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A fruitful collaboration continues in the Philippines

A whole white tagged fish retrieved at the Socsksargen Federation of Fishing and Allied Industries, Inc. for biological sample collection. (image: © Caroline Sanchez, SPC)

Over the past decade, the Pacific Community (SPC) has worked closely with the Philippines' Bureau of Fisheries and Aquatic Resources (BFAR) and established a close collaborative arrangement with Socsksargen Federation of Fishing and Allied Industries, Inc. (SFFAII) on port-based biological sampling and tag recovery in General Santos, Philippines. A key aspect of this collaboration involves obtaining high-quality data on lengths and weights from tunas captured by the Philippines' industrial and artisanal fisheries, and deriving from these data, accurate conversion factors that relate length to weight. Reliable conversion factors (CFs) underpin the models SPC uses to assess the status of tuna stocks across the western and central Pacific Ocean (WCPO), and the work programme in the Philippines is contributing substantially in this regard.

Notably, during late 2019 and early 2020, port sampling efforts involving SPC, SFFAII and BFAR staff working together in General Santos led to the collection of length-weight data for very small (i.e. < 30 cm fork length) yellowfin, bigeye and skipjack tunas captured by local purse-seine and ring net fisheries. This is the first time that length-weight measurements have been systematically recorded for such a large sample of juvenile tunas; measurements that have allowed SPC scientists to develop new CFs specific to juveniles for each species under Western and Central Pacific Fisheries Commission (WCPFC) Project 90. Under the same partnership, length-weight information is being collected for large (i.e. > 100 cm fork length) yellowfin and bigeye tunas captured in the Philippines' handline fishery.

In addition, SPC is working with SFFAII on the logistics of collecting important "gilled and gutted" and whole weight CF data from these same handline-caught tunas. Such data are difficult to obtain elsewhere throughout the WCPO due to the nature of the fishing gear used, the at-sea processing systems in place, and the requirements of the markets that support these fisheries.

As a direct result of the Philippines' port sampling work, new CFs for length-weight have been derived for skipjack, yellowfin and bigeye, with a series of CFs relating various key measures of fish length (e.g. fork length, total length, pectoral fin to second dorsal fin length) derived for larger yellowfin and bigeye. These CFs have now been added to

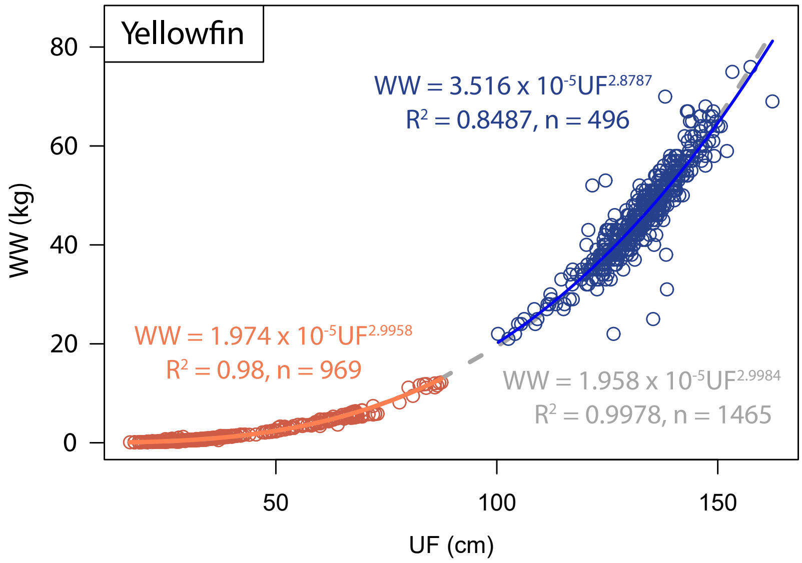

Figure 1. New length-weight conversion factors for yellowfin tuna sampled from the Philippines' ring net, purse-seine and handline fisheries in late 2019 and early 2020. Orange circles are small fish in their 1st or 2nd year of life; blue circles are larger individuals. Curves, lines and equations relating fork length (UF) and whole weight (WW) are plotted for small and large fish separately, and for all fish combined (grey dashed lines and text). n = sample size; R^2 = describes the strength of the relationship between length and weight.

a publicly available database developed and maintained by SPC,[1] an extract of which is presented in Table 1. This database serves as an evolving repository of CFs for both target and bycatch species captured by commercial fisheries across the WCPO, and is accessed regularly by SPC and external scientists for biological studies and stock assessment inputs.

Despite ongoing COVID-19 restrictions, in-port collection of length-weight data continues in General Santos, with all sampling targets and project milestones achieved to date. A new contract has recently been signed for extension of this important inter-agency collaboration, which also includes work components on tuna tag recovery and general biological sampling.

As annual tuna tagging campaigns continue under the auspices of the Pacific Tuna Tagging Programme (PTTP), the collection of reliable information on recovered tags helps optimise the use of these data in stock assessments and tuna fisheries management measures. The efforts of SFFAII and BFAR personnel onboard vessels, both at the market and at the canneries to locate and return all tags with complete information, is critical to the success of this work. Equally important in this context is SFFAII's ongoing engagement with the fishing industry and management agencies in publicising the PTTP and promoting tag recovery activities. The location of SFFAII's office within the General Santos Fish Port Complex further encourages stevedores, local fishermen, and crew from foreign vessels unloading in General

[1] Accessible here with a login: www.spc.int/ofp/preview/login.php

Collection of biological samples from juvenile yellowfin (left), bigeye (middle), and skipjack tuna (right) and (< 20 cm fork length) captured by ring net in Philippines' waters. The yellow circle highlights the sagittal otoliths that measure < 4 mm in length, taken from a yellowfin of 15.5 cm fork length. (images: © Caroline Sanchez, SPC)

Table 1. Examples of provisional length-weight conversion factors drawn from the conversion factor database. Species codes are as follows. ABU = sergeant-major (*Abudefduf saxatilis*); AGS = spotted sardinella (*Amblygaster sirm*); ALB = albacore tuna (*Thunnus alalunga*); ALN = scribbled leatherjacket filefish (*Aluterus scriptus*); ALS = silvertip shark (*Carcharhinus albimarginatus*); ALV = thresher shark (*Alopias vulpinus*). Formula, describes the modelled relationship between length (UF = fork length; SL = standard length; TL = total length) and whole weight (WW) for a given species. n = sample size. R2 = describes the strength of the relationship between length and weight. Source, is the data source used to fit the relationship. Note that there can be several CFs per species, reflecting different datasets used, and times and regions of data collection. Note also that data entry and quality checking is ongoing.

Species	Convert from (cm)	Convert to (kg)	Formula	Sample information		Source	Comments
				n	R^2		
ABU	UF	WW	$WW = 1.64 \times 10^{-5} \times UF^{3.142}$	35	0	Bohnsack and Harper 1988	
AGS	UF	WW	$WW = 1.18 \times 10^{-4} \times UF^{2.075}$			Pauly et al. 1996	
ALB	UF	WW	$WW = 1.43 \times 10^{-5} \times UF^{3.100}$			Williams et al. 2012	
ALB	UF	WW	$WW = 2.97 \times 10^{-5} \times UF^{2.901}$	8891	0.89	Fisheries observer data	
ALN	UF	WW	$WW = 2.19 \times 10^{-6} \times UF^{3.000}$	71		Bohnsack and Harper 1988	
ALS	SL	WW	$WW = 3.04 \times 10^{-6} \times SL^{3.243}$			Kulbicki et al. 1993	
ALV	TL	WW	$WW = 1.87 \times 10^{-4} \times TL^{2.519}$			Kohler et al. 1995 and references therein	Western North Atlantic
ALV	UF	WW	$WW = 1.88 \times 10^{-4} \times UF^{2.519}$	88	0.88	Kohler et al. 1995 and references therein	Western North Atlantic, range WW = 54–211 kg, range UF = 154–262 cm

Port sampling in General Santos, Philippines, during early 2020. Activities focused around obtaining accurate tuna length and weight measurements under the collaborative partnership between Socsksargen Federation of Fishing and Allied Industries, Inc., the Bureau of Fisheries and Aquatic Resources and the Pacific Community. (images: © SFFAII)

Santos to report their tags and to bring whole tagged fish to the SFFAII office so that biological samples can be collected. To date, 270 tags have been recovered in this manner, 11% of these left within the whole fish – a scenario that maximises scientific benefits for tag-finder efforts.

With regard to general biological sampling, data derived from otoliths, muscle tissue, dorsal spines, gonads, stomachs and livers collected by port samplers in General Santos are needed to support studies on growth rates, stock structure, reproductive biology, movements and diets of tuna, billfishes, mahi-mahi and wahoo across the region. SPC uses these data in combination with the aforementioned length-weight data, tagging data, observer data and logsheet data to conduct stock assessments. SFFAII has played a key role in ensuring that the sampling programme continues, even under current challenges presented by COVID-19, and that the samples themselves and metadata associated with them are complete and of high quality.

The success of the partnership between SPC, SFFAII and BFAR is based on the strong ties that have been built up among the organisations over many years. It is a truly collaborative effort, and its continuation is essential to delivering the best scientific advice for the management of the region's important tuna resources.

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Va'ulele Yaubula pearl-meat farm personnel deploying 5-m lengths of spat rope bearing hatchery-seeded pearl oysters onto a backbone rope of their pearl farm longline. (image: © Tim Pickering, SPC)

It was a proud moment for members of the community pearl-meat farm at Va'ulele Village in Savusavu Bay, when the farm's longline structures were installed in their traditional fishing rights area and spat lines bearing juvenile oysters were deployed.

The farm aims to grow blacklip pearl oysters, *Pinctada margaritifera*, to a size of 80 g. This is different from what is typically done when growing oysters for pearls, where juveniles are grown to a size of 200 g^{+} before they are seeded with nuclei to make round pearls. In anticipation of post-COVID-19 economic recovery, these smaller oysters will be supplied either fresh or frozen in the shell to high-end hotels, restaurants and oyster bars in Fiji and east Asia. Advantages of growing oysters for pearl-meat include: 1) the grow-out time is shortened from two to three years for round pearl oysters, to 18 months for pearl-meat oysters; and 2) pearl-meat farms are not dependent on highly skilled (and highly paid) pearl seeding technicians in the production process.

Through this initiative, the Fisheries, Aquaculture and Marine Ecosystems (FAME) Division of the Pacific Community (SPC) is working with the Wildlife Conservation Society (WCS) and JHunter Pearls (JHP) to bring about meaningful engagement in Fiji's pearl aquaculture industry by coastal communities. This is in fulfilment of commitment #2 of the 16 voluntary commitments made by Fiji at the United Nations Oceans Conference in 2017. This commitment recognises the sustainable initiatives of Fiji's pearl industry and the Fijian government's support in developing the industry through community-owned and -operated farms as a means of providing tangible economic benefits for coastal indigenous communities while safeguarding coral reef ecosystems.

FAME, though its New Zealand Government-funded Sustainable Pacific Aquaculture Project, is contributing toward construction costs of this prototype pearl-meat longline farm, which is in the pristine waters fronting Va'ulele Village in Savusavu Bay. SPC's Mariculture Specialist, Jamie Whitford, is providing training to Va'ulele community members in the technicalities of farm management and maintenance. As described in an earlier *Fisheries Newsletter* article,[1] WCS has been assisting the Va'ulele community with business aspects of the venture, such as mentoring to set up a legal entity to farm pearls in their traditional fishing rights area, and in business literacy to manage their new farm operations. SPC has provided revenue and costings projections for the community's business plan.

In late November 2020, the first 1000 m of spat ropes bearing juvenile oysters were moved onto the Va'ulele Yaubula farm from JHP's hatchery and nursery at Savusavu. Guided in their tasks by JHP's Atish Kumar, Va'ulele community members involved in the farm were onboard JHP's barge in order to gain work experience in the handling and setting of pearl oyster spat lines. The spat will take around 18 months

[1] http://purl.org/spc/digilib/doc/yi8pz

During a training session led via Zoom from Noumea by SPC Mariculture Specialist Jamie Whitford, Va'ulele Yaubula staff Salanieta Wavanua, Laisiasa Ravolaca, Akariva Rogocake and Vasiti Vakarauleka practice the correct knots for use in pearl farm longline operations. (image: © Tim Pickering, SPC)

to grow to a harvestable size, where they will be ready to serve steamed in the half-shelf like a scallop, as a new seafood specialty in high-end restaurants.

In the planning stages of this initiative, it was envisaged that the training of pearl farm personnel at two communities in Fiji would be provided by SPC's pearl expert Jamie Whitford. COVID-19-related travel restrictions, however, have dictated that in-person training sessions be replaced by online training via Zoom, with practical components carried out through work experience attachments within JHP's farm operations, and with follow-up technical support provided by Jamie when COVID-19-related travel restrictions are lifted.

Va'ulele Village is just out of range of internet connectivity, so 45 community members travelled by truck to Ra Marama Hall in Savusavu for a Zoom tutorial by Jamie in Noumea on pearl biology. SPC's Inland Aquaculture Advisor, Tim Pickering, set up the computers for the Zoom conference, and WCS's Vutaieli Vitukawalu provided Fijian translations of key points. Practical exercises included dissection to show the anatomy of a pearl oyster, and correct knots for use on a pearl oyster longline farm. Va'ulele participants expressed appreciation for the training, saying it was very useful and had increased their understanding about pearl farming.

This is the first of a planned series of community pearl farms associated with JHP, which will support livelihoods through supplementary income while promoting the sustainable use of marine resources.

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First leadership training for regional aquaculture enterprises

The Pacific Community (SPC), through the Sustainable Pacific Aquaculture Development Project (PacAqua), worked with Megan Streeter, lead trainer, to deliver a first-of-its-kind training on leadership targeted at regional aquaculture enterprises. The training was directed towards enhancing the leadership skills at aquaculture enterprises, which can lead towards behavioural change. A survey – conducted with the existing PacAqua enterprises – identified their key leadership skill priorities for the training.

The training targeted two key areas: 1) effective leadership of self and others, and 2) managing people and leading teams.

In total, 17 trainees participated in the training, representing 8 enterprises from the Federated States of Micronesia, Fiji, Papua New Guinea (PNG), Solomon Islands and Tonga. The training was delivered over a six-week period beginning in mid-October 2020, with half-day contact sessions occurring every two weeks, and one-on-one mentoring with the trainer in between each contact session.

Mr and Mrs Yogomul are tilapia cage-culture farmers in PNG. Mr Yogomul stated that "the training helped me to have a better perspective of myself as a leader and to identify my strengths and weaknesses while working and managing our family team and farm. Also, it is important to work better with other farmers as we are leaders as change agents, introducing something new that is not traditional." An area that needs improving was related to better communication, where the Yogomuls remarked that "there is room for a lot of improvement as a leader especially in sincere open communication and effectively sharing goals and objectives in developing tilapia cage farming and learn to listen effectively to understand in the context of the individual and group".

Aquaculture interns at the Fisheries, Aquaculture and Marine Ecosystems Division of the Pacific Community who also participated in the training highlighted that it was their first exposure to such a training and that it was useful to gain experience and knowledge. Intern Neelam Bhan stressed that enhanced communication skills to deal with difficult conversations or conflict situations will be useful in their workplace, in their studies and in future opportunities. Intern Titilia Tikovata also highlighted that building confidence to stand by themselves and not be pressured to go with the status quo was also an important lesson.

Due to travel restrictions caused by the COVID-19 pandemic, the training was mostly conducted online, although some participants from the greater Suva area in Fiji were able to attend face-to-face sessions. All mentoring exercises were undertaken virtually. There is an opportunity to further enhance leadership skills of enterprises in the future, and this will enable better decision-making, conflict resolution, growth, and understanding on how to manage people to achieve better outcomes for themselves and their organisations.

The PacAqua project is funded by the New Zealand Ministry of Foreign Affairs and Trade.

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Mrs Lencie Yogomul of ASK Sanctuary in PNG standing in front of her cage farm in Yonki dam. She and her husband Guna Yogomul participated in the leadership training.
(image: © Avinash Singh, SPC)

Gender and social inclusion training for aquaculture enterprises, a first for the Pacific

A first-of-its-kind regional gender and social inclusion training for small- and medium-sized aquaculture enterprises by the Pacific Community (SPC) took place 24–26 November 2020. The training was tailored to captivate the enterprises and build on their understanding of gender equality, social inclusion and, more broadly, human rights. The training provided a basic understanding of what gender and social inclusion (GESI) issues are and what these fundamental principles mean in the aquaculture and fisheries sector.

The training was planned, designed and conducted in a highly collaborative manner between SPC's Fisheries, Aquaculture and Marine Ecosystems Division under the Sustainable Pacific Aquaculture Development Project (PacAqua), the Pacific-European Union Marine Partnership (PEUMP) programme, and SPC's Human Rights and Social Development Division. Due to travel restrictions caused by the COVID-19 pandemic, training was delivered online for most participants that could not attend in person, albeit a few attended the training at SPC's Suva office.

GESI refers to how resources are accessed and used in a manner that allows everybody to benefit from them. A people-centred approach is particularly important for entrepreneurs because it is about shared and equal opportunities of working together to build Pacific businesses that can use the full potential of its people in order to grow and provide benefits for its employees, their families and the greater community.

Sixteen participants – representing eight enterprises from Fiji, Kiribati, Tonga, Papua New Guinea and Solomon Islands – completed the three-day training. These small- to medium-size enterprises are mainly family operated, some are women led, and most provide employment opportunities to a wide range of people. Most of these enterprises produce goods for export or domestic markets.

During the training sessions, the various barriers that are often faced by specific groups – because of their gender roles or because of their age, ethnicity or other characteristics – were highlighted. Examples, stories, lessons were shared to illustrate the barriers, but also to provide solutions that aim for making positive changes towards more equal participation of all players. The training presented GESI from an entrepreneurial perspective, which highlighted specific barriers, issues and solutions that matter in the private sector. For example, GESI issues within value-chains were presented, as well as stories of change from a lead business in Fiji that has embraced GESI in its community-based tourism work. The enterprises were then asked to develop an action plan to include in their day-to-day activities.

In addition, a panel discussion was held on gender-based violence (GBV) to sensitise participants from a personal and entrepreneurial point of view. A presentation of Pacific legal frameworks allowed a better understanding of the normative base, and support services were highlighted while also stressing the impacts of GBV on individuals, the community and the enterprise itself. Given the sensitivity of this topic, GBV was approached carefully during a question-and-answer session.

Guna and Lency Yogomul from Papua New Guinea, both of whom participated in the training, said they found it very useful to be aware of the obstacles in their partnerships and the need to use open and inclusive dialogue. Additionally, they highlighted the need to encourage women to be equal partners and to empower them to lead according to their capacity and skillsets in aquaculture. They stated that "… issues surrounding GESI in our Pacific culture is engrained into our cultural belief systems. Stronger linkages between awareness programmes, community trainings and relevant authorities engaged in awareness and regulating can lead to slow change."

One of the learnings from the training was that it makes good business sense to utilise various people's skills, including women, youth and people with different abilities to maximise everybody's talents and contributions. For example, it was stressed that by building the capacity of one employee, the trust, loyalty, performance and dedication of this employee will contribute to the business. As a result, this can lead to a lasting long-term and mutually beneficial relationship. Diversity is important not only to grow a business, but to relate to and meet different customer needs. In addition, gender inclusive corporate structures may also be embedded in Pacific legislative frameworks, such as health and safety standards or maternity provisions. By applying these, enterprises implement and enforce minimum human rights standards, and promote equality. Proactive social inclusion considerations will further prevent unintended marginalisation of vulnerable groups while allowing them to access employment opportunities and showcase their talents. In this way, enterprises can prevent discriminatory practices and empower diverse community members who will pay back the business, a win-win situation for all.

The PacAqua project is funded by the New Zealand Ministry of Foreign Affairs and Trade, and the PEUMP programme is funded by the European Union and the Government of Sweden.

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Providing scientific and technical support to countries in a COVID-19 world

Capacity building and collaborative work with country counterparts are two major activities of the Pacific Community's Coastal Fisheries Programme that had to be completely reorganised due to travel restrictions in the Pacific Islands region. Traveling to member countries to work with fisheries officers on a specific issue, conduct a field survey, or run a training programme was no longer possible and alternative solutions were used to continue providing scientific and technical support to Pacific Community (SPC) member countries.

The technologies to "meet in person" online already existed, but the current situation accelerated the use of video conferencing, remote assistance tools and the adoption of online and mobile solutions. This paper relates some of the alternatives to travel that were trialled, and lessons learned.

Virtual workshops

In 2020, the Coastal Fisheries Programme conducted several virtual workshops using Zoom and Microsoft Teams, and several training formats were tested:

- Full-day training with participants in several locations, presentations and practise with online tools.
- Short presentations in the morning and practical practise videos recorded in the afternoon for later debriefing.
- Presentations in plenary and discussions in breaking groups.
- A mix of video, presentations, assignments, and presentations of assignment results.
- Consultation of focus groups of stakeholders facilitated by national authorities.

The use of video conferencing between SPC headquarters and national counterparts generally works but is still a challenge for places that rely on satellite communications for their internet connection. To reduce network and bandwidth issues, country participants were gathered in a limited number of locations that have good internet connection, such as campuses of the University of the South Pacific (when possible) or government offices.

Time and day differences across the Pacific also needed be taken into account when organising regional workshops involving participants from various time zones, and, often, the best option was to hold the video conference in the morning (Noumea time) and not on a Monday (as this is Sunday in the countries east of the international date line).

Virtual workshops require more preparation that in-person workshops to prevent technical glitches and more work to keep participants engaged for the duration of the workshop. They are generally easier to conduct when the participants previously met in person or are physically present in a few locations with a local facilitator. In training workshops, the local facilitator can also relay questions and issues that may arise during practical sessions. Moreover, the virtualization of the workshop allows for the participation of speakers from various countries with no associated travel costs.

Case study 1:

Remote focus groups in Nauru build an awareness campaign on fish aggregating devices (FADs)

In collaboration with SPC and the Nauru Fisheries and Marine Resources Authority (NFMRA), an Australian-based creative agency (S1T2) was engaged to help develop an awareness campaign on FADs, under the governance of the New Zealand-funded Effective Coastal Fisheries Management Project and the Pacific-European Union Marine Partnership (PEUMP) programme. As a first step, a research phase was conducted with the goal of working with target audiences to establish an information strategy and identify effective and efficient ways to develop an awareness campaign about artisanal FADs in Nauru.

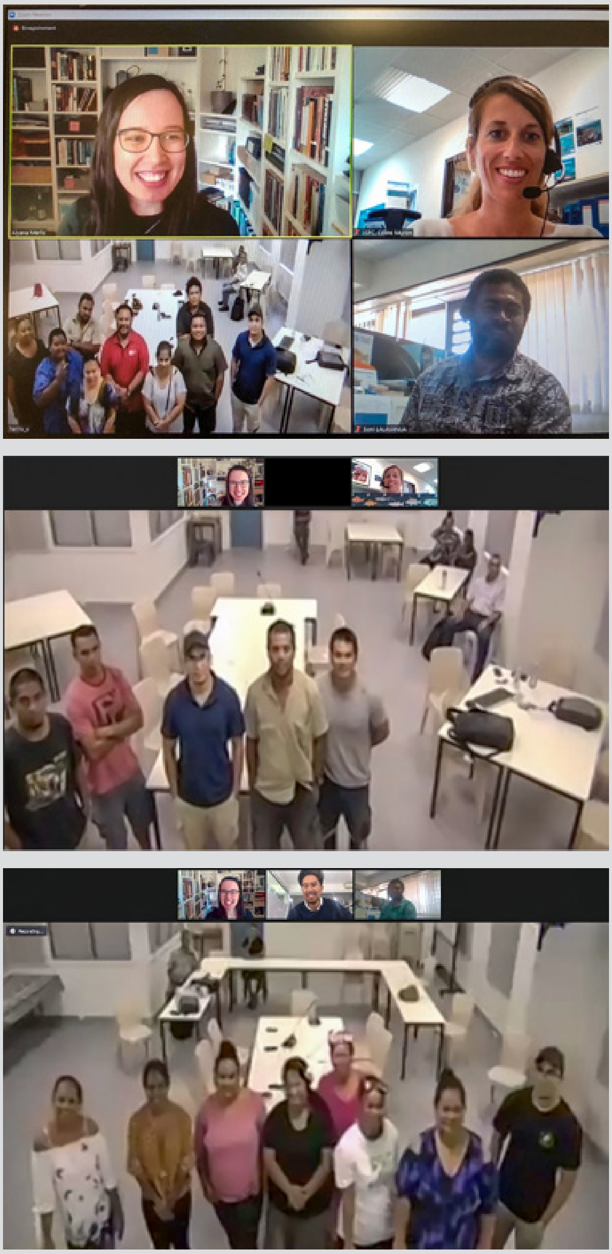
Three remote focus group sessions were conducted with target audience groups – fishers, coastal communities, and women's and youth associations – during the week of 27 September to 2 October. The goal of these sessions was to engage target audiences in the process of identifying effective and efficient ways to develop a FAD awareness campaign in Nauru.

Each session ran for 90 minutes and was facilitated by S1T2 via Zoom, while participants gathered at the University of the South Pacific Nauru Campus, with NFMRA officers assisting.

Through focus group discussions it was determined that the majority of the general community did not know much about FADs. Even those with fishers in the family, or who may have seen FADs in the harbour, were likely to be unaware of what they really are, how they work, and their benefits. Participants across all focus groups agreed that it would be good for the wider community to be better informed about FADs. Following the focus group discussions, a campaign strategy was developed, with "FADs for family" as a core message of the Nauruan campaign.

Key comments by participants:

- "Fishing is a lifestyle for the people of Nauru. We go catch fish for a living."
- "I've known about FADs ever since I started diving. But I didn't know that there were a lot of fish around FADs, or that they attract fish."
- "FADs keep fishermen close to the island. It's safer for the fishermen."
- "Fish are the main source of food security. FADs are what bring the fish to the fishers."



Group photos from the focus groups with fishers and divers (top), community leaders (middle), and women's and youth representatives (bottom).

Online training

In addition to video conferencing, SPC is currently undertaking the production of online training modules and trialling the Moodle platform, a system used by a large number of universities in the Pacific such as University of the South Pacific, University of New Caledonia and University of Guam for distance learning. The SPC learning website will allow enrolled users to follow courses to acquire new skills or refresh existing ones when required. The Moodle mobile app allows the downloading of courses for offline viewing.

Online course creation by SPC staff is in progress as the development of a proper online course and curriculum is substantially different from a traditional PowerPoint presentation followed by practical exercises in a training room. Keep trainees engaged requires a mix of lessons, short introductory videos, reference materials, and quizzes and assignments.

The assessment of competencies for graduation in an academic context remains a challenge during the COVID-19 pandemic, but solutions such as video recording and assignments are currently being investigated.

Case study 2:

Online training workshop on fisheries monitoring, control and surveillance in Kiribati

Preparing a market inspection, improving communication skills, and learning how to use the compliance book were part of the Kiribati training on monitoring, control, surveillance and enforcement, organised from New Caledonia and New Zealand by SPC and the New Zealand Senior Compliance Adviser, thanks to funding from the New Zealand Ministry of Foreign Affairs and Trade. As part of the one-week programme, 30 fisheries officers participated in several exercises between online sessions. These included conducting inspections to improve their practices, creating draft scripts of radio dramas to anchor messages, and learning how to create a radio drama series.

After the fisheries officers drafted their scripts, each group presented its radio drama. The whole group then had the opportunity to peer review the radio dramas: Did they grab one's attention? Were the messages clear? Did they trigger the will to act?

Awareness and training videos

While SPC has a long history of producing training videos, requests for SPC assistance for the production of videos increased in 2020: introductory videos that are part of training courses in development, as well as awareness videos targeting communities and adapted to the context of the various Pacific Island countries and territories.

Travel restrictions have limited the options for video shooting locations and local actors. The mix of animations and staged sequences with SPC staff from various countries allows for the creation of videos that can be later translated and contextualised for specific countries and situations.

Training videos can be used as learning tools before online training workshops or before a specific workshop session.

Videos are published on YouTube for general audience with access to the internet, and are provided to media on request for local broadcast.

Web databases, tablet applications and remote maintenance

Internet in the Pacific Islands region improves thanks to the deployment of new submarine cables, an activity that continues despite the COVID-19 situation. Many countries are already connected to a submarine cable and new cables are in deployment, such as the Southern Cross NEXT Cable that will connect Fiji, Samoa, Tokelau and Kiribati (Kiritimati) to Australia, New Zealand and United States (completion expected in 2022).

The transition from desktop client-server applications to web applications and mobile apps for offline data entry was initiated several years ago with the improvement of landline and mobile internet (ADSL, 3G, 4G) and the re-development of the remaining legacy regional databases as web modules is currently undertaken.

Practical training sessions on web databases and mobile apps have been successfully conducted during virtual training workshops. The only caveat is to arrange the screen so that both the presenter's video stream and a web browser (or app) can be opened and visible at the same time, which can be challenging on a small screen.

Remaining in-country servers are remotely maintained through the internet: a server has even been fully reinstalled from scratch with the assistance of local IT staff. The challenge at the moment is to send spare parts or IT equipment (such as tablets) to Pacific Island countries as the shipment of goods is disrupted by the limited number of flights.

Case study 3:

Ocean Wardens: A snapshot of an inspection with the monitoring, control and surveillance team

The video can be viewed at: https://youtu.be/fAJbfz5g-RQ

It summarises one component of the monitoring, control and surveillance training: the various steps of a proper inspection.

The video gives a few tips such as: The best way to approach a fisher for an inspection and ensure his collaboration.

After COVID-19

While some activities such as field surveys, on-the-job training and community-related work should resume once travel restrictions are lifted, it is likely that some of the changes in practices imposed by the COVID-19 pandemic will continue, such as regular use of video conferencing, online training and web tools. As the internet improves, online collaborative platforms – as well as real time streaming and augmented reality – will likely be used as part of training workshops and meeting tools, and the physical presence of an instructor or expert will be less necessary, especially if an in-country person can promote and facilitate the use of the new technologies and relay feedback on technological glitches that might happen at the beginning.

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Adaptability is key to sustaining capacity development and technical support for Pacific Island member countries during the COVID-19 crisis

As COVID-19 infections spread across the globe in early 2020 and governments shut down international travel, the Pacific Community' Coastal Fisheries Programme (CFP) was forced to stop business-as-usual and confront how to deliver its work programmes when the primary conduit for the flow of information and training had halted indefinitely.

One of CFP's primary objectives is to provide in-country capacity development in fisheries science through training and technical assistance. The coronavirus pandemic, however, quickly and severely disrupted CFP's ability to provide this support. Further compounding the situation, private sector job losses and the subsequent global economic downturn forced many communities across the Pacific to turn increasingly to coastal fishery resources as a means for supporting families, which in turn, placed more pressure on these resources. As a result, timely data collection programmes to inform management became more pertinent and urgent than ever. Many fisheries authorities across the Pacific were required to increase their efforts to obtain quality and timely information on the health of their marine resources so that they could manage the unexpected pressures on their fisheries as best as possible.

With increasing country requests for assistance, the coastal fisheries science and database teams needed to come up with solutions that would: 1) allow capacity development and technical assistance to continue throughout the region, and 2) help facilitate rapid data collection programmes that were needed in response to a spike in harvesting pressure on coastal fisheries stocks. Fortunately, CFP was not starting from "ground zero", as the team had already begun development of an integrated e-data framework and presentation of numerous tools to facilitate working in such a system. This framework became the foundational backbone of our capacity development solutions to the unanticipated consequences of the global pandemic and subsequent economic downturn. Our approach was to make significant improvements to existing data collection programmes, coupled with remote training approaches without asking countries to find significant extra resources, which was especially relevant given that national budgets were coming under increasing strain. CFP also recognised the importance of, and moved quickly to create, partnerships with other regional organisations such as the University of the South Pacific, Secretariat of the Pacific Environment Programme, and TRAFFIC to help achieve our goal of continuing the development of scientific capacity within fisheries staff from member countries across the region.

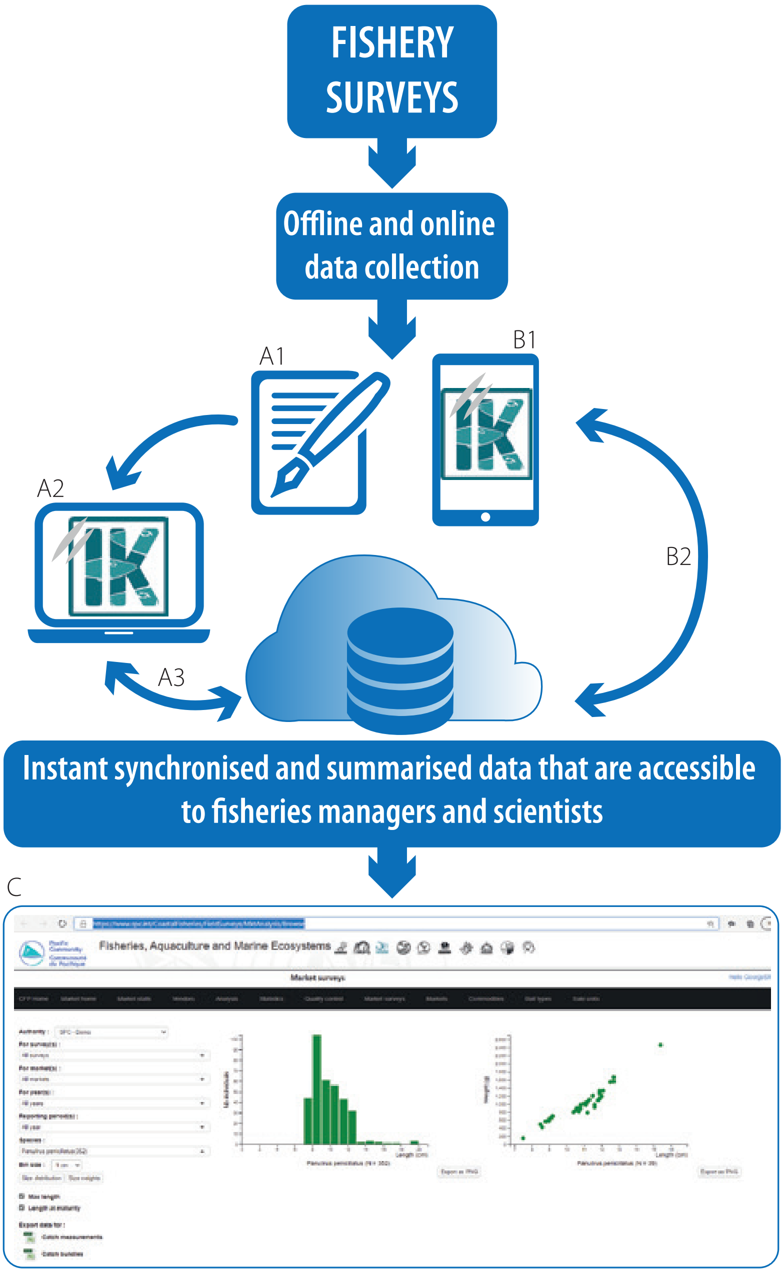
Using a tablet to record data during interviews in Abemama, Kiribati. (image: © Pauline Bosserelle, SPC)

The science and database teams with the Pacific Community's Coastal Fisheries Programme have spent the past 18 months building and trialling e-data systems that can potentially transform the ability of coastal fisheries departments across the Pacific to collect quality coastal fisheries data on a regular basis. The e-tools used for data collection (e.g. Ikasavea, Landing Survey, and Field Survey) and training (PacFishID) were expanded and adapted so that CFP can increase its capacity to provide the necessary assistance to fisheries staff in member countries. Virtual communication platforms such as "Zoom" and Microsoft's "Teams" were also used as a starting point to enable the training. An added benefit of CFP's initial quick-response approach was that the lessons learned are now being used to guide further improvements in the design and implementation of online interactive training courses tailored for Pacific Island fisheries.

Our remote capacity development projects have thus far been implemented for fishery-dependent and fishery-independent monitoring of sea cucumbers, coconut crabs and coastal reef fish in Fiji and Kiribati. These fisheries are an easily accessible coastal fishery resource that are increasingly the focus of communities across the Pacific in response to COVID-19. Together, they make up a significant proportion of income derived from artisanal and subsistence fisheries in these countries. Fisheries management authorities in Fiji, Kiribati and elsewhere have also recognised the necessity of being proactive under this coronavirus-driven increase in harvesting pressure on stocks, and have made these fisheries the focus of management improvement programmes.

The core data-collection module of our e-data framework is called "Ikasavea", an Android-based application for both online and offline use, which can be installed on phones or tablets (Fig. 1). Ikasavea synchronises with two web-browser modules called "Landing Survey" and "Market Survey, both hosted by SPC. These data collection platforms have been designed with an integrated field-to-report approach in mind, whereby all aspects of the data chain – from data collection, storage, curating, analysis and reporting – are connected. Together with our partners at the University of the South Pacific, remote training in their use has been provided to colleagues and peers within the ministries of fisheries in Fiji and Kiribati. Training in fishery-dependent and fishery-independent survey methods for coconut crabs and finfish has been successfully implemented, and field data is currently being collected across these multiple fisheries. For *in-situ* fishery-independent surveys, such as those for coconut crabs, the Field Survey (online, web-based platform) was used for the first time by Fiji's MoF and USP staff in Naqelelevu Island Fiji. Data from this initial survey are currently in the curation phase and continued data-collection across the wider Fiji-fishery is underway. Together, the suite of e-tools has provided a comprehensive "e-toolbox" for coastal fisheries scientists and managers to undertake much-needed quality data-collection programmes efficiently and effectively.

Assistance and technical capacity development are also being provided to Fiji's Ministry of Fisheries (MoF) staff to determine the status of the sea cucumber fishery, which is currently under an ex-



A1: data are recorded on a logsheet
A2: data are copied from the logsheet to one of SPC Coastal Fisheries Programme web apps on a computer
A3: data are automatically transferred to the cloud

B1: data are directly recorded in the IKASAVEA app using a phone or a tablet when offline or online
B2: data are automatically transferred to the cloud as soon as internet is available

C: various instant analyses are available to managers and scientists as soon as the data have been received

Figure 1. The flow of coastal fisheries data through Ikasavea and CFP web apps from collector to fisheries managers and scientists.

Using the integrated Ikasavea and web apps would streamline and simplify the collection of data from a typical Fijian mixed species coastal fishery market stall. (image: © Andrew Halford, SPC)

port moratorium. The Government of Fiji requested information from MoF on the status of sea cucumber resources across Fiji, with the aim of opening the fishery in response to the COVID-19-related economic downturn. In response, MoF requested support from the Pacific Community to assist with determining the status of the sea cucumber fishery so that MoF could make scientifically informed management decisions when the fishery is reopened. Surveys and training were underway at the time of writing, although on 17 December, category 5 Cyclone Yasa passed directly through the southern end of Fiji's northern island of Vanua Levu, causing death, major property damage, and the displacement of hundreds of families. This unfortunate event has further inhibited MoF's ability to respond to the urgent need for information, and the immediate effect of Cyclone Yasa on the sea cucumber fishery is unknown. However, it is hoped that CFP's model of virtual training and the suite of e-tools developed will aid in Fiji's fisheries quick response to this crisis so that MoF can continue to gather vital information on their fisheries.

The listing of the two teatfish sea cucumber species – *Holothuria whitmaei* and *H. fuscogilva* on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) – is an added management requirement for Pacific Island countries and territories (PICTs) to develop non-detriment findings (NDFs) and, if needed, adjust current management frameworks when exporting these species. A major bottleneck, however, is the lack of technical expertise and understanding of the NDF process. This limitation has so far impeded the development of NDFs of four out of the five PICTs that are signatories to CITES. Virtual workshops and NDF support have already been provided by SPC and partners, Secretariat of the Pacific Environment Program and TRAFFIC, to member countries and the lessons learned from these workshops will now guide the development of an e-tool that can be used to support PICTs in building management strategies that comply with the scientific requirements of CITES. Using our virtual training and e-tool development platform, a first stage in a wider programme is to build a web-based application that can be used by PICTs as a guide to develop NDFs. With this tool available, PICT scientific authorities should be able to prioritise the necessary scientific work required for NDF assessments so that exports comply with CITES's trade regulations.

Online virtual training platforms will never fully replace a face-to-face training environment. This is especially the case around the technical aspects of undertaking surveys and the analysis of data, which are much better taught with hands-on training. Nevertheless, significant investment in e-data systems and online teaching tools has enabled CFP to quickly respond to the needs of its member countries, despite the roadblocks imposed by the COVID pandemic. The crisis has had a positive aspect in that there has been a significant re-focusing of resources towards enabling online and e-data systems to become as effective as possible. The use of these systems has allowed member countries to obtain significant improvements in their data-collection programmes. Data collected using the suite of e-tools, and entered directly into these apps in the field, has provided direct access to managers, instant curation, and the ability to interrogate the data efficiently and effectively. The virtual training model has also allowed us to respond quickly to urgent requests for addressing significant environmental or social crises now and in the future.

Once the COVID pandemic is controlled enough to enable travel to resume, CFP staff envision the e-data and on-line learning systems as continuing to provide sustained capacity building and technical support above and beyond what periodic travel can sustain. With the e-tool platform, we now have another product in our toolbox as we seek to help member countries manage their resources effectively.

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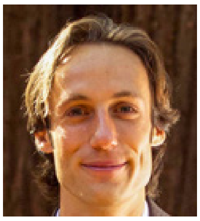
Remote legal internship on coastal fisheries and aquaculture – a successful experience!



I thoroughly enjoyed my time as a remote intern with the Fisheries, Aquaculture and Marine Ecosystems (FAME) Division of the Pacific Community (SPC) this past summer. My main project was researching aquatic biosecurity legislation in three different Micronesian countries—the Federated States of Micronesia, the United States Territory of Guam, and the Republic of Palau. I got a chance to exercise my research skills as a law student and leveraged SPC's REEFLEX database (Fig. 1) in addition to other sources. Learning about the different laws and legal structures of these island nations, especially as they handled and applied to pressing issues with fisheries and aquaculture, was very enriching for me and my education in international environmental law.

Aside from my research and work on aquatic biosecurity legislation, I had the opportunity to join some activities that I would not have been able to if not for the remote internship. I was able to participate in SPC's Gender, Social Inclusion and Human Rights Workshop and learn about progress being made in different Pacific Island countries and territories. I was also able to join a discussion on the Ocean Rights and Kinship Network on incorporating traditional knowledge into negotiations among nations for a treaty on biodiversity in areas beyond national jurisdiction. Lastly, I joined a presentation with the Oceans and International Environmental Law Interest Group on alternative negotiation strategies for nations in seeming conflict during the formation of international agreements, such as the Antarctic Treaty System. The access I had to these extracurricular activities further enhanced my exposure and understanding of current issues in oceans and Pacific communities. The extra exposure broadened my frame of reference when I investigated issues related to my work with FAME, and were very beneficial.

The remoteness of the internship did not impede its high quality. New Caledonia and US West Coast time zones overlapped enough that I was able to stay in touch and meet through video conference with my manager, Ariella D'Andrea, SPC Coastal Fisheries and Aquaculture Legal Adviser, throughout the internship. The technical team at SPC was also very responsive and helped set up all the technical tools necessary for me to access and share resources for my work with FAME, including virtual support for presentations and work groups at the GSI and Human Rights Workshop. Video conferencing was of high quality and vital to my participation in the internship.

Given the disruption of the whole world with the COVID-19 pandemic, I was uncertain and uneasy about my ability to have a successful and meaningful legal internship experience this summer. However, my remote internship with FAME was an excellent experience for my greater education in environmental law and policy, and I am very grateful to SPC for the opportunity.

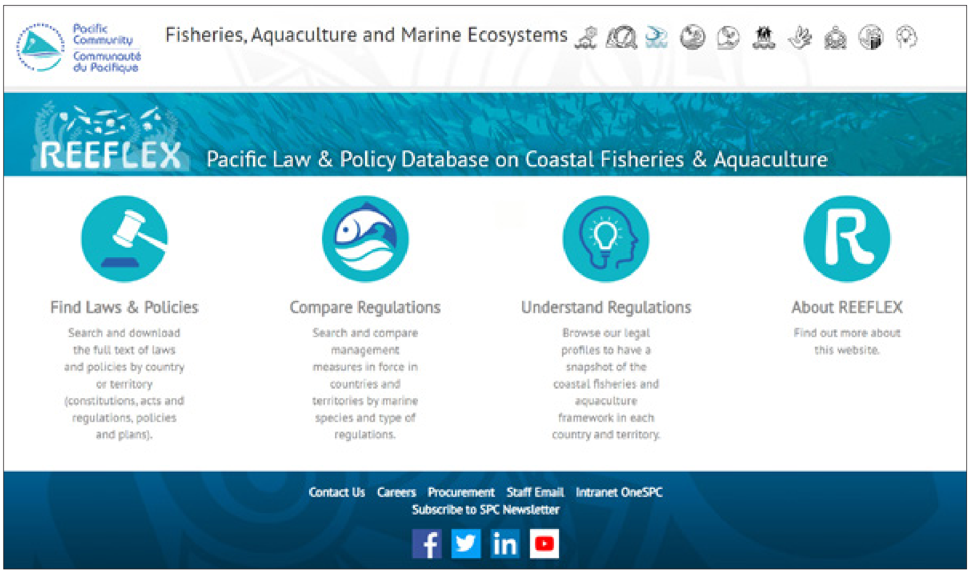


Figure 1. The SPC REEFLEX web application (https://www.spc.int/CoastalFisheries/Legislation/main) comprises three different tools to help users familiarise themselves with the legal framework for coastal fisheries and aquaculture in Pacific Island countries and territories.

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Sharing knowledge and building collaboration to guide research and development on fish aggregating devices in the Pacific

Background

In the late 1970s, fish aggregating devices (FADs) were introduced in the Pacific Islands region to support industrial tuna fishing. Initially, FADs were anchored (a-FADs) (Fig. 1) to the seabed in archipelagic waters away from inshore reefs and islands, and the aggregated tuna were harvested mostly by pole-and-line fishers. While oceanic purse-seine operators had long realised that setting on drifting logs or even whales or whale sharks could produce good tuna catches, the use of purpose-built FADs was not practical in deep oceanic waters. With the development of radio buoys in the 1980s, and satellite global positioning system tracking technology through the late 1990s and early 2000s (Fig. 2), this situation changed. FADs could be set free to drift throughout oceanic waters, aggregating tuna species (skipjack, yellowfin and bigeye) as they drifted, and then be easily relocated by fishing vessels. The use of these drifting FADs (d-FADs) has now become widespread by industrial tuna purse-seine fleets. The addition of affordable echosounder technology to these buoys beginning in the mid-2000s further increased the attractiveness of d-FADs because skippers could make informed decisions on which d-FAD was likely to produce suitable catches, given travel distances and other operational considerations. These technological developments in d-FAD buoys have transformed the way oceanic tuna purse-seine fleets operate in the Pacific and elsewhere.

The operational and economic benefits of these new buoy technologies are plainly demonstrated by their uptake, with recent data indicating that 99% of d-FADs in the western and central Pacific Ocean now have satellite echosounder buoys (Escalle et al. 2020a) (Fig. 2). There are concerns, however, regarding how this technology is being used and managed. Dedicated research and development work is required to address these concerns. For example, there is a need to improve data collection and monitoring systems for d-FADs, mitigate ecological and marine pollution impacts, and better understand the implications of large-scale d-FAD use for tuna behaviour and the interpretation of catch and effort data used in stock assessments (Leroy et al. 2012; Escalle et al. 2020a; Vidal et al. 2020). Finally, d-FADs have no doubt increased the effectiveness of purse-seine tuna fishing, such that a day of purse seine fishing now likely returns, on average, greater catches for the same stock abundance than it would have, say, 10–20 years ago. While this improved effectiveness is desirable for the economics of the fishery, quantifying how much this "effort creep" has influenced catch rates is important as it may have implications for effective application of effort-based management approaches, such as the successful vessel day scheme.[1]

[1] https://www.pnatuna.com/vds

Figure 1. L: Anchored FAD used by pole-and-line tuna vessels. (image: © Lindsay Chapaman, SPC, 1982) R: Drifting FAD, equipped with a radio buoy with a GPS system to locate it, used by tuna purse seiners. (image: © Jeff Dubosc, SPC, 2015)

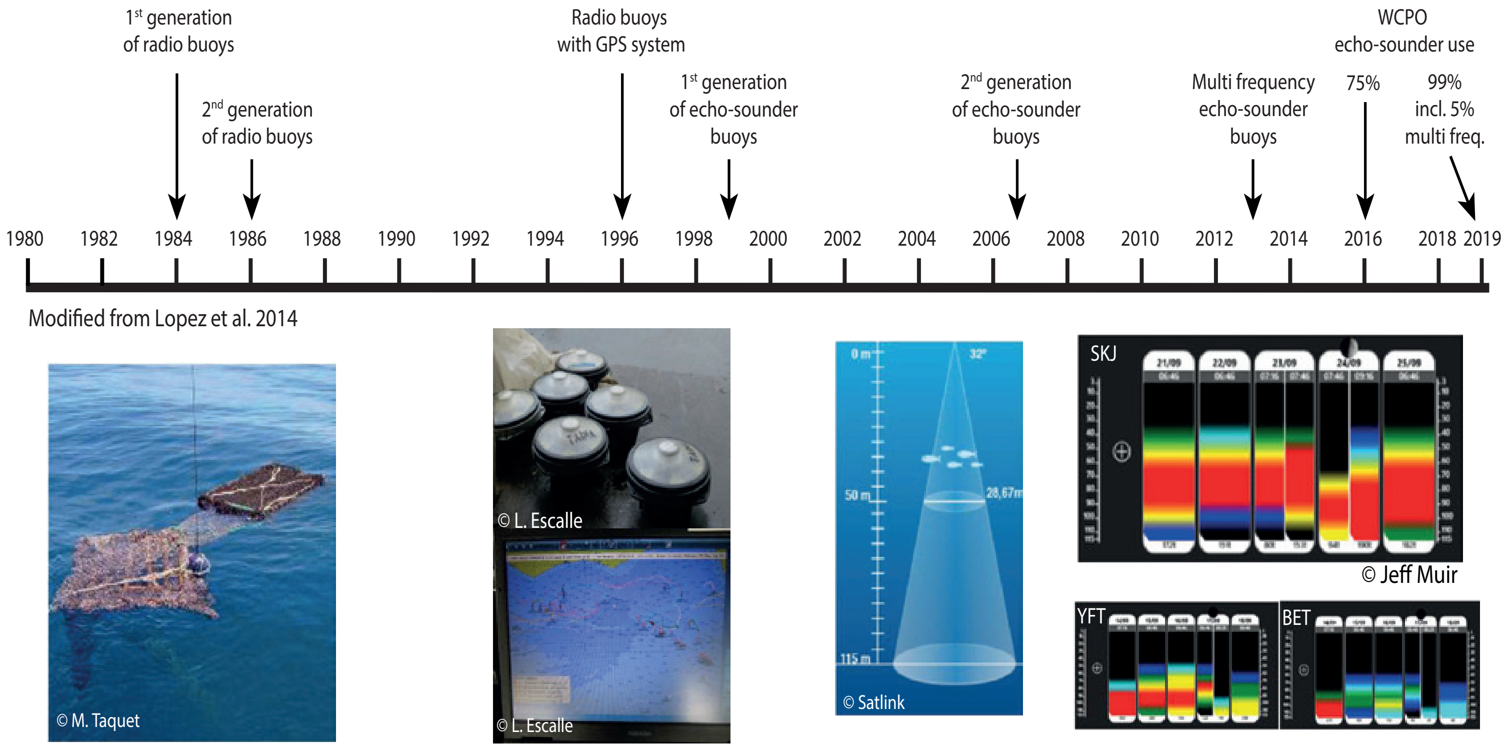

Figure 2. Drifting FAD use development timeline (modified from Lopez et al. 2014).

As the industrial tuna fleet switched to d-FADs, interest from coastal communities in the use of a-FADs closer to shore increased (Fig. 3). Interestingly, awareness of the potential of nearshore a-FADs to benefit artisanal, subsistence and small-scale commercial fishers in the western tropical Pacific was apparently sparked by the pole-and-line fishery, which harvests live baitfish from nearshore waters and lagoons. Crew on pole-and-line vessels often came from island communities. They observed how the FADs worked in aggregating tuna and asked the pole-and-line companies to place a-FADs closer to shore for their communities to utilise in return for the harvesting of baitfish from their local waters. Farther east, a-FADs, were also being developed in Hawai'i under the guidance of Japanese practitioners. By the 1980s, a-FADs, also referred to as artisanal FADs, were being deployed in various locations throughout the tropical Pacific region (Desurmont and Chapman 2000).

Early experience with a-FADs in inshore locations suggested that they could provide enhanced fishing opportunities and food supply to island communities, among other perceived benefits. More recently, the use of a-FADs has also been suggested to have potential benefits in alleviating overexploitation of reef fish species, but this has yet to be clearly demonstrated by any studies. While it is thought that a-FADs can enhance opportunities for artisanal and small-scale commercial fishers to access pelagic fish resources (e.g. tunas, mahi mahi, mackerels) (Bell et al. 2015), sustainable long-term a-FAD programmes remain elusive for many Pacific Island countries and territories.

Developing effective and sustainable a-FAD programmes continues to be limited by several information gaps, some that have been recognised for a number of years (Campbell et al. 2016). In particular, despite a-FADs being deployed in some Pacific Island countries, territories or states for over 20 years (e.g. French Polynesia, Hawai'i, Cook Islands, Fiji, Kiribati), there are limited data available on catches, effort, and socioeconomic or ecological benefits of a-FADs (but see Albert et al. 2014; Tilley et al. 2019). It is also recognised that success involves more than just a-FADs attracting fish; communities need to be equipped with vessels, gear and the necessary skills to fish the FADs safely and effectively. Without this information across various locational contexts, it is difficult to support cost–benefit analyses to establish cases for sustained funding and government staff commitments to underpin resilient a-FAD programmes (Campbell et al. 2015; Albert and Sokimi 2016). a-FAD deployments in most Pacific Island countries and territories have thus been *ad hoc* and dependent on intermittent donor or government funding and sporadic staff support from fishery agencies. This appears to have been the case for several decades in many countries (Desurmont and Chapman 2000). Furthermore, there is a lack of information from appropriately designed comparative studies to inform the development of practical guidelines on where, when, how and what types of a-FAD designs will be most effective at aggregating specific species and producing the desired social, economic or ecological benefits, while minimising any negative environmental impacts.

Figure 3. L: Fishing around an artisanal a-FAD in Niue. (image: William Sokimi, SPC) R: Rounding a d-FAD with the purse seine. (image: © SPC)

Finally, the increased use of d-FADs by industrial tuna fleets is now having the consequence that island communities are experiencing increased interactions with d-FADs as they drift into nearshore waters, snag on reefs and mangroves, and wash up on beaches (Escalle et al. 2019, Escalle et al. 2020b).

Currently, most d-FADs are not recovered by industrial fleets once their productive life is over, or they drift out of a company's geographic fishing area, and many others are simply lost (Escalle et al. 2020a). The implications of lost and abandoned d-FADs for island communities and marine pollution, along with other ecological and fishery implications of their large-scale use, are slowly being understood. This has generated increased interest by environmental non-governmental organisations and the general public, which are questioning the legality and management of d-FAD use (Hanich et al. 2019, Gomez et al. 2020) and asking the purse-seine tuna industry how they intend to mitigate, manage and reduce the negative implications of large-scale d-FAD use.

At this point of time in the history of FADs in the tropical Pacific, there is an interesting contrast between the situation with a-FADs and d-FADs. For a-FADs, many countries desire to expand their use to achieve socioeconomic objectives. Development is however constrained by the lack of basic information on return for investment, how a-FAD programmes integrate with broader food security and livelihood strategies, and limited resources. For d-FADs, there are concerns that their use has expanded too much and a recognition of the need for better information to inform sustainable management and mitigation of undesirable impacts. Recent research efforts to design and test non-entangling and biodegradable d-FADs, and improve systems of recording and tracking d-FAD deployments, are seen as positive steps forward.

The FAME FADs Workshop

Due to the common interests in FAD research and development, and the extensive FAD-related experience and skillsets within the Fisheries, Aquaculture and Marine Ecosystem (FAME) Division of the Pacific Community, FAD research and development is an obvious area to explore opportunities for collaboration and integrative programming.

On 24 and 25 November 2020, staff from FAME's Oceanic Fisheries Programme (OFP) and Coastal Fisheries Programme (CFP) convened a workshop to share knowledge, talk about their work areas and challenges, and explore collaborative opportunities in the area of FAD research and development. The workshop was also attended by several guest speakers who gave presentations on their FAD-related work, and visions for FAD research and development in their countries and farther abroad.

Outcomes

Presentations from OFP and CFP staff highlighted their breadth of knowledge about FADs and outlined the current research and development work that FAME is involved in. Staff also highlighted areas where FAME could contribute further to regional progress in FAD issues through greater internal collaboration.

The CFP team are regional experts in the technical aspects of a-FAD design, construction and deployment (see "Lessons learned from deploying 380 fish aggregation devices" p. 23 in this issue). Specifically, their main FAD-related work and interests centre around:

- the design of a-FADs;
- the development of manuals on a-FAD materials, design and deployment;
- providing training in a-FAD design, construction and deployment (Fig. 4);
- supporting countries in developing a-FAD programmes; and
- providing education on sea safety and fishing techniques related to a-FADs.

The OFP team are regional leaders in scientific research and monitoring of industrial d-FADs (Fig.5), with high-level skills in tuna biology and behaviour, data collection and management, modelling and statistical analysis. Specifically, their main FAD-related work and interests centre around:

- improving data and approaches for monitoring trends in the use, distribution and number of d-FADs in the western and central Pacific Ocean, in partnership with the Parties to the Nauru Agreement, NGOs and several fishing companies;

- understanding the implications of d-FADs for increasing fishing efficiency (referred to as effort creep) and fishery-dependent data used in stock assessment;
- determining the bycatch and ecological implications of d-FADs and options for mitigation, including non-entangling and biodegradable d-FADs;
- understanding the impacts of d-FADs on target tuna species behaviour and fitness;
- examining d-FAD beaching; and
- supporting citizen science monitoring, mitigation, public awareness and communication.

A key outcome of the workshop was to make progress towards combining these practical and analytical skill sets in collaborative research efforts to fill knowledge gaps and guide solutions to regional development barriers and issues around FAD use. Through several breakout groups, the following areas were identified as initial priorities for collaborative projects between OFP and CFP:

Improving the information base and approaches for monitoring and evaluating fishery, social and economic performance of artisanal a-FADs

- Conduct an initial desktop project to map and analyse available data held by SPC on a-FAD fishing activities and deployments,
- Develop feasible best practice approaches to monitor and evaluate the performance of a-FADs within the Pacific Island context.

Adding value to a-FAD deployments

- Trialling acoustic buoys on a-FADs to explore the value these may add for a-FAD users, and increasing understanding of fish-FAD interactions and interpretation of acoustic buoy data.
- Contribute to research on the development of biodegradable materials and designs for d-FADs by testing biodegradable materials, in particular flotation materials, on a-FADs.

Communicating SPC's regional science and technical role in the area of FADs

- Developing an integrated SPC FAD communications strategy and approaches, including defining SPC's mandate and key messages for FAD-related research and development and communication on key issues.

These project ideas will now be further developed and options for funding support explored as necessary.

We would like to thank the presenters and participants who contributed to the workshop, with special acknowledgement of the guest speakers: Mainui Tanetoa (Senior Fisheries Development Officer, Directorate of Marine and Mining

Figure 4. William Sokimi, SPC Fisheries Development Officer (Fishing Technology) assembling an a-FAD. (image: © Boris Colas, SPC)

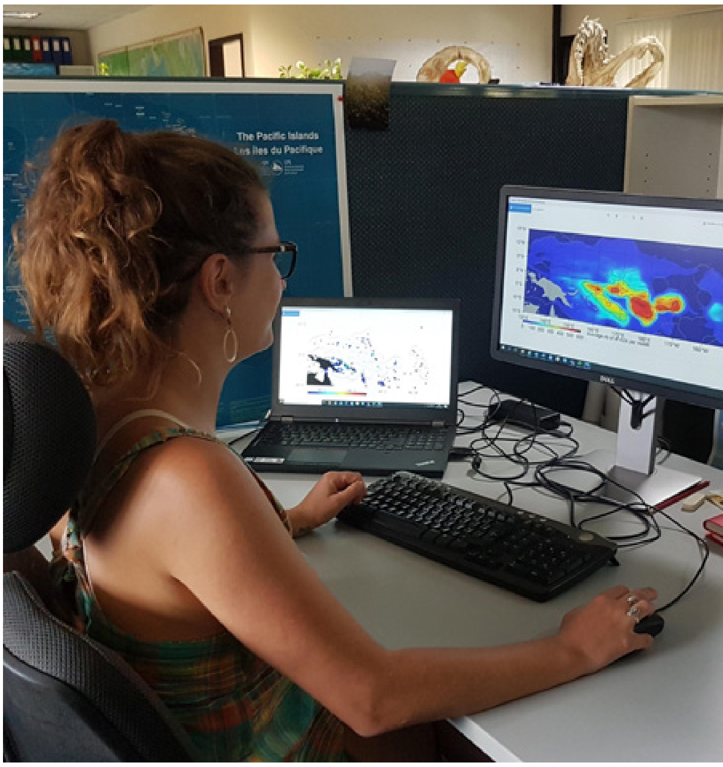

Figure 5. Lauriane Escalle, SPC Fisheries Scientist (Purse-seine Dynamics), analysing d-FAD data. (image: © Elizabeth Heagney, SPC)

Resources, French Polynesia), Alex Tilley (WorldFish, Asia Pacific), James Wichman (Vice President, Pohnpei Fishing Club, Federated States of Micronesia) and Clay Hedson (Coastal Fisheries Specialist, Office of Fisheries and Aquaculture, Pohnpei State, Federated States of Micronesia), and Johann Bell (Professorial Fellow at the Australian National Centre for Ocean Resources and Security, University of Wollongong, Australia).

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Lessons learned from deploying 380 fish aggregation devices

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Background

In October 2020, as an activity of the Food and Agriculture Organization of the United Nations (FAO) FishFAD project, a series of interviews were held with six fish aggregation device (FAD) experts. All of these people had experience deploying FADs in multiple countries spanning several decades. These people were (in alphabetical order of surname) Ian Bertram, Lindsay Chapman, David Itano, Robert U. Lee, Michael Savins and William Sokimi. The six experts were involved in a combined total of about 380 FAD deployments. Most of their FAD experience was in the Pacific Islands region, but their work also included Southeast Asia, Southwest Indian Ocean, East and West Africa and the Caribbean. In short, the six people interviewed know their way around FADs.

These FAD experts were asked about their strong feelings with regards to FADs and any lessons learned in eight FAD-related topics: 1) FAD design, 2) ordering FAD materials, 3) FAD assembly, 4) FAD deployment, 5) post-deployment maintenance of FADs, 6) factors affecting the longevity of FADs, 7) factors affecting the biological productivity of FADs, and 8) a miscellaneous category. The topics covered the "nuts and bolts" aspects of any FAD programme.

Some study details

This short article is not intended to be an instruction handbook. Regional agencies, especially the Pacific Community (SPC), have produced excellent FAD manuals covering the details of FAD design, planning, rigging, deployment and maintenance. This article aims to emphasise specific points that a group of FAD experts feel are especially important based on their past FAD work.

It is recognised that the topics covered in this article do not represent the full range of activities of an effective national FAD programme. Subjects such as cost accounting, interaction with FAD stakeholders, training of fishers, monitoring, and institutional aspects are important, but the present study was tightly focused on materials and procedures associated with FADs. Other important aspects of a national FAD programme are covered in other components of the FAO FishFAD project.

Drawing out the strong feelings and important lessons learned from the six experts involved more than just recording their answers to questions about gear and procedures, as often those responses were simple thoughts, anecdotes or instructions as opposed to more profound insights gained by, for example, analysing multiple observations that span a considerable period. Sometimes a lesson or strong feeling was obtained from an expert in an interview that involved some discussion.

For most of the topics, the discussions with the experts resulted in remarks in several areas. For example, within the topic of FAD assembly, several areas were brought up by the various experts, including splices, supervision and electrolysis. The methodology used by the present study, for each general topic, was to examine the areas that were brought up by at least two of the experts – except for a few points made by a single expert that have special merit. The sections below are organised by the eight topics and much of the information presented is about the common areas within each of those eight topics. It is recognised that this methodology does not capture all the strong opinions for each expert, but rather is more oriented to capturing the consensus of the group of what is important (i.e. giving credibility to areas that are shared).

To avoid confusion, some attention to nomenclature is required:

- The terms "strong feelings" and "lessons learned" are used interchangeably in this article, but there is a tendency for the latter to be somewhat more complex or the result of some analysis.
- Both conventional metal anchors (e.g. Danforth, Hall) and cement blocks are used to moor FADs. For simplicity, when referring to both types of mooring devices together, the term "anchor/block" is used.

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- The term "nearshore" causes some confusion. In the FAD literature of the Pacific Community (e.g. Policy Brief 19/2012[8]), a nearshore FAD is one that is set very close to the reef. The term is also used by SPC to refer to the fishing area between the coastal fisheries zone and the offshore fisheries zone, as seen on the SPC Coastal Fisheries website[9]. In this article, a "nearshore" FAD refers to one deployed close to the reef in water that is generally less than 300 metres in depth.

FAD designs

The experts were asked about FAD designs, and were free to bring up areas related to FAD design that they considered important. The areas that were commonly reported in the responses of several experts were:

- The best reference manual for FAD designs
- The most favoured general FAD design
- Ideas on the spar buoy type FADs
- Appropriate anchors
- Sandbags as anchors
- Reduction in rope diameter
- The use of wire rope
- "Affordable materials"
- Characteristics of pressure floats
- The need for an aggregator

Almost all experts felt strongly that the best reference for FAD designs and associated hardware is the 2020 SPC manual (Sokimi et al. 2020), although there was some mention that this manual makes reference to the 2005 SPC manual (Chapman et al. 2005) so to be complete, the earlier manual is also required. One expert was adamant that the 1984 SPC manual (Boy and Smith 1984) "started it all off" because one of the authors was an experienced buoy engineer. Another comment was that the 1996 SPC manual (Anderson and Gates 1996) was very good for FAD planning.

On the most favoured general FAD design, most of the experts specifically indicated that the Indo-Pacific FAD (Box 1) is generally the most appropriate for national FAD programmes. This was qualified, however, by some experts who indicated that this design required additional care to rope chafe caused by the floats, and the use of more robust surface pressure floats (rated to at least 200 metres). One expert felt strongly that more attention be given to electrolysis (i.e. use of dissimilar metals underwater) than given in the Indo-Pacific section of the SPC FAD manuals. Another did not trust the use of purse-seine floats as spacers between the pressure floats due to the possibility of compression when

deeply submersed. Some of the experts felt that other FAD designs are more appropriate than the Indo-Pacific model in specialised situations; for example, the lizard FAD and the subsurface FAD when there is the possibility or vandalism or in areas with high boat traffic, and the spar buoy when buoys are strictly regulated by law.

The spar buoy type FAD was the design originally promoted by SPC in the mid-1980s. The FAD experts that spoke of this type of FAD mostly felt that the design has been replaced by more appropriate designs in recent decades. Comments included:

- "The spar buoy has too many things going against it: cost, skills and required experience."
- "Spar buoys can be found easily but they are heavy, cumbersome, and more maintenance is required."
- "Spar buoys have tremendous resistance to waves that stress the system whereas designs like the Indo-Pacific or the lizard FAD slip through swells."

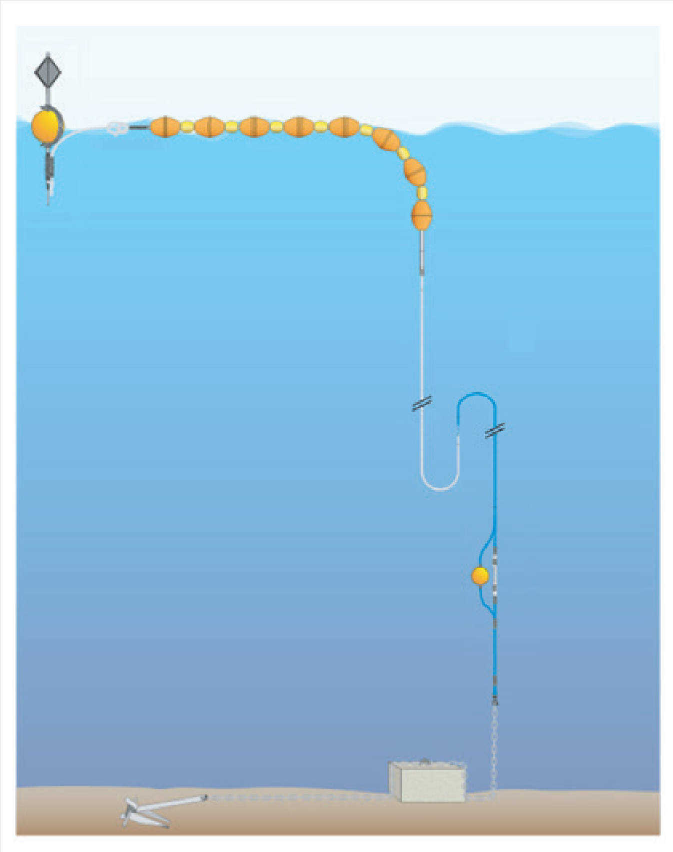
Most of the experts expressed strong feelings on FAD anchors/blocks. The most common ideas expressed concerned the practicality and safety of the anchors, the required weight, and the desirability of sandbag anchors. In terms of practicality and safety, the ideas centred around the idea that, although a large anchor is good for FAD longevity, the size and/or weight must be appropriate for the deploying vessel. Consequently, several of the experts stressed concepts such as more than one relatively small concrete block

[8] http://purl.org/spc/digilib/doc/89tm5
[9] https://coastfish.spc.int

Box 1: The Indo-Pacific FAD

The Indo-Pacific FAD is a renaming of the previously known SPC Indian Ocean FAD. The new name accounts for the design's origin (Indian Ocean) as well as the modifications to the design by Pacific Island FAD technicians. The Indo-Pacific FAD is a robust FAD design that can be deployed in strong currents, and was developed primarily as a tool to support small-scale commercial fishing. There have been a number of refinements and modifications to the Indo-Pacific FAD since the 2005 SPC FAD manual was produced. The increased availability of multistrand rope in the region has largely replaced the use of three-strand rope and related hardware (shackles and swivels). Cost being previously one of a FAD's most vulnerable points, a reduction in hardware also means a reduction in cost. In recent years the Indo-Pacific FAD has been successfully deployed in nearshore environments, using fewer floats in the upper flotation section.

Source: Sokimi et al. (2020)



(modular concept), or the use of a less weighty conventional anchor (e.g. Danforth or Hall). The experts were less enthusiastic about sandbag anchors. As expressed by one expert: "Sandbags are now heavily promoted but have limited applicability. Good in some places but bad when there is abrasion – which is often the case."

Some of the experts expressed feelings on the evolution of the diameter of rope. The original SPC FAD manual (Boy and Smith 1984) was based on a rope diameter of 20 mm. Expert opinions included: "Reduction of line from 18 and 20 mm to 16 mm has reduced cost without sacrificing quality", "16 mm rope is now judged to be as good as 18 mm or 20 mm, but less cost and less drag", and "Heavy rope is expensive and has more drag". The lesson learned is that the progression to smaller rope diameter has been positive.

Although the use of wire rope (i.e. steel cable) in the FAD design was only mentioned by two experts, one of those experts (perhaps the one with most FAD experience) indicated that his view on wire rope was one of the strongest feelings he had on FADs – hence the inclusion of the subject here. Quite simply, wire rope should not be used in a FAD. This is because the metal in the wire is most often different from the other metal FAD components, which causes electrolysis, and the wire becomes brittle after months in the marine environment.

In discussions of FAD designs in the region, the term "affordable materials" is often heard. For those experts that brought up this subject, they appeared to mean using locally available materials whenever possible. Only one expert was in favour of this concept, with the others expressing almost opposite opinions: "Affordable materials is nonsense: chain, rope, swivels, shackles and floats are required and are not available locally", and "not in favour of going cheap".

In retrospect, the difference in opinions could be due to the experts referring to different FAD models, such as community or private ownership versus FADs for a national government programme. A wise comment from one of the experts was:

> "When doing FAD work, we need 'durable materials'. If it's affordable but not durable, then there's no point in using it for FADs. It will be a waste of time. On the other hand, if it's affordable and durable, then by all means that should be the way to go. This is the whole process that a FAD technician should be looking at: reduce the cost of putting FADs in place without compromising its durability. So, in this context, I would support using locally available materials, such as coconut fronds for aggregators and bamboo for flag poles. "

Several of the experts voiced opinions on pressure floats, probably because their favoured design, the Indo-Pacific FAD, is highly dependent on them. There was little consistency in the views of four experts who had strong feelings on pressure floats:

- "Hard to find reliable pressure floats"
- "There is a need for vendors to accurately describe each float in detail; it is difficult to order floats due to inconsistent way in which they are described"
- "Need to use 200-metre working depth for surface floats"
- "Not a fan of big floats"
- "The pressure floats that keep the rope off the bottom should be ABS [acrylonitrile butadiene styrene] high pressure trawl floats (with centre hole or lug ears) rated for about twice their working depth".

Aggregators are various types of attachments to the upper part of a FAD that are thought to have a positive effect on the attraction of fish. Coconut leaves, purse-seine netting, plastic strips, and other materials have been used as aggregators. Of the four experts that included aggregators among the subjects where they had strong feelings, their opinions ranged from a mild requirement ("On the need for an aggregator, the jury is still out but something is necessary") to being adamant ("Aggregators are very important. Fishers complain when a FAD has no aggregator").

In reviewing the above ideas on FAD designs, the main lessons appear to be that there is considerable confidence in the SPC FAD manuals and there is general satisfaction with the Indo-Pacific FAD design. Because there is considerable ongoing activity in refining several FAD components (especially anchors and floats and the use of lighter materials), this suggests that there is still considerable room for innovation in FAD design.

Ordering FAD materials

Because the ordering of FAD materials can be challenging for staff of national FAD programmes, the six experts were requested to offer any lessons they have learned in purchasing FAD hardware. Their responses covered a variety of subjects within this general area, with subjects being common to the responses of several experts:

- Favoured supply countries
- Favoured supply companies
- Ideas regarding the trade-offs between cost and quality of FAD materials.

Most of the FAD experts identified New Zealand and Taiwan as their favoured supply countries. New Zealand has the advantage of easy shipping to Pacific Island countries south of the equator and being the home to some of the historically reliable companies. Taiwan has cost advantages, a wide selection of materials, and easy shipping to Pacific Island countries north of the equator. One expert cited the United States as his least favoured country because of the high prices. An interesting observation made by one of the FAD experts was that "preferences by FAD technicians for specific countries or companies are irrelevant as all national governments and donors require a tender process in which it is not possible to select one's preferred supplier".

Two companies were named by two or more of the FAD experts as being good suppliers of FAD materials:[10] Bridon Cookes in East Tamaki, Auckland, New Zealand (www.bridon-bekaert.com) and Sea Master Enterprise Company in Kaohsiung, Taiwan (www.seamaster.com.tw).

Two interesting observations were made regarding the trade-offs between cost and quality of FAD materials: "There is a tendency for FAD technicians to blame poor materials when a FAD breaks loose", and "If going cheap, go all cheap; a FAD is only as strong as the weakest component so it is a waste of money to buy a few top-quality components". Half of the experts expressed an idea that can be summarised as "Top-dollar FAD equipment is not worthwhile, therefore go for the B or B+ quality", and "In the balance of cost and quality, go for the middle quality". Another expert did not disagree with that idea but advised that FAD technicians who are unsure of the quality of materials should "err on the side of quality".

The major lessons learned in ordering FAD materials appear to be that FAD technicians need to be very quality conscious, but nobody seems to be in favour of paying "top dollar" for FAD components.

Assembly of FADs

Because the two recent SPC FAD manuals give detailed instructions on assembly, the FAD experts were instructed to give their assembly-related comments on points that deserve extra attention. Therefore, this section is not intended to be a recipe for assembling a FAD.

Each FAD expert had his own list of areas related to assembling a FAD where he had strong feelings or learned lessons. The subjects stressed by more than one expert were:

- Someone needs to be in total control of the FAD assembly operation. The boss needs to focus on quality control and should closely scrutinise every single connection to verify that it has been done properly. A concept mentioned in the material ordering section above is also relevant here: a FAD is only as strong as the weakest component.

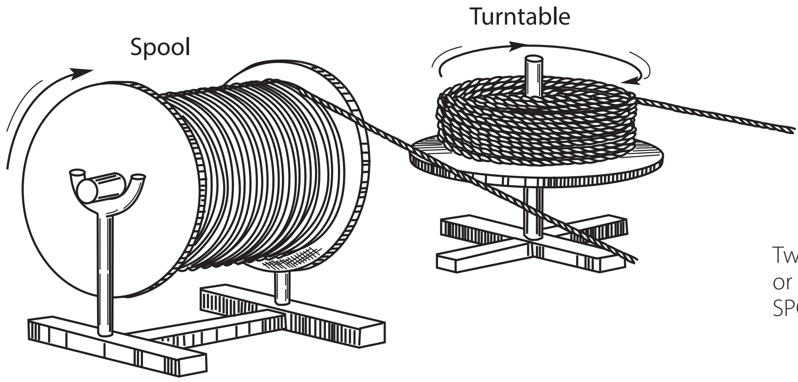
[10] The citing of suppliers here does not imply that the Pacific Community endorses these companies or their products.

- Special attention needs to be paid to splices. As different types of ropes (e.g. three-strand, multi-strand) require different types of splices, the appropriate splice must be used. One expert went so far as to state that lots of people damage the mainline when they splice, so "unless they can make the appropriate splice properly, knots should be used as connectors instead: a double sheet bend or blood knot, both secured with whipping".
- There is a need for secure storage of FAD materials: "a big expensive lesson is that people love to steal FAD materials". FAD materials need to be stored in a locked dry container. There should be an inventory of FAD materials after each fabrication and the materials used for each FAD should be documented.
- If practical, fishers need to be part of the assembly process. There is a feeling that this could contribute to greater understanding of the FAD components, identification with the goals of the FAD programme, and a reduction of vandalism.
- The mainline of the FAD must be protected at all times, so to avoid kinks in it, a turntable or spool arrangement should be used for uncoiling the rope.

The subject of electrolysis (where two different metals are in contact in seawater) is treated differently by the various FAD experts in this study. Some did not acknowledge its importance, some made casual mention (e.g. the need to swap out the stainless steel pins of galvanised shackles), one thought it was quite important, while another expert referred to electrolysis as a "black box". It is interesting to note that the first SPC FAD manual (Boy and Smooth 1984) has a section on electrolysis, while there is no mention of electrolysis in the two most recent SPC FAD manuals (Chapman et al. 2005; Sokimi et al. 2020). The lesson here appears to be that there is considerable inconsistency in the perceived importance of electrolysis among the experts.

Several experts commented on the practice of national FAD technicians departing from materials specified in the FAD manuals. The comments of the experts on this practice included "minor departures can result in major failures", "If you do not know much, always follow the manual", and "this is OK if the technicians are very familiar with why the recommended materials are used".

From the information presented above and the enthusiasm of the experts during the interviews, the major lesson learned in the assembly of a FAD appears to be that careful attention must be given to doing each connection properly, and there should be close supervision of the process and meticulous inspection of the finished connections.



Two ways of properly uncoiling a rope spool or bundle, as shown on page 28 of the 2005 SPC FAD manual (Chapman et al. 2005).

The base of an office chair can be used as a turntable. (image: © William Sokimi, SPC)

FAD deployment

The strongest feelings expressed on FAD deployment by the experts were in the areas of surveys of bottom topography, safety, anchor/block handling, and logistics.

There was consensus that a pre-deployment survey of the bottom topography is absolutely necessary. Charts should not be trusted for either depth or contour as there have been problems in the past. The survey must be done before a FAD is assembled so that the length of the rope can be calculated. The strongest feeling from one of the experts was: "Assuring the system's rope length is correct in relation to deployment depth".

Both a survey prior to the day of deployment (days or even years before the date) and "a few runs on the day of deployment" are needed. The deploying vessel must have an echo-sounder with suitable depth range and a GPS (global positioning system) chart plotter.

Deploying a FAD can be very dangerous, and the most risky aspects are: 1) the damage that an anchor/block can do during loading onto the deploying vessel and transporting it on the vessel to the deployment site; and 2) during the actual deployment, the rope catching on a crewmember or fixtures of the deploying vessel. The mitigation measures offered by the experts included: 1) having somebody in firm control of the whole deployment operation, with close coordination and good communication between the helmsman and the person in control; 2) having the anchor/block very secure on the trip out to the site; 3) having a clean layout of rope (e.g. flaking-out the rope in a box if possible); and 4) doing only float-first deployments, with the possible exception of subsurface FADs, and then only for a very experienced crew. One expert had another sensible suggestion: "take only a small number of crew on the deployment vessel; if there is excess crew, there is a greater chance that somebody will get snagged by the rope, so any observers should be on a separate boat".

With respect to anchor/block handling, it is critically important that the deploying crew are knowledgeable about the procedures for loading and storing heavy anchors/blocks. The position on the deployment vessel is critical: the device can slip into the water or back into the boat, and both situations are hazardous. The anchor/block should not be connected until the deployment vessel arrives at the deployment site. The deployment vessel should be appropriate for the size of the anchor/block, with an important lesson being that the small boats used by small-scale fishers often cannot deploy heavy anchors/blocks with the necessary degree of safety.

Deployment logistics were also an area for which the FAD experts had strong feelings. The FAD should be loaded on the vessel the day before deployment as there is too much going on during the deployment day. Deployment should be rescheduled if weather or sea conditions are not good. If there is doubt about conditions, the deployment should be rescheduled. If possible, deployment should take place in the early morning when sea and wind conditions are often the calmest.

Two experts had strong feelings about shallow-water deployments, and those views were quite similar. The idea is that the farther offshore a FAD is deployed, the better the water quality is for tuna, which are characteristically repelled by low salinity or warm water that is often found close to islands. Typically, shallow-water FADs are more appropriate

Deploying FAD anchors made of cement blocks can be very dangerous, especially from a small craft. (image: © William Sokimi, SPC)

for small atolls and reef islands (typically with oceanic water quality close to shore) than for big atolls and high islands with freshwater runoff. Often, the sites for shallow-water FADs have more forces at work (waves, current) and consequently additional attention must be paid to anchoring and bottom topography.

The main lessons learned regarding FAD deployments include: 1) they can be very dangerous, and a number of measures need to be taken to lower the risk; and 2) pre-deployment surveys of the bottom topography are absolutely necessary.

Post-deployment maintenance

All experts were in favour of some form of maintenance of FADs after they are deployed, but not many strong feelings were expressed on the details of that maintenance. The main point was the importance of periodically checking the FAD components that can be safely changed with the available gear and expertise. One expert was adamant that FAD components should only be lifted into a vessel if there is slack (most often at the lowest tide), and the removal of any coral from the rope should be carried out only if it can be done without damaging the rope. One expert emphasised the idea of repetitive motion (i.e. shifts in the gear with each swell) and the need to inspect those components that are subjected to the associated stresses. Another expert indicated that one of the lessons he learned about deployment maintenance is that there is always some fun involved: spearing fish and retrieving snagged fishing lures.

Factors affecting FAD longevity

The experts were presented with a list of factors that could conceivably affect how long a FAD would remain in position. The list consisted of materials, electrolysis, skills and experience of the FAD technicians, vandalism, FAD design, bottom topography, and others. The experts were asked to identify which of those factors were the most important in determining FAD longevity.

As expected, there was diversity in the responses. Several indicated that most, or all, of the factors were important, or something similar to the idea that "a chain is only as strong as its weakest link". It is quite significant that this concept also emerged in the above discussion of FAD materials.

Of the specific longevity factors thought to be important, the ones cited most often were materials, bottom topography, and skills. It was pointed out that the latter is crucially important because the skill of a FAD technician is cross-cutting as it can affect most of the other longevity factors.

Besides the longevity factors listed above, some additional items were mentioned by the experts. These included: 1) the quality of the supervising technician; 2) the correct length of rope for the depth of water; 3) the prevalence of cyclones; 4) the amount of vessel traffic in the area; 5) pressure to respond to political directives; and 6) "less about the materials but more about the way the materials are put together". It is interesting to note that, although the list of longevity factors is largely about technical issues, several of the experts commented on institutional issues being important in FAD longevity.

- "The lack of accountability of lost FADs by FAD fisheries departments; if FADs are lost on deployment or soon after, it is just considered "unfortunate", and at no point is any analysis undertaken or person held accountable."
- "Lying to cover up failure, and no action being taken to rectify the real cause of FAD loss."
- "If anyone is tasked to install FADs, it is their duty to make every effort to install a system that lasts; not just throw in something that looks like a FAD then tick a box for 'FAD deployed' ".

The impact of cyclones on FAD longevity deserves special attention. The one expert who mentioned this longevity factor offered some mitigation measures. There is more chance of a FAD surviving a cyclone if there is a large amount of rope scope. On steep slopes, however, that increased scope can lead to chafing on the bottom, so the lesson is that in areas of high incidence of cyclones, deployment on a flat bottom is important. In addition, the pressure floats used must be stronger than the normal ones. Prior to a cyclone's arrival, beacons, floats and aggregators should be removed from a FAD.

The main lesson on FAD longevity appears to be that for a FAD to remain in place for a long period, a FAD technician must diligently carry out a large number of tasks, especially choosing appropriate materials, assembling them correctly, and choosing a site with suitable bottom topography.

Factors affecting biological productivity

"Biological productivity" refers to the amount of fish and other organisms that a FAD is able to aggregate. In this study, the experts were presented with a list of factors that could conceivably affect biological productivity. The list includes the distance offshore, FAD placement in naturally productive areas, and the use of aggregators. The experts were asked to identify which of those, or other factors, are important in determining the biological productivity of a FAD.

Most of the experts mentioned the importance of all three factors: distance offshore (or the closely related water quality), naturally productive areas (or the closely related areas where local fishers often see birds and surface schools of tuna), and to a lesser degree, aggregators.

As mentioned in the section on FAD deployment, the farther offshore, the better the water quality is for tuna, which are characteristically repelled by turbid, low salinity or warm water that is often found close to islands. Although other species can be attracted by FADs in low-quality water, their biomass is typically far less than that of tuna schools around FADs. As explained by one of the experts, the distance offshore can be a proxy for water quality. Other experts commented: "a FAD needs to be at least three miles offshore except when there are canoes fishing for pelagics" and "FADs in less than 500 m of water and within 1 mile of land are often unproductive: the dead zone".

Most of the experts felt quite strongly about using both local knowledge ("where they go to catch tuna") and visual sightings of birds to determine naturally productive areas. In places where a FAD is unproductive, local fishers often grumble "why didn't they ask us where the FAD should go?"

The experts' opinions on the impacts of aggregators are covered in the section on FAD designs above. In summary, of the four experts who had opinions that ranged from a mild requirement ("On the need for an aggregator, the jury is still out but something is necessary") to being adamant ("Aggregators are *very* important"). One expert had an interesting observation: "Aggregators are needed in the period just after deployment, but once a tuna school has arrived, they are not needed".

The main lesson with respect to the biological productivity of FADs is that a small number of factors (distance offshore, proximity to productive areas, and perhaps aggregators) seem to account for much of the variation between FADs in amounts of fish aggregated.

Conclusions

To summarise, the main lessons learned and the strong feelings expressed from the six experts regarding the FAD-related categories are as follows.

- **FAD designs:** There is considerable confidence in the SPC FAD manuals and general satisfaction with the Indo-Pacific FAD design. There is much ongoing activity in refining several FAD components, especially the anchors and floats and in the use of lighter materials.
- **Ordering FAD materials:** FAD technicians need to be very quality conscious but none of the experts seem to be in favour of paying "top dollar" for FAD components.
- **FAD assembly:** Careful attention must be given to doing each connection properly and there should be close supervision of the process and meticulous inspection of the finished connections.
- **FAD deployment:** 1) Pre-deployment surveys of the bottom topography are absolutely necessary, and 2) deployments can be very dangerous and a number of measures need to be taken to lower the risk of an accident.
- **Post deployment maintenance:** It is important to periodically check FAD components that can be safely changed with the available gear and expertise.
- **FAD longevity:** For a FAD to remain in place for a long period, a FAD technician must diligently carry out a large number of tasks, especially choosing appropriate materials, assembling them correctly, and choosing a site with suitable bottom topography.
- **Biological productivity of FADs:** A small number of factors (distance offshore, proximity to productive areas, and aggregators) seem to account for much of the variation between FADs in terms of the amount of fish that aggregate around them.

The idea of "a chain is only as strong as its weakest link" has been mentioned in earlier sections of this article. The concept is applicable to several aspects of FADs, including FAD design, materials, assembly and deployment. This emphasises that a small deficiency in any one of a large number of areas can be disastrous, hence the importance of attention to detail and constant diligence by FAD technicians.

This article shows the evolution in preferred FAD designs (e.g. ropes, anchors), and highlights the differences in what FAD experts feel strongly about. Taken together, these two concepts suggest there is much room for future FAD improvements and innovations.

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The importance of global transshipment guidelines: An opportunity for Pacific Island countries

Esther Foss Wozniak[1]

A tuna longline vessel transshipping at sea. (image: ©Jiri Rezac)

Introduction

In 2018, 66% of tuna landings in the world, worth USD 26.2 billion (end value), came from the Pacific (McKinney et al. 2020). For many of these fisheries, transshipments continue to be an important component of the seafood supply chain. The practice of transshipment, however, is also widely recognised as one of the main ways that illegally caught fish finds their way to market. Within the western and central Pacific Ocean, it has been estimated that USD 142 million per year of tuna and tuna-like products are involved in illegal, at-sea transshipments (MRAG 2016). There is a clear need for improving and harmonising the monitoring and control of transshipment in the world's high-seas fisheries, and Pacific Island countries will have the opportunity in early 2021 to support and participate in a Food and Agriculture Organization of the United Nations (FAO) process that will develop a set of these global guidelines.

Regulation in the Western and Central Pacific Fisheries Commission

The convention establishing the Western and Central Pacific Fisheries Commission (WCPFC) defines transshipment as "the unloading of all or any of the fish onboard a fishing vessel to another fishing vessel either at sea or in port" (WCPFC Convention Article 1). Article 29 (1) of the WCPFC Convention states, as a general rule, "In order to support efforts to ensure accurate reporting of catches, the members of the Commission shall encourage their fishing vessels, to the extent practicable, to conduct transshipment

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in port." Recognising this point, the Commission adopted Conservation and Management Measure (CMM) 2009-06, which states that there shall be no transshipment on the high seas except where a CCM[2] has determined, in accordance with certain guidelines (para 37) that it is impracticable for certain vessels to operate without being able to transship on the high seas and has advised the Commission of such (see para 34 of CMM 2009-06).

The current situation in the western and central Pacific Ocean

In recent years, the number of reported at-sea transshipments within the WCPFC Convention Area increased by 166%; from 554 transfers in 2014 to 1472 in 2019 (WCPFC 2020a). Furthermore, as of 13 November 2020, 62% of vessels on the Record of Fishing Vessels (WCPFC 2020b) were authorised to transship in the high seas (WCPFC 2020b). High seas transshipments are now the norm, rather than the exception.

Monitoring and management issues

Although the monitoring of in-port transshipments is generally good in the Pacific Islands region, a Pew-sponsored study (MRAG 2019) showed that there are a number of problems in the monitoring of at-sea transshipments.

- There is limited use of standardised forms or manuals, and only a fraction of data collected by observers has made its way to the WCPFC. The absence of observer information on catch volumes and species composition, limits the capacity of the WCPFC Secretariat to independently verify information submitted in transshipment declarations.
- There is no agreement around guidelines for "impracticability". A key component of CMM 2009-06 is a prohibition on vessels transshipping on the high seas unless "it is impracticable for certain vessels ... to operate without being able to tranship on the high seas..." Despite a few attempts, no guidelines have yet defined "impracticability".
- There has been no serious attempt to encourage vessels to transship in port. In the spirit of encouraging vessels to transship in port, paragraph 35 (v) of the CMM requires CCMs of both offloading and receiving vessels involved in high seas transshipments to "submit to the Commission a plan detailing what steps it is taking to encourage transhipment to occur in port in the future". Apparently, no WCPFC member has ever submitted a plan.

The 2020 WCPFC Annual Transshipment Report notes that "the majority of CCMs who were involved in high seas transshipment in 2019 seemed to affirm that all high seas transshipments conducted in 2019 were 100% covered by observers." Yet, the report does not include any information about observer reports received by the Secretariat (Pew 2020). In 2017, the Secretariat reported at the 13th WCPFC Technical and Compliance Committee meeting that it had received only one observer report for the 955 high-seas transshipping events that were reported to have occurred in the Convention Area in 2016 (WCPFC 2017). The WCPFC Secretariat clarified that, to date, the Commission has not prescribed the minimum data fields that Regional Observer Programme (ROP) observers are expected to collect when they monitor high-seas transshipment activities. Consequently, the data and information that are collected by ROP observers deployed on vessels involved in high-seas transshipments, are not currently required to be provided to the Secretariat, but may be available to the national or subregional observer programme that deployed the observer on the vessel.

The way ahead

Improving and harmonising management and oversight of transshipments should be a priority of regional fisheries management organisations (RFMOs), including the WCPFC. There is not, however, a standardised approach to ensure uniform and effective regulations of these high-seas operations across the world's ocean basins. Recognising this need, FAO has begun the process to develop overarching guidelines for consistent transshipment reporting and monitoring globally and will take further steps in the upcoming months.

At the 2018 meeting of FAO's Committee on Fisheries (COFI), members "called for in-depth studies to support the development of guidelines on [transshipment] best practices..." In response, FAO prepared a background study that collated results from surveys of states, RFMOs, relevant non-governmental organisations and industry stakeholders on global transshipment practices. This report also presented two case studies – transshipment in tuna and squid fisheries – and discussed their operations, economic rationale, and regulations.

The study identified five key types of transshipments, summarised in the FAO Transshipment Pamphlet,[3] and provides key recommendations for non-binding global guidelines, such as the use of International Monetary Organization numbers, vehicle monitoring system, vessel lists that ensure vessels are flagged to relevant RFMO members where transshipments occur, and standardised transshipment declaration forms that include all species transshipped. The study

[2] CCM = Commission Members, Cooperating NonMembers, and Participating Territories of the WCPFC
[3] http://www.fao.org/documents/card/en/c/cb0987en

also includes a recommendation to implement formal information-sharing procedures among relevant flag, coastal and port states and RFMO secretariats.

The findings of the report were discussed throughout the month of December 2020 and will also be in January 2021 through a series of webinars hosted by FAO. The webinars gave fisheries representatives from around the world, including the Pacific, an opportunity to properly discuss the report. At these webinars, FAO presented key findings from their report and highlighted elements to be considered in the development of global transshipment guidelines such as requirements regarding notification, authorisation and reporting.

Once finalised, these voluntary guidelines will help support the development of clear and effective transshipment monitoring and reporting at all the RFMOs, including the WCPFC. As FAO member states, Pacific Island countries have the opportunity to share their vast knowledge and experience with transshipment, and play a key role in the development of global guidelines at the upcoming COFI meeting. As members prepare for the COFI 34 virtual meeting in February (2021), Pacific Island countries that want to get involved can:

- contact their national FAO focal points to ensure they are registered for the meeting;
- formally intervene and lead discussions at the meeting to ensure FAO develops transshipment guidelines that support consistent oversight; and
- unite to vocally support FAO's work to draft transshipment global guidelines at the COFI meeting.

Through the FAO process, Pacific Island countries can help the global fisheries community take a large step towards improving the overall transparency and stability of the fisheries they manage, safeguarding the many species that fishers and communities depend on.

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Piloting a community-driven catch monitoring approach in Kiribati

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Introduction

The people of Kiribati depend heavily on marine resources for nutrition and livelihoods. Due to the scarce availability of land, fish is the main source of animal protein, and coastal fisheries are the main provider of fish for local consumption. Because the society is now driven by a cash economy, overfishing is increasing along with the use of destructive fishing gear and methods. Such practices are causing a rapid decline of fisheries resources and, therefore, management is needed to sustain these resources. The Community-Based Fisheries Management (CBFM) Project of Kiribati's Ministry of Fisheries and Marine Resources Development (MFMRD) works collaboratively with communities to sustainably manage their coastal fisheries. Many of the communities interested in the CBFM approach have developed their own village management plan, which requires implementation, monitoring and evaluation to assist with reviewing and adapting rules, if necessary.

In 2019, a new tool for collecting catch data was introduced to five CBFM communities: Kuuma and Tanimaiaki in Butaritari, Ribono in Abaiang, Tabonibara in North Tarawa and Autukia in Nonouti. This community-based catch monitoring approach was developed in partnership with MFMRD as part of the Pathways Project (Andrew et al. 2020; Sami et al. 2020). This catch monitoring approach differs from more traditional methods because it is optimised for supporting CBFM. Instead of collecting catch data to inform stock assessment models, or to inform government decisions, the community-based catch monitoring approach collects data specifically to inform community management plans. Sampling methods were also designed to facilitate local participation, and allow closer engagement between the communities and the CBFM team, building those relationships that strengthen CBFM.

This article details the piloting of the community-driven catch monitoring approach in Kiribati, how this tool was used, where in Kiribati this tool has been used, and some of the data collected from the target villages during our first trip using this approach. We will also share our experiences, lessons learned, and challenges encountered while using this approach, and discuss any limitations as well as ways forward in improving its usefulness for CBFM.

Methodology

Training

Before any field work was conducted, catch monitors were trained in how to collect data using the catch and fishing context survey forms, and how to take useable catch photos using a camera or tablet and custom-printed catch mats (a vinyl mat with 10 x 10-cm squares printed on it). A map of one community's coastal fishing area was also used to teach catch monitors how to plot each fisher's fishing grounds. The training was delivered by CBFM officers and the project assistant coordinator from the University of Wollongong in Australia, and was conducted over two sessions: one session dedicated to theory, and one dedicated to practical skills. Refreshers were also conducted by the catch monitoring coordinator in Kiribati before each data collection round.

In the community: Briefing sessions

Upon arriving at the village for the first time, the CBFM team raises awareness about the catch monitoring programme and focuses on clarifying the methodology, the collection of information from villagers, and the return of results. During our initial round of catch monitoring, we explained the concept and background of the catch monitoring programme and the links of the catch monitoring activity with the village management plan, and gave villagers an understanding of how the data would be collected, the types of data to be collected, and the schedule of the catch monitoring programme. The content of the village briefings changed in subsequent rounds, and briefing sessions were used to clarify results and discuss the evidence behind the findings from previous rounds of catch monitoring. Awareness briefings are always delivered to a different audience of women, men and youth in order to encourage questions and participation of all target groups during the data collection period.

Data collection

Data collection occurs over a two-week period, during which the catch monitors stay in the village being surveyed. Within that period, catch monitors walk around the village looking for any village members who are fishing, or returning from fishing (Fig. 1). Catch monitors also ask household

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Figure 1. Returning fishers who could be interviewed. (image: © Toaiti Vanguna, MFMRD)

members if anyone in their family is planning to go fishing or have gone fishing that day to ensure the catch monitoring team would be present and ready when fishers returned.

Catch monitors interview fishers using the fishing context and catch survey forms. The quantitative catch survey is similar to a creel survey, where the catch (fish or invertebrate) is photographed but measured later when processing the photos. This survey was conducted each time a fisher or gleaner returned from fishing. The catch survey principally collects information about: 1) how the community's fisheries resources are used over the two-week sampling period; 2) the kinds of fishing gear used; 3) which of those gear types are used most often; 4) which habitats fishers and gleaners favour; 5) which habitats experience the most fishing pressure; and 6) which fish and invertebrate species are most heavily targeted.

The fishing context survey, on the other hand, was conducted only once for each interviewee during the two-week sampling period. This survey collects longer range data, and is conducted with as many fishers and gleaners as possible, even those who did not fish or glean over the two-week sampling period. This survey collects information that helps gauge: 1) the seasonality of catches; 2) whether there are habitats that need to be protected; 3) whether fishing and/or gleaning has become harder or easier over time; and 4) levels of knowledge of, and compliance with, each community's management plan.

If the first time a fisher or gleaner was encountered during the two-week sampling period when he or she was returning from fishing or gleaning, the two surveys were usually conducted at the same time. However, in instances where the fisher or gleaner was too tired, an appointment was made to conduct the fishing context survey either later that day or the next day (Fig. 2).

Photos of fishers' and gleaners' catches were photographed each time a catch survey was conducted. Taking a catch photo involved laying the catch out on the catch mat with a 10 x 10-cm grid printed on it, and taking a photo from directly overhead. Care was taken to ensure individual animals did not overlap, and the entirety of each animal was visible in the photograph. This is to allow for the accurate estimation of length of individual specimens after data collection.

Each fisher was also asked to mark their fishing location on a map of their local fishing area, over which a grid was superimposed. The x and y coordinates were recorded, and the mark removed to preserve the anonymity of the fishing location before the next fisher or gleaner was interviewed.

The data gathered using these methods were used to characterise the fishing patterns within each community, and give communities an indication of whether their fisheries management plan needed adjusting, and what the levels of

Figure 2. Conducting a context survey interview. (image: © Toaiti Vanguna, MFMRD)

compliance are with the management plan.

Data analysis

Among others, the data collected was used to answer the following questions:

- Who are the fishers/collectors in the community?
- Where are people fishing/gleaning?
- Are certain demographics within the community more likely to be affected by certain management interventions?
- What kinds of animals are people catching?
- How big are those animals (length and weight)?
- Which animals make up the largest proportion of a community's catch?
- Are the populations of those animals in a healthy state, or are some management interventions required?
- Is there any suggestion that existing management interventions are having an effect on the sustainability of the fisheries?
- What are some trends that community members have noticed that might require management interventions?

Responses to these questions allowed us to characterise each community's fishery and help community members decide how their coastal fisheries should best be managed. The data collected during the first round of monitoring have begun to paint a picture of diversity between the fisheries of the five communities visited (Table 1). We see differences in the diversity of the catch compositions, the number of fish harvested during the survey period, and the species that comprise the greatest weight of the catch. However, there are also similarities – in all communities, the greatest proportion of the catch was caught either from the lagoon, or from the reef flat adjacent to it.

Our data also revealed the importance of invertebrates to communities. Among the catch photos collected from Autukia in Nonouti, 75 photos consisted entirely of invertebrates (some catches numbered in the hundreds of individuals), and only 29 photos contained fish.

Community engagement

Involving community members in the catch monitoring programme proved advantageous in several ways. Asking community members to help catch monitors arrange the catch on the mat (Fig. 3), helped our catch monitors photograph the catch more quickly, and each fisher was allowed to move on sooner. This improved efficiency meant that catch monitors did not miss as many fishers when multiple fishers were unloading their catch at the landing point at the same time. The

Figure 3. Community members help to lay out the catch of their family members before preparing the meal. (image: © Toaiti Vanguna, MFMRD)

recruited community members also helped catch monitors schedule survey appointments with fishers later on.

As fishers were surveyed more frequently, they also became increasingly aware of local regulations (e.g. bans on gill nets with small mesh sizes, and size limits for certain fish species).

In subsequent visits, the team presented the results of each catch monitoring trip to the communities of Kuuma and Tanimaiaki in Butaritari, Ribono in Abaiang, Tabonibara in North Tarawa and Autukia in Nonouti (Table 1) to give a bit of understanding to what sort of data were collected, and how the information can help the village make collective decisions to secure their resources and adapt the rules of their community management plan if needed. Presentations were prepared to address major findings, including common fish species, fish size length and weight, and village awareness of and perceived compliance with the management plan. These results were presented in graphs and tables to ensure the message was easily understood by the community. This is considered to be one of the important parts of the monitoring programme in which villagers engage with the data and start considering how the information could be used to adapt rules.

Community members found that the information returned to them was useful for informing discussions about how their management plans could be improved. For instance, when the presentations were first given, most villagers became interested in introducing size limits to their fisheries, and began discussing the importance of continuing to raise awareness about local rules so that people can effectively comply. One of the elders from Kuuma mentioned that the sharing of the catch monitoring programme's results

Table 1. A breakdown of catch diversity and abundance across the five sites visited during the pilot phase.
NB: instances where habitat type was not recorded are not presented in this table.

	Islands of community sites				
	Autukia	Kuuma	Ribono	Tabonibara	Tanimaiaki
No. fish	415	1700	913	838	530
No. families	15	22	22	16	16
No. species	39	95	77	45	47
Three most prevalent families	Mojarras (Gerreidae)	Trevallies (Carangidae)	Tropical emperors (Lethrinidae)	Tropical snappers (Lutjanidae)	Tropical snappers (Lutjanidae)
	Mullets (Mugilidae)	Tropical emperors (Lethrinidae)	Parrotfish (Scaridae)	Mojarras (Gerreidae)	Goatfish (Mullidae)
	Milkfish (Chanidae)	Tropical snappers (Lutjanidae)	Tropical snappers (Lutjanidae)	Mullets (Mugilidae)	Tropical emperors (Lethrinidae)
Three most important species by weight	Silver biddy (*Gerres* sp.)	Bluefin trevally (*Caranx melampygus*)	Hump-headed Maori wrasse (*Cheilinus undulatus*)	Silver biddy (*Gerres* sp.)	Roundjaw bonefish (*Albula glossodonta*)
	Yellowmargin triggerfish (*Pseudobalistes flavimarginatus*)	Orange-striped emperor (*Lethrinus obsoletus*)	Pacific longnose parrotfish (*Hipposcarus longiceps*)	Mullet (*Mugil* sp.)	Rusty jobfish (*Aphareus rutilans*)
	Pufferfish (*Arothron* sp.)	Pacific longnose parrotfish (*Hipposcarus longiceps*)	Orange-striped emperor (*Lethrinus obsoletus*)	Orange-striped emperor (*Lethrinus obsoletus*)	Yellowfin tuna (*Thunnus albacares*)
Most commonly harvested habitats	Lagoon (311 fish)	Lagoon (673 fish)	Reef flat – lagoon side (471 fish)	Lagoon (723 fish)	Lagoon (398 fish)
	Milkfish pond (54 fish)	Reef flat – lagoon side (447 fish)	Lagoon (196 fish)	Reef edge (20 fish)	Reef edge (72 fish)
	Mangroves (21 fish)	Reef flat – ocean side (71 fish)		Reef flat – ocean side (10 fish)	Reef flat – lagoon side (45 fish)
Most common fishing gear used	Gill net, spoon and knives, fishing line and hook	Spear, gill net, fishing line and hook	Gill net, spear, fishing line and hook, spoon and knives	Gill net, spoon and knives, spear, fishing line and hook	Gill net, spoon and knives, spear, fishing line and hook
	Canoe	Canoe	Canoe	Canoe	Canoe and boat

is crucial, because it warned everyone about community rules and regulations:

> *"...without this sharing, it would be very difficult for our people to understand their fishing behaviour and whether or not they comply with the regulation."*

Also, many village members appreciated the feedback because it showed how their fishing behaviours aligned with their village's management plan. Because most of the monitoring information is related to villages' management plans, villagers will use this tool to check and monitor the rules in their management plan. The former chairman of Kuuma Village, stated that "the feedback also encourages and strengthens the relationship of the village with their management plan".

Challenges

As with any catch monitoring programme, our initial trip revealed some issues, which will be addressed in subsequent rounds of work.

Figure 4. Young community members often helped to lay out the catch collected with their mothers. (image: © Toaiti Vanguna, MFMRD)

There were instances where there were too few catch monitors allocated to a village. At times, five or six fishers returned from fishing at the same time, and only two catch monitors were present, and so the catch monitors could only survey two fishers each, and were forced to let the other fishers leave. Asking fishers to wait would not have met with favourable responses because fishers are often tired, and the catch can spoil in the heat as they wait.

Related to the above issue, some fishers chose a specific landing site for all monitoring activities, although most fishers were unable to use that landing site because it was difficult for people living in more remote areas (whether alongside the lagoon or in the bush) to access. The existence of multiple landing sites means more catch monitors will be needed to ensure coverage, even in more remote areas.

Occasionally, fishers feared being approached by catch monitors. These fishers thought that they would be reported if they had caught undersized fish, and sometimes, fishers would lie to the catch monitors, declaring that they had not been fishing or would hide part of their catch. The catch monitors would then need to reassure those fishers that the data collected would not be used against them, but was important for ensuring the success of the community's management plan.

There were also instances where women avoided catch monitors because they did not realise their gleaning activities were relevant to the catch monitoring programme. This situation was mitigated through more intensive engagement with the communities, thus ensuring that women realised that capturing the data from their catches was also extremely important for informing the community's management plans and fisheries management approaches.

Quantifying invertebrate catches is also proving challenging. Invertebrates are often harvested in the hundreds in Kiribati (Fig. 4), making the data management techniques used for fish inappropriate. And, many invertebrates are soft-bodied and removed from their shells upon harvest, making length measurements impractical. Every CBFM plan finalised thus far in Kiribati mentions concerns about the harvesting of invertebrates, and the control of invertebrate harvests features heavily in the management interventions listed within every management plan. In recognition of this, we are working with the Pacific Community (SPC) towards a solution for quantifying invertebrate catches. The gleaning of invertebrates is an extremely important livelihood for women in Kiribati, who can be affected disproportionately when marine protected areas are employed as part of CBFM plans.

Cultural complexity

When conducting a community-driven catch monitoring programme, it is imperative to understand the local culture and the context of the fisheries and fishing activities relative to the community's traditions, norms, beliefs and cultural festivities.

Bivalves in some communities are valued differently than in others. In Ribono on Abaiang Island, where fish is the main source of protein for villagers, those who feed their families bivalves are considered poor fishers, or lazy. Our team experienced instances where fishers refused to be surveyed or have their catch photographed because they were ashamed of their bivalve catches. Conversely, in Autukia on Nonouti Island, our team witnessed a huge preference for bivalves seasonally – catch photos containing invertebrates outnumbered those of fish by more than two-fold. This preference was mainly observed during data collection in December 2019. The team became interested in understanding the large proportion of bivalves being harvested by men, women and youth. Community members explained that in December, villagers prepare for the dance festival and dance competitions during the Christmas season, and it is believed that eating a large quantity of bivalves help with energy during the dance competition.

Our team also encountered instances where an I-Kiribati tradition limited their ability to collect spatial data. In Kiribati, every fisherman secretly has their own *atiibu* or *kabwate* (fishing ground) for different fish species, and these locations can only be shared with family members. In Ribono, this tradition was still strong, and some fishers felt insecure about showing these fishing locations that had been passed down by their forefathers with the catch monitoring team.

Several times, our team also encountered fishers who were uncomfortable about having catch monitors waiting for them to return.

In some communities, there is a belief that a fisher who has someone looking for them or expecting them to return while they are out at sea will experience poor fishing, and could end up with no catch.

Conclusion

The presented method of community-driven catch monitoring has proven to be more efficient and less time-consuming than traditional methods. The surveys were designed to collect information using tick boxes, simple numerical scales, and short comments from fishers. Fish were measured in-office using catch photos, and weights could be calculated using length-weight relationships supplied by SPC. This measurement tactic is considerably less time-consuming than taking manual measurements in the field using rulers and spring scales, especially for fishers who return with many fish.

The community-driven catch monitoring programme is a very useful tool for characterising the fishing activities of each village. The data give a better insight into what fish are being caught, by count and species, length and size, fishing gear used, and habitats where the fish are harvested from. The programme not only looks at finfish but also captures information on invertebrates, and covers a broad range of information around fishing that are useful for village decision-making, the island council and the MFMRD.

Given the rich information that this catch monitoring programme provides, it should be adopted as one of MFMRD's monitoring tools. The scope of the catch monitoring is different from the creel survey that is currently used because it is village-based and is done over a 14-day period although the content is quite similar. This tool complements existing creel surveys by filling in gaps where existing creel surveys fall short by gathering information about invertebrate catches and gathering data over a two-week period.

Expanding the use of this catch monitoring approach to more than five villages will be quite overwhelming for the CBFM team as it exists. However, some possible avenues to explore for the expansion of this programme could be the training of Fisheries Extension Officers to carry out catch monitoring on their respective islands, and working closely with the Research and Monitoring Unit under the Coastal Fisheries Division, and integrating the community-driven catch monitoring with existing monitoring activities.

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Acknowledgement for Rutiana Teibaba Kinonoua (MFMRD officer)

The CBFM team in Kiribati and the whole Pathways team sincerely acknowledge the contribution of Fisheries Assistant trainee Mrs Rutiana Teibaba Kinonoua, who passed away on the 14th of August 2020 of pneumonia. She was 29 years old.

Rutiana was first attached to the CBFM project in late 2015, and later formally recruited as Fisheries Assistant in 2017. As a newly recruited Fisheries Assistant, she spent three years in the office as a trainee before being posted to her island duty station. During her time as a trainee, she accompanied CBFM staff on many community consultations to develop and follow up on management plans. She was also appointed as one of the data enumerators for the catch monitoring. Rutiana was passionate about her work with communities, and was known to be very proactive and committed to all the tasks assigned to her. Her great sense of humour made an impact on everyone around her, especially community members who came to know her during community visits.

Thank you very much our dearest colleague, Mrs Rutiana Teibaba Kinonoua and may your soul rest in eternal peace. . . Gone from our sight but never from our hearts. . .

Kuuma's journey toward a sustainable coastal fishery

Beia Nikiari,[1] Aurélie Delisle,[2] Tarateiti Uriam[1] and Owen Li[2]

Figure 1. Fishermen returning from handline fishing on the reefs. (image: © Rutiana Kinonoua, MFMRD)

Introduction

Kiribati's population is highly reliant on fisheries in terms of livelihoods, food and nutritional security. Although offshore fisheries account for a large proportion of the national income through tuna fishing licensing fees, coastal fisheries support the well-being of I-Kiribati, providing healthy food to the domestic population and generating income for communities.

Coastal fisheries are under pressure from: 1) a growing human population; 2) potential impacts of climate change; and 3) fishing for local consumption and economic benefits. Sustainable fisheries management practices are, therefore, crucial to ensuring that coastal fisheries can continue to play an important role in securing food for local communities, now and in the future (MFMRD 2013; Delisle et al. 2016).

In line with other Pacific Island nations, The Kiribati Ministry of Fisheries and Marine Resources Development (MFMRD) recognises the important role of communities in the sustainable management of their coastal fisheries. Due to the intrinsic relationship between I-Kiribati people and the marine environment, the management of coastal resources by communities is not new. However, increasing threats and the erosion of traditional ecological knowledge mean that new forms of community-based approaches to fisheries management are needed.

Formalised community-based fisheries management (CBFM) is still relatively new in Kiribati, and started in 2014 with a pilot CBFM project from MFMRD with support of the Australian Government. This approach involves working with communities on coastal fisheries management, and aims to initiate and improve marine management at the community level (Delisle et al. 2016). The purpose is to reinvigorate communities' engagement and central role in fisheries management with support of government partners at the national and island levels. To date, information and awareness has been provided to 11 islands. Fourteen villages have completed their fisheries management plans, and 51 communities are at different stages of working on establishing local community fisheries rules.

This achievement builds on the foundation and lessons learned from working with five CBFM communities during the pilot phase of the project from 2014 to 2017. Out of the five pilot sites, this article focuses on Kuuma Village, and its history as a community working with CBFM since 2014. The article provides information on: 1) the involvement of the village with the project; 2) the establishment of the village's fisheries management plan; 3) the impacts of the management plan on people's lifestyle; and 4) the community's progress in implementing their village management plans.

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Figure 2. Kuuma's women preparing and cooking fish. (images: © Rutiana Kinonoua, MFMRD)

Kuuma as a community

Kuuma is the northern-most village on the mainland of Butaritari island, one of the islands in the Northern Gilbert Group that makes up the Republic of Kiribati. The population of Kuuma is 290, and has been growing since the last population census conducted in 2015 (Kiribati NSO 2016). Fish and other marine resources are important and major sources of protein, while imported rice, locally grown root crops, and fruit make up most of the rest of the local diet. Approximately 3% of the population is employed as public service officers, while the majority of the population depends on copra, vegetable exports and fish as a source of food and income (Delisle et al. 2016).

History of Kuuma with CBFM

Introductory meeting

The CBFM introductory meeting was conducted with the full Butaritari island council, including the mayor, the councillors of all villages, the island clerk, and a representative from the elder's association. Basic information about the CBFM project and approach were provided (e.g. background, objectives, goals, and a selection of attributes for pilot sites). After initial discussions, Kuuma was selected as one of the pilot sites of the CBFM project. At the time, the councillor of Kuuma was very interested in the programme and wanted to champion CBFM in his village. The island

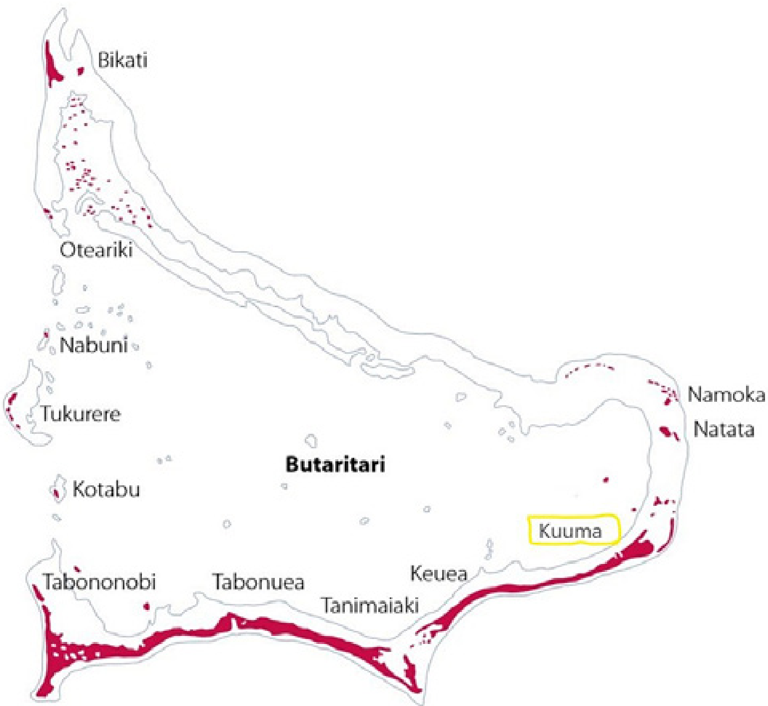

Figure 3. Butaritari Atoll, with study area outlined in yellow. Source: MFMRD.

Figure 4. First meeting with the island council and members of Kuuma Village. (images: © Rutiana Kinonoua, MFMRD)

council agreed that Kuuma would become one of three CBFM pilot sites at Butaritari and that lessons from the sites would be useful to other villages in the future.

The CBFM process

Between late 2014 and early 2015, a series of visits were conducted as part of a scoping process to develop the village's first fisheries management plan. The process involved empowering the community and building awareness on how communities could manage their fisheries, and facilitating focus group discussions for elders, men, women and youth on the importance of obtaining different perceptions of the status of their fisheries. Each group discussed a number of topics, including identifying major marine resource threats, potential management solutions, key species to manage, and resource mapping. At the end of the discussion, each group presented their input to the other groups during a plenary meeting to assist the community with thinking about their coastal fisheries as a whole and consider the different target species of groups within Kuuma. During subsequent visits, the CBFM project team continued to provide information that would assist community members formulate rules to sustainably manage the identified important species for the communities.

The management plan

After three visits to Kuuma, the village's executive committee – together with the CBFM project team – decided that community members were ready to finalise their management plan. Upon advice from the elders of the village and the village executive committee, the project team decided to work with four main community groups (elders, men, women and youth) on different days. Drafting the management plan involved each community group separately working and drafting their group's fisheries management plan. On the final day, during a whole community meeting, the groups' respective management plans were presented, discussed and reviewed to draft into one whole community management plan. In August 2015, the village's first fisheries management plan was completed and finalised with elders, men, women and youth. Some of the rules adopted in the final management plan included the banning of destructive fishing gear, and the use of size limits. The project team provided advice on possible ways that the community could oversee the implementation of their management plan. The community decided that they would form a village CBFM committee that would be in charge of raising awareness and implementing the plan, and for setting up potential penalties applied to offenders. Throughout the years, community members and the Kuuma CBFM committee have reviewed rules, adding new rules or removing previous rules if they were considered to have negative impacts on community members' livelihoods.

Working independently

Between 2016 and 2018, the village was actively and independently working on its management plan. For about 20 months, the CBFM project team was unable to visit and assist the village with their management plan. During this time, the team continued to provide support by organising meetings with community representatives off-site (annual stakeholder meetings; on request trainings on communication or enforcement) and advised representatives of the three pilot sites on setting up an island-wide CBFM forum which gradually became the Butaritari island-wide CBFM committee; a place where CBFM villages could inform, discuss and gain support from the rest of the island on their village CBFM activities.During that time, the first CBFM committee became relatively inactive due to some conflicts between wards. Elders then took responsibility for the management plan and shared their vision of how different management strategies could bring benefits and changes to the village's fisheries. After several meetings and talks among villagers, representatives from Kuuma's different wards decided to be part of one single CBFM committee, which allowed for

Figure 5. Villageres discussing their management plan. (images: © Rutiana Kinonoua, MFMRD)

better communication. The elder association also decided that new rules should be added to the management plan as the rules could improve important fisheries not currently considered in the plan. The protection of bonefish during its spawning seasons was one new rule added to the management plan. Elders believed that improving fishery resources that most people depend on for cash, could be hard in the short term but that efforts could improve the future livelihoods of villagers.

Kuuma adds bonefish to their management plan

Bonefish are comparatively rare on Butaritari, so the villagers felt they could sell the fish at a higher price to people in other villages and, thus, derive a good income. To achieve this, the village added another rule to their management plan in December 2017, which was a ban on harvesting bonefish during their spawning aggregation. The ban is in place three days before and after the full moon and third quarter moon during spawning season. The village perceived an increase in the number of bonefish a few months after imposing the spawning closure.

Commitment to management plan

Kuuma community members have been working on their management plan since the village was first visited by the CBFM team in 2014. The use of gill nets with small mesh sizes (i.e. less than 5 cm) was instantly banned in 2014 and is still prohibited. The catch monitoring assessment in 2019 and in March 2020 witnessed fishers' transitioning from using nets with small mesh sizes to nets with mesh sizes greater than 5 cm. Interviews with fishers also showed that more than 70% of fishers were well aware of the management plan's prohibition of destructive gear, especially gill nets with mesh sizes less than 5 cm.

The management arrangements around bonefish were well known in the village; some villagers even talked about it with their relatives in other villages. Elders realised that working alone would not achieve their management goals due to the fish crossing through different jurisdictions, which the village does not have the power to control. First, the sea does not have any territorial restrictions for fishing activities, and everyone can access marine resource freely. It was, therefore, essential to reach out to other villages and gain their cooperation and support. Without the other villages' support, the bonefish management arrangements would be useless, since the new regulations (fisheries conservation and management of coastal marine resources regulation) that backed village management had not been implemented at that point, meaning that penalties and enforcement of the management arrangements could only happen with cooperation between the villages. In mid-2018, when the bonefish management was first launched, two fishing boats from outside the village broke the new regulation. The fine was not imposed in this instance given the fishers who broke the regulation were not aware of the new management arrangements. The village brought the new management to the island council's meeting and elders association for endorsement, support, and broad recognition. Because both parties have village representatives and monthly meetings who regularly share meeting agendas (including bonefish management) with village members, the management arrangements were popularised and supported in most villages within five months. The CBFM team are now working on a billboard that will show the rules of the management plan. This will help people from outside the village to familiarise themselves with the local management rules.

Benefits from the management plan

In late 2019, villagers started noticing more bonefish in their lagoon. During meetings and talks during catch monitoring assessments, some fishers began to mention that they were catching small numbers of bonefish in their nets while fishing for other species, something that did not happen often before. The incidental catching of bonefish does not, however, necessarily indicate stock recovery. Still, it is something that local fishers mentioned rarely ever happened outside the spawning season. One of the elders also mentioned that 2–4 bonefish were being caught by fishers during a single

Figure 6. Bonefish caught as part of mixed catches during gillnetting. (images: © Rutiana Kinonoua, MFMRD)

trip, which rarely happened before the bonefish management arrangements were put in place, and this change was noticed by many fishers.

These catch rates might not be considered high elsewhere, but because bonefish are considered a rare species in Butaritari, villagers believe this improvement is an indication of increasing numbers of bonefish.

As the villagers' knowledge of marine resource management improves, some men and elders are planning to extend their management plan to protect other species. Giant clam is one of the next species to be addressed. The community's perception is that giant clam is in high demand in Kiribati, and is currently in a declining state. Therefore, giant clams need proper management if they are to support villagers' livelihoods. The strategy involves establishing a marine protected area for giant clams, and this is where the community needs support and demarcation materials from CBFM and MFMRD.

Conclusion

Kuuma villagers have been on a long journey of managing their coastal fisheries resources. The village started things slowly with a few measures, but quickly took ownership of the process. The village is working towards adding more measures including a marine protected area for giant clams, and the people of Kuuma have full ownership of their management plan. They have made sacrifices but are seeing positive effects from these. Village members are now focusing on building awareness, recognition, and broader support of new management arrangements. Various groups, including the CBFM team, island council, and the island elders association, are partnering with the people of Kuuma to do this work. Community-driven catch monitoring has also been identified as being crucial for providing robust information and evidence for gauging whether certain management measures are working or not. Without further catch monitoring, we cannot be fully certain that the management plans are truly benefitting the local fisheries. The CBFM team will continue to monitor the catches of bonefish and other fish species, work with the community to detect any changes to the fisheries, and continue refining Kuuma's CBFM plan by reviewing and adapting the management plan every few years.

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Developing a system of sustainable minimum size limits to maintain coastal fisheries in Solomon Islands

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Abstract

Since 2014, the World Wide Fund for Nature (WWF) has worked with local fishing communities around Ghizo Island in the Western Province of Solomon Islands to assess the status of reef fish stocks and inform sustainable management. An article in the previous issue of the *SPC Fisheries Newsletter*[5] described the catch sampling programme conducted, and the species assessments that resulted. This article describes how those data were used to develop pragmatic advice about how the fishery could be made sustainable. We used a multi-species yield model to evaluate alternative ways of grouping the 96 fish species that made up 95% of surveyed catches, into a pragmatically few minimum size limits. For alternatively optimised minimum size limit groupings, the analysis estimated the aggregate sustainable yield and the number of species left prone to eventual local extinction by high fishing pressure. Our results make explicit the cost, in terms of biodiversity and food security, of not effectively managing the reef fish fishery, indicating that eventually, approximately 70% of the potential yield, and more than 50% of the species will be lost. On the positive side, the implementation of just four multi-species MSLs could prevent local extinctions and sustain more than 90% of the potential reef fish yields, even under regimes of high fishing pressure. If the abundance of larger- and medium- bodied species can be restored and maintained with effective MSLs before depletions become too severe, a simpler arrangement of three MSLs for the main 20–30 larger-bodied species may well achieve similar results.

Introduction

The depletion of reef fish stocks across the South Pacific poses a major threat to both food security and the preservation of biodiversity (Newton et al. 2007; Sale and Hixon 2015). Highly prized, large-bodied groupers, snappers, parrotfish and wrasses have become harder to catch and smaller, less common and more expensive in markets everywhere. Once common, these species are now rare or locally extinct in many places. Researchers are predicting that many species will face global extinction if effective management is not implemented (Sadovy et al. 2003; Dulvy and Polunin 2004). Most Pacific Island countries and territories (PICTs) have yet to develop the administrative capacity needed to tightly manage fishing pressure or the amount of fish being caught. Therefore, the simplest and most effective way to sustain reef fish stocks will be to protect species with minimum size limits (MSLs) until they reproduce sufficiently to replace themselves.

Prince and Hordyk (2018) demonstrated with simulation modelling, that even under very heavy fishing pressure, fish stocks can be sustained by setting MSLs to protect fish until they have completed at least 20% of their natural unfished level of spawning potential (20% SPR). In addition to sustaining stocks, setting MSLs to protect 20% SPR prevents fish being caught before reaching their full growth potential, thus ensuring that fishing communities attain optimal yields. Prince and Hordyk (2018) also demonstrated that for most fish, the size at which 20% SPR is achieved can be simply approximated by multiplying a species' length at maturity (L_m) by a factor of 1.2. By circumventing the need for complex yield-per-recruit analyses, this simple rule of thumb greatly simplifies the process of establishing MSLs for data-poor fisheries. However, even with this simplification, setting MSLs for the large number of reef fish species that typically comprise PICT catches remains technically challenging, and implementing large numbers of species-specific MSLs is impractical. Our catch sampling programme around Ghizo Island in the Western Province of Solomon Islands (Prince et al. 2020) recorded that 15 species numerically comprised ~50% of the catch, while 96 species comprised ~95% of the catch. Clearly implementing and enforcing individual MSLs for each species in such an assemblage is virtually impossible. Instead, species need to be grouped into pragmatically few MSLs, in a way that sustains as much potential productivity as possible, and prevents any individual species from being badly depleted.

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Gizo fish market, Solomon Islands. (image © Andrew J. Smith, WWF-Australia)

Prince et al. (2018) described the application of a novel multi-species yield-per-recruit model that was developed specifically for the purpose of grouping species in Fiji into MSLs. This paper describes the application of the same multi-species yield-per-recruit model to the data collected by WWF in the Western Province of Solomon Islands (Prince et al. 2020).

Methodology

The multi-species yield-per-recruit model was developed to evaluate the trade-offs between yield and species vulnerability, which result from grouping diverse species assemblages into differing numbers of MSLs (Prince et al. 2018). For any number of MSL groupings, the analysis estimates the expected aggregate sustainable yield, and the number of species left prone to eventual extinction under high fishing pressure. As with standard yield-per-recruit modelling, this analysis is equilibrium-based, estimating states that are predicted to exist in the long term, after all transitional dynamics have passed through the modelled populations. In other words, the model estimates the final state that populations will stabilise around, if the modelled conditions were applied constantly into the future.

The model proceeds by:

1. First estimating the MSL for each species in the assemblage being analysed in order to optimize that species' long-term sustainable yield and reproductive potential (SPR).

2. The species-specific MSLs are then grouped into all the possible number of groupings. In this case, from 1 to 96, because there are 96 species in the analysis (see below). Groupings are initially formed using the similarity of the species-specific MSLs, with the overall MSL for each group being set to the average of the species-specific MSLs in that group. For example, if there are five species in a group with individual species-specific MSLs of 30, 35, 40, 40, 45 cm, the MSL for that group will be 38 cm.

3. In the next step, the model adjusts the average MSL for each group so as to optimise the expected yield from each group by giving greater weight to the most productive and abundant species in each group.

4. Finally, the MSLs for each group are optimised for ease of implementation by being rounded to the nearest 5 cm, and any resulting change in yield, caused by the final rounding, is estimated (but is usually very small).

Model output

The trade-offs associated with each of the alternative groupings of MSLs are calculated and plotted in terms of the: 1) relative yield expected at equilibrium from each species in the assemblage; 2) aggregated relative yield expected at equilibrium from the entire species assemblage; and 3) number of species expected to have gone extinct at equilibrium.

These measures are estimated assuming that both moderate fishing pressure (F = 0.3), which even without MSLs is expected to produce pretty good yields and minimise species extinctions, and heavy fishing pressure (F = 0.9), which is expected to depress yields and maximise species extinctions. These default reference levels of fishing pressure (F) can be adjusted within the model, but were used throughout this analysis. An important constraint of the model's configuration is that fishing pressure is applied equally across all species (i.e. no targeting of preferred species).

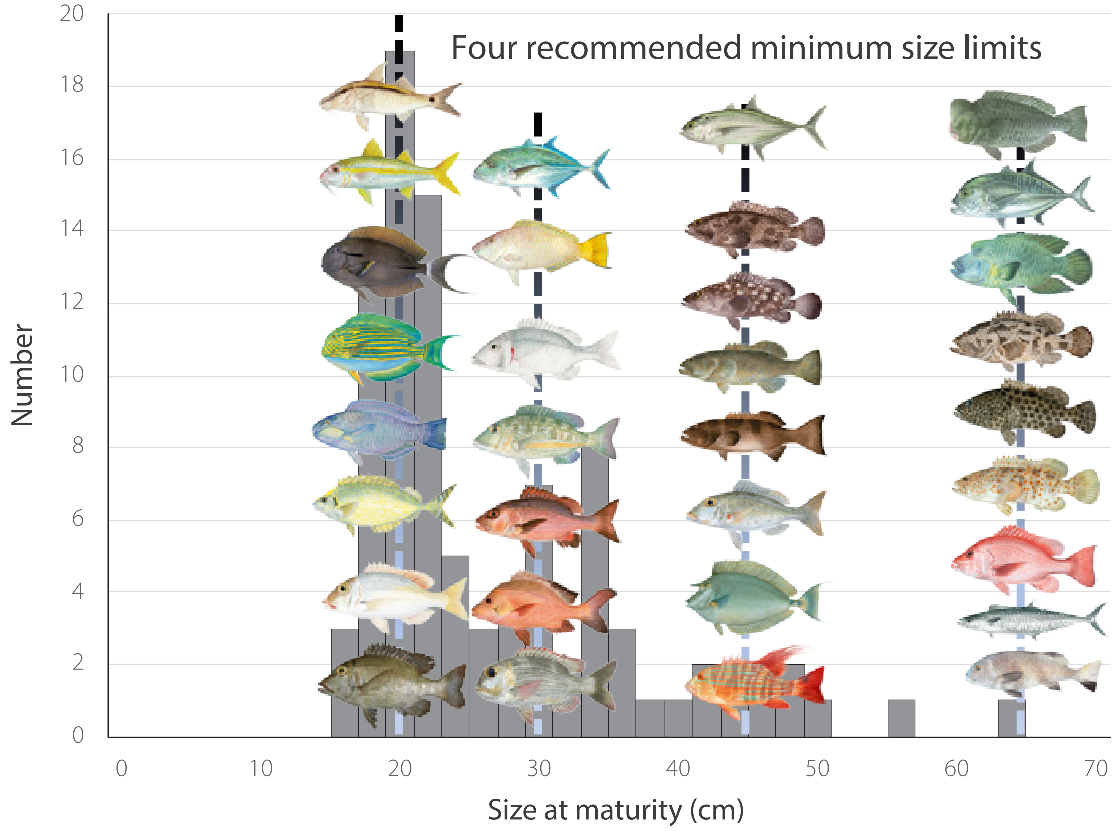

Figure 1. Frequency histogram (grey bars) of the 96 size-at-maturity estimates used in this analysis. The four dashed lines indicate the distribution of MSLs estimated to be optimal by scenario 3. Scenarios 1 and 2 suggest setting the third MSL at 40 cm rather than 45 cm. The thumbnail pictures of fish indicate some of the main species included in each of the four MSL groupings.

The final outputs of the modelling are lists of species in any number of 5-cm-rounded MSL groupings.

Input parameters

Species list

The most fundamental input for the model is the list of species comprising the assemblage being modeled. A list of 96 species was developed for this purpose on the basis that these species comprised ~95% (by number) of the catches sampled around Ghizo Island (Prince et al. 2020).

Size at maturity

Size at maturity for each species was specified, with estimates of the size classes at which 50% (L_{50}) and 95% (L_{95}) of individuals mature. We estimated L_{50} and L_{95} for 63 of the 96 species modelled from our own samples (Prince et al. 2020, Table 3). For one other species (*Bolbometopon muricatum*), estimates were available from the literature (Hamilton et al. 2008). Comparing L_m estimates between Solomon Island and Fiji for the same species (Prince et al. 2018, Table 1), we estimated that, on average, the Solomon Island estimates were 0.81 of the Fijian estimates (SD = 0.146, n = 36). We understand this difference to be a result of Solomon Islands' lower latitude and warmer water, resulting in low oxygen levels in coastal waters, causing reef fish to complete their life cycles at smaller body sizes (Pauly 2010). We used this factor (0.81) to estimate unknown L_m values in Solomon Islands from our Fijian L_m estimates for the same species. Figure 1 depicts a frequency histogram of all 96 L_m estimates used in this analysis.

Biomass distribution

To provide weighting factors for species within each MSL group, the multi-species yield analysis requires starting estimates of relative species composition of the unfished (virgin) biomass. These assumptions are not as critical to the analysis as L_m estimates, and mainly affects how species are grouped when a suboptimally low number of MSL categories (two to three) are being modelled. In that context, the model prioritises the creation of MSL categories to optimise the yield of species (and groups of species), with larger biomass, at the expense of those with less biomass. As our interest focuses on solutions with a larger number of MSL categories (four to ten) estimated to achieve close to 100% of potential yields and zero species extinctions, our results are relatively insensitive to our assumptions of initial estimates of relative virgin biomass.

We based our estimates of virgin biomass composition on a synthesis of published studies:

- Biomass surveys of relatively remote and/or pristine locations: Friedlander et al. (2010) surveys of Kingman Reef in the Line Islands of the central Pacific, Friedlander et al. (2012) surveys of Coco Park off Costa Rica, and Williamson et al. (2006) surveys of closed areas in the Great Barrier Reef Marine Park in Australia.
- Earlier studies of catch compositions in Palau (Kitalong and Dalzell 1994) and Fiji (Jennings and Polunin 1995; Kuster et al. 2005) when the fish assemblage might have been expected to be less impacted by fishing.
- Estimates of the sustainable catch composition in New Caledonia (Labrosse et al. 2000).

These studies show that in unexploited or lightly exploited states, the reef fish biomass of the tropical Pacific tends to be dominated by larger-bodied predatory species, and is distributed relatively uniformly across the main family groups (acanthurids, lethrinids, lutjanids, scarids, serranids). We weighted our modelled biomass composition accordingly.

For our base case scenario 1 (Table 1, left-hand column), we aimed to reflect the species composition of the catches we sampled around Ghizo (Prince et al. 2020, Table 2), which contained relatively high proportions of small- to medium-bodied emperors, goatfish and snappers. The exception to this being that, because Hamilton et al. (2016) documented an historic depletion of *Bolbometopon muricatum*, we assumed a much higher biomass of *B. muricatum* than was actually observed by our catch monitoring. Extending the idea that the catch composition we observed (Prince et al. 2020) has been impacted more broadly by historic fishing (Hamilton and Matawai 2006; Hamilton et al. 2016), we also developed an alternative initial biomass composition. For this alternative biomass, we assumed the proportion of large-bodied serranids and the labrid *Cheilinus undulatus* was higher than we observed (Table 1, right-hand column), and this assumed virgin species composition was used for scenarios 2 and 3.

Table 1. Assumed composition of the initial (virgin) biomass in Western Province, Solomon Islands, by family, used to parameterise the multi-species yield analyses. Left-hand column shows the initial biomass composition used for the base case model (scenario 1), which reflects the species composition of sampled catches (Prince et al. 2020); right-hand column has a higher proportion of serranid and labrid biomass than indicated by current catch compositions and was assumed for scenarios 2 and 3.

Family	% biomass Scenario 1	% biomass Scenarios 2 and 3
Acanthuridae	8.0	6.8
Carangidae	5.3	4.5
Labridae	1.7	4.0
Lethrinidae	20.4	17.5
Lutjanidae	14.7	12.6
Mullidae	1.2	1.0
Scaridae	18.8	16.0
Serranidae	20.3	29.3
Siganidae	2.3	1.9
Pelagic predators	4.5	3.9
Caesionidae and scads	2.1	1.8
Haemulidae	0.9	0.8
Total	100	100

Size selectivity

The minimum size at which each species is caught is an important input parameter for this analysis. This is called the size selectivity of fishing and is specified with SL_{50} and SL_{95}, respectively, the size at which 50% and 95% of individuals encountering fishing gear are retained or "selected" for catching. These two parameters are estimated by the length-based spawning potential ratio (LBSPR) assessment, and for scenarios 1 and 2 we used our own estimates for the species we had assessed (Prince et al. 2020). For species we could not assess due to small sample sizes, we used the results of our parallel studies in Fiji (Prince et al. 2018) and Palau (Prince et al. 2015) to determine whether their size selectivity was typically similar to L_m, or smaller. If similar, we assumed that their size selectivity was the same as our Solomon Islands L_m estimate. For larger-bodied species for which size selectivity smaller than L_m was indicated (*B. muricatum, Caranx ignobilis, Cheilinus undulatus, Epinephelus caeruleopunctatus, E. fuscoguttatus, E, polyphekadion, E. tauvina*) we assumed SL_{50} = 30 cm and SL_{95} = 40 cm. For medium-bodied species in which selectivity smaller than size at maturity was indicated (*Caranx melampygus, C. papuensis, C. sexfasciatus, Cetoscarus oscellatus, Chlorurus microrhinos, Naso annulatus*) we assumed SL_{50} = 25 cm and SL_{95} = 30 cm.

Our multi-species yield analysis assumes the same size selectivity when modelling the impact of both low (F = 0.3) and high (F = 0.9) fishing pressure regimes; when in reality, fishers respond to stock depletion by targeting progressively smaller fish. Because the results of our LBSPR assessment (Prince et al. 2020) suggested relatively moderate fishing pressure on assessed species, we might assume that should the reef fish resource be depleted further, the size selectivities we observed will decline. To model this eventuality, we developed scenario 3 to explore the possible impact of

Jeremy Prince showing how to measure various species of reef fish in Gizo, Solomon Islands. (image © Andrew J. Smith, WWF-Australia)

smaller than current patterns of size selectivity. For scenario 3, we assumed the same higher initial biomass of large-bodied serranids and labrids used in scenario 2 (Table 1, right-hand column), and that the SL_{50} and SL_{95} of species would decline to around the size of the smallest size classes observed in our sampling of catch compositions. Smaller-bodied species were assumed to be selected at SL_{50} = 15 cm and SL_{95} = 20 cm, medium-sized species at SL_{50} = 20 cm and SL_{95} = 30 cm, and the largest species at SL_{50} = 30 cm and SL_{95} = 40 cm.

Other biological parameters

Biological parameters describing the growth and longevity of each species are required by the model in the form of the two life history ratios (LHRs) that characterise the life history strategies of species and entire families of fish:

1) M/K which is a species' natural rate of mortality (M), divided by the von Bertalanffy growth parameter K, a measure of how quickly each species grows to the average maximum size (L_∞); and

2) L_m/L_∞ the relative size at maturity, which is L_{50} divided by L_∞.

Approximations of individual life history parameters – asymptotic size (L_∞), the rate of natural mortality (M) and the rate of growth to asymptotic size (K) – are also required. The LHRs assumed here are the same as assumed for our parallel LBSPR assessments (Prince et al. 2020, Table 1). These average estimates by family were derived from a database of over 1300 published age and growth studies, which was compiled for a meta-analysis of teleost LHR to be published elsewhere (Prince et al. in prep). In the case of the family Caesionidae, there are no estimates in our database, so we assumed they are the same as for Carangidae. This we rationalized on the basis that the similar lightly scaled and semi-pelagic body shapes and behaviours might suggest similar life history strategies and LHRs. Estimates of L_{50} for each species were then used together with the assumed L_{50}/L_∞ of the family to estimate L_∞. The LHR database was used to estimate average M by species. Where no prior estimates of M were found for a species, the average of similar-sized species in the same family was assumed. With the assumed M and the estimate of M/K for each family, a value of K was estimated for each species.

Results

Base case results

With our base case scenario 1, the model estimates that with optimal management, the 30 most important species comprise >85% of the catch. The 10 most important species in order of importance are: humpback red snapper (*Lutjanus gibbus*), pink ear emperor (*Lethrinus lentjan*), two-spot red snapper (*Lutjanus bohar*), longfin emperor (*Lethrinus erythropterus*), blue-line surgeonfish (*Acanthurus lineatus*), streamlined rabbitfish (*Siganus argenteus*), humpnose bigeye bream (*Monotaxis grandoculis*), Pacific longnose parrotfish (*Hipposcarus longiceps*), yellowcheek parrotfish (*Chlorurus bleekeri*), orangespined unicornfish (*Naso lituratus*) and bumphead parrotfish (*Bolbometopon muricatum*).

Without size limits, the model estimates that 92.5% of the potential yield can be obtained if fishing pressure is managed at moderate levels (F = 0.3); nevertheless, in the long term, three large-bodied species are still prone to extinction (Table 2). With heavy fishing pressure (F = 0.9) and without MSLs, the relative potential yield falls to 74% and 22 of the 96 species assemblage are predicted to be prone to extinction. These 22 species are denoted by double asterisks in Table 3 and also depicted across the bottom two panels of Figure 2. Those most at risk are the large- and medium-bodied groupers, parrotfish and wrasses, many of which we observed to already be rare in the catch composition (Prince et al. 2020).

If only one MSL were implemented, the model suggests that this should be set at 20 cm (Table 2). With moderate fishing pressure, the single small MSL results in a slightly lower relative yield than no MSL (88% vs 92.5%), and only reduces the species vulnerable to extinction from three to two. With heavy fishing pressure, a single 20 cm MSL improves potential yield from 74% to 82%, but only reduces the number of large-bodied species at risk of extinction from 22 to 21. The model suggests a single small size limit at this stage of the analysis because of the predominance of small-bodied species in the assumed virgin species assemblage, and the assumption that all species are targeted equally. With these assumptions, the model optimises yield under high fishing pressure and a single MSL by protecting the assumed large biomass of small-bodied species, at the expense of protecting the assumed smaller biomass of larger-bodied species. The reason that under moderate fishing pressure potential yield initially falls and the extinction of only one species is prevented is that, a single small MSL provides little or no protection to vulnerable medium- and large-bodied species, but causes some of the smaller species that, even without an MSL would have been sustained, to go underfished.

The model optimises two MSLs by giving protection to small species with a 20-cm MSL, and medium-bodied species with a 40-cm MSL (Table 2). With two MSLs and moderate fishing pressure, only one species remains prone to extinction and potential yield increases to 89%. With heavy fishing pressure, relative potential yield increases from 74% to 85%, but 10 large- and medium-bodied species remain prone to extinction (*Bolbometopon muricatum, Caranx ignobilis, Cheilinus undulatus, Epinephelus coioides, E. fuscoguttatus, E. tauvina, Lutjanus bohar, Lethrinus erythracanthus, Naso annulatus, Plectorhinchus albovittatus*).

The model optimises yield with three MSLs by finessing the protection and yield of small- to medium-bodied species with 20- and 35-cm MSLs, while introducing some protection for larger-bodied species with a 65-cm MSL (Table 2). Yields with moderate fishing pressure increase from 89% to 96%, and under heavy fishing pressure from 85% to 90%. This scenario predicts that no species remain prone to extinction with three MSLs.

Four MSLs are optimised, with a 20-cm MSL protecting small-bodied species, and with three MSLs protecting mid- and large-bodied species (30, 40, 65 cm). Under moderate fishing pressure, potential yields only increase from 96% to 97%, and from 90% to 92% with heavy fishing pressure (Table 2). One species (*Naso annulatus*) that was previously protected with a 35-cm MSL, is estimated to be left prone to extinction under heavy fishing pressure, by the 40-cm MSL. This result is due to the model's processes of yield optimisation, averaging and rounding across species groups, and the assumed small biomass of *N. annulatus*. The extinction risk for this species could be remedied by repositioning it within the 30-cm size limit group, which would result in an almost complete loss of production from the species, but given its assumed relatively minor biomass, that would result in only a slightly lower yield than the model's estimated optimum.

The model spaces five MSLs relatively evenly across the size range (15, 25, 35, 50, 70 cm). Yields increase to 99% with moderate fishing pressure and 95% with heavy fishing pressure (Table 2). No species remain vulnerable to extinction, even with high fishing pressure.

With six MSLs, relative yields increase to ~100% of the maximum potential with moderate fishing pressure and 97% with heavy fishing pressure, and no species are prone to extinction with high fishing pressure (Table 2). The model splits the previous 35-cm and 50-cm MSLs with 32 species between three MSLs set at 35, 45 and 55cm.

Additional MSLs are predicted to result in only marginal yield increases (Table 2).

Other scenarios

With scenarios 2 and 3 the initial unfished biomass is assumed to have higher levels of large bodied serranids and labrids. The model estimates that with optimal management the 30 most important species comprise >86% of the catch

Table 2. Tabulated model results for scenarios 1–3, showing for 0–14 minimum size limits (first column) the expected percent of potential yield relative to the maximum possible, and numbers of species extinction at moderate (F = 0.3, columns 2 and 3) and high fishing pressure (F = 0.9, columns 4 and 5), and the number of species grouped into each (25–90 cm) MSL category (columns 6–20).

Number of size limits	Potential yield with moderate fishing pressure (% of max. possible)	Number of species extinct with moderate fishing pressure	Potential yield with high fishing pressure (% of max. possible)	Number of species extinct with high fishing pressure	Number of species (n) in each size limit category (cm)											
Scenario 1					15	20	25	30	35	40	45	50	55	60	65	70
0	92.5	3	74.1	22												
1	88.0	2	81.8	21		96										
2	89.3	1	84.8	10		70				26						
3	95.7	0	89.6	0		59			27						10	
4	96.6	0	91.7	1		54		19		14					9	
5	99.1	0	95.4	0	34		26		23			9				4
6	99.8	0	96.7	0	34		25		16		11		6			4
7	100.0	0	97.7	0	34		21	11	10		10		6			4
8	100.0	0	97.8	0	34		21	11	10		10		6		2	2
9	100.0	0	98.0	0	32		20	18		7	9		6		2	2
14	100.0	0	99.3	0	25	18	11	16	6	7	3	2	4		2	2
Scenario 2																
0	89.5	3	71.1	22												
1	85.4	2	78.3	21		96										
2	89.3	1	84.1	9		70				26						
3	93.2	0	88.5	0		59			27						10	
4	96.6	0	92.4	0		54		19		14					9	
5	96.4	0	93.9	0	34		26		23			9			4	
6	99.6	0	97.1	0	34		25		16		11		6		4	
7	99.9	0	98.0	0	34		21	11	10		10		6		4	
8	100.0	0	98.1	0	34		21	11	10		10		6		2	2
9	100.0	0	98.4	0	32		20	18	7		9		6		2	2
14	100.0	0	99.7	0	25	18	11	16	6	7	3	2	4		2	2
Scenario 3																
0	80.7	9	28.9	50												
1	82.3	5	71.5	33		96										
2	88.5	1	80.4	17		70					26					
3	89.9	0	85.4	2		58					28				10	
4	95.3	0	90.5	0		53		18			16				9	
5	96.1	0	91.3	0		53		17			15		7			4
6	99.4	0	97.3	0		33	25	15			13		6			4
7	99.7	0	98.2	0		33	23	14		8	8		6			4
8	99.8	0	98.3	0		33	23	14		8	8		6		2	2
9	99.8	0	98.6	0		24	34	12		8	8		6		2	2
14	100.0	0	99.8	0	6	27	20	11	6	7	10		5		2	2

and in contrast to scenario 1 includes a range of large bodied species. The ten most important species in order of importance being; humpback red snapper (*Lutjanus gibbus*), pink ear emperor (*Lethrinus lentjan*), longfin emperor (*L. erythropterus*), camouflage grouper (*Epinephelus polyphekadion*), Napoleon wrasse (*Cheilinus undulatus*), squaretail grouper (*Plectropomus aerolatus*), humpnose bigeye bream (*Monotaxis grandoculis*), streamlined rabbitfish (*Siganus argenteus*), blue-line surgeonfish (*Acanthurus lineatus*), Pacific longnose parrotfish (*Hipposcarus longiceps*).

Scenario 2, which assumes the same "current" pattern of size selectivity as scenario 1, produces almost the same results as the base case scenario (Table 2). The potential relative yield with no MSLs is slightly lower with moderate (89.5% vs 92.5%) and high fishing pressure (71.1% vs 74.1%), but the number of species expected to be prone to extinction with no to four MSLs and the estimated optimal length of MSLs are almost identical.

In contrast, the results of scenario 3, which modelled the effect of the size selectivity being smaller than currently observed, were markedly different (Table 2 and Figure 2). With no MSLs and moderate fishing pressure, relative potential yields fell from >92% in scenario 1 to 81% in scenario 3, and with no MSLs and high fishing pressure, from >74% to just 29%. Some 50 of the 96 species are predicted to be prone to extinction with high fishing pressure and no MSLs, up from just 22 species in scenario 1 (Table 3; Fig. 1). Consequently, the potential benefit to be gained from introducing MSLs is much greater, with all species extinctions being prevented, and >90% of the relative potential yield being achieved, even under heavy pressure, with four or five MSLs. The distribution of the MSLs as they are progressively added, is also a little different. A 45-cm MSL being the second to be added, instead of the smaller 40-cm MSL in scenarios 1 and 2, and is eventually preferred in the optimal arrangement of four or five MSLs.

Discussion

Depending on the scenario assumed, these results suggest that without management between 20 and 70% of the potential yield of reef fish, and between 22 and 50 of the 96 species modeled, will eventually be lost from the Western Province reef fish assemblage, but that extinctions could be prevented, and >90% of the yield protected, by a system with as few as four or five MSLs.

The slight discrepancies between scenarios, for example with 1 and 2 suggesting the third MSL at 40cm, and scenario 3 suggesting it should be set at 45cm, is indicative of the fact that yield curves for fish have broad flat tops. This allows relatively optimal yields to be obtained over a wide range of size classes, especially, when the yield curves are aggregated across groups of fish, as they are in this analysis. As these results illustrate, the effect of an MSL is determined by both its size relative to the L_m of the species, and the level of fishing pressure applied. Thus, relatively optimal yields for each species maybe attained over relatively broad size bands, so that relatively large shifts in MSL, often make relatively little difference to potential yield and SPR (Prince and Hordyk 2018). This confers some flexibility on the process of setting the MSLs. A fact our modelling explicitly takes advantage of, forcing the model into a final step, that rounds the optimized estimates of MSL to the nearest 5cm, simply to make them more pragmatic for eventual implementation. Our observation is that this constraint rarely makes a noticeable difference to the estimate of potential yield.

Compared with scenario 1 in which the potential yield under heavy fishing pressure increases from 91.7 to 95.4% with the addition of a fifth MSL, scenarios 2 and 3 predict yield gains of ~1% with the addition of a fifth MSL. This suggests that the four-MSL system (20, 30, 40–45 and 65 cm) could be the optimal trade-off between yield, conservation and simplicity of implementation. On the basis that we prefer scenario 3's assumptions of a higher original biomass of larger-bodied serranids and labrids, along with smaller sizes of selectivity in the event of resource depletion, we prefer the MSL arrangement suggested by that scenario (i.e. 20, 30, 45 and 65 cm). Although within the context of the above discussion, we remain flexible with regard to this recommendation. The grouping of species within these four MSLs is provided in Table 3 and partially illustrated in Figure 1.

All modelling is limited by the simplifying assumptions used to approximate the real world. The effects of these assumptions need to be considered when interpreting modelled results. The most important assumptions to be mindful of here are:

1) the size at which fish are selected for catching is fixed at the sizes we observed in our samples for scenarios 1 and 2, and for scenario 3 the smaller sizes we observed in more depleted regions of the Pacific (Prince et al. 2020); and

2) fishing pressure is applied equally across all species.

Should smaller sizes than assumed start being caught as stocks are depleted, the effect of this first assumption will be that we have under-estimated the long-term loss of species and yield under the heavy fishing pressure scenarios. The second assumption will cause our results to overemphasize the need to protect small-bodied species with MSLs.

Observing reef fish fisheries across the Pacific Islands clearly reveals that the size of the fish being selected for catching depends on each fishery's depletion. Where large species are available to be caught, fishers target them in preference to catching smaller fish. As large fish become scarce, fishers respond by targeting progressively smaller fish. This is seen by comparing catch compositions between countries,

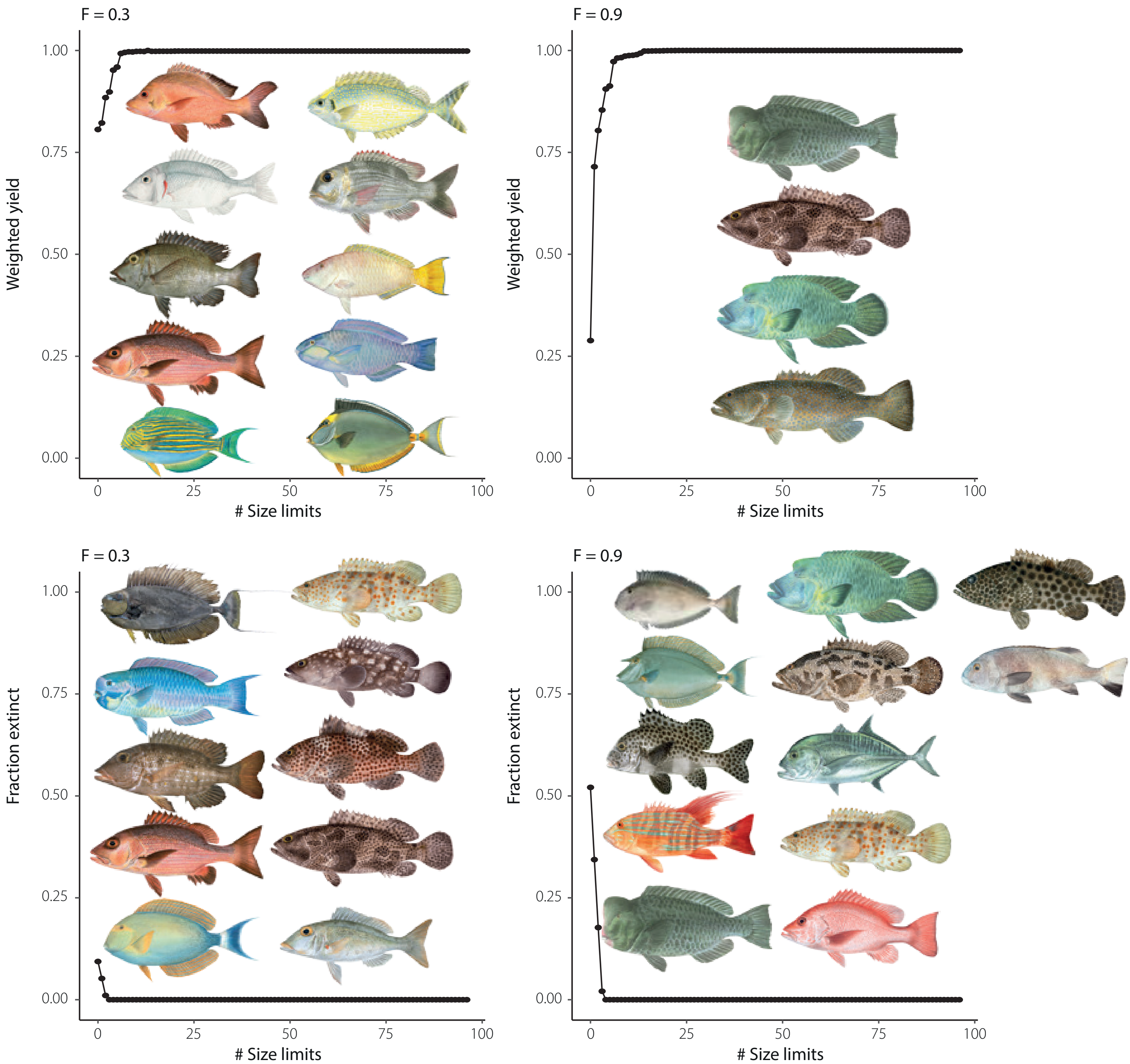

Figure 2. Model results of scenario 3. Top panels plot the estimated relative yield by number of minimum size limits (x-axis), and the bottom plots the proportion of the 96 species prone to extinction limits, under moderate fishing pressure (F = 0.3) in the left-hand plots, and heavy fishing pressure (F = 0.9) in the right-hand plots. Thumbnail pictures in the two top panels illustrate the species predicted by the three scenarios to be among their 10 most productive species with optimal management. Thumbnail fish pictures in the bottom two panels depict the 22 species predicted by all three scenarios to be prone to extinction under heavy fishing (F = 0.9) and without MSLs (Table 3).

and between regions close to population centers, with those from remote lightly fished areas. Fisheries ecologists refer to this process as "fishing down the food web", and "fishing down size structure" (Pauly et al. 1998). At this stage of development, our model cannot take this into account, instead assuming that the size of fish being selected will remain as assumed for that scenario regardless of the state of depletion.

In this analysis, we have tried to account for this reality with scenario 3. Its starker predictions of a 70%, rather than a 20%, loss of yield with heavy fishing pressure, and 50, rather than 22, species being prone to extinction, reveal the impact of our first simplifying assumption. In reality, the assumptions used in scenario 3 are also likely to be conservative. A parallel project north of Madang in Papua New Guinea, where local accounts tell us that 20–30 years ago there was

Table 3. Groupings of species into four minimum size limits as optimized by scenario 3 to prevent species extinctions and produce >90% of relative potential yields. Species predicted to be vulnerable to extinction with no minimum size limits and heavy fishing pressure (F = 0.9) in scenarios 1–3 are indicated with two asterisks, and with one asterisk if only predicted by scenario 3 to be vulnerable to extinction.

Size limit (cm)							
20	Ext	30	Ext	45	Ext	65	Ext
Acanthurus blochii	*	*Acanthurus nigrofuscus*	*	*Acanthurus xanthopterus*	**	*Bolbometopon muricatum*	**
Acanthurus lineatus		*Caranx melampygus*	*	*Caranx sexfasciatus*	*	*Caranx ignobilis*	**
Acanthurus nigracauda	*	*Caranx papuensis*	*	*Epinephelus areolatus*	**	*Cheilinus undulatus*	**
Caesio caerulaurea		*Cephalopholis cyanostigma*	*	*Epinephelus caeruleopunctatus*	**	*Epinephelus coioides*	**
Caesio cuning		*Cetoscarus ocellatus*	*	*Epinephelus maculatus*	**	*Epinephelus fuscoguttatus*	**
Caesio lunaris		*Chlorurus microrhinos*	**	*Epinephelus polyphekadian*	**	*Epinephelus tauvina*	**
Carangoides plagiotaenia		*Choerodon anchorago*	*	*Lethrinus olivaceus*	*	*Lutjanus malabaricus*	**
Cephalopholis miniata	*	*Epinephelus corallicola*		*Lethrinus xanthochilus*	**	*Plectorhinchus albovittatus*	**
Chlorurus bleekeri		*Epinephelus ongus*	*	*Naso annulatus*	**	*Scomberomorus commerson*	*
Epinephelus fasciatus		*Gymnocranius grandoculis*	*	*Naso unicornis*	**		
Epinephelus spilotoceps		*Hipposcarus longiceps*		*Plectorhinchus chaetodoinoides*	**		
Lethrinus atkinsoni	*	*Lethrinus erythracanthus*	**	*Plectropomus aerolatus*	*		
Lethrinus erythropterus		*Lethrinus lentjan*		*Plectropomus leopardus*	*		
Lethrinus harak		*Lethrinus microdon*	*	*Plectropomus maculatus*	*		
Lethrinus ornatus		*Lethrinus obsoletus*	*	*Sphyraena forsteri*			
Lethrinus rubrioperculatus		*Lutjanus bohar*	**	*Symphorus nematophorus*	**		
Lethrinus semicinctus		*Lutjanus ehrenbergii*	*				
Lutjanus biguttatus		*Lutjanus gibbus*	*				
Lutjanus fulvus	*	*Lutjanus monostigma*	*				
Lutjanus kasmira		*Lutjanus semicinctus*					
Lutjanus quinquelineatus		*Monotaxis grandoculis*	*				
Lutjanus rufolineatus		*Naso brevirostris*	*				
Monotaxis heterodon		*Scarus rubroviolaceus*	*				
Mulloidichthys vanicolensis		*Variola albimarginata*					
Naso lituratus		*Variola louti*					
Naso vlamingii	**						
Parupeneus barberinus							
Parupeneus crassilabris							
Parupeneus cyclostomus							
Parupeneus indicus							
Parupeneus multifasciatus							
Scarus dimidiatus							
Scarus ghobban							
Scarus globiceps							
Scarus niger							
Scarus oviceps							
Scarus psittacus							
Scarus quoyi							
Scarus rivulatus							
Selar boops							
Siganus argenteus							
Siganus canaliculatus							
Siganus doliatus							
Siganus lineatus							
Siganus puellus							
Siganus punctatus							

a relatively "normal" Indo-Pacific reef fish assemblage, is recording catch compositions with few fish of body sizes > 20 cm, and in which emperors, snappers are serranids of any size, are virtually absent. Anecdotal accounts about reef fish stocks closer to Honiara and around Malaita Island, as well as published reports (Green et al. 2006) suggest that some regions of Solomon Islands have been depleted similarly. Thus, the predictions above, produced by scenario 3 assuming heavy fishing pressure and no size limits, are probably reasonable for the Western Province over the medium term (15–20 years) but are likely to be conservative over the long term (>20 years) unless effective management is implemented.

The positive side of our model's limitations in describing the flexible way fishers target fish by size and species is that, if the more highly preferred large-bodied species can be successfully managed, our results overemphasise the need to manage small-bodied species. Generally, fishing pressure only intensifies for smaller species once larger-bodied species become scarce, leaving fishers without other choices. If the abundance of larger species can be restored and maintained with effective MSLs, there will be less need for the smallest MSL categories. In this situation, it could be that successfully implementing a simpler three-MSL system for the ~20 main medium- and large-bodied species (i.e. 30, 45 and 65 cm) might circumvent the need for the smallest size limit (20 cm) and the inclusion of a larger number of species.

Conclusions

The cost to Pacific Island countries and territories (PICTs) of leaving reef fish resources unmanaged is undoubtedly going to be great, in terms of lost biodiversity and food security. Our modelling suggests that in the Western Province of Solomon Islands, >70% of yield and >50% of species will be lost. A similar outcome is likely in most other PICTs as well. On the positive side, the results of our multispecies yield analyses suggest that extinctions can be prevented and >90% of the potential yield protected by a system of just four multispecies MSLs set at 20, 30, 40–45 and 65 cm. If the abundance of larger- and medium- bodied species can be restored and maintained with effective MSLs before depletions become too severe, a simpler arrangement of three MSLs (30, 45 and 65 cm) for the main 20–30 medium- and larger-bodied species in the catch, may well achieve similar results.

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