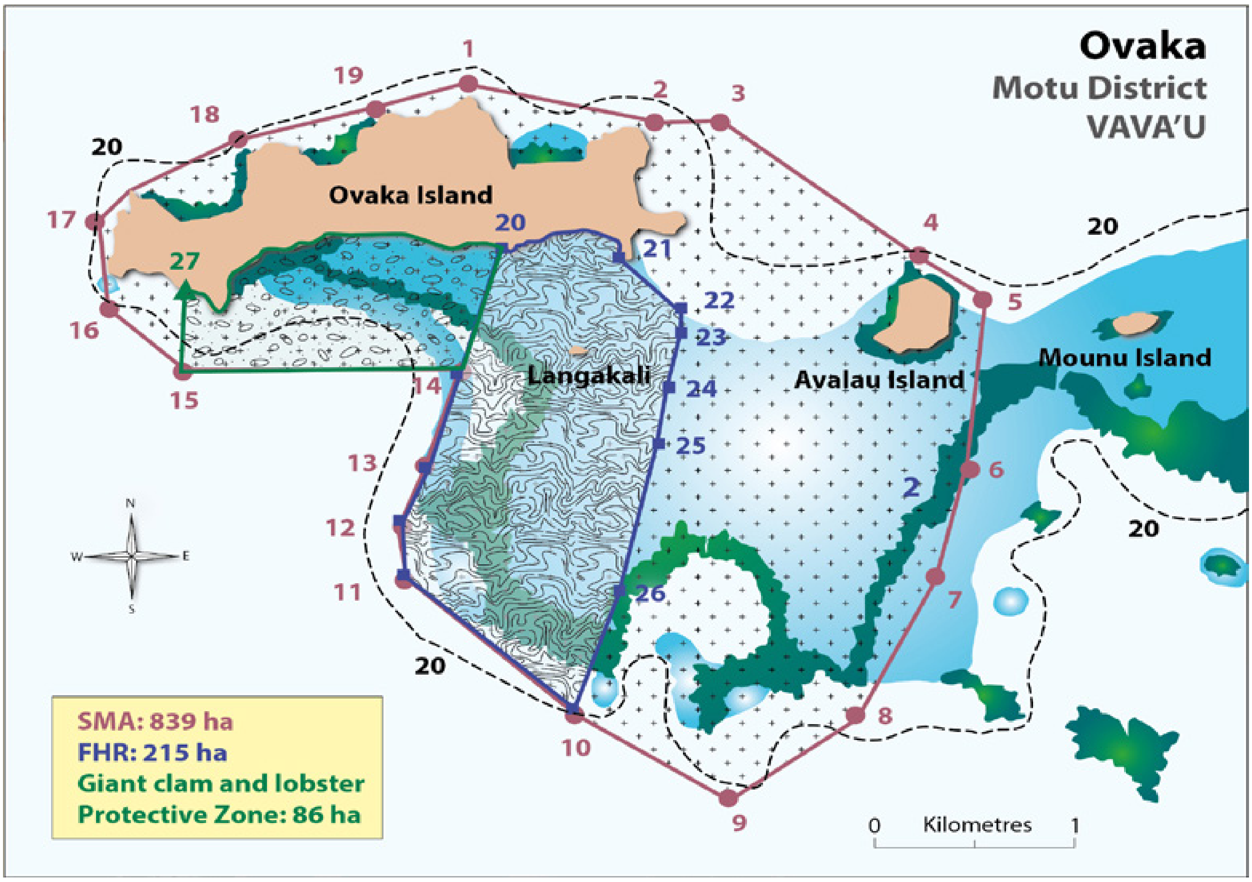
- Awareness of the process of establishing an SMA.
- Establishing alternative livelihoods to support an SMA, including both fisheries and non-fisheries (e.g. agriculture) alternatives.
- Effective enforcement strategy that allows cases of breaching of SMA rules to be well accepted in court. There are needs for capacity building for an enforcement committee on the proper approach to handling poachers and collecting sufficient evidence.
- Clear line of communication between the enforcement committee and relevant enforcement agencies: this should also clearly define the roles of community, Ministry of Fisheries, police and magistrates when it comes to monitoring, control, surveillance and enforcement.
- Familiarisation of enforcement agencies with SMA regulations; this will assist in building strong cases in court.
- Enforcement equipment to assist with enforcement committees, such as binoculars, cameras, boats.

The Fiji Locally Managed Marine Network

Thanks to the Pacific-European Union Marine Partnership (PEUMP) programme, the three-day workshop also provided an opportunity for a Fiji community representative to share his experiences, lessons learned and good practices on broader community-based fisheries management issues implemented in his country.

As explained by Kiniviliane Buruavatu from the Fiji Locally Managed Marine Area Network (FLMMA), the network brings together public and private partners and associations to support local communities in managing their natural resources and developing sustainable subsistence. Since the network was set up in the 1990s, over 400 villages have been involved, accounting for 71% of Fiji's coastal villages, and 79% of coastal fisheries are actively managed.

[3] Source: https://www.spc.int/DigitalLibrary/Doc/CCES/INTEGRE/Regional/Rapport_atelier_regional_peches_cotieres_DEF.pdf



Ovaka SMA map. The fish habitat reserve (FHR) is a permanent no-take area. In the protective zone (green), it is forbidden to collect giant clams and lobsters.

Buruavatu shared his experience in working with communities in his district in Fiji.

Community resource monitoring

Local communities were trained in how to monitor their marine resources. With the help of partner organisations, data were collected, analysed and presented to local communities. Among the challenges faced in this approach include: a turnover of youths or members trained in the villages, and monitoring data equipment getting misplaced or damaged. A refresher training after six to eight months is costly but necessary to keep engagement and maintain interest.

Community empowerment

Community empowerment through participatory approaches, awareness building and community training has been the main activity in engaging communities in resource management. When engaging communities, it is important to consider the existing governance structures (in the village or district). Carrying out a scoping exercise is a good way for the organisation working in the area to gauge not only the natural resources component, but also broader aspects such as livelihoods and governance.

Community monitoring, compliance and enforcement

Communities have been empowered to monitor and enforce management rules related to coastal fisheries through fish wardens. One of the lessons learned is that it is hard for community members to police one another.

Reference and further reading

Gillett M.N. 2010. Success of special management areas in Tonga. SPC Fisheries Newsletter 130:27–30.

Petelo A., Matoto S. and Gillett R. 1995. The case for community-based fisheries management in Tonga. Background paper #61.SPC/FFA workshop on the management of Pacific Island inshore fisheries in the South Pacific. Noumea, New Caledonia, 26 June–7 July 1995.

Acknowledgements

The authors would like to thank the participants of the special management area workshop for their contributions during the workshop and the donor sponsors for their financial support.

Nenisi Kava, Coastal Community Management Committee member, Tufuvai SMA

‘I have learned a lot from this field trip. I have listened to the chief of Ovaka SMA. Now, when it is high tide, the Ovaka community sees more mullets than it has in years.’

Lisiate Teulilo, Town Officer, Tofoa

‘I have learned more information on how to establish SMAs as well as the benefits the communities will have from them. This is the future for our country. Having this type of meeting allows us reaching out to the communities from the youngsters to the elders.’

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A field trip to their SMA was organised by Ovaka community members. (image: Céline Muron, SPC)

Electronic reporting logsheet systems: Beauty and the beast

Electronic reporting (ER) logsheet systems available to tuna longline fishing vessels continue to attract interest from the Pacific Community member countries. The 'beauty' is the fact that the vessel captain is the only person who enters the data, thereby allowing fisheries officers to spend time on verifying and analysing the data rather than on entering the data manually while reading a (not always clearly written) paper loghseet. The 'beast' is the amount of work needed to ensure that the implementation of ER tools is conducted in a standardised manner so that fisheries officers and vessel captains can build their confidence and willingness to use a new reporting system.

Standardising this implementation begins with a training, including a detailed lesson plan for the trainer to follow, and appropriate training materials such as an easy-to-read user manual for the application, and a species identification guide. Training needs to be well prepared and be conducted in a quiet environment (free of distractions) and, importantly, not rushed. The initial training is just one piece of the implementation process. Although ER tools are designed to be user-friendly, not all users can be expected to immediately accept a new tool. It is essential that fishery officers find time to meet with each captain when the vessel is back in port. This allows the exchange of information to ensure that the application is used correctly, and establishes and maintains a constructive relationship between the fisherman and the fishing authority.

The dynamics of tuna longline fishing vessels operating in the western and central Pacific Ocean are complex. For example, a vessel may fish in one country but offload its catch in another country. This is where inter-country collaboration is important, as a fisheries officer from the country where the vessel is unloading may have to meet with the captain to exchange feedback on behalf of the licencing country.

The implementation of ER tools is progressing at a rapid rate in the Pacific Islands region, and because of this, it will be essential to marry the 'beauty' and the 'beast'. This includes improving the training protocol for captains, and establishing a network of trained fisheries officers across the region who will be able to provide training and support where and when required (typically on short notice).

'Electronic reporting apps have eased our data entry workload, giving us more time to allocate to other duties and better our data reporting. With data sent via the OnBoard app., we have noticed a better reporting of bycatch species, something that was rarely done with paper logbooks.'

Lui Bell Jr, Senior Fisheries Officer, Samoa

The transition from paper to electronic roadmaps is a major challenge, and one that must be met, as it will bring tangible benefits, namely an improvement in the quality, availability and timeliness of data. Scientists and fisheries managers need quality data, almost in real time, in order to manage the rapidly evolving tuna fishing industry. And, the challenge of implementing the new ER technology will require commitment from all parties involved.

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Samoa Ministry of Fisheries and Agriculture staff Mrs Laurian Finau Groves (right) and Mrs Tuapou Ariu (left) are trained by Malo Hosken on the use of the OnBoard application developed by SPC to facilitate electronic reporting from tuna longline vessels.

• SPC activities •

PROTEGE takes off

Some of the main characteristics of Pacific Island countries and territories include high population growth rates, increasing urbanisation, significant economic reliance on national-government transfers, and difficulties in creating economic sectors. The natural ecosystems of the Pacific Islands region provide essential services that support countries' economies, and offer economically viable solutions for addressing climate-resilient development issues. Local communities continue to rely heavily on the quality of both their resources and natural environments, which provide their livelihoods and are vehicles for their social and cultural well-being and identities.

Building sustainable development and climate-resilient economies in French overseas countries and territories (OCTs) by focusing on biodiversity and renewable resources will be the main goal of a new project, named PROTEGE – which stands for the 'Projet régional océanien des territoires pour la gestion durable des écosystèmes' (in English: Pacific Territories Regional Project for Sustainable Ecosystem Management).

PROTEGE has a total budget of EUR 36 million, and has two main objectives: strengthening key primary sectors' sustainability, climate-change adaptation and autonomy; and enhancing ecosystem-service security by protecting water resources and biodiversity.

PROTEGE comes under the 11th regional European Development Fund (EDF). A four-year agreement was signed last October between the European Union and the Pacific Community. The project will operate in Wallis and Futuna, New Caledonia, French Polynesia and Pitcairn.

Four themes

PROTEGE has four themes: fisheries and aquaculture, agriculture and forestry, water, and invasive species. Expected outcomes for each theme are listed below.

Fisheries and aquaculture *(budget: EUR 6.64 million)*

- ✓ Aquaculture techniques and production development methods suited to island economies are trialled and implemented at pilot scales and then transferred to the rest of the Pacific Islands region (OCTs and ACP countries).
- ✓ Aquaculture activities are sustainably integrated into the natural setting by documenting and minimising any negative interactions.
- ✓ Participatory management and integrated planning (at the local, territorial and regional level) of the resources used are continued and strengthened.
- ✓ Optimal use is made of fisheries and aquaculture products.

Mangrove crab fishing in New Caledonia. (image: Matthieu Juncker)

Agriculture and forestry (budget: EUR 7.96 million)

- ✓ Viable agro-ecosystems are validated technically and transferred to crop and livestock farmers.
- ✓ At the territorial and regional level, an integrated forestry and agro-forestry policy is established for each forest stand.
- ✓ The marketed volumes of certified-organic products and those from the wood and coconut sectors increase by providing those areas with appropriate structures and making them sustainable.
- ✓ Agro-ecology and organic products are integrated into Pacific Island food systems.
- ✓ Cooperation among OCTs and between OCTs and ACP countries is strengthened through operational tools and coordination.

Forest regeneration work in Futuna. (image: SPC/INTEGRE)

Invasive species (budget: EUR 4.4 million)

- ✓ Biosecurity is improved through the development of strategies and action plans, and the acquisition of technology.
- ✓ Certain invasive alien animal and plant species (IAS) are managed and even eliminated at key biodiversity and ecosystem-services sites.
- ✓ Systems are set up to monitor the status of natural settings (including water resources), damage caused by IAS, and management efforts.
- ✓ Cooperation between OCTs and between OCTs and ACP countries is strengthened.
- ✓ These objectives and expected outcomes will be implemented at various geographic levels (i.e. local, territorial and regional).

Image: SPC/INTEGRE

Water (budget: EUR 7.36 million)

- ✓ Water-management knowledge and skills are improved by strengthening regional cooperation and laying the foundations for water monitoring agencies in each OCT and among OCTs.
- ✓ Drinking water resources are managed, protected and restored.
- ✓ Resilience to health risks, flooding and drought is enhanced.

The PROTEGE team

The team consists of 10 staff from the Pacific Community (SPC) and 1 staff from the Secretariat of the Pacific Regional Environment Programme (SPREP)

Project Manager
Administrative Assistant
Project Finance Officer
Communications Officer
Coordinator – French Polynesia
Coordinator – Wallis and Futuna
Coordinator – New Caledonia
Coordinator – Agriculture/Forestry
Coordinator – Fisheries/Aquaculture
Coordinator – Water
Coordinator – Invasive Species

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Funded by the European Union

Pacific Community
Communauté du Pacifique

SPREP
Secretariat of the Pacific Regional Environment Programme

Strengthening small aquaculture businesses through improved financial literacy

The Pacific Community (SPC) recently delivered financial literacy training to small-scale tilapia fish farmers and mabe pearl farmers from Fiji's Western (Nadi) and Northern (Savusavu) divisions. The three-day training in both locations was well received by all participants.

Twenty-nine people, including fish farmers and staff from Fiji's Ministry of Fisheries and SPC, attended the first module of the three-day training at Tanoa Skylodge Hotel in Nadi between 11 and 13 February 2019. Similarly, 29 people, including mabe pearl farmers, tilapia fish farmers and staff from the Ministry of Fisheries and SPC convened at Daku Resort in Savusavu between 18 and 20 February 2019 to participate in the training, organised through the New Zealand Ministry of Foreign Affairs and Trade 'Sustainable Pacific Aquaculture Development Project' (PacAqua) in collaboration with Fiji's Ministry of Fisheries, and the Cooperative College of Fiji.

According to consultations with the Aquaculture Division of the Ministry of Fisheries, and the Fiji Development Bank, the lack of financial literacy among aquaculture farmers is a major risk that impedes lending to the aquaculture sector. Therefore, the training focused on building financial literacy among fish farmers so that they can operate their farms on a more business-like footing. The training included lectures, discussions and group presentations with a variety of thought-provoking topics covered: financial literacy, income and expenditure; saving, budgeting and goal setting; financial positioning; legal forms of businesses; value added tax; causes of business failure; and marketing and record keeping (e.g. cash, expenses, sales book, cash float to develop monthly statement).

The mixture of both experienced and new farmers provided good opportunities for networking and sharing knowledge on real costs, marketing and experience. Meliki Rakuro, Fisheries Technical Officer (Aquaculture Division), added that encouraging farmers to accumulate savings assists with sustaining their business through effective reinvestment. Many new subsistence or semi-commercial farmers who were fully funded to start their projects by the Ministry of Fisheries, or some funding agency, end up spending all the revenue from their first crop cycle on other activities. This leaves the farmers with no funds to start their next production cycle. Many subsistence farmers face challenges opening savings accounts, planning and managing their businesses, and dealing with life events. Improved financial literacy will assist them with overcoming these challenges.

According to 32-year-old Samuela Tukai of Nagigi Village, Cakaudrove Province on Vanua Levu, the training opened

Participants to the 11–13 February 2019 training at the Tanoa Skylodge Hotel, Nadi, Fiji.

his eyes to the endless opportunities of running a successful business: 'I am the leader of the Mataqali Korolevu Youth Group, and this training has taught me a lot of things. We have a tilapia pond and are looking at expanding into another three ponds. I cannot wait to share with my fellow youths back in the village everything that I have learnt for the past three days'.

Raviravi Women's Group representatives from Macuata – Kalesi Nabobo and Jojivini Dikubou – said that they will certainly implement the great lessons that they learned: 'We are part of the Navutudua Women's Group, consisting of around 30 women in the village, and we produce mabe pearls,' said Nabobo. 'We have been running our business but are lacking in so many finer aspects of it, so when we return home we will certainly be gathering the women in the village and passing on the knowledge.' Both women also agreed that they would implement it as well in the running of their finances at home (see: https://www.facebook.com/fisheriesfiji/).

The mabe pearl market in Savusavu is considered lucrative because demand is high and local handicraft distributors are very keen to get more products.

It was encouraging to have a good turnout from the women farmers participating in the training, with eight participants from the Western Division and fifteen from Savusavu. Given that women play significant roles in the aquaculture sector, increasing women's participation and empowerment through training programmes is equally important. Ms Alili Laite, a farmer from Nadeli Community pond, says that learning saving goals to better utilise money for their farm was very useful, and using income from sales to cover major expenses such as feed costs, along with cost-saving mechanisms will encourage them to make further improvements.

The Fiji Development bank recognises the certificates issued by the Cooperative College of Fiji. In this way, participation in this business training for aquaculture can positively help fish farmers gain better access to finance from commercial lending institutions in order to grow their farms.

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Participants to the 18–20 February 2019 training at the Daku Resort, Savusavu, Fiji.

Golden sandfish farming in Tonga – initial trials underway

Aquaculture production of sea cucumbers is a hot topic in the aquaculture world these days. The high value of many sea cucumber species, the increasing demand for this commodity in various export markets (mainly from Asia), and the depletion of natural stocks in the wild have generated significant interest in the possibilities of sea cucumber aquaculture.

Several Pacific Island countries and territories have devoted substantial human and financial resources to farming sea cucumbers, with variable results. Successful examples of sea cucumber breeding and larvae rearing can be found in the Federated States of Micronesia, Fiji, Kiribati, New Caledonia and now Tonga.

These countries have well-established sea cucumber hatcheries where animals are bred and larvae are reared until the juvenile stage. New Caledonia, for example, has been involved for many years in various restocking programmes in the Northern and Southern provinces of the main island using juvenile reared at the sea cucumber hatchery.

Sea ranching of juvenile sea cucumbers is still difficult, however, for many technical and socioeconomic reasons, such as suitable farming strategies, availability of farming sites, conflicts with other users and sectors, and poaching.

Tonga has concentrated on farming the golden sandfish, *Holothuria lessoni,* which is among the highest value sea cucumber species on the Chinese market. This species is native to Tonga, but has become difficult to find because of the depletion of natural stocks due to overfishing.

The Tongan-Chinese company Vast Ocean (Tonga) Aquaculture Company Limited, with strong experience in farming sea cucumbers and other invertebrates, is currently focused on the development of this aquaculture activity in Tonga. The company has established a hatchery and nursery facility on Tongatapu. Next to the hatchery, this same company has built a small processing plant.

Six local staff will be working at the hatchery and processing plant, and it is planned that additional local staff will be employed to follow up on grow-out activities in the field. It is hoped that the staff involved in farming and processing will capitalise on the skills and experience they will acquire while working for the sea cucumber farm; skills that will be useful in Tonga for developing other aquaculture activities.

Golden sandfish that were born and raised at the Vast Ocean (Tonga) Aquaculture Company Limited hatchery are taken to a suitable area in the lagoon for grow out. From L–R: Sione Mailau, Siosifa Folauhola and Victory Lu. (image: Eileen Fonua)

The high-tech hatchery has been built next to the Ministry of Fisheries hatchery on Tongatapu. The newer hatchery operates 30 concrete raceways, where larvae and juveniles are maintained. The facility also includes a small nursery area where juveniles are kept for several weeks until they reach the appropriate size to be released into the oceanic nursery, as is usually done in sea ranching. The Ministry of Fisheries, in collaboration with Chinese experts, has already identified a suitable site for grow-out, where local sea cucumber stocks are relatively low and the natural habitat is adequate for this species.

The enterprise has managed to conduct five successful spawning runs since December 2018, with a production of

Golden sandfish are carefully released and randomly distributed in a suitable sandy area that will be closely monitored to assess growth and survival. (diver: Viliami Fatongiatau, images: Eileen Fonua)

around 2 million juveniles in total. The first 10,000 juveniles were successfully transferred into a selected sea ranching aquaculture area on 23 March 2019. After five to seven months of sea ranching, the animals will be harvested.

Based on the results of this first trial, around 1.5 million juveniles will be released in the same grow-out area. The company expects to be able to export some of the processed animals around July or August this year.

Following an official request from Tonga's Ministry of Fisheries, the Pacific Community will be involved in the monitoring of grow-out activities, and in the development of a new regulation for aquaculture, which will consider aspects such as processing, exports, biosecurity and farming strategies.

We look forward to seeing this activity as one of the successful examples of sandfish farming in our region.

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Mozuku farming in Tonga: Treasure under the sea!

Mozuku nets fixed to the seabed. (image: Masa Kawaguchi)

Mozuku is a unique brown seaweed known scientifically as* Cladosiphon okamuranus*. This algae is popular in Japanese cuisine and has been farmed for more than 35 years on the island of Okinawa, where it is a key element of the local economy. Mozuku brown algae has also been found to be naturally occurring in Tongan waters where it is locally known as* limu tanga'u*. There are very limited studies regarding the distribution of this species in the Pacific Islands region, although certain researchers have mentioned its existence in New Caledonia (Isle of Pines) and Samoa, in small amounts. A preliminary survey was conducted in 1996[1] around Tongatapu in Tonga (during the algae's gametophyte phase) to assess its general occurrence.

Mozuku belongs to the brown seaweed family, which plays a key role in the ecology of oceans. Brown algae are also called 'seaweed beds' or 'underwater forests' because many marine organisms use these algae as nursery grounds.

On top of its ecological benefits, mozuku has important health properties, because it is a natural source of fucoidan, which has unique tumour-suppressant and anti-coagulant properties. It has exhibited anti-cancer characteristics during laboratory tests. The aquaculture sector believes that ensuring consistent production levels of mozuku would allow widespread consumption of this healthy seaweed, which is already used in food supplements.

Seaweed consumption has been actively promoted by nutritionists due to the high levels of certain micronutrients, such as tyrosine, vitamins A, B, C, E and K, minerals (iodine, selenium, calcium and iron), and a wide variety of antioxidant compounds (flavonoids, carotenoids and fucoxanthin, among others). Although the protein levels are not very high in any of the edible seaweeds, they are slightly higher than in most green vegetables. The brown algae mozuku has other qualities as well: a unique texture and flavour, which is sought after by culinary enthusiasts.

Tongans have been harvesting mozuku from their coastal waters for many years, and a number of attempts have been made to culture the species. The local enterprise South Pacific Mozuku Tonga Ltd has been involved in harvesting and farming seaweeds since 2015. Farming activities started to be relatively successful in 2017, when around 72 tonnes of wet mozuku were produced and exported to different markets in Japan, the European Union and the United States. Production increased slightly in 2018, with around 80 tonnes of wet mozuku produced and exported to similar markets.

[1] Bueno P.R. 2014. Lessons from past and current aquaculture initiatives in selected Pacific Island countries. TCP/RAS/3301. FAO Sub-Regional Office for the Pacific Islands. Rome, Italy: Food and Agriculture Organization of the United Nations. 146 p.

[2] Sporulation: algae form special cells called spores, which can produce new individuals without the need for another parent (asexual reproduction).

Mozuku brown algae is naturally occurring in Tongan waters (left). (image: Masa Kawaguchi)
Harvested mozuku being processed at South Pacific Mozuku Tonga Ltd facilities (right). (image: Masa Kawaguchi)

The manager of the enterprise, Masa Kawaguchi, has been extremely active in finding new markets for this species, including the pharmaceutical industry, thanks to mozuku's high levels of bioactive ingredients. It should be noted that the price paid per kilo of wet mozuku by pharmaceutical companies could double the price paid by food companies.

Thanks to the establishment of a modern processing plant in Tongatapu, South Pacific Mozuku Tonga Ltd is also assessing new processing and value-adding strategies. Some of the final products offered by the company are dried seaweed, dried and pressed seaweed, salted seaweed, powdered seaweed, and fresh and frozen seaweed.

The farming area is on one of the small outer islands near Tongatapu, where around 300 farming nets (each net is 12 m long x 3 m wide) are deployed in May, when the natural mozuku sporulation[2] takes place, until August, when the nets are fully covered by the seaweed and are brought in.

The Pacific Community (SPC) is providing technical assistance to the private company and to the Ministry of Fisheries through the evaluation of new farming sites and farming strategies. SPC is also assisting the private company with the qualitative analysis of the final product(s), as a way to improve and increase market access. Different seaweed products (fresh, frozen, dry and salted) are being analysed to assess the following parameters: proximate analysis, the presence and content of heavy metals, and the presence and content of bioactive ingredients.

Hopefully, based on this initial assistance, South Pacific Mozuku Tonga Ltd will be able to increase mozuku production in Tonga and maintain and improve market access for the final products. At the same time, SPC is assisting the Ministry of Fisheries in Tonga with the amendment of the current Aquaculture Regulation (2005), in order to incorporate articles related to processing and exports of aquaculture products. This amendment will assist local aquaculture enterprises in their attempt to engage in fair-trading practises.

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2018 Market price update for beche-de-mer in Melanesian countries

Hugh Govan[1]

In 2017, the Fisheries Technical Advisory Committee of the Melanesian Spearhead Group (MSG) of countries agreed that MSG countries should collect and share data on prices paid to fishers, traders and exporters as a first step towards ensuring that a fair proportion of the value of beche-de-mer remains within countries and in the pockets of local fishers.

This brief provides a compendium of available data across three broad areas of the value chain: 1) retail sale at the end market (China); 2) prices paid by importers to national exporters; and 3) prices paid locally and nationally. Data are not fully reliable as most depend on relatively few surveys, quality of trader responses, or whether price lists reflect prices actually paid. Nevertheless, these data provide the best information available. Caution should also be exercised when comparing figures at different levels of the value chain as survey methods and other conditions vary substantially.

Retail prices in China

The main information sources available include the survey undertaken by Purcell et al. (2018), which provides 2016 updates for a previous price survey in 2011 (Purcell 2014). Other available information includes Dumestre (2017) and Fabinyi (2015).

Table 1 shows the surveyed retail market prices in Hong Kong and Guangzhou in mainland China. The most notable features from these studies are that:

- average retail prices were higher in Hong Kong (about 50%) than in Guangzhou, Beijing or Shanghai;
- average prices for high-value species range up to USD 369 kg^{-1}, and a maximum of USD 1898 kg^{-1} was recorded for exceptional quality products; and
- prices have tended to increase in Hong Kong and, for most species in Guangzhou, at an annual rate of around 2.4%.

Prices are exponentially higher for larger specimens of the three high-value sea cucumber species: *Holothuria fuscogilva* (white teatfish), *H. lessoni* (golden sandfish) and *H. scabra* (sandfish). Prices for seven other species (price per unit weight) did not relate significantly to product length. In addition, products that were traditionally lower value now appear more accepted in the marketplace. The results from the surveys by Dumestre (2017) and Fabinyi (2015) support the prices found by Purcell and colleagues (2018).

The higher prices of large individuals of high-value species lends weight to calls for stricter enforcement of minimum size limits at the production end. Interpretation of retail prices needs to take into account taxes and other costs the retailer may incur, as well as the risks that traders perceive when advancing capital for purchasing sea cucumbers (Fabinyi et al. 2017). Mitigating or compensating for risk is a significant factor for traders. The cost of living in Hong Kong is higher than in mainland China, which may explain some of the price differences observed. A forthcoming study (James P. in prep.) will examine this in more depth.

Importer prices

Very little data are available regarding the prices that importers pay or are willing to pay for beche-de-mer, and importers (or national exporters) are generally reticent to share such information. Mangubhai et al. (2016) produced the only extensive data based on a survey of exporters in Fiji who were working mainly with buyers from China and Hong Kong. Peter Waldie (pers. comm., Coastal Fisheries Manager, Melanesia Program, The Nature Conservancy, 17 October 2017) interviewed Hong Kong traders about the prices they were willing to pay (and the prices they ultimately paid) for sandfish and white teatfish of high quality and certifiable sustainable origin in Papua New Guinea (PNG). Data relating to export values collected by governments (e.g. Solomon Islands and Fiji) is generally unreliable because they rely on unverifiable exporter declarations. Such data are not included here.

Table 2 presents the information available. The figures provided for Fiji likely relate to the markets in China and Hong Kong, where most exports go although not exclusively. Notable features include: 1) actual values recorded as paid in Hong Kong for good-quality PNG product were USD 180–200 kg^{-1} for sandfish, and USD 95–140 kg^{-1} for white

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Table 1. Prices of processed beche-de-mer in China (USD per kilo) – figures in green indicate an increase from 2011 to 2016, and red indicates a decrease.

			Retail price										Wholesale price			
			November 2011[1]				November 2016[2]				Sep. 2015[4]	Sep. 2014[3]	Sep. 2015[4]			
			Hong Kong		Guangzhou		Hong Kong		Guangzhou		Hong Kong	Hong Kong	Hong Kong	Guangzhou	Beijing	Shanghai
Common name	**Scientific name**	**FAO Code**	Avg. price	Max. price	Avg. price	Max. price	Avg. price	Max. price	Avg. price	Max. price	Range	Avg.	Range	Range	Range	Range
Amberfish	*Thelenota anax*	HLX			22	32			31	47						
Black teatfish	*Holothuria whitmaei*	JDG	180	230	68	116	208	294	161	194	166–294	208	191–319	96–156	128–156	96–152
Blackfish	*Actinopyga miliaris*	KUQ			79	95										
Brown curryfish	*Stichopus vastus*	JPW					230	230								
Brown sandfish	*Bohadschia vitiensis*	BDV			48	48	209	209	55	81				40–60		36
Burying blackfish	*Actinopyga spinea*	YGS			79	95										
Chalkfish	*Bohadschia similis*	BDX?														
Curryfish	*Stichopus herrmanni*	JNG	197	214	121	159	350	358	145	219					96–128	96
Deep water redfish	*Actinopyga echinites*	KUE			63	63			69	69						
Deepwater blackfish	*Actinopyga palauensis*	YGP			106	116	145	145	77	131						128
Dragonfish (Peanutfish in SI)*	*Stichopus horrens**	KUN			69	83			119	119						
Dragonfish (Pink curryfish in PNG)*	*Stichopus naso**	JPR					145	145	91	94						
Dragonfish*	*Stichopus monotuberculatus**	JPQ			118	133	188	188	127	204						
Elephant trunkfish	*Holothuria fuscopunctata*	HOZ			15	19			22	78					128	128
Eye-spot curryfish	*Stichopus ocellatus*	JPT			111	111			78	78						
Flowerfish	*Pearsonothuria graeffei*	EHV														
Golden sandfish	*Holothuria lessoni*	JCO	385	787			389	849			84–359	481	196–338	64–156	128–220	96–252
Greenfish	*Stichopus chloronotus*	JCC			79	95			100	125						
Lollyfish	*Holothuria atra*	HFA							31	31						
Pinkfish	*Holothuria edulis*	HFE							110	110						
Prickly redfish	*Thelenota ananas*	TFQ			130	231			107	219	63				96–128	96
Sandfish	*Holothuria scabra*	HFC	303	1 668	137	200	369	1 898	153	251	84–359	353	196–338	64–156	128–220	96–252
Snakefish	*Holothuria coluber*	HHW			38	38			37	37						
Stonefish	*Actinopyga lecanora*	YVV			94	108	166	166	76	107						
Surf redfish	*Actinopyga mauritiana*	KUY	145	145	75	79			72	72						
Tigerfish	*Bohadschia argus*	KUW			58	63			63	70						
White teatfish	*Holothuria fuscogilva*	HFF	192	274	120	165	219	401	154	219	166–294	243	191–319	96–156	128–156	96–152

1 Purcell 2014
2 Purcell et al. 2018
3 Dumestre 2017 for between 10 and 95 sample size
4 Fabinyi 2015; Fabinyi et al. 2017
* Possible misidentifications in this group because of look-alikes.

teatfish; 2) larger sandfish and white teatfish commanded higher prices.

Import prices are some of the most important data required for establishing fair local and national fisher prices and export levies, and it is important for countries and researchers to increase efforts to collect such information. Data from exporters who report on the prices they receive from importers are currently unreliable and need to be improved.

National and local buying prices

Data are available from a variety of sources on local prices for beche-de-mer. Care must be taken as the most commonly available information pertains to price lists provided by traders or established by government, which is unlikely to reflect actual prices paid to fishers.

Table 3 presents a summary of the available information; some key features of these data and the supporting studies are:

- Grading may be by size or quality, and variations in this limit comparability across countries.
- PNG reports in several cases that grade is based foremost on size.
- Reprocessing by buyers is common, and an extreme case of this is Fiji where 76% of fishers sell raw product.
- There is evidence that buyers pay little regard to minimum legal-size limits to the extent that some price lists show prices for undersized animals.
- In Fiji, the price received by fishers may be 25–50% of what traders receive after on-selling to exporters, and 10% or less of importer prices paid in Hong Kong.
- In in Malaita, Solomon Islands, the prices received by fishers are frequently less than half the value provided in buyer price lists.

Table 2. Importer prices reported (USD per kilo).

		China/Hong Kong 2015[1]			Hong Kong 2017[2]	
Common name	**Scientific name**	Avg	Min	Max	Buyer 1	Buyer 2
Amberfish	*Thelenota anax*	45	21	68		
Black teatfish	*Holothuria whitmaei*	148	72	186		
Blackfish	*Actinopyga miliaris*	96	41	145		
Brown sandfish	*Bohadschia vitiensis*	38	29	52		
Chalkfish	*Bohadschia similis*	17	10	26		
Curryfish	*Stichopus herrmanni*	97	57	145		
Deep water redfish	*Actinopyga echinites*	103	52	166		
Deepwater blackfish	*Actinopyga palauensis*	113	62	166		
Elephant trunkfish	*Holothuria fuscopunctata*	28	7	83		
Flowerfish	*Pearsonothuria graeffei*	46	8	83		
Golden sandfish	*Holothuria lessoni*	103				
Greenfish	*Stichopus chloronotus*	110	57	152		
Lollyfish	*Holothuria atra*	18	16	41		
Peanutfish	*Stichopus horrens*	124	31	155		
Pinkfish	*Holothuria edulis*	13	13	41		
Prickly redfish	*Thelenota ananas*	94	26	166		
Sandfish	*Holothuria scabra*	83	52	103	103	167
Snakefish	*Holothuria coluber*	36	31	42		
Stonefish	*Actinopyga lecanora*	68	51	166		
Surf redfish	*Actinopyga mauritiana*	68	36	124		
Tigerfish	*Bohadschia argus*	45	31	62		
White teatfish	*Holothuria fuscogilva*	183	83	228	90	142

Buyer 2 (prices paid)	
Sandfish (<200g)	180
Sandfish (>200g)	200
Whiteteat (<300g)	95
Whiteteat (300–500g)	128
Whiteteat (>500g)	140

[1] Mangubhai et al. 2016 data reported by exporters in Fiji, February 2015

[2] Peter Waldie. The Nature Conservancy. Unpublished data. Eight buyers were surveyed in Hong Kong and only two made tentative offers to offer good-quality, sustainably harvested product. Buyer 2 supplies premium hotel chains and, thus, offered higher prices. The remaining buyers were not willing to match even the lower prices offered by Buyer 1.

Table 3. Local prices in USD per kilo of grade A product, where graded.

Common name	Scientific name	FAO code	Fiji[1] 2015 (trader)	Fiji[1] 2015 (fisher)	Vanuatu[4] 2015	PNG[2] 2017 (NIP)	PNG[3] 2017 (MBP)	PNG[7] 2018 (price list) (MBP)		PNG[8] 2018 (price list) (MBP)		PNG[9] 2018 (price list) (NIP)		Solomon Islands[5] 2018 (6 Honiara traders' price lists - Grade A)			Solomon Islands[6] 2018 (Fisher sales - Malaita. Grade A)		
			Average	Average	Average	Best price	Best grade	Small	Large	Small	Large	Min	Max	Avg	Min	Max	Avg	Min	Max
Amberfish	*Thelenota anax*	HLX	6	3	3	6			3	3	6	9		7	5	9			
Black teatfish	*Holothuria whitmaei*	JDG	24	13	26	40		12	23	20	65	31	49	30	26	32	12	7	26
Blackfish	*Actinopyga miliaris*	KUQ		8	10		22		22			22		28	24	32	20	13	26
Brown curryfish	*Stichopus vastus*	JPW												16	8	32			
Brown sandfish	*Bohadschia vitiensis*	BDV	6	5	8	9		8	9	3	11	12	15	12	9	13	11	3	20
Burying blackfish	*Actinopyga spinea*	YGS												5	3	6			
Chalkfish	*Bohadschia similis*	BDX?	8	8	7	5			2		6	12		7	7	7	15	3	33
Curryfish	*Stichopus herrmanni*	JNG	19	7	9	28	25	12	25	9	22	34		29	15	34	12	7	14
Deep water redfish	*Actinopyga echinites*	KUE	13	12										5	5	5			
Deepwater blackfish	*Actinopyga palauensis*	YGP	23	5	30					11	25			26	26	26			
Dragonfish (Peanutfish in SI)*	*Stichopus horrens**	KUN		6	7									37	28	58	31	3	52
Elephant trunkfish	*Holothuria fuscopunctata*	HOZ	23		1	3			2		2	6		5	4	6		7	7
Eye-spot curryfish	*Stichopus ocellatus*	JPT																	
Flowerfish	*Pearsonothuria graeffei*	EHV	7	1	4							5		3	2	3		3	3
Golden sandfish	*Holothuria lessoni*	JCO				55	23					62		13	13	13			
Greenfish	*Stichopus chloronotus*	JCC	43	11	13	29	15	15			32	37		38	32	45	13	3	28
Lemonfish/candyfish	*Thelenota rubralineata*	JDZ												3	3	4	3	3	20
Lollyfish	*Holothuria atra*	HFA	3	5	3	5		2	2	1	6	12		6	4	10	3	2	33
Pinkfish	*Holothuria edulis*	HFE	3	2										4	2	6			
Prickly redfish	*Thelenota ananas*	TFQ	28	15	17	32	19	11		18	34	37		34	26	42	19	3	46
Red snakefish	*Holothuria flavomaculata*	JCI												7	7	7		3	3
Sandfish	*Holothuria scabra*	HFC	29	6	30	65	34	12	34	11	92	62	111	28	19	34	18	3	39
Snakefish	*Holothuria coluber*	HHW	6	4	3	7						5	9	6	5	6	7	5	20
Stonefish	*Actinopyga lecanora*	YVV	18	8	3	34	25	9	25	11	28	31		34	26	45	19	13	52
Surf redfish	*Actinopyga mauritiana*	KUY	18	3	21	31	20	6	20	20	26	18	31	35	26	45	22	3	39
Tigerfish	*Bohadschia argus*	KUW		3	22		9		9	5	12	12	15	14	9	23		6	19
Tigertail fish	*Holothuria hilla*	JCK															5	5	5
White teatfish	*Holothuria fuscogilva*	HFF	51	49	57	49	37	14	37	12	68	62	111	48	41	71	12	3	39

1 Mangubhai et al. 2016. Average onselling price for a. traders (i.e. to exporters) and b. fishers to middlemen or traders. Reprocessing occurs up the value chain. 76% of fishers sell raw product.
2 Kinch J. Papua New Guinea National Fisheries Authority. pers. comm. New Ireland, Best trader price.
3 Kinch J. Papua New Guinea National Fisheries Authority. pers. comm. Kiwali, Milne Bay.
4 Using DW conversion ratios from Carleton et al. 2013 applied to Table 9, which records wet weight prices from Leopold et al. 2016.
5 Solomon Islands Ministry of Fisheries and Marine Resources compilation of trader price lists.
6 van der Ploeg J. pers. comm. Prices actually paid to fishers. Lau Lagoon and Langalanga Lagoon. Worldfish, Solomon Islands. Average of grade A prices paid but minimum and maximum figures are across all grades.
7 Kinch J. Papua New Guinea National Fisheries Authority. pers. comm. Kiwali Exports, Alotau, Milne Bay Province, Papua New Guinea. Very large white teatfish are priced at USD 49 kg^{-1}. Very small <10 cm sandfish are priced at USD 6.1 kg^{-1}. Where a single price is given without specifying size by the buyer, it is entered in the table as 'large'.
8 Kinch J. Papua New Guinea National Fisheries Authority. pers. comm. Asia Pac Ltd, Alotau Milne Bay Province, Papua New Guinea. Maximum prices are for G1, large or super-large and minimum prices are for small or G2.
9 Hair C. pers. comm. New Ireland, trader price.
* May include other *Stichopus* species of the same group such as *S. monotuberculatus*, *S. naso* or *S. vastus*.

Governments and researchers need to better understand prices actually paid to fishers as it is unclear whether buyers are underpaying or fishers are selling low grade produce but, there are indications of major discrepancies between prices paid to fishers and buyer price lists or importer prices.

Online availability

This report and the data in Excel spreadsheet format are available online at: https://coastfish.spc.int/en/component/content/article/497

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Melanesian Spearhead Group I Le Groupe fer de Lance Mélanésien

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WORLD BANK GROUP

Scientists collect the world's deepest mesophotic coral: A hope for rescuing shallow-water corals

Ghislain Bardout's diving computer indicates a depth of 172 m. A mesophotic coral had never been discovered at such a great depth! (Image: © Agence Zeppelin, Under The Pole)

On 4 April 2019, in French Polynesia's Gambier Islands, Ghislain Bardout (cofounder of Under The Pole Expeditions) and two divers from his team brought back the world's deepest mesophotic coral ever collected,* Leptoseris hawaiiensis *(at 172 meters depth). Scientists from CRIOBE (Insular Research Center and Observatory of the Environment) – Laetitia Hédouin, Michel Pichon and Héloïse Rouzé who were present on that day – were able to identify the species and validate this record. In total, 4000 samples of mesophotic corals were collected by the divers during the expedition. This now represents the largest collection of its kind, worldwide. These discoveries contribute to supporting the hypothesis that the mesophotic environment acts as a refuge for shallow-water corals and, therefore, gives hope to restoring these coral types.

Since July 2018, the team of the expedition Under The Pole III, led by Emmanuelle Périé-Bardout and Ghislain Bardout, has been focusing on the research programme 'DeepHope', a survey of mesophotic corals – found between 30 m and 150 m depths – in partnership with CRIOBE in French Polynesia. It was during this project that a specimen of *Leptoseris hawaiiensis* was collected at 172 m depth.

A unique collection worldwide

Michel Pichon, a world-renowned expert in coral reefs and coral identification who has been studying corals for over 50 years, does not hide his enthusiasm: 'I've been waiting for this kind of discovery for over 40 years. All the samples gathered by the end of the expedition will represent the largest collection of mesophotic corals in the world, especially for samples collected deeper than 90 m. The partnership Under The Pole – DeepHope is the most intense and efficient programme to this day, and the results arising from it, as well as their impact, are of critical global interest.'

Mesophotic corals: a hope for shallow-water reefs

The discovery of *Leptoseris hawaiiensis*, combined with this unique collection, prove that shallow-water corals migrate to greater depths to find shelter and thrive. 'The results represent a robust foundation on which to test the capacity of mesophotic corals to act as a refuge for shallow-water reefs that have been impacted by global climate change, and these corals' ability to play a role in the restoration of those reefs,' said Michel Pichon.

Laetitia Hédouin, who is in charge of research at the National Centre for Scientific Research (CNRS), and an expert in coral biology, concurs: 'We will never be talking about coral reefs anymore without taking into consideration the ocean depths as being a potential survival raft. The mesophotic corals represent a real hope to restore the reefs,' she explains.

Without the contribution of mesophotic coral larvae to recolonise shallow-water reefs, the chances of shallow-water reefs surviving unprecedented global climate changes would be very slim. By shedding some light on a widely unknown part of the reefs, we hope to contribute to the implementation of management and protection measures to preserve those reefs. These discoveries reveal a completely new vision on how reefs function. They operate as a continuum from the surface to the mesophotic areas, with different coral communities living next to each other. Up until this day, we thought that about 25% of corals could live from the surface down to greater depths. What we have discovered is that this trend is completed inverted, with over 60% of species being present at depth. This is a fundamental discovery and it supports the hypothesis that corals could find shelter in deeper water, where the environment is less impacted than in shallower water environments. The collection of a mesophotic coral at 172 m depth triggers new intriguing questions about the ability of corals to live in hostile environments. The expedition will continue during the next three months, and the results following the completion of this program will have a global outreach and will certainly set the new baseline of knowledge on mesophotic reefs.

‘We will never be talking about coral reefs anymore without taking into consideration the ocean depths as being a potential survival raft. The mesophotic corals represent a real hope to restore shallow-water reefs.’

Laetitia Hédouin, a researcher at the National Centre of Scientific Research (CNRS) at CRIOBE. (Image: © Agence Zeppelin, Under the Pole)

‘With the existing ecological urgency, it is critical to do whatever it takes to acquire the knowledge that will help us protect the oceans and manage their resources in a sustainable way.’

Ghislain Bardout, co-founder of Under The Pole Expeditions. (Image: © Agence Zeppelin, Under The Pole)

Michel Pichon, coral reef expert biologist. (Image: © Agence Zeppelin, Under The Pole)

‘I’ve been waiting for such discoveries for 40 years. These results will constitute the absolutely necessary baseline to test the hypothesis regarding the capacity of mesophotic corals to act as a refuge.’

Coral ecosystems: the tropical forest of the oceans

Life on Earth started 3.5 billion years ago. After centuries of scientific expeditions about 2 million species have been discovered, one-third of which come from the oceans. In the oceans, coral reefs occupy an extremely small area, less than 1% of the planet, but they are one of the most diversified ecosystems. They are home to 25% of all marine life and their biodiversity is equivalent to tropical forests. Reefs are one of the last prolific habitats on Earth that remain widely unknown despite feeding over 500 million people and being the basis of a touristic economy estimated at USD 9.6 billion yearly. Coral reefs are not just useful for insular populations, but their impressive marine biodiversity is like an underwater pharmacy with encouraging leads for medical research. Medicines from corals have been already developed to treat cancer, asthma and arthritis.

Collected specimen identification time for Michel Pichon and Héloïse Rouzé onboard the research vessel. (Image: © Agence Zeppelin, Under The Pole)

Collecting samples of mesophotic corals. (Image: © Agence Zeppelin, Under The Pole)

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Mainstreaming gender into fisheries and aquaculture in Samoa

Ulusapeti Tiitii,[1] Ana Laqeretabua[2] and Joanne Lee[3]

It is widely recognised that development and governance processes are only effective and sustainable if both women and men participate in and benefit from such processes. Samoa Fisheries recognises the importance of mainstreaming gender into its work, and the Pacific Community (SPC) provides ongoing support in this area.

In recognition of the importance of mainstreaming gender into its work, Samoa Fisheries conducted a gender analysis to: 1) evaluate the impact of community aquaculture on household incomes; and 2) analyse the roles of men, women and youth within the community, as well as their commitments to daily household tasks. This work was carried out within the framework of the project 'Improving community-based aquaculture in Fiji, Kiribati, Vanuatu and Samoa' (FIS/2012/076), which was coordinated by SPC, with funding from the Australian Centre for International Agricultural Research. The present study is one of several ongoing gender mainstreaming initiatives being carried out by Samoa Fisheries, in collaboration with SPC, and aims at ensuring women benefit equitably from all development projects.

Fisheries staff and Ana Laqeretabua (second from left) conducting an interview with one of the participants. (Image: Ulusapeti Tiitii, Samoa Fisheries)

The Coastal Fisheries, Advisory and Aquaculture sections of Samoa Fisheries participated in three weeks of training and mock trials on conducting gender surveys and analyses. Emphasis was placed on capacity building of staff in gathering qualitative data. The training also underlined the importance of power relation dynamics, decision-making, and access to resources, and allowed a better understanding of the impact of aquaculture and fisheries activities on women and men.

Although the project originally focused on tilapia aquaculture, it was enlarged to cover village-owned fish reserve activities under the Samoa Fisheries' Community-Based Fisheries Management Program (CBFMP), as well as other aquaculture activities involving freshwater and marine species (e.g. tilapia, giant clams, trochus and sea grapes). The study also allowed the collection of information on gender perspectives in the setting up of fish reserves within the villages that had approved village fisheries management plans under the CBFMP. More than 60 surveys were carried out in villages and with private and individual tilapia farmers from Upolu, Manono and Savaii islands.

Findings from the study reflected entrenched gender roles, with women spending more time than men in carrying out family care activities (e.g. looking after children and the elderly) or household chores, including the preparation of meals. As expected, men spend more time than women on productive or paid activities, which is in line with the gender roles traditionally assigned to men and women in Samoa. Men also appeared to spend more time than women on community activities such as village meetings and communal gatherings. On tilapia farms, however, feedback from key informant interviews reflected that management responsibilities were fulfilled by both women and men, with women spending slightly fewer hours than men on productive activities.

The training and results of the study led to a shift in the understanding of Samoa Fisheries staff on the role of women in aquaculture activities, and will ensure that women are included as key informants during training activities, consultations and other activities conducted in communities. The training was an eye opener for staff in terms of the valuable contribution of women to aquaculture activities, a contribution that had not been properly recognised before.

Acknowledgements

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A roadmap for managing Vanuatu's coastal fisheries in the future

Wednesday, 20 March 2019, marked a significant milestone for the management and development of coastal fisheries in the Republic of Vanuatu. It was the date on which the 'Vanuatu National Roadmap for Coastal Fisheries: 2019–2030' was approved by the Minister responsible for Fisheries. The approval came after a final stakeholder consultation workshop in Port Vila at the end of 2018. The signing and launching of the 'roadmap' culminated after a year's worth of work that started in November 2017, and involved a series of planning, design and review workshops with the Vanuatu Fisheries Department's staff and partners. The roadmap will guide the management and development activities along Vanuatu's coastlines.

Inshore [or coastal] fisheries provide the primary or secondary source of income for up to fifty percent of households in the Pacific region. Amongst rural populations, 50–90% of the animal-sourced protein consumed comes from fish. At the national level, coastal fisheries carry significant cultural and economic value. They are estimated to contribute 49% of the total fisheries contribution to GDP, demonstrating that they are central to the Pacific way of life. [1]

Vanuatu is no exception to this. As the cornerstone protein source supporting Ni-Vanuatu living in coastal zones, coastal fisheries are critical to the social, economic and food security of these people. This is evident in that an estimated 72% of households in coastal communities engage in fishing activities in coastal zones for subsistence or commercial purposes[2] and a per capita consumption of fish ranging from 16–26 kilograms per person.[3] Culturally, coastal fisheries are also very important to the people of Vanuatu, and their management is deeply engrained in local custom. In some islands sacred, or *tabu*, areas mean people cannot visit, fish or harvest specific fish species because of their cultural beliefs.

In Vanuatu, coastal fisheries generally refer to fishing activities occurring within 12 nautical miles territorial waters, with the majority of activities concentrating within the limits and peripheries of fringing reefs.

However, Vanuatu's coastal fisheries resources are not in a good shape. There have been noticeable declines for most economically important marine species, such as trochus, sea cucumbers, green snails, lobsters, coconut crabs and giant clams. Figure 2 shows a declining trend in export quantity (tonnes) of trochus, sea cucumbers and green snails.

In areas close to highly populated urban centres, declines in reef finfish resources and shellfish are particularly evident.

Looking into the future, it is projected that coastal marine resource stocks will decrease by 2–5% by 2035, 20% by 2050

Figure 1. From L–R: Hon Hosea Nevu, Minister responsible for Fisheries; Moses Amos, Director-General Ministry of Agriculture, Livestock, Forestry, Fisheries and Biosecurity; and Sompert Gereva, Deputy Director Coastal Fisheries, during the signing ceremony. (Image: Vanuatu Fisheries Department)

and 20–50% by 2100. These decreases are due, in part, to a predicted rise in sea surface temperatures and an increase in ocean acidification, as well as greater runoff due to higher rainfall and cyclone intensity.[4]

Increased human pressure will also have a significant effect. In 1999, Vanuatu's population was 186,678; a decade later it had risen to 234,023 (2009).[5] Today, the population stands at around 270,000, with two-thirds of the people living within 1 km of the coast, and depending substantially on coastal fisheries as a source of food and livelihood. While the population continues to grow, the reef area remains the same at 408 km^2; the pressure on marine resources will, therefore, intensify as the population grows. Without proper policy guidance and management controls to ensure sustainability, chronic food shortages and poverty will become likely.

The Vanuatu Fisheries Department (VFD) is the mandated government agency responsible for the management, development and conservation of coastal fisheries through the

[1] A new song for coastal fisheries – pathways to change: The Noumea Strategy/ compiled by the Pacific Community.

[2] Preliminary Report AGRICULTURE CENSUS 2007. National Statistics Office Port Vila, Vanuatu (https://vnso.gov.vu/index.php/document-library?view=download&fileId=3075)

[3] http://www.fao.org/fi/oldsite/FCP/en/VUT/profile.htm

[4] http://www.spc.int/climate-change/fisheries/assessment

[5] https://vnso.gov.vu/index.php/document-library?view=download&fileId=3071

Fisheries Act. VFD has recognised these challenges ahead and, through the vision and leadership of former Director Kalo Pakoa, has taken a significant decision to put in place a policy roadmap that will guide and assist sustainable management to ensure long-term continuous benefits from coastal fisheries for current and future generations.

To realise this, VFD collaborated with partners under the auspices of the Australian government-funded Pathways Project, including the Pacific Community (SPC) and the University of Wollongong. After initiating the process in late 2017, VFD developed its draft roadmap through several planning and drafting stages and subjected it to extensive stakeholder consultation in 2018. The main objective of the consultation process was to present the draft roadmap to all relevant government and non-government stakeholder groups in order to incorporate broader interests, views and activities towards finalising the draft. This consultation provided an opportunity for coastal fisheries stakeholders to discuss the various programmes and activities being implemented within the coastal zone.

The roadmap has a long-term vision that states ‘By 2030, secure sustainable coastal fisheries, underpinned by community-based approaches to ensure the resilience and wellbeing of our people’. Figure 3 shows the roadmap’s framework structure.

The vision is supported by four overarching outcomes, which refer to different thematic components that make up the vision. These outcomes include resilient communities; effective coastal resource governance, productive and healthy coastal ecosystems, and happy, healthy and wealthy people.

Underneath the four overarching outcomes, six action areas identify clusters of actions that will be addressed. These are critical to realising the overarching outcomes, vision and ultimately the overall success of the roadmap. These action areas include governance, information and knowledge, ecosystem management, markets, health and nutrition, and livelihoods and wellbeing.

Its recent launching will see the roadmap become the key guiding policy document assisting VFD and its stakeholders in the sustainable management, development and conservation of Vanuatu’s coastal fisheries resources.

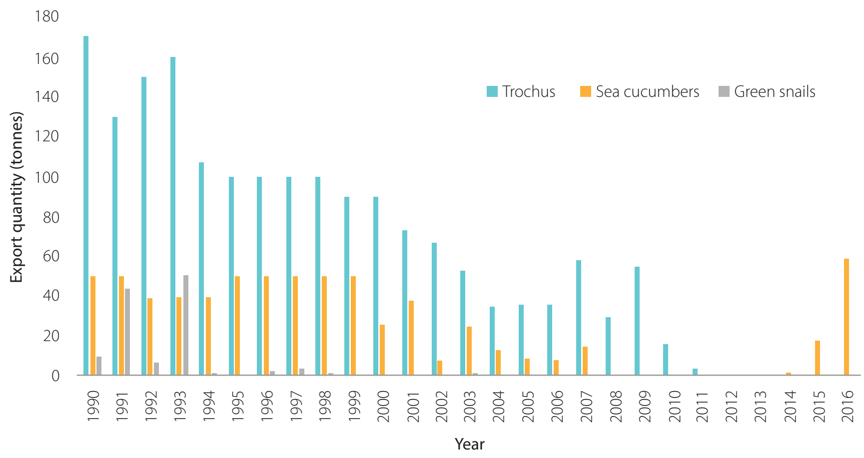

Figure 2. Total export volume of trochus, sea cucumbers and green snails over a period of 26 years, from 1990 to 2016.

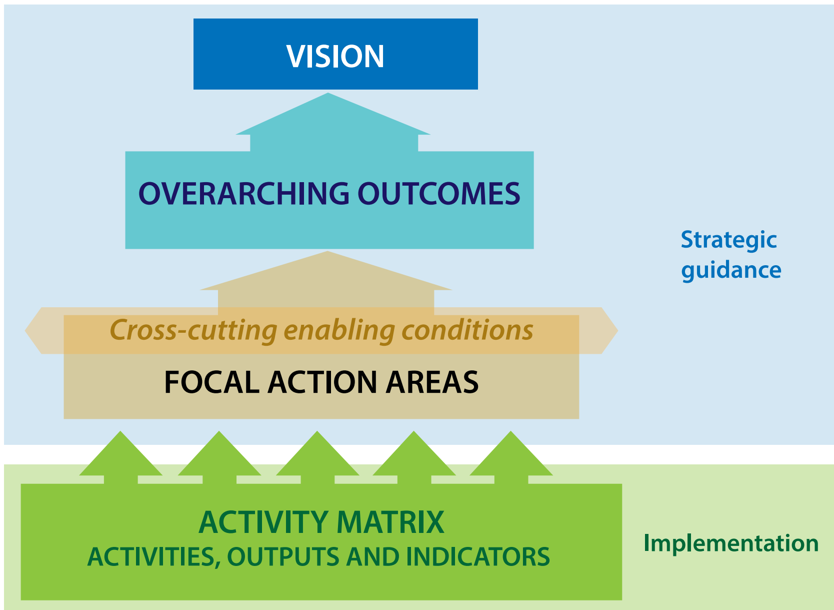

Figure 3. Basic framework structure of the roadmap.

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Obituary: Fiji's most successful pioneer tilapia farmer

Mr Abdul Sadiq Sr sampling tilapia in his pond to determine growth and feeding rates. (image: Avinash Singh, SPC)

Every day, early in the morning, Abdul Sadiq used to walk around his ponds watching his fish swim up to his familiar shadow. To the great sadness of all the people who had the chance to cross his path, Mr Sadiq passed away on 4 December 2018 after being sick for several months.

Mr Sadiq was one of the main pioneers of successful commercial tilapia farming in Fiji. He was a kind and generous farmer who first ventured into tilapia farming in 1991. He built the first two ponds on his farm with the support of his family and technical guidance from the Fiji's Ministry of Fisheries. Using the income generated by his fish farm, Mr Sadiq was able to replace his corrugated-iron shack with a four-bedroom concrete house on the hillside overlooking his fishponds on Baulevu Road, Tailevu. This large and impressive home became well known among the Fiji fish farming community as 'The house that tilapia built'.

Later, Mr Sadiq expanded his farm with the addition of two more ponds in 1998 and another pond after he retired in 2005, again with support from the Ministry of Fisheries. Mr Sadiq also diversified into ornamental fish production, including goldfish, koi carps, platies and gourami, along with livestock such as ducks, chickens and goat to supplement his income.

Mr Sadiq primarily sold his fish alive at the Nausori market, and was a familiar smiling face well known for the high quality of his products. He was also a founding member of the Tailevu Tilapia Farmers Cluster Group. He was always keen to share ideas he had developed and knowledge he had acquired about fish farming, and he eagerly coached new farmers with his methods for successful farming and marketing of tilapia fish.

His son and family continue the fish farming business, and aim to build on the legacy and successes of Mr Sadiq.

Spawning potential surveys reveal an urgent need for effective management

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Summary

Since 2014, a Fijian programme of sampling reef fish catches has measured 16,404 fish from 180 species. A new stock assessment technique called length-based spawning potential ratio assessment has been applied to these data to develop stock assessments for 29 of the most common species in catches. More than half of the species (17) are assessed as having less than a 20% spawning potential ratio (SPR), an international limit reference point above which fish stocks should be maintained to minimise the risk of long-term stock decline. Fourteen of these species are estimated as having <10% SPR, the international reference point for SPR_{CRASH} below which fish populations are expected to collapse. Closer examination of species with a low SPR suggests that spear-gun fishing and gillnetting are currently posing the biggest threat to reef fish sustainability in Fiji. Our results suggest an urgent need to reform the management of Fiji's reef fish stocks so that fish are not caught before reproducing they have had a chance to replace themselves and keep populations stable. To this end, the existing regulation of minimum size limits and mesh sizes needs to be revised, and the implementation of additional restrictions on fishing methods should be considered.

Introduction

With the aim of assessing the status of Fiji's reef fish stocks, a group of non-governmental organisations – funded by the David and Lucile Packard Foundation – have been working collaboratively with Fiji's Ministry of Fisheries staff since late 2014 to sample reef fish catches. In March 2018, those partners participated in a workshop where they pooled their data to estimate the size at maturity for 46 of the main reef fish species in Fiji (Prince et al. 2018). In August 2018, the partners met again to develop stock assessments using their estimates of size at maturity and the size composition of the catch data they had collected. This article provides an initial report of those analyses.

In Fiji, and most other Pacific Island countries and territories, there are too many reef fish species and insufficient data on catch trends and biology to apply standard methods for assessing trends in biomass (total weight). A new technique – called the length-based spawning potential ratio (LBSPR) assessment – has been developed specifically for fish stocks for which only data on catch size composition can feasibly be collected (Hordyk et al. 2015a, b; Prince et al. 2015a). The LBSPR methodology enables catch size composition to be used with an estimate of local size at maturity to produce a snapshot estimate of a fish population's spawning potential ratio (SPR). SPR is a measure of a population's potential to continue replenishing itself and whether it is likely to be declining, stable or increasing. Left unfished, fish complete their full life span and fulfil their natural reproductive (spawning) lives, achieving 100% of their natural spawning potential. When fishing occurs, the average life span of the fish in any population is reduced, because some fish are caught before completing their natural life span, thereby reducing the population and its spawning potential below the natural unfished level (100%). SPR is the proportion of the natural unfished spawning potential remaining in the population when it is being fished. Studies from around the world have shown that down to around 20% SPR fish populations still retain the capacity to rebuild their numbers after fishing, although the rate at which a fish stock can rebuild declines as SPR falls to around 20% (Mace 1994). The level of 20% SPR is internationally known as the 'replacement level', around which populations are expected to maintain their current level but have little ability to rebuild. Below 20% SPR the supply of young fish to the population is expected to decline over the succeeding years, while 10% SPR is commonly called 'SPR crash', below which populations are likely to decline rapidly and, if not corrected, is likely to result in local extinction.

Using the concept of SPR to assess fish stocks is similar to assessing human population trends by estimating how many of children from one couple will survive to adulthood. On average, if couples have 2.1 children surviving through to adulthood, populations replace themselves and remain stable. Above the replacement level for human reproduction, populations grow, and below that they decline. With fish populations, 20% SPR provides the same replacement level reference point as 2.1 surviving children per couple; both

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are pivotal reference points around which populations of humans and fish either increase or decline.

This collaborative project aimed at measuring the SPR of the main reef fish species caught in Fiji, with the hope of providing information to fisheries managers and local communities on the state of their stocks, and to facilitate discussions about the need for new or more effective reef fish management measures.

Methods

The LBSPR assessment methodology compares the size of the fish being caught with the size at which they reach sexual maturity. If fish are all caught before reaching sexual maturity their populations have little spawning potential (i.e. 0% SPR). On the other hand, if there is little fishing effort, fish live close to their natural life spans, thus allowing them to grow larger than their size at maturity, with some attaining the natural average maximum size (L_∞) of the population; when this happens, SPR is close to 100%. The LBSPR algorithms enable this information in catch size composition, relative to size at sexual maturity, to be quantified in terms of SPR and relative fishing pressure (*F/M*, where *F* is 'fishing mortality', and *M* is 'natural mortality').

The data inputs required for the LBSPR methodology are:

1. Catch size composition data that are indicative of the size of the adult fish in a population. If the type of fishing being conducted fails to catch the largest size classes of a fish species, then the estimate of SPR produced for that species will be too small.

2. Estimates of the size at which fish become adults (size at maturity) which is defined by L_{50} and L_{95}, the sizes at which 50% and 95%, respectively, of a population are observed to be mature.

3. The two life history ratios that are characteristic of each species of fish. The life history ratios are:

   a. the relative size at maturity; this is the size of maturity (L_{50}) divided by the average maximum size a species can naturally attain without fishing (L_∞); and

   b. a species' natural rate of mortality (*M*), which is the rate at which fish die due to natural causes, divided by the von Bertalanffy growth parameter *K,* which is a measure of how quickly each species grows to the average maximum size (L_∞).

Community members recording fish size and gonad maturity stage, Macuata District, Fiji. (image: Laitia Tamata, WWF)

The first two of these data inputs need to be measured locally for each fish species because they vary from place to place; but, the more technical life history ratios are estimated generically from the available scientific literature as they are characteristics of species and families of species, and remain relatively constant across their entire range (Holt 1958; Prince et al. 2015a,b).

For this analysis the algorithms needed to apply the LBSPR methodology were accessed at the freely available website: http://barefootecologist.com.au

Data inputs

Length and maturity data

The data used for this analysis have been compiled from 13 sets of size and maturity data from catch data collected around Fiji for this purpose.

In late 2014, the World Wide Fund for Nature (WWF) began working with the local reef management committee (*Qoliqoli* Cokovata Management Committee), and communities living in Macuata District along the north coast of Vanua Levu in the Northern Fisheries Division, training a network of community members to measure fish length and assess each fish's stage of maturity (juvenile or adult and male or female, if possible). Through initial community-based workshops, 20 species were selected to focus on, based on: 1) the importance of these species to communities, 2) community perceptions about whether the species were declining, and 3) the extent to which local fish names coincided with scientific names so that the species being sampled could be reliably identified to the species level. WWF staff also conducted sampling of the same species at the Labasa fish market. Throughout 2017, WWF also set up community-based sampling projects around Savusavu on the south side of Vanua Levu, Tavua on the north coast of Viti Levu and the Yasawa Islands off the northwestern coast of Viti Levu in the Western Division. Each of these programmes focused on a list of species decided on by each community, but also collected data on some additional species.

In 2016, the Wildlife Conservation Society (WCS) also conducted similar training to communities in Bua on the west coast of Vanua Levu, training community members to measure four main species in their own catches. In partnership with fish sellers and the Suva City Council, WCS staff also began a programme of market sampling at the Bailey Bridge market in Suva, which mostly sources its fish from the Northern Fisheries Division, and the Labasa fish market. Sampling at the Labasa fish market was also undertaken by Kolinio Musudroka.

In late 2016, staff from the University of the South Pacific's Institute of Applied Science collected catch composition and catch rate data in communities in Ba Province along the north coast of Viti Levu, and on Gau Island in Lomaiviti Province. They also spent several weekends collecting length and maturity data for the locally important emperor fish, *Lethrinus harak*.

Beginning in 2016, the Ministry of Fisheries's Research Division established multiple market sampling programmes from Nadi in the southeast of Viti Levu, around to Rakiraki in the west, where Western Division staff assisted them.

Size at maturity estimates

Initial estimates of size at maturity were determined by an analytical workshop in March 2018 (Prince et al. 2018); where significantly more data have since been added to the dataset, initial estimates have been revised for the analysis. Table 1 presents the inputs used for this analysis, and the results by species. In this table size at maturity has been revised for this analysis and have been indicated with an asterisk; none of the revised estimates are very different to the original March 2018 estimates.

Life history ratios

The estimates of life history ratios used for the LBSPR assessment (Table 1) were developed through a synthesis of all available age, growth and maturity studies for Indo-Pacific species (Prince unpubl. data).

Results

The database used for this assessment contained 16,404 records of fish caught in Fiji from 180 species.

Initially, we were interested in determining whether our size data for each species varied by region, so we developed separate assessments for the four to fivc most common species in our database. The confidence intervals around these assessments overlapped, suggesting that there were no significant differences for any of the species between Viti Levu and Vanua Levu. It is possible that this lack of obvious regional differences is due to the geographic distribution of our sampling, rather than a 'real' lack of regional differences. The species composition of catches we sampled varied markedly between locations, suggesting there were real differences, thus complicating our comparisons. Groupers and larger-bodied emperor fish and parrotfish were prevalent in samples from the north coast of Vanua Levu, farthest away from Fiji's main population centres and markets on Viti Levu, while smaller-bodied species were mainly found on Viti Levu where they dominate catches. It is possible that we failed to observe regional differences for any species because inevitably we ended up comparing a large sample from one location producing a robust estimate of SPR with narrow confidence intervals, with a relatively small sample size from the other region producing a relatively preliminary assessment with broad confidence intervals.

Table 1. Tabulated input parameters and results. Column headings are defined in the text. An asterisk next to a species name indicates the size at maturity estimate has been revised since Prince et al. 2018.

Species	*M/K*	*Lm/L∞*	*L∞*	L_{50}	L_{95}	Sample size	SL_{50}	SL_{95}	*SPR*	*F/M*	Type of fishing
Acanthurus xanthopeterus	0.35	0.8	383	306	345	747	180	221	0.41	0.8	Speargun
Caranx papuensis	1.6	0.6	550	330	400	91	184	218	0.76	0.14	Handline and speargun
*Cetoscarus ocellatus**	0.65	0.7	564	395	470	125	447	533	0.1	28.7	Speargun
Chlorurus microrhinos	0.65	0.7	536	375	450	249	366	500	0.26	2.06	Speargun
Crenimugil crenilabis	2.4	0.55	585	322	380	200	412	538	0.34	4.35	Net
Epinephelus coeruleopunctatus	0.75	0.6	660	396	480	179	377	542	0.07	6.54	Speargun and handline
Epinephelus coioides	0.75	0.6	975	585	700	69	388	575	0.04	4.27	Speargun and handline
Epinephelus fuscoguttatus	0.75	0.6	987	592	690	125	264	382	0.14	1.7	Speargun and handline
Epinephelus maculatus	0.75	0.6	662	397	480	118	286	394	0.04	4.7	Speargun and handline
*Epinephelus polyphekadion**	0.75	0.6	715	429	500	435	403	523	0.03	12	Speargun and handline
Hipposcarus longiceps	0.65	0.7	521	365	440	859	322	435	0.1	4.03	Speargun
Lethrinus atkinsoni	0.7	0.7	361	253	330	912	188	247	0.34	0.97	Handline and net
Lethrinus harak	0.7	0.7	331	232	290	1444	215	261	0.1	4.63	Net and handline
Lethrinus lentjan	0.7	0.7	294	206	240	95	188	204	0.23	2.06	Handline and net
Lethrinus nebulosus	0.7	0.7	589	412	500	489	238	307	0.22	1.24	Handline
Lethrinus obsoletus	0.7	0.7	357	250	310	713	208	247	0.05	5.66	Net and handline
*Lethrinus olivaceous**	0.7	0.7	736	515	640	589	574	902	0.3	2.36	Handline and speargun
*Lethrinus xanthochilus**	0.7	0.7	557	390	480	438	237	314	0.49	0.51	Handline and speargun
Lutjanus argentimaculatus	0.5	0.75	589	442	570	755	229	324	0.02	5.04	Handline and speargun
Lutjanus gibbus	0.5	0.75	397	298	380	1700	219	276	0.09	3.29	Speargun and net
Monotaxis grandoculis	0.7	0.7	494	346	420	305	277	366	0.35	1	Handline and speargun
*Naso unicornis**	0.35	0.8	510	408	490	1394	210	300	0.24	1.35	Speargun
Parupeneus indicus	2.4	0.55	591	325	400	178	240	286	0.02	4.43	Net
Plectorhinchus chaetodonoides	0.5	0.75	583	437	520	176	246	339	0.08	2.75	Speargun
Plectropomus areolatus	0.75	0.6	708	425	520	828	444	613	0.05	10.5	Speargun and handline
Plectropomus laevis	0.75	0.6	830	498	675	165	279	385	0.18	1.6	Speargun and handline
*Plectropomus leopardus**	0.75	0.6	730	438	540	118	211	255	0.17	1.56	Speargun and handline
*Scarus rivulatus**	0.65	0.7	444	311	380	747	231	265	0.01	10.2	Speargun and net
*Siganus vermiculatus**	1.9	0.55	440	242	270	398	218	286	0.4	0.83	Net

Although we may have failed to detect real differences between regions, we chose to proceed by aggregating our data from across all regions so as to increase sample sizes as much as possible, and broaden the number of species we could assess. In this context, however, it should be remembered that, although our data have been collected from many sites, the data for each species predominantly come from one or more regions.

Consequently, our assessments primarily reflect the status of each species in the region from which most of the samples were collected, rather than some sort of countrywide average for each species. In general, small-bodied species tend to reflect the fishery around Viti Levu, while and large-bodied species tend to reflect the fishery along the north coast of Vanua Levu.

Ideally, for this approach, samples sizes greater than 1000 individuals would always be available for analysis so that the largest individuals in each population are fully represented (Hordyk et al. 2015b). This is because the LBSPR analysis is strongly influenced by the size of the largest fish in a sample, relative to the average maximum size inferred from size at maturity. The largest individuals in a population are the rarest, meaning there is a high chance that small samples will fail to fully represent them.

Statistical studies show that sample sizes of 1000 are required to ensure the largest individuals are fully represented (Erzini 1990). Under-representation of the largest size classes with small samples sizes results in lowered estimates of SPR.

In the real world of Pacific reef fish sampling, sample sizes of more than1000 individuals are rare, and so it is necessary to use whatever data are available. In our experience, sample sizes greater than 100 are worth analysing (Prince et al. 2015b), and if the length frequency histogram coherently describes an adult mode, an indicative assessment can be made (i.e. heavily fished, moderately fished or lightly fished). If sample sizes can then be increased to more than 1000 individuals with the same input assumptions, the original SPR assessment may increase by 0–30% SPR, but almost invariably the originally preliminary estimate proves indicative of the final estimate.

For many of reef fish species in Fiji, sample sizes were too small (<100) to make an assessment worth attempting. From the data on 16,404 fish from 180 species we were able to use 14,641 records to develop assessments for 29 species (Table 1).

- Three species assessments have more than 1000 individual measurements of paddletail snapper (*Lutjanus gibbus*), thumbprint emperor (*Lethrinus harak*) and bluespine unicornfish (*Naso unicornis*), and are considered complete and unlikely to change to any significant extent with additional data. Only a large revision of our estimate of size at maturity is likely to change these assessments.

- Twelve species assessments are based on 400–1000 individuals of Pacific yellowtail emperor (*Lethrinus atkinsoni*), Pacific longnose parrotfish (*Hipposcarus longiceps*), squaretail coralgrouper (*Plectropomus areolatus*), mangrove jack (*Lutjanus argentimaculatus*), surf parrotfish (*Scarus rivulatus*), yellowfin surgeonfish (*Acanthurus xanthopterus*), orange-striped emperor (*Lethrinus obsoletus*), longface emperor (*Lethrinus olivaceus*), spangled emperor (*Lethrinus nebulosus*), yellowlip emperor (*Lethrinus xanthochilus*), camouflage grouper (*Epinephelus polyphekadion*) and vermiculate rabbitfish (*Siganus vermiculatus*), and can be considered robust, although some marginal change (0–10% SPR) might be expected if >1000 samples can eventually be collected. A large revision in estimates of size at maturity would also change these estimates.
- Fourteen species assessments have more than 300 individuals of humpnose big-eye bream (*Monotaxis grandoculis*), steephead parrotfish (*Chlorurus microrhinos*), whitespotted grouper (*Epinephelus coeruleopunctatus*), Indian goatfish (*Parupeneus indicus*), many-spotted sweetlips (*Plectorhincus chaetodonoides*), blacksaddled coralgrouper (*Plectropomus laevis*), spotted parrotfish (*Cetoscarus ocellatus*), brown-marbled grouper (*Epinephelus fuscoguttatus*), highfin grouper (*Epinephelus maculatus*), leopard coralgrouper (*Plectropomus leopardus*), pink ear emperor (*Lethrinus lentjan*), brassy trevally (*Caranx papuensis*) and orange-spotted grouper (*Epinephelus coioides*), these should be considered preliminary, but can be assumed to be indicative of their likely status. These assessments might change appreciably (0–30% SPR) if samples can be increased to more than1000. Building up the samples sizes is also likely to improve their estimates of size at maturity, which could also affect their assessment.

Taking these qualifications into consideration, our 29 assessments present a coherent and internally consistent view of the status of Fiji's reef fish stocks, which even with the addition of new data are unlikely to be significantly altered, even as the assessment of some species are improved.

More than half of the species (17) are assessed as having <20% SPR, the international limit reference point above which fish stocks should be maintained to minimise the risk of stock decline. Fourteen of these species are estimated as having <10% SPR, the international reference point for SPR_{CRASH}, below which fish populations are expected to collapse. On the other hand, five species have 20–30% SPR, which internationally would class them as currently sustainable, and seven species have 30–76% SPR levels, which, using the same international reference points, would rate them as either well-managed and/or moderately fished.

Discussion

Combined, these 29 assessments provide a 'big picture' view of the extent to which overfishing is currently affecting Fiji's reef fish. However, before discussing that big picture, several species-level caveats and qualifications are necessary.

The five assessments producing the highest estimates of SPR are based on sample sizes of less than 500 individuals, and could well change as sample sizes are increased, and size at maturity estimates are revised. While increasing samples sizes can be expected to increase future SPR estimates, improving size atmaturity estimates with more data can result in large changes in either direction to the SPR estimate.

The assessment for the mangrove jack (*Lutjanus argentimaculatus*), cannot be considered indicative of the adult

Assessing mullets' gonad maturity at the fish market. (image Watisoni Lalavanua)

population as it is likely that the actual SPR of this population in Fiji could be much greater. This is because juveniles of this species inhabit shallow mangrove areas where community members catch them, but the species is known to move to deeper water (30–200 m) as they mature (Pember et al. 2005; Russell and McDougall 2008). Apart from spawning females, adult mangrove jacks rarely visit or are caught in mangroves. Our results show that community catches contain almost no adults and have low (<2%) SPR, which is consistent with the fish's known biology and is probably not indicative of the actual status of this stock. The size composition of adults from deeper water is needed to accurately assess this species.

With these caveats in mind, these 29 assessments tend to support the predictions of the March 2018 workshop's theoretical modelling that, without effective management, in the long term, 39 ecologically and locally important reef fish species are vulnerable to being depleted to the point of local extinction (Prince et al. 2018). Based on the difference between size at maturity and size of first capture in Fiji that modelling predicted, the 23 species of reef fish are prone to local extinction. Two of these species, the bumphead parrotfish and the humphead wrasse have been protected by moratoriums on fishing under the Offshore Fisheries Management Decree and Endangered, Protected Species Act and the Convention on International Trade in Endangered Species, and should have been in our samples less often than they were. Many other species identified by the March 2018 workshop were not assessable from our samples because they were uncommon (i.e. less than 100). From these low sample sizes and anecdotal accounts of these species having previously been larger and more numerous, we infer that if we ever have sufficient sample sizes, assessments for these species would reveal their SPR to be lower than for the species we have assessed.

Of the 11 species listed in the March 2018 workshop that we have been able to assess, only 2 were assessed as having greater than 20% SPR: the steephead parrotfish with 26%SPR and the bluespine unicornfish with 24%SPR. The parrotfish assessment might change with better data as it is based on a relatively small sample size (n = 249) and a preliminary aize at maturity estimate. However, the bluespine unicornfish assessment is based on a relatively large sample size (n=1394) and a higher quality size at maturity estimate, so the relatively higher estimate of 24% SPR is more reliable. As with LBSPR assessment studies in other countries, this species commonly stands out as being under lower fishing pressure than other similarly sized species in the reef fish assemblage (Prince 2015b; Cuetos-Bueno 2018). Biological factors that might confer some greater degree of relative resilience for this species are suggested by genetic evidence that unlike many other reef fish, bluespine unicorn fish disperses its larvae relatively broadly (Horne et al. 2013), perhaps maintaining a supply of young fish over fishing grounds from more lightly fished and remote populations. Bluespine unicornfish also forages away from the reef into the water column, which perhaps also make it less vulnerable to fishing for periods of time.

Based on assessments in other countries, the yellowlip emperor (*Lethrinus xanthochilus*) is another species that commonly appears to be less overfished than might be expected purely on the basis of its relatively large body size and expected attractiveness to fishers (Prince 2015b; Prince unpubl. data), and in Fiji we estimated it to have 49% SPR (n = 438). There are few, if any, accounts of this species forming aggregations that can be targeted for fishing during any stage of its life cycle, as apparently it lives very singularly, and is caught almost entirely incidentally while fishing for other species. Perhaps because it cannot be targeted as effectively as other species, such as the bluespine unicornfish, it is more robust to fishing pressure than other species.

In an interesting contrast to the predictions from the March 2018 workshop's modelling, which identified primarily large-bodied species as being prone to local extinction, these assessments suggest that a whole range of small-bodied species are also being very heavily fished, such as surf parrotfish (*Scarus rivulatus*), Indian goatfish (*Parupeneus indicus*), paddletail snapper (*Lutjanus gibbus*), Pacific longnose parrotfish (*Hipposcarus longiceps*), orange-striped emperor (*Lethrinus obsoletus*) and thumbprint emperor (*Lethrinus harak*); all were estimated to have an SPR of less than 10%. These direly low SPR estimates are mainly based on reasonable samples sizes (n >500) and solid size at maturity estimates, and as discussed above, may not reflect the status of stocks throughout Fiji. They do, however, undoubtedly reflect the region from which their samples mainly came (Viti Levu). Starkly illustrating that at least in some areas of Fiji, the 'fishing down of the foodweb' (Pauly et al. 1998) has proceeded to the extent that small-bodied species are now being fished so heavily that stocks are experiencing long-term declines in the recruitment of young fish.

In Table 1, the final column lists the main capture methods for our samples, with the first method named being the principal method used in our sampled areas. Excluding mangrove jack from this discussion, for reasons outlined above, it is interesting to note that all species with <20% SPR are primarily caught by speargun fishing, which nowadays means mainly night-time speargun fishing, or by gillnetting. Species estimated to have >20% SPR are predominantly caught by hook and line. This comparison suggests that, currently, the practices of speargun fishing and gillnetting are the greatest threat to reef fish sustainability in Fiji. These two methods have in common: a) the fact that they are used in nursery grounds, in the case of night-time speargun fishing shallow coral reef flats, and in the case of gill nets seagrass flats; and b) both are very effective at catching small immature fish.

The only fish species caught by speargun that we assessed to have a high SPR (41%), is yellowfin surgeonfish (*Acanthurus xanthopterus*; n = 747), which was mainly sampled in the Northern Division (n = 611). This is a medium-sized, less preferred species of surgeonfish that only tends to be fished heavily when the preferred larger-sized surgeonfish species have been depleted. It has, however, proved prone to eventual depletion in many places. Unless this result is an artefact of the current dataset, or an indication that our current size at maturity estimate is too small, it suggests that depleted stocks of larger-bodied groupers, parrotfish and surgeonfish along the outer coral edges on Vanua Levu's north coast are caused by spearfishers now heavily targeting medium- and small-bodied species.

Improving the management of Fiji's reef fishes

Implementing the 'set size' system of minimum size limits, which is being discussed in Fiji (Prince et al 2018a), could go a long way to stabilising and increasing SPR levels among the main reef fish stocks by ensuring fish are caught and released, or not speared, until they have fulfilled at least 20% SPR (Prince and Hordyk 2018).

Research and experience from other jurisdictions suggest that with the support and goodwill of fishers, speargun fishing and hook-and-line fishing in shallow water can both be effectively size selective, as small fish can be avoided or released alive. Gill nets, however, commonly catch a range of sizes according to the size of mesh being used, and fish are normally badly damaged in the net and unlikely to survive after being returned to the water. To some extent gill nets can be size selective, with the regulation of minimum legal mesh sizes to ensure smaller fish cannot be caught. Fiji has regulations governing minimum mesh size limits, such as 1.25 inches for whitebait and sardines, and 2 inches for other fish. However, at least for 'other fish', our results show that many net-caught species have a very low SPR, suggesting that the current mesh size regulations are either too small, or not being complied with. The LBSPR analytical framework can easily be used to develop or review such policies and our results suggest this would be a useful exercise.

The size of fish that each type of fishing gear and method catches can also often be improved by regulating the time and place they are used (e.g. not fishing in nursery areas). Such regulations need to be developed with a deep knowledge of local geography and fish habitats, and can only be effectively implemented and enforced with the support of local communities. While there is a clear role for the national government in establishing regulations regarding minimum size limits and legal types of fishing gear, spatial and temporal regulations that help make fishing more size selective will also need to be developed and implemented through local management committees of the Fiji Locally-Managed Marine Area network.

Our results are likely to ignite discussion about the impact of night-time speargun fishing, which takes a wide variety of species as well as small juveniles. Theoretically, at least, night-time speargun fishers could be taught to comply with minimum size limits, thereby making this fishing technique sustainable. However, operating at night in the shallow coral reef nursery grounds of many species, they are likely to find compliance challenging and much less rewarding than current practices.

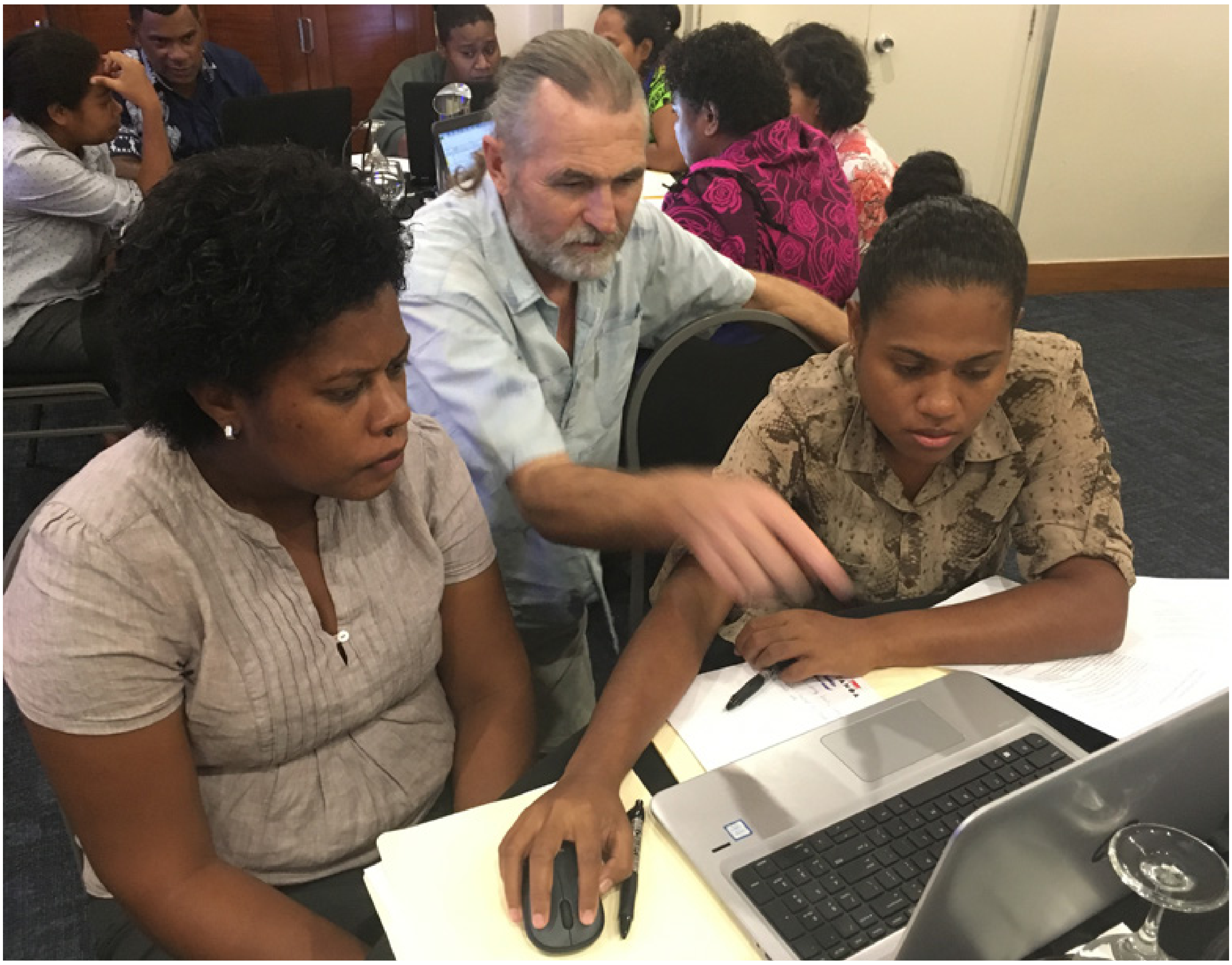
Some fishing practices are inherently difficult to make size selective (e.g. deepwater fishing and trawling catch a wide size range of fish that are mortally damaged in the process). Sustainably managing these types of fishing practices require effectively constraining controls on fishing pressure, supported by real-time monitoring and adaptive management measures. These are governmental capacities that developed countries struggle to deliver to small-scale fisheries such as those for tropical reef fish. Pacific Island countries are also likely to struggle for some time to effectively and adaptively control fishing pressure on reef fish stocks. Consideration, therefore, should be given to prohibiting activities that cannot be made size selective, or at least restricting such activities to remain at a small scale in restricted areas.

On the grounds of good fisheries management, it can easily be argued that communities and government should reconsider implementing and/or enforcing the ban on night-time speargun fishing. A national regulation of this type would probably be controversial and unpopular with many communities, especially as some communities who previously implemented such bans have since failed to enforce them. New Caledonia has implemented a different form of regulation to achieve a similar effect, which might also be more broadly acceptable in Fiji. Fishers may catch fish to feed their families by speargun fishing, but fish caught by speargun fishing cannot be sold in markets (Gillett and Moy 2006). This has the effect of limiting speargun fishing pressure to catches needed only to support local fishing families, while also reserving that part of coastal fisheries resources for local food security. In revisiting the issue of making speargun fishing sustainable, this form of policy deserves discussion.

Conclusion

This study illustrates the cost-effective utility of the new LBSPR methodology for assessing reef fish stocks. Through the collaboration of project partners, the status of 29 species has been determined for the first time, providing a snapshot of coastal fisheries around Fiji. This snapshot shows that overfishing of reef fish is occurring in Fiji parallels observations reported from across Pacific Island countries (e.g. Newton et al. 2007; Sadovy 2005; Sadovy de Mitcheson 2013) and, indeed, the entire tropical Indo-Pacific region (McClanahan 2011).

In conclusion, the assessments clearly show that the inshore fish stocks that communities depend upon are in crisis in many areas. Around the main island of Viti Levu, the



Ministry of Fisheries staff working with Dr Jeremy Prince to analyse data collected on size at maturity of reef fish in Fiji. (image: Sangeeta Mangubhai, WCS)

large-bodied species of groupers, wrasses, parrotfish and surgeon fish were rarely recorded in our samples, and even populations of small-bodied emperors, parrotfish and goatfish were estimated to have had their spawning potential reduced to levels likely to be cause long-term population declines. An almost complete assemblage of larger-bodied species was recorded in our samples from along the northern coast of Vanua Levu, but our results show that in this area these species are all likely to be declining (i.e. SPR<20%) and many rapidly declining (i.e. SPR<10%).

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Size, species, capture location: What makes tuna get high on mercury?

Anne Lorrain,[1] David Point[2] and Valérie Allain[3]

Tuna, in both cooked and raw forms, is found on restaurant menus, in sandwiches, and on the family table. While tuna flesh is widely appreciated, it does contain a natural toxin known as methylmercury, which is generating a considerable number of questions and concerns. A multidisciplinary study (Houssard et al. 2019) has accurately mapped the methylmercury content of a number of tuna species of the central and southwest Pacific for the first time. This is the zone in which more than half of the world's tuna is caught and subsequently exported, ending up on the plates of consumers. This study reveals that the methylmercury content of tunas depends not only on the size and species of the fish, but also on where they were caught. These results enable us to inform and advise tuna lovers.

To address the potential health risks associated with the naturally occurring methylmercury, the French Institute of Research for Development (IRD), the Pacific Community (SPC) and the University of New Caledonia (UNC) undertook research on the mercury content of a number of tuna species in the western and central Pacific Ocean.[4] Using specimens collected since 2001 by Pacific national observer programmes and stored in the tuna tissue bank managed by SPC (Sanchez et al. 2014), IRD has in recent years performed more than 1000 muscle tissue mercury content assessments on yellowfin, bigeye and albacore tunas.

Importance of landed fish size

Based on flesh samples from tuna captured in a large area stretching from Australia to French Polynesia, it came as no surprise that the highest mercury concentrations are found in the largest tunas (Fig. 1). In tuna flesh, mercury essentially occurs as methylmercury, which is the organic form of mercury that builds up naturally as tuna grow older and bigger; this process is known as bioaccumulation. Methylmercury is eliminated by marine organisms at a slower rate than it is accumulated (see Box 1). For the great majority of fish tested, the values recorded remain lower than the recommended threshold of 1 mg of mercury per kg of fish (wet weight) (USFDA 2006; WHO/UNEP DTIE Chemicals Branch 2008), especially for tuna under 1 m in length (Fig. 1). It has also been observed that this threshold may be exceeded in some albacore and bigeye tunas over 1 m in length, while this is only infrequently true of yellowfin tunas over 1.2 m in length.

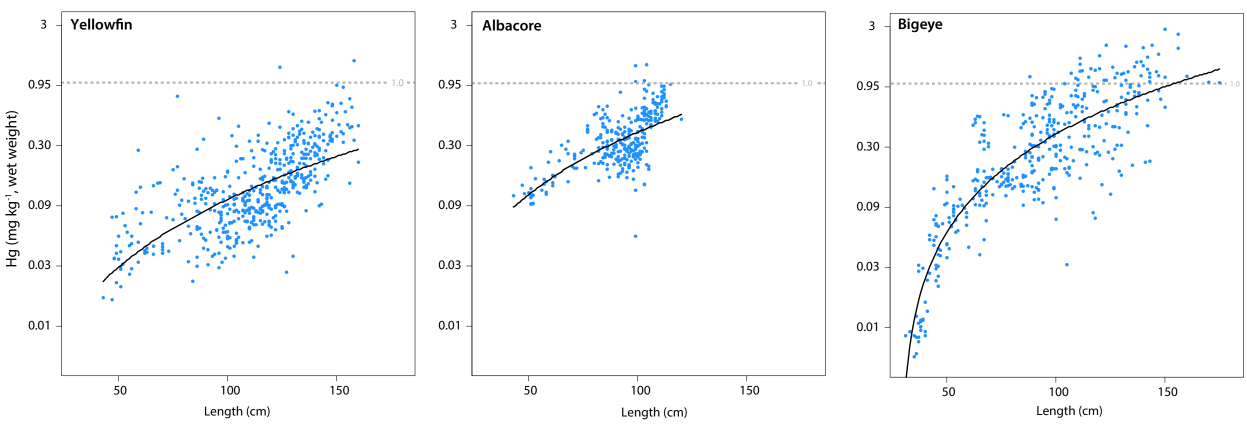

Figure 1. Mercury content trends as influenced by fish size in yellowfin, albacore and bigeye tunas in the western and central Pacific. The dotted horizontal line shows the recommended limit of 1 mg of mercury per kg of fish (wet weight).

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[4] VACOPA Project funded by the French Pacific Fund and the Government of New Caledonia (doctoral thesis, Houssard 2017).

Importance of depth and fishing zone

Researchers for the present study have also observed variations in mercury content between species, with bigeye tuna showing higher concentrations than yellowfin or albacore tunas (Fig. 2A). This difference between species can be explained by lifespan variations, different feeding habits and different physiological capacities, which, in particular, influence the respective depths at which they feed. Bigeye tuna live longer than the other two species and will, therefore, accumulate more mercury throughout their lifetime. In addition, bigeye tuna can dive deeper than the two other species, thus spending more time in the zone where natural methylmercury production in the ocean is highest (see Box 1). Bigeye tuna, therefore, show higher methylmercury concentrations than both albacore tuna, whose habitat is shallower, and yellowfin tuna, which tend to swim closer to the surface (Fig. 2B).

In addition to the effect of size and interspecific differences among tunas, our research made it possible to go even further by demonstrating that significant geographical differences also exist. In fact, within the same species, bigeye tuna for example, mercury content levels may vary by a factor of two or three or even more, depending on location. Around New Caledonia and Fiji for example, mercury levels are higher than they are at the equator (Fig. 3). Electronic tuna tagging research results (Evans et al. 2008; Fuller et al. 2015; Houssard et al. 2017) have shown that bigeye tuna dive deeper in New Caledonia than they do at the equator, again demonstrating that the deeper a tuna's habitat, the higher the methylmercury concentrations it contains, because it feeds within a habitat where methylmercury production is higher (see Box 1).

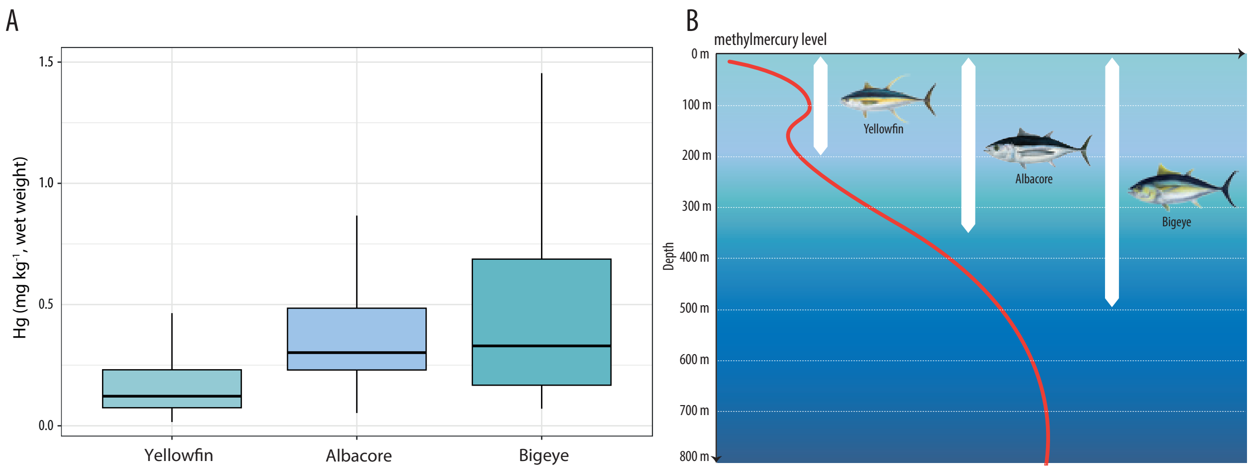


Figure 2. A) Median mercury content levels in yellowfin, albacore and bigeye tunas in the western and central Pacific, and B) representation of the vertical habitat of tunas, with the curve of methylmercury content in the water in relation to depth.

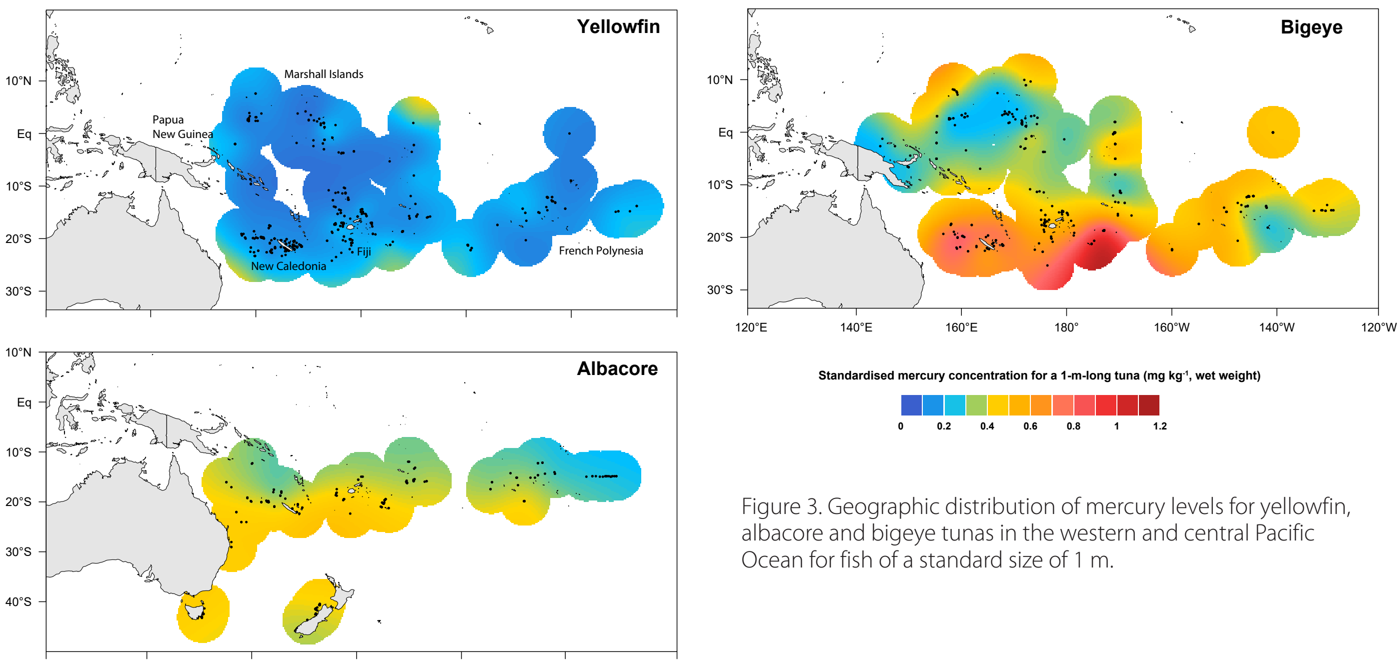


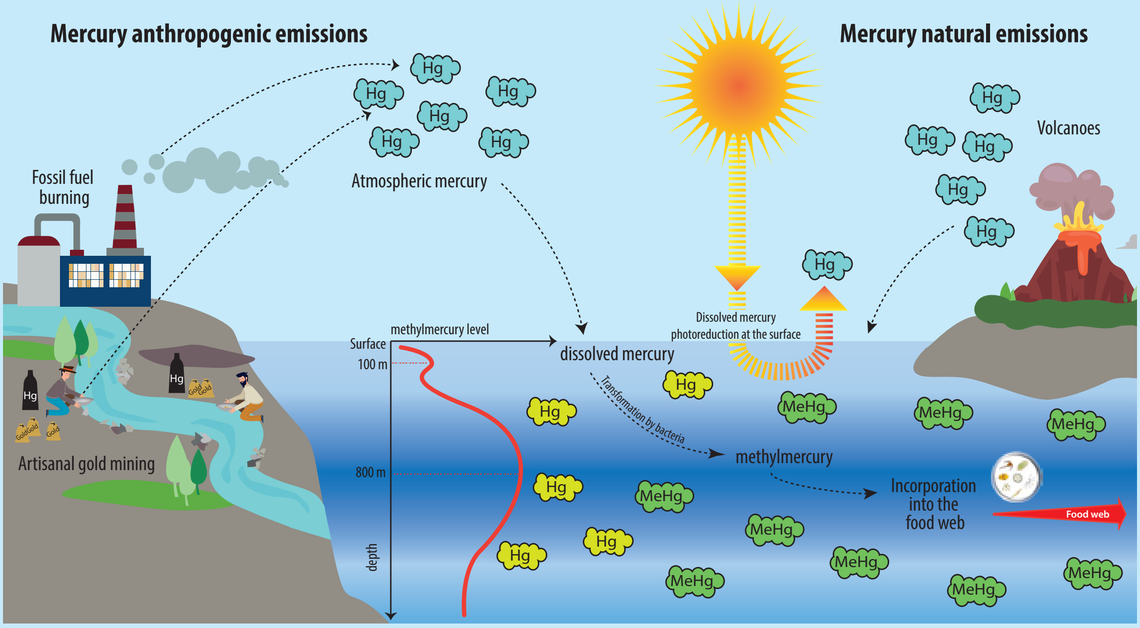
Figure 3. Geographic distribution of mercury levels for yellowfin, albacore and bigeye tunas in the western and central Pacific Ocean for fish of a standard size of 1 m.

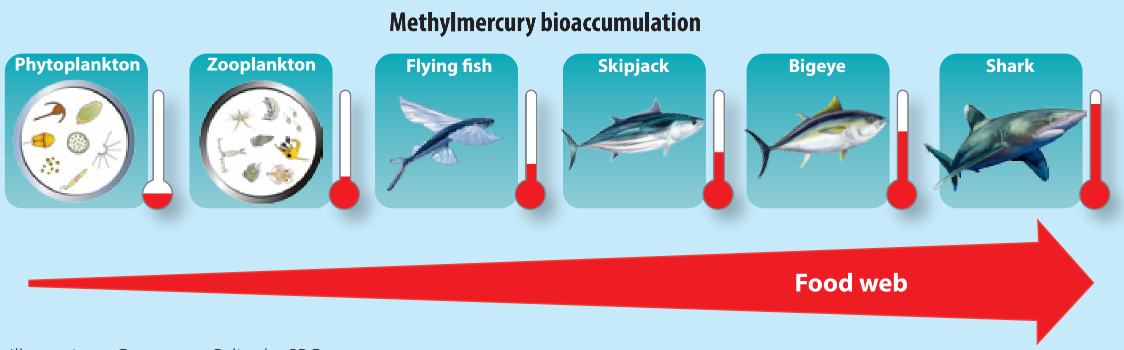
Box 1

Where does the methylmercury in the ocean come from?

Mercury is emitted into the atmosphere through natural sources such as volcanoes, but more extensively through human activities such as burning coal and fossil fuels, industrial waste, and small-scale gold mining. The gaseous form of mercury in the atmosphere is gradually deposited into the oceans in the form of dissolved mercury, or methylmercury. Human-caused mercury emissions have been, for example, responsible for a threefold increase in mercury concentrations dissolved in the surface layers of the world's oceans since the industrial revolution (Lamborg et al. 2014). A fraction of the dissolved mercury is naturally converted into methylmercury by sulphate-reducing bacteria, in which case the process is referred to as mercury methylation. This conversion is particularly intense in the less oxygenated deeper ocean waters (between depths of 400 m and 800 m). Also, in the surface layers, the dissolved methylmercury and mercury are degraded by light and re-emitted into the atmosphere in a gaseous mercury form (photo-reduction process). The production of methylmercury in the oceans, therefore, depends on the balance between methylation, which is more intense in less oxygenated zones (deeper ocean layers), and photo-reduction, which is more intense in surface ocean layers. The balance between these reactions explains the trend towards an increase in methylmercury concentrations with depth.

This methylmercury is highly bioavailable for ingestion and fixing by the living organisms at the base of the food web. Its concentration increases naturally, by accumulation, because it is only eliminated in very small quantities by organisms, from the very first stages in the food web (plankton), up to the top predators (tuna and sharks), which contain the highest methylmercury levels. There are, however, many more grey areas in the ocean mercury cycle.





Illustrations: Constance Odiardo, SPC

Mercury limits are infrequently exceeded

Despite the combined influence of size, species and feeding depth, the recommended mercury limits (1mg kg^{-1} wet weight) are infrequently exceeded. Only 1% of yellowfin and albacore tuna catches and 11% of bigeye tuna landings showed concentrations higher than the maximum recommended levels. Values over the maximum recommended level were mostly for larger specimens (1 m or more in length). Bearing in mind tunas' demonstrated nutritional benefits, with special reference to omega-3 fatty acids and essential elements (such as selenium) that reduce the risk of some cardiovascular diseases, there is no justification for any ban on eating tuna; all that is required is a recommendation to consume it in moderation as per established guidelines. Relevant authorities in every country publish recommendations on the quantity and species of tuna that can be consumed weekly with regard to relevant population groups (e.g. pregnant women, young children). The Government of New Caledonia and its Health and Social Affairs Department, in cooperation with the researcher team involved in the present study, produced and disseminated leaflets setting out the amount of tuna that can be consumed weekly and by population group to keep the public in New Caledonia informed.[5]

Box 2

The Minamata Convention, or how to restrict mercury pollution

The international Minamata Convention,[a] which came into force in August 2017, pursues the goal of controlling and reducing anthropogenic mercury emissions into the atmosphere. This convention is named after the town of Minamata in Japan, where a petrochemical factory leaked industrial methylmercury, from the production of acetaldehyde, for more than 30 years, between 1930 and 1960. This pollution poisoned thousands of people who endured severe neurological impacts. The health risks are particularly high for foetuses and young children. Many countries have ratified, or are in the process of ratifying, the Minamata Convention and are, therefore, committed to reducing mercury pollution by controlling and better managing the use of mercury in small-scale gold mining or by reducing emissions into the atmosphere.

[a] http://www.mercuryconvention.org/

New research under way in the three oceans

If we compare mercury content levels in the Pacific with available data in the literature for other oceans (Indian, Atlantic, North Pacific) (see Houssard et al. 2019), the levels fall within the same value ranges for bigeye tuna and, indeed, are even lower when it comes to yellowfin and albacore tunas of a similar size (Fig. 4). These studies are, however, based on limited datasets and show major variations around mean values. In order to confirm these results, our team has begun a large-scale study with supplementary high-spatial-resolution analysis to determine mercury levels in every ocean.[6] Mercury-specific isotope markers will, for example, be used to try and understand what the various mercury sources are (natural or human caused) and how and where they bioaccumulate in top predators, in an effort to determine the risks and benefits of consuming tuna caught in a particular place.

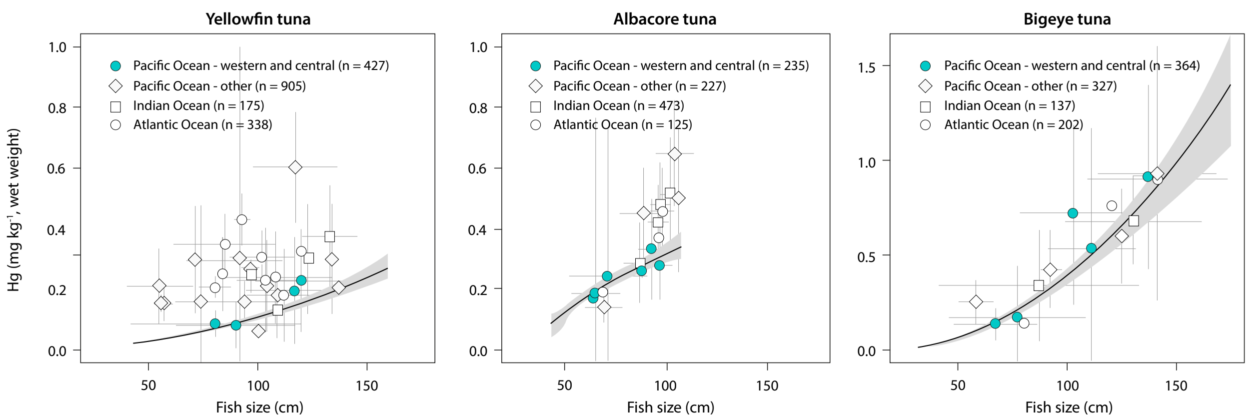


Figure 4. Trends in mercury content by fish size for yellowfin, albacore and bigeye tunas in the three oceans. The mean values from our study, which originate in various parts of the western and central Pacific, are shown in colour, with the general trend (black curve) and variability around that trend (shaded zones) also shown. The mean values from the scientific literature (see Houssard et al. 2019), which originate from other parts of the Pacific, Indian and Atlantic oceans are represented by white symbols. Horizontal and vertical lines show the range of values on either side of the mean. Figures in brackets represent the number of specimens tested in order to calculate mean values.

[5] Available from: https://urlz.fr/8Yss

[6] As part of the MERTOX project (2018–2021) funded by Agence Nationale de la Recherche Française and the doctoral thesis by Anaïs Médieu (Université de Bretagne Occidentale, France).

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Image: Valérie Allain, SPC

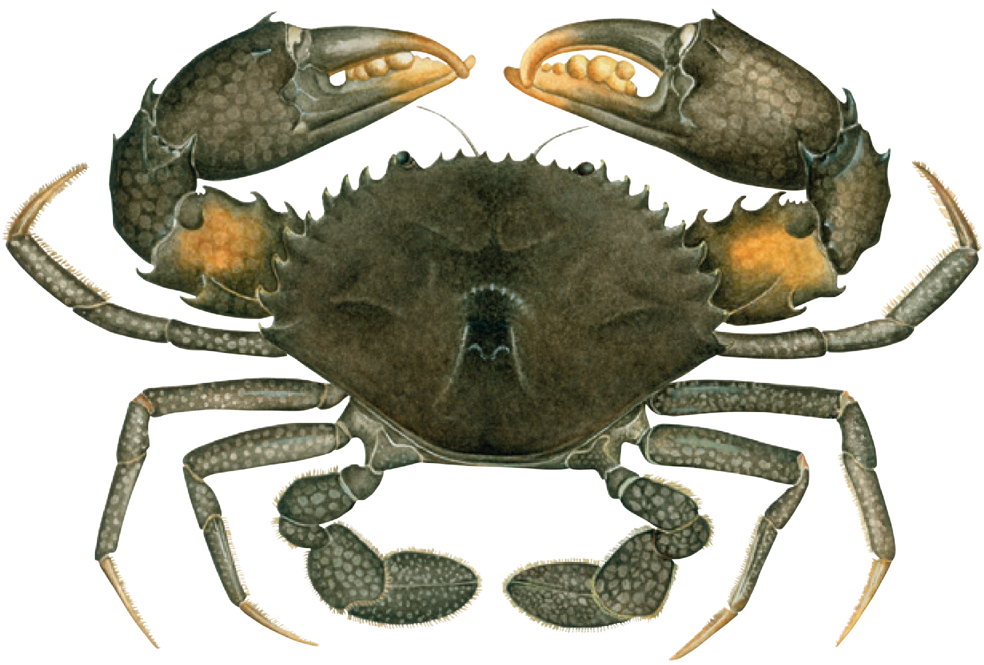
The mangrove crabs of Pohnpei Island, Federated States of Micronesia: A timely intervention to ensure sustainability of a favoured resource

Andrew R. Halford[1] and Pauline Bosserelle[2]

Introduction

The mud crab or mangrove crab, *Scylla serrata*, is a highly desirable crustacean species that is widespread throughout the Indo-west Pacific region, where it lives in close association with mangrove ecosystems (Fig. 1). Genetic analysis has demonstrated that there are at least three distinct stocks of mud crabs in the region: western Indian Ocean, eastern Australia and the tropical Pacific Ocean, and northwestern Australia (Fratini et al. 2010). The larvae of *S. serrata* can drift at sea as part of the plankton for up to 75 days, enabling them to colonise habitats far from the home of their parents, resulting in genetically well-mixed populations.

The life cycle of these crabs is complex, involving an extended period in the planktonic phase where they go through five developmental stages before settling into habitat close to mangroves. As they grow, individuals move incrementally farther into the mangrove system. Sexually mature females undergo long-distance migrations of up to 90 km, to offshore waters to spawn and renew the cycle (Fig. 2). Crabs can reach maturity in as little as 12–18 months in tropical latitudes but can take as long as 24 months in more temperate locations. Sexual maturity for *S. serrata* also occurs at different sizes throughout their geographic range. For example, male crabs in South Africa reach sexual maturity at a carapace width (CW) of 11–12 cm, compared with Pohnpei, which is quite close to the equator, where they are a full 1 cm larger at 12–13 cm CW (see Table 2 in Alberts-Hubatsch et al. 2015). Mud crabs typically only live for a maximum of three to four years, such that constant recruitment is necessary to keep the population replenished and stable.



The mud crab or mangrove crab, *Scylla serrata.* (illustration Rachel O'Shea, SPC)

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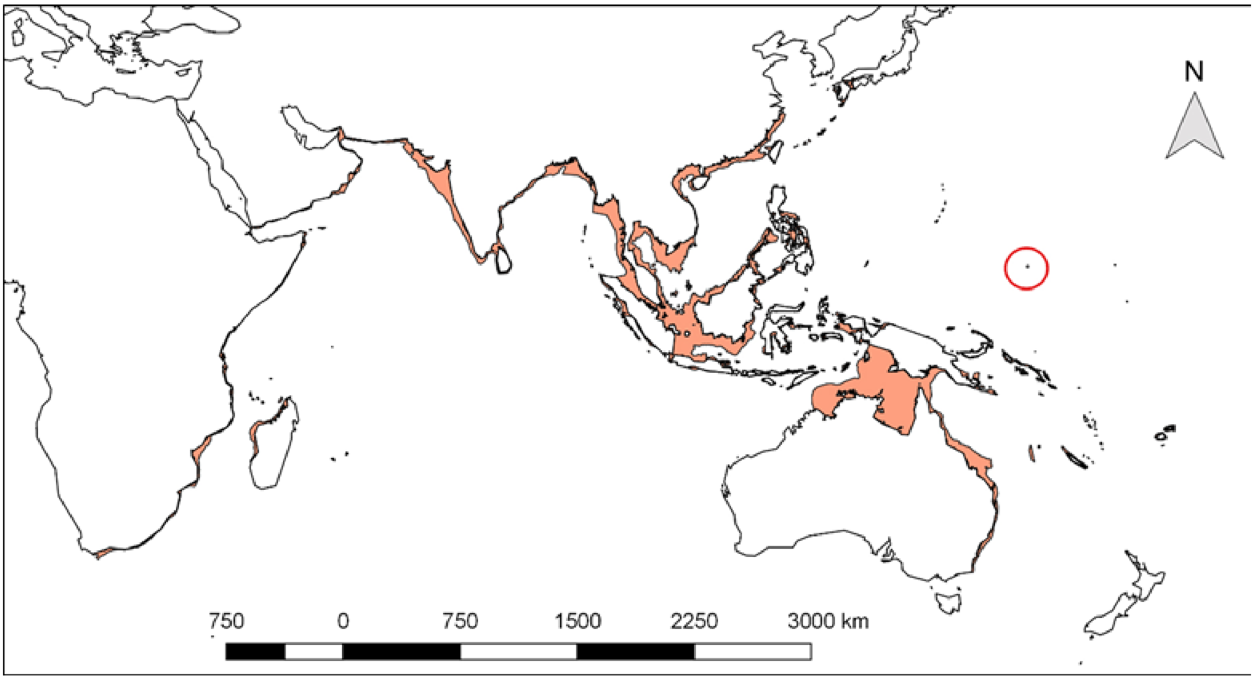

Figure 1. Global distribution of the mangrove crab *Scylla serrata*. Red circle indicates the location of Pohnpei. (Map details from FAO, GeoNetwork website)

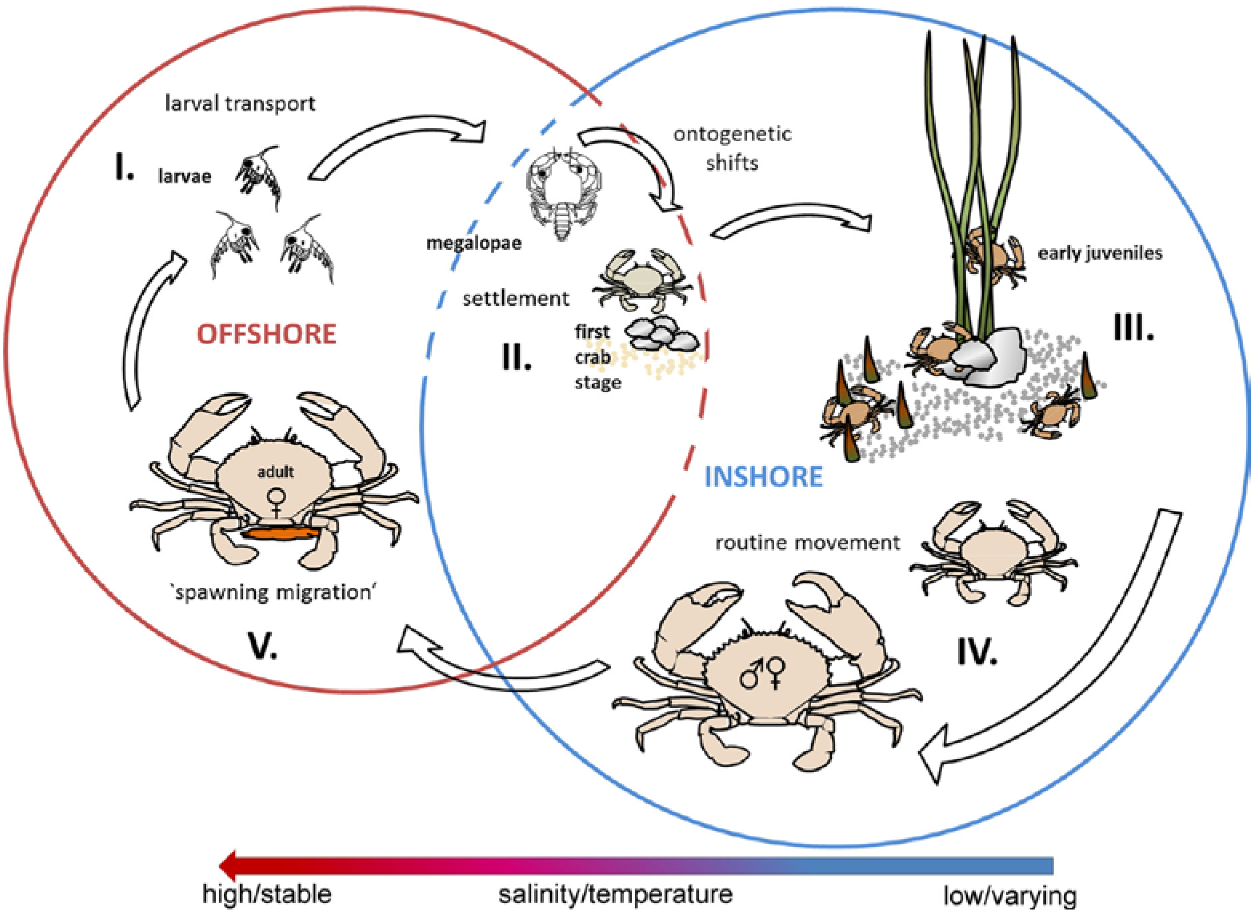

Figure 2. The life cycle of the mangrove crab *Scylla serrata*. Salinity and water temperature are influential throughout the life cycle. (Source: Alberts-Hubatsch et al. 2015)

The timing and extent of spawning and recruitment varies with latitude. In cooler climates, spawning is constrained to the summer months, while closer to the equator where temperatures are less variable spawning can occur year-round.

Mature crabs are found in all areas of the mangrove ecosystems that they are closely associated with. Where significant mud banks exist, they dig holes up to 2 m deep for sheltering in. They are also found within the root systems of mangrove trees, in hollows of more mature trees, and on the mud and seagrass flats that often exist adjacent to and within mangroves and estuary systems. While capable of making significant migrations, as evidenced by female spawning behaviour, tagging studies have shown that most crabs move less than a few kilometres from where they are initially captured (Hyland et al. 1984; Bonine et al. 2008).

Mud crabs are a highly desirable seafood. Their sweet, delicate flesh is highly sought after by consumers who are willing to pay a high price for a meal of these crustaceans. Prices for wild-caught, live mud crab can be as high as AUD 80 per kilo in Australia and Japan. Indonesia has the largest catches of mud crabs, with 64,602 tonnes caught in 2017, and Singapore being a primary export destination. Australia by comparison had a total commercial catch of ~1500 tonnes in 2018, while Thailand's catch was estimated at 412 tonnes in 2017 (Aldon and Nagoon 1997; FAO statistics [http://www.fao.org/figis/servlet/TabSelector]; Shelley 2008; www.fish.gov.au/report/155-MUD-CRABS-2018). Most countries that report their catches to FAO show a declining trend in annual harvests.

The increasing global demand for mud crabs is placing enormous pressure on wild stocks, driving calls for more investment in farming these species. However, despite progress in the culture of mud crabs in Japan, Vietnam and the Philippines, most culture facilities still rely heavily on wild-caught crablets and juveniles, with culture successes remaining low and inconsistent (Waiho et al. 2017). Considerable research is still needed before larval culture and rearing of mud crabs becomes a viable alternative to the harvesting of wild stocks.

While the largest populations of mud crabs are found in countries with the most extensive and mature mangrove ecosystems, such as those throughout Southeast Asia and Australia, there are nevertheless well-established mud crab populations throughout many smaller countries that contain mature mangrove forests, including many Pacific Island countries and territories. Within the Federated States of Micronesia (FSM), all four states – Yap, Chuuk, Pohnpei and Kosrae – contain mature mangrove stands with resident populations of mud crab. Pohnpei, however, has significantly more mangrove area (~5500 ha) than the other states combined (Yap, ~1100 ha; Chuuk, ~300 ha; Kosrae, ~1500 ha) (Smith 1992).

Although the mangrove systems of small island states such as FSM are not capable of producing enough crabs to be a major contributor to gross domestic product, this resource is nevertheless important as a high-value product within local markets. The animals can be kept alive out of water for up to a week if stored properly, which is an advantage in areas where post-harvest processing and transportation facilities may be less than adequate. Setting up a crabbing operation requires minimal capital investment and as the product is highly sought after by the tourist and restaurant trade where it commands a high price, it provides ready cash for artisanal fishers and their families. Mud crabs from Pohnpei are considered particularly tasty in the greater region and, hence, are in high demand.

Previous research into mud crab populations within FSM focused on Kosrae and, to a lesser degree, Pohnpei. These reports and papers provide substantial insights into FSM's mud crab populations, and served as a baseline for the 2018 assessment of Pohnpei's mud crab populations. Male mud crabs in Kosrae display biological and ecological characteristics similar to those reported elsewhere: they are significantly larger than females, their movements are restricted, their maximum size is 20–24 cm CW, and their maximum lifespan is 3–4 years (Bonine et al. 2008). Observed differences in the size structure of crab populations from different parts of the island were correlated with variable harvest pressure, reflecting the distribution of the human population and location of emerging commercial harvest operations (Bonine et al. 2008; Ewel 2008).

Prior to the 2018 survey, Pohnpei's mud crab populations were last studied in 1977–1978, over 40 years ago (Dickson 1977; Perrine 1978). These older studies nevertheless identified similar biological and ecological parameters to the studies on Kosrae's crabs, undertaken 20 years later. They also highlight strong spatial differences in the size structure of mud crab populations between locations where crab trapping occurred. These differences correlate with the density of people living nearby and the spatial extent of the local mangrove forests, again similar to the results from the Kosrae studies. It was concluded, however, that Pohnpei's mud crab populations at that time were not being overexploited and that fishing restrictions were unnecessary.

Forty years later, FSM's human population has risen by ~ 70% and the pressure on natural resources is high. Responding to increased concerns from constituents about an apparent long-term decline in the abundance and size of mud crabs, a national senator requested help from the Pacific Community to undertake an assessment of the health of Pohnpei's mud crab stocks, and to provide advice on the most effective management strategies.

To obtain the information necessary to assess the health of Pohnpei's mud crab stocks, the following objectives were undertaken:

- An extensive island-wide trapping programme within the major mangrove areas around Pohnpei.

- Surveys of local fishermen to understand catch and effort, and spatial distribution of effort.
- Surveys of local fish markets to understand volume, size and price of mud crabs being sold, and to whom.
- Surveys of exports through the local airport to better understand the volume of mud crabs being exported from Pohnpei.
- Review of current data collection, storage and reporting activities by national and federal government agencies.
- Review of current legislation regarding the exploitation of mud crabs.

Methodology

Data needed for the assessment were allocated across five separate areas encompassing fisheries-independent trapping surveys, market surveys, fisher creel surveys, airport surveys and export studies (Fig. 3).

Trapping

Trapping locations were chosen to ensure coverage around the whole island and, where possible, to overlap with areas that were trapped by Perrine in 1978 (Fig. 4).

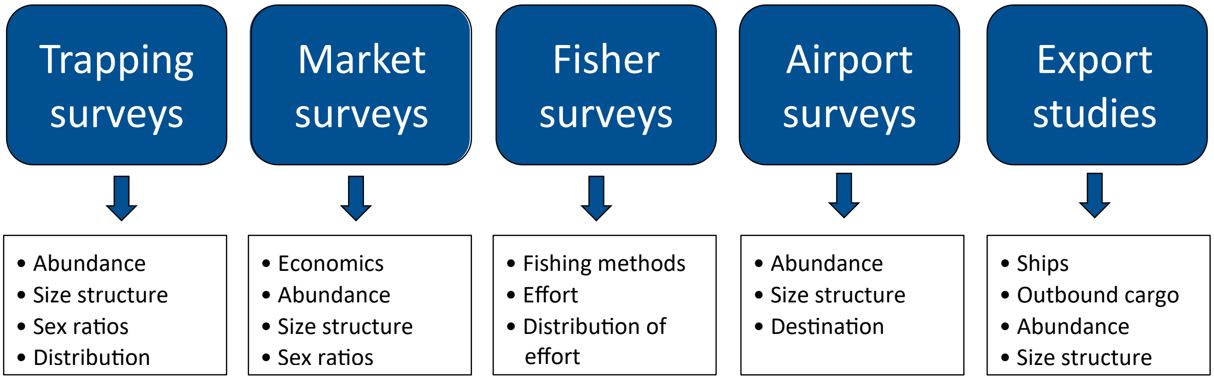

Figure 3. The five areas where data collection was focused, and the range of outcomes that can be derived from each data collection method.

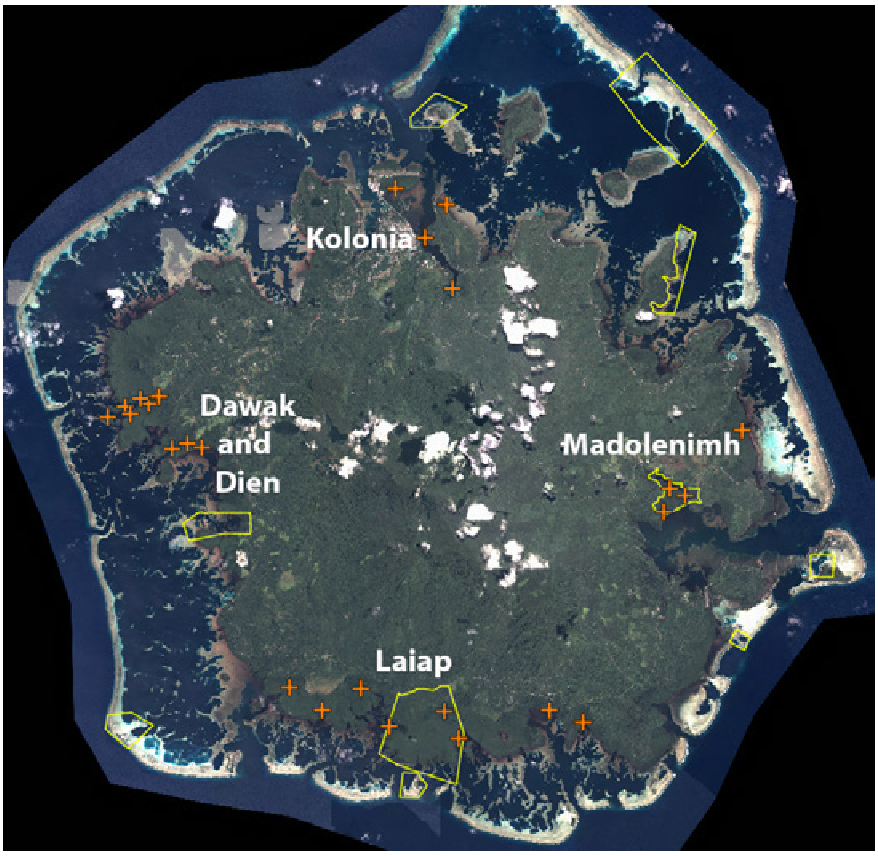

Figure 4. All locations on Pohnpei Island where trapping was undertaken (orange crosses). Yellow polygons represent mangrove protection areas.

Thirty traps of proven design for maximising mud crab catches, were purchased (Fig. 5).

At each general location three groups of 10 traps were set upstream, downstream and outside the river mouth. This amount of replication was reduced after the first week of trapping because of the loss of a number of traps. Subsequent groups consisted of 7, 7 and 6 traps set at least 50 m apart to avoid overlap in the catching zone of individual traps. Traps were baited with 500 g of skipjack tuna, which was replaced every 24 hours, or less if the bait was taken within this period. Traps were fished for a minimum of three days, or more if catches did not decline during this period.

Individual traps were checked approximately every 10–12 hours on a morning and evening schedule, although spring low tides sometimes made it difficult to stick to this schedule. The sex, weight and CW of all mud crabs caught were determined and recorded. The crabs were then released after painting an identifying number on their shell using a tippex pen and attaching a coloured cable tie to the base of one of their swimming legs (Fig. 6). Crabs were marked to distinguish them from new crabs that were caught during subsequent trappings. Each time, new crabs were marked while previously marked crabs that were re-caught were noted on the datasheet and returned to the water. This mark-and-recapture programme provides data from which estimates can be calculated for the total number of adult crabs inhabiting a particular mangrove ecosystem.

Figure 5. Fisheries officers from Pohnpei and Kosrae, and Conservation Society Pohnpei staff, assembling crab traps and bait bags prior to beginning the trapping programme. (image: Andrew Halford, SPC)

Figure 6. A captured crab has been marked with the number '11' using a tippex pen, and its rear left swimming leg has a blue cable tie attached to aid with identification if recaptured. (image: Andrew Halford, SPC)

Market surveys

Three individual markets were identified as the main buyers and sellers of mud crabs in Kolonia, Pohnpei's capital: H&D, Ellens's and Saimon's. Market stalls were visited at least once a day to check on the presence of crabs; and, with the permission of the stall owner, all crabs for sale were weighed, measured and their sex determined (Fig. 7). The buying and selling of crabs can happen at any time of the day but in general catches of crabs were sold to the market stalls at the market's opening and evening times, with sales occurring at any time crabs were available.

Fisher surveys

Identifying individual fishers to interview was a time-consuming process, given the remoteness of many of the main fishing areas and the inability to contact individuals by phone. Finding interviewees required driving to individual villages and speaking to people until we found someone willing to participate in the survey. We were eventually successful in interviewing 12 fishermen over the course of one month (Fig. 8). Interviews were conducted using standard creel survey questions that seek to understand the effort, cost and outcomes of targeting mud crabs.

Figure 7. Measuring mud crabs at Saimon's Market. (image: Andrew Halford, SPC)

Figure 8. Interviewing a mud crab fisherman. (image: Andrew Halford, SPC)

Airport surveys

Because they are highly prized throughout the region, many travellers leave Pohnpei with mud crabs they purchased from the local markets. Regulations allow the export of 15 mud crabs per individual per trip; regular flights out of Pohnpei, therefore, could potentially have significant numbers of mud crabs onboard. After gaining permission from all relevant government departments, and the airlines, we were able to check the coolboxes (a.k.a. ice chests) of travellers who were taking crabs out of Pohnpei, and to measure, weigh and determine the sex of all crabs observed.

Other

Anecdotal evidence from numerous sources identified another potentially significant source of mud crab sales and transactions: the sale of mud crabs to individuals from longline and purse-seine vessels moored in the harbour. Formal interviews were not possible with anyone directly involved with this process, so information was gathered from the observations of customers visiting the markets and general discussions with market stall personnel.

Results

Trapping

A summary of all mud crabs trapped in 2018 revealed a 12% bias in favour of male crabs caught, for a total of 190 males and 147 females caught. Mean CW was effectively the same for males and females at 14 cm (Fig. 9).

When the trapping results are grouped by location (Fig. 10), clear differences can be seen in the size structure and abundance of the crabs. Laiap in the south had the largest mean size of male and female crabs, although the total number of crabs caught was only 16, while Madolenimh in the east had the smallest crabs but the total number of crabs caught was 174.

Market surveys

In total, 307 crabs from the markets were measured, with an overwhelming majority of these being males (70%). The median CW was 7 mm larger for males, and mud crabs from the markets were consistently larger than the average size of crabs caught through our trapping programme (Fig. 11).

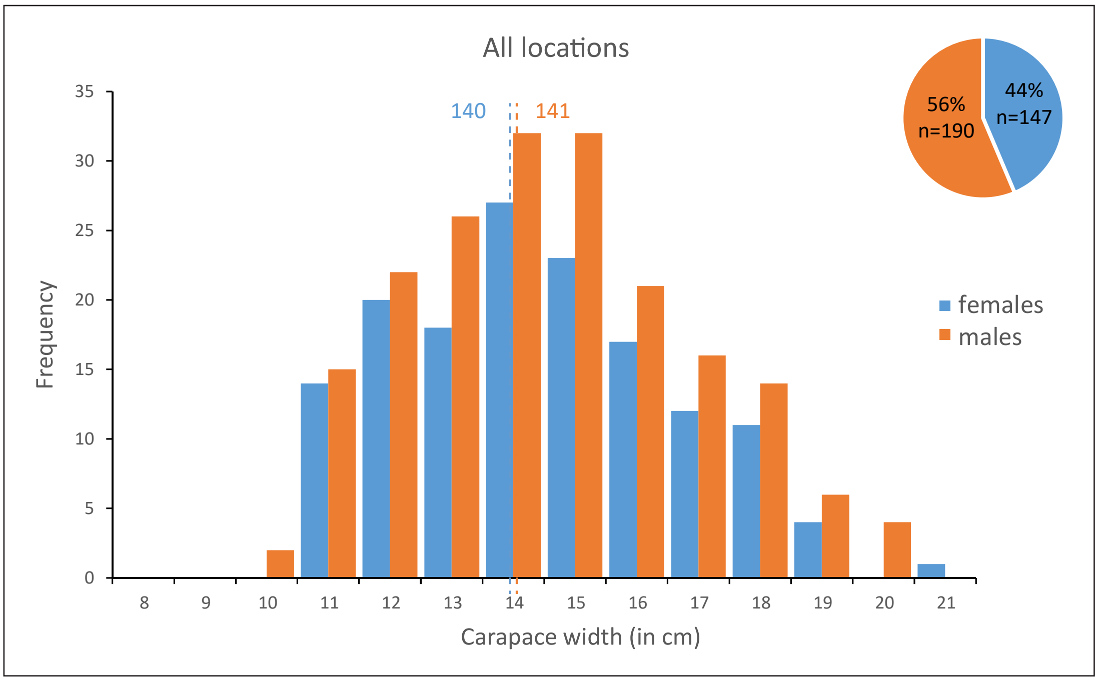

Figure 9. Size structure and overall sex ratio of all mud crabs captured.

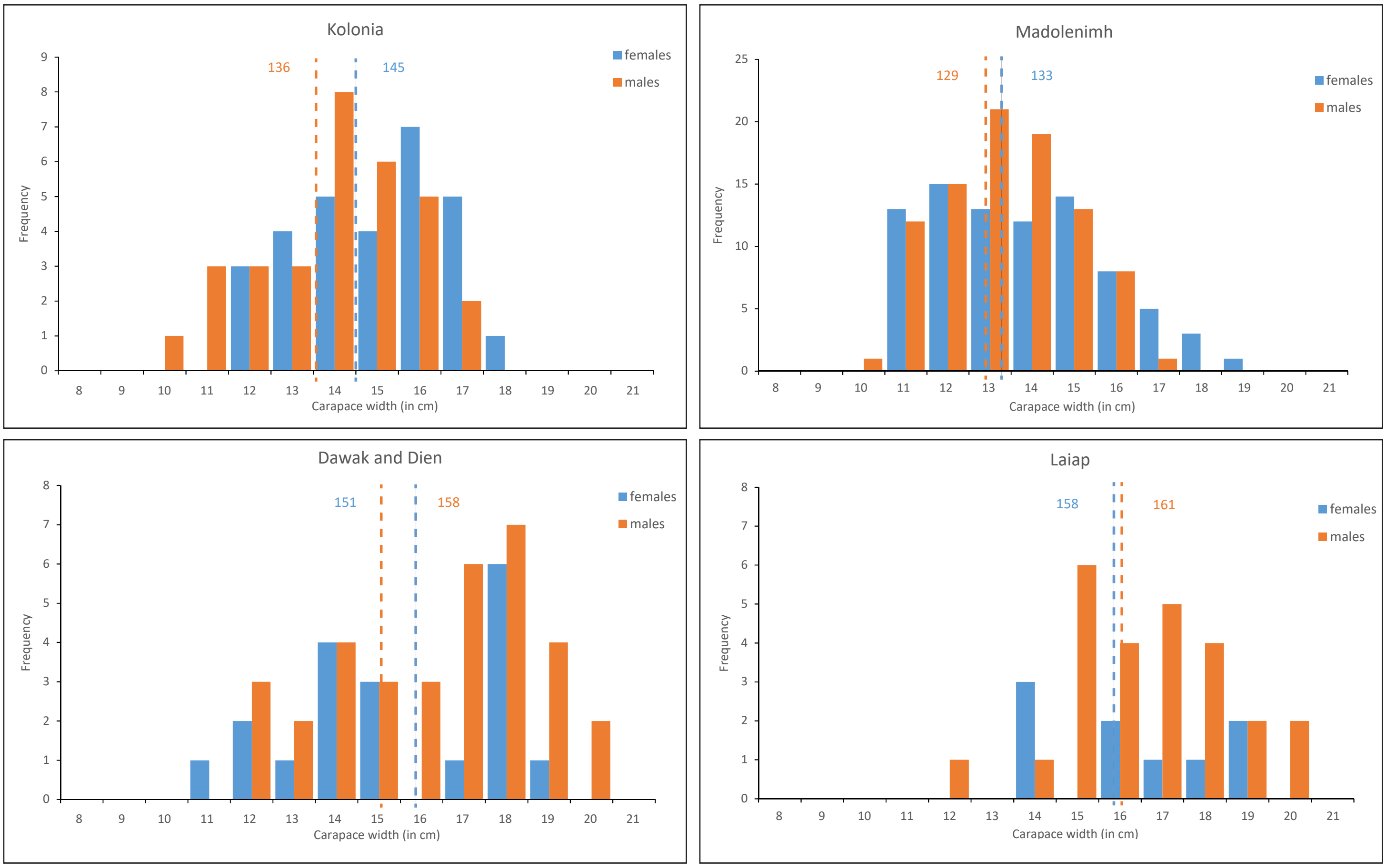

Figure 10. Size structure of male and female mud crabs from four locations around Pohnpei. Vertical dashed lines indicate median carapace width for each sex.

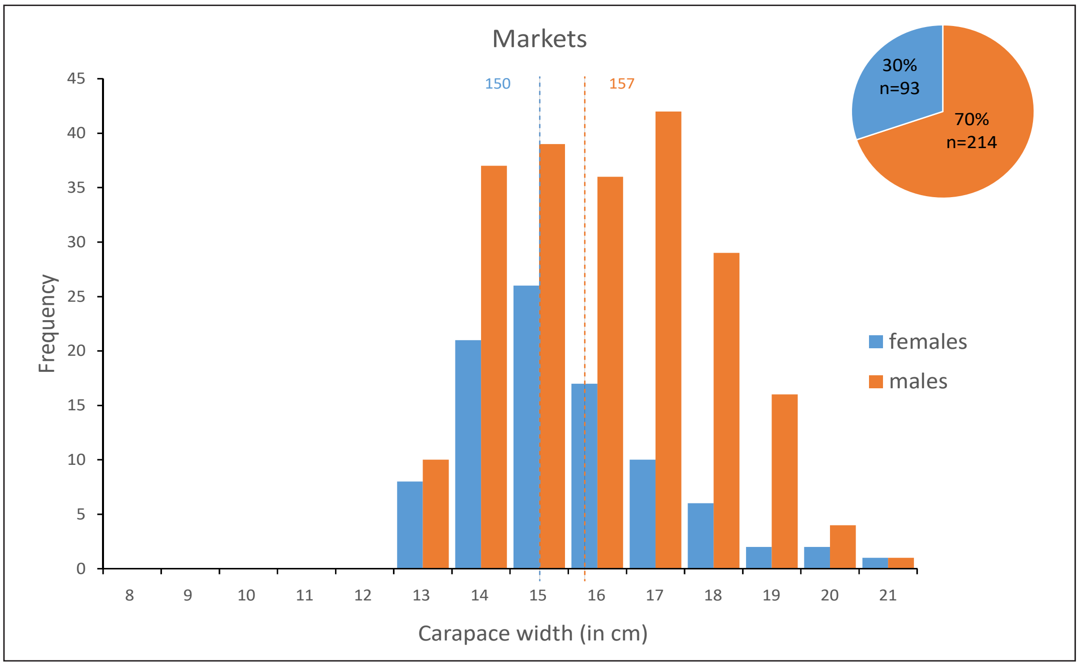

Figure 11. Size structure and overall sex ratio of all mud crabs surveyed at markets.

Fisher surveys

We conducted 12 interviews with mud crab fishers: one woman and 11 men. Fishers were from all parts of Pohnpei Island, with the majority coming from the south and west regions where most crab fishing occurs (Fig. 12). A variety of fishing methods were used, with trapping the most common followed by hand collection by walking through the mangroves, and snorkelling.

Airport surveys

Six flights were checked for the exportation of mud crabs. Four of the flights were west bound to Guam and had a total of 33 crabs. The other two flights were east bound to Honolulu, and had no crabs. It should be noted that an AirNiugini accident at Chuuk had a significant impact on passenger numbers flying during the time we were surveying outgoing flights from Pohnpei. We were also informed by airline staff that it was not a busy time of the year for people travelling into and out of Pohnpei.

Other surveys

Anecdotal information suggests there is a regular trade in mud crabs between fishers and markets, and crew onboard foreign fishing vessels. We were unable to conduct interviews to gain a more detailed understanding of this aspect of the fishery, although informal discussions with fishers and market sellers, and personal observations at the markets, indicated that up to 80 crabs may be sold by the markets at one time, and that the crabs are regularly purchased by foreigners from foreign fishing vessels. The frequency of these purchases is dependent on the flow of crabs to the markets, but if catches are good then these purchases may be conducted multiple times a week.

Discussion

Our surveys indicate that the median size of mud crabs around Pohnpei is smaller than it was in 1978 when the last surveys were conducted. The median size of all crabs trapped in 2018 was around 15 cm CW compared with a median CW of about 16 cm in 1978. This is not surprising given that FSM's population has increased by 70% since 1978 and there are more people fishing for mangrove crabs now. There is no minimum size limit for harvesting mud crabs in Pohnpei, with management regulations limited to a prohibition on taking female crabs that are carrying eggs, and exporting crabs for commercial purposes. People are allowed to take 15 crabs out of the country for personal use on any given trip, upon purchase of a permit to do so.

When mud crab catches were summarised by location there were clear differences in the number of crabs caught and the median size of males and females. Those areas with the largest crabs have smaller populations of people living nearby

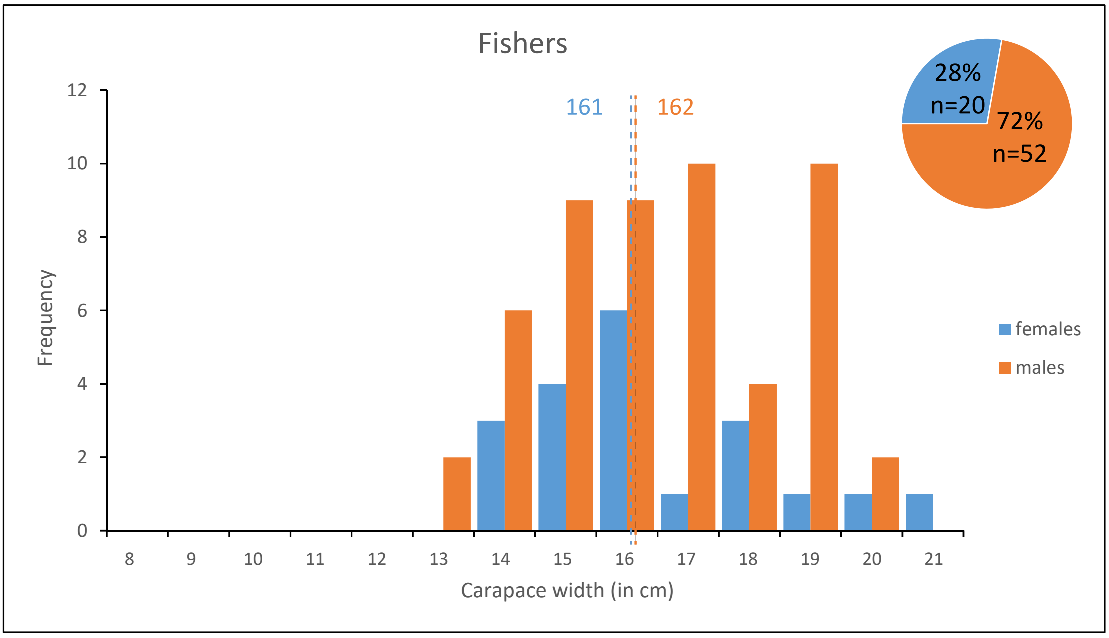

Figure 12. Size structure and overall sex ratio of all mud crabs caught by interviewed fishers.

and the largest areas of mangrove forests, which is a pattern consistent with previous work in the region. Male crabs were also larger than females in these locations. In contrast, those locations closest to human population centres, such as Kolonia, had much smaller crabs overall, and the median size of male crabs was smaller than female crabs, which is not typical in an undisturbed population. These locations are clearly under greater fishing pressure, where more males from the population are being captured than females.

Crabs in the markets were 1 cm greater in median size, at 15–16 cm CW, than the overall crab population, as determined through trapping. The ratio of males to females was also more skewed towards males than in the general population. This indicates that fishing is preferentially targeting larger crabs in the population, which typically are males. This makes sense economically because the largest crabs fetch the most money.

The median CW size of crabs at the markets in 1978 were 15–16 cm for females and 16–17 cm for males, with a 20:80 ratio of females to males. In 2018, the median CW size was 14–15 cm for females and 15–16 cm for males with a 30:70 ratio of females to males. This indicates a longer-term reduction in the maximum size of male and female mud crabs over time, which is a primary indicator of a response to fishing pressure.

The median CW size of females in the population at around 14 cm is above the estimated width at maturity, indicating that there is still adequate recruitment occurring within Pohnpei's mud crab population. However, there has clearly been a long-term decline in the size and abundance of mud crabs around Pohnpei, with changes most evident in the male population. This reality is also perceived by the people fishing for crabs, with 9 of the 12 fishers interviewed stating that they believed the number and size of crabs was declining.

Our surveys – both in-water and at the markets – give us a good general understanding of the structure of crab populations around Pohnpei, which show signs of overfishing. While too many crabs being harvested is the primary reason for the current situation, what is less clear is the primary drivers of overfishing. A larger population will inevitably lead to more fishing effort but there are also external drivers that can inflate the level of fishing above what a local economy would normally undertake. In this study the one area we have not been able to quantify is the trade in crabs between fishers and crew aboard foreign fishing vessels. Current laws do not prohibit individuals from purchasing as many mud crabs as they like from the markets, although one person is only allowed to take 15 crabs out of the country, and only with a permit. Anecdotal evidence indicates that far more crabs than could reasonably be eaten at any given time are being bought by crew aboard foreign fishing vessels. While this trade from the markets to the boats is legal, unless they are being exported, there is also anecdotal evidence that fishers are dealing directly with the boats. This trade pathway does not have any of the checks that exist through a more formal market system, and can easily encourage increased fishing intensity and the retention of smaller crabs. Any attempts at instigating effective management plans will not be effective unless this area of trade in crabs is documented and well understood.

A more detailed analysis of the data collected within this study is still ongoing and will help Pohnpei better understand the current situation with regard to the health of its mud crab populations. There is clearly a need for an improved management regime to ensure the sustainability of this favoured resource. The issues encapsulated within this fishery are typical across the Pacific, and lessons learned elsewhere will help inform management protocols to be implemented in Pohnpei. The important first step is recognising that there is a problem, and this has already been acknowledged. The equally important second step of collecting data to inform decision-making is being carried out. There are, therefore, no impediments to introducing effective management plans; the challenge is to implement them as effectively as possible.

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The hardworking team of fisheries officers from Pohnpei and Kosrae without whom the mud crab survey would never have been possible. From L-R, front: Anderson Tilfas, Ryan Ladore, Sam Isaac; back: Dwight Damian, Itaia Fred, Jonathan Dewey. (image: Andrew Halford)

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