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Editorial

Anchored fish aggregating devices, which facilitate small-scale fishers' access to offshore fish such as tuna, are considered to be one of the most promising fishing tools in the Pacific Islands region. These FADs help compensate for declining reef fish resources and help meet the growing need for protein associated with a rapidly growing human population. But, as William Sokimi explains in his article (p. 24), if anchored FADs are to become an essential component of the livelihoods of fishers and coastal communities, national fisheries authorities need to implement sustainable FAD programmes that are backed by stable and recurrent funding, dedicated specialist staff, and spare parts to replace lost FADs.

The few hundred anchored FADs in the Pacific are assumed to have a low impact on coastal resources and the environment, but the 30,000 to 65,000 drifting FADs (dFADs) deployed each year in the western and central Pacific Ocean by the industrial tuna fisheries raise concerns of a different magnitude (see article by Lauriane Escalle and colleagues, p. 32). Knowing that a large proportion of these FADs are lost at sea, it is easy to imagine their impact on ecosystems, either at sea where they can ensnare protected species such as turtles or sharks, or on land where they can damage reefs and associated ecosystems when they become beached. Several management options are being considered, including further limiting the number of dFADs used by each vessel, using biodegradable materials, and recovering FADs at sea before they become lost or stranded.

FADs are, of course, not the only topic covered in this issue, which will take you to the high seas, American Samoa, Fiji, Kiribati, Papua New Guinea, Samoa, Solomon Islands and Tonga, to talk about aquaculture, tuna tagging, reef conservation... and even spies! I hope you will enjoy.

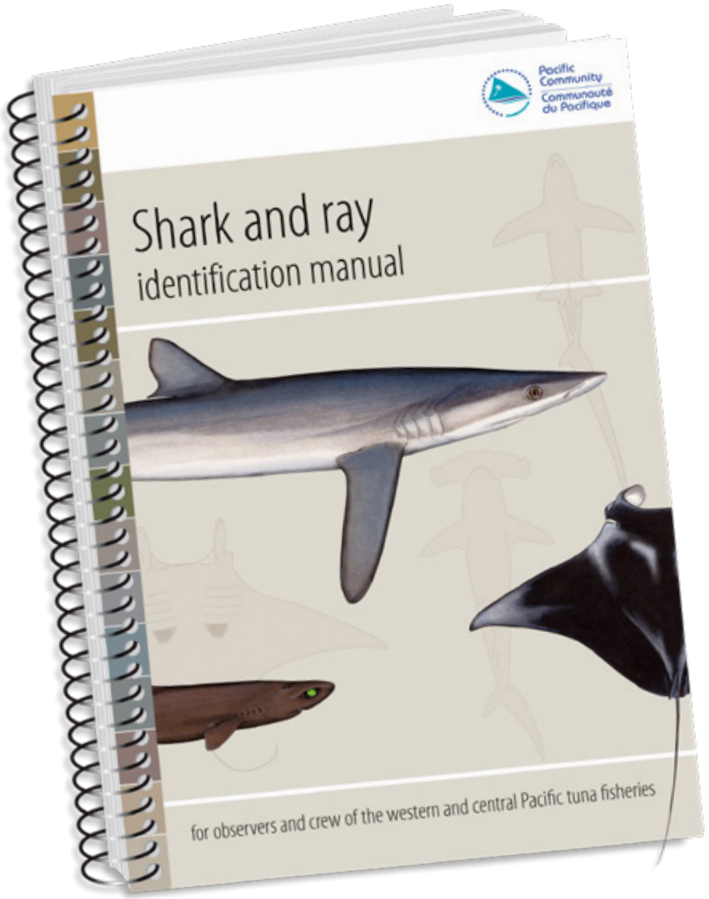
Aymeric Desurmont, *Fisheries Information Specialist, SPC*

Katarina Baleisuva checks the broodstock in her tilapia hatchery in Fiji. (image: Avinash Singh)

FAME
Fisheries, Aquaculture and Marine Ecosystems Division

Release of new shark and ray identification manual

The Pacific Community (SPC) has just released a new shark and ray identification manual detailing 44 species of pelagic sharks and rays encountered in tropical tuna fisheries.[1] The manual features a completely new set of colour illustrations by renowned shark and ray scientist and scientific illustrator Dr Lindsay Gutteridge (née Marshall), of Stick Figure Fish fame. Lindsay's previous work includes 633 illustrations for the book "Rays of the World"[2] published by the Commonwealth Scientific and Industrial Research Organisation and over 1200 illustrations for the online "Chondrichthyan tree of life" project[3]. She also developed a fin morphology protocol for identifying shark species, and produced "Shark fin guide – Identifying sharks from their fins"[4] for the Food and Agriculture Organization of the United Nations.



Description of the manual

SPC's "Shark and ray identification manual" is intended to be used as a field guide for more accurate identification of shark species for Pacific Island fisheries observers and tuna vessel masters to improve their catch reporting.

The guide includes three main sections:

1. A dichotomous identification key that uses a series of steps of paired alternative anatomical descriptions with illustrations that identify or contrast a feature that is reliable (always found in live and dead forms and both sexes of the species), consistent (present throughout the year and across the range), and clear or measurable. Each couplet is a branch that either subdivides the remaining species into two groups or identifies one species from the remainder. Use of the key features should become a routine manner when identifying shark and ray species, and then confirmed with the detailed illustrations in the following section.

2. The 44 species of pelagic sharks and rays have been carefully illustrated to show the key features as well as their natural colours when alive, for use on board a vessel at the time of capture. The species are in the same order as they are identified in the identification key, with the most similar species placed on opposing pages to help with a visual comparison of characteristics, and are grouped into families.

Each page of these two sections also provides:

- the scientific and common English names of the species, and of the family it belongs to;
- a reference to the chain of specific keys used to identify the species;
- further obvious characteristic features that distinguish the most similar species;
- vernacular names in six other languages – Cantonese, French, Japanese, Korean, Mandarin and Spanish – to facilitate communication between observers, crew and other fisheries agency field staff; and
- a figure to compare the maximum known size of each species with that of a six-foot tall human as some similar looking species have significant size differences.

[1] https://coastfish.spc.int/en/component/content/article/44-handbooks-a-manuals/507-shark-and-ray-identification-manual
[2] https://www.nhbs.com/rays-of-the-world-book
[3] https://sharksrays.org/
[4] http://www.fao.org/3/a-i5445e.pdf

3. Shark and ray handling guidelines, with illustrations, to inform crew and observers of best-practice handling methods recommended by the Western and Central Pacific Fisheries Commission (WCPFC) for the release of sharks and rays to minimise injury to sharks, rays and crew. This will also assist observers reporting on the fate, condition and method of release for the key shark species.

There is also a glossary of terms and an illustrated glossary to define terms used in the identification key.

Why do we need a new "Shark and ray identification manual"?

Bycatch species are those species of marine animals that are not targeted to be caught for sale but may be incidentally caught. Bycatch species that are discarded because they are unwanted or regulated as protected species tend to be poorly reported in catch logs so their actual regional catch is not well documented. Sharks and rays are a significant part of tuna fisheries' discarded bycatch and some shark and ray populations appear to be significantly impacted by tuna fisheries. This impact is exacerbated in species with traits of being apex predators or having a long life span and low fecundity, which makes large shark and ray populations vulnerable to fishing.

Fisheries scientists require accurate and timely data on catch and fishing operations to accurately assess the state of a species' population status. Fundamental to accurate shark and ray catch estimates is the reliable identification of their species.

SPC's previous shark identification guide comprised 30 species of sharks and rays, the new manual comprises 44 shark and ray species that are impacted by tuna fisheries. The additional species are included to further improve their identification and refine shark identification accuracy. Some of

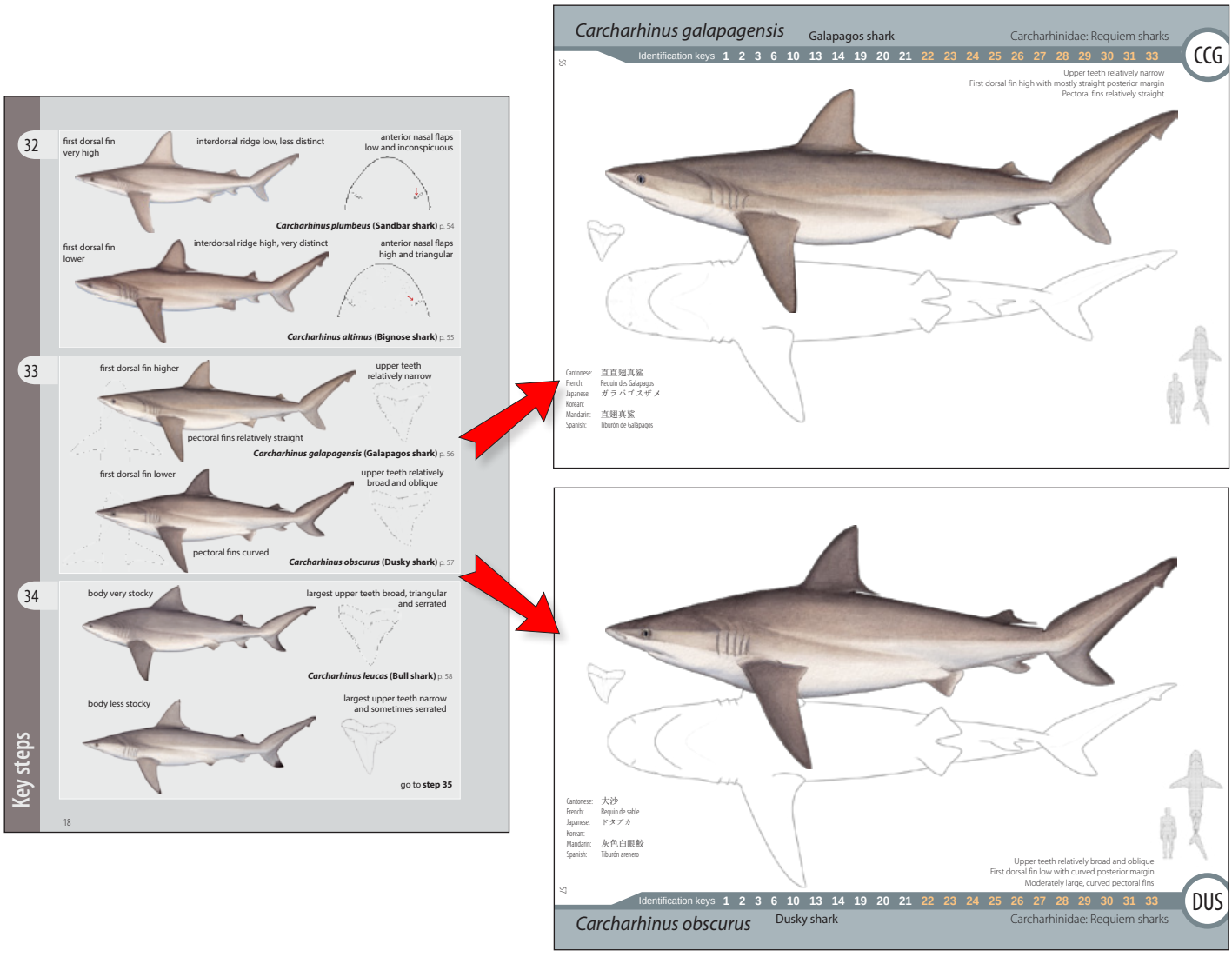


Figure 1. Following the key steps (left) allows the user to properly identify 44 species of tropical shark and ray species.

these have also recently become regulated species by the WCPFC, requiring further reporting of catch by species.

This manual features a completely new set of improved illustrations with more accurate anatomy and colour detail, and ventral line illustrations showing otherwise "hidden" features. This is a significant improvement over the illustrations used in the previous pocketsize guide produced in 2005 by SPC, titled "Shark identification in tropical offshore fisheries".[5]

What is featured?

The 44 shark and ray species in this manual include species with adaptations to being pinnacle predators, huge planktonic feeders or small parasitic predators of large pelagic fish and mammals. These species are included because they are impacted by the tuna fishery when they are caught incidentally, or are set on because of their association with tuna, or interact through depredation (feeding on) of the target catch in the western and central Pacific Ocean (WCPO) pelagic tuna fisheries.

Importance and special designation

Owing to the impact of tuna fisheries on pelagic shark and ray populations, WCPFC has designated 14 shark species and six mobulid species as key shark species (for data provision). Vessels fishing in the WCPO and fisheries observers are required to report their catch for each of these 14 key shark species.

Furthermore, some of these key shark species have been designated as Species of Special Interest. The shark and ray species that are of special interest are the oceanic whitetip shark, the silky shark, the whale shark and six species of mobulid rays (manta and devil rays). These are regulated as no-catch species (oceanic whitetip and silky sharks), no-intentional-set-on by purse-seine vessels (whale shark), and all require that specific data be collected by observers, including location, length, sex, fate and condition. Observers should also record their interactions with the primary fishing gear (line or net).

How will the manual be used?

SPC's "Shark and ray identification manual" will be used for observer training. In particular, the use of an identification key as a tool is a new method for species identification by Pacific Island Regional Fisheries Observers. Introducing the identification key process in observer training will standardise the process and improve transparency of species identification by observers. The identification process and best practice handling guidelines will, hopefully, become adopted with the distribution of the guide and advice of flag-state agencies

When will it be distributed?

The "Shark and ray identification manual" will be printed and distributed in early 2020. Distribution will initially be to national and regional fisheries agencies and fishing companies operating in the WCPO.

Acknowledgements

Verification of species names, the identification key, and accuracy of the illustrations were provided independently by Dr William White (Commonwealth Scientific and Industrial Research Organisation, Australia) and Dr Malcolm Francis (National Institute of Water and Atmospheric Research, New Zealand).

Translations of commonly used vernacular names were provided by Dr Nan Yao, (Cantonese and Mandarin), Dr Yukio Tekeuchi and Dr Ken Okaji (Japanese), Dr Seonjae Hwang (Korean) and extracted from the FAO AFSIS list of species (English, French and Spanish).

The manual was compiled by SPC staff: Tim Park (Observer Programme Advisor), Aymeric Desurmont (Fisheries Information Specialist), Boris Colas (Technical Assistant – Graphic Design) and Neville Smith (Director, Division of Fisheries, Aquaculture and Marine Ecosystems).

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Renown Australian artist Dr Lindsay Gutteridge (née Marshall) painting a shark species.

[5] http://www.spc.int/coastfish/index.php?option=com_content&Itemid=30&id=354

Over 16,600 tunas tagged during the July–September 2019 cruise

Figure 1. FV *Soltai 105* in Palau.

Introduction

The Pacific Tuna Tagging Programme has been providing crucial data for the assessment of regional tuna stocks since 2006. In 2019, the Pacific Community (SPC) implemented a new tagging experiment from July to September. Following the recommendation of the 12th Scientific Committee meeting of the Western and Central Pacific Fisheries Commission (WCPFC), this experiment targeted skipjack tuna, a species that represents 70% of the catch volume in the western and central Pacific Ocean.

To achieve this work, SPC chartered a pole-and-line vessel (*Soltai 105*, see Fig. 1) from the National Fisheries Developments/Tri Marine fishing fleet based in Noro, in the Western Province of Solomon Islands. The fifth western Pacific (WP5) tagging cruise departed from Noro on 22 July and released tagged tuna in the waters of Papua New Guinea (PNG), Palau and the Federated States of Micronesia (FSM) before coming back to its home port on 20 September (see cruise track in Fig. 2).

Fisheries authorities in PNG, Palau and FSM provided research permits and support to the work being implemented in their exclusive economic zones. In addition, special authorisations were obtained to undertake research within the different countries visited.

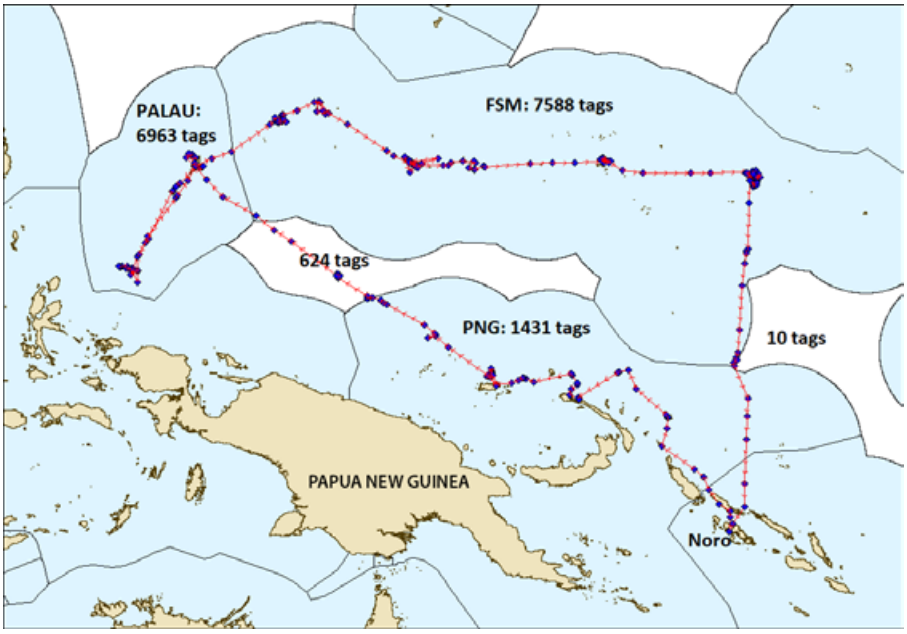

Figure 2. The track of the fifth western Pacific tagging cruise and the number of tags released per country. White areas are international waters.

Summary results

In total 16,616 fish were tagged and released during the cruise at an average of 446 fish per fishing day. The number of fish tagged in each country and high sea pockets is shown in Figure 2. The species composition was 93% skipjack, 6% yellowfin and only 1% bigeye.

The number of fish tagged per species and their school association are detailed in Table 1.

While the total and average number of fish tagged per fishing day were very similar to the results of tagging experiments conducted in the same area in 2008, the share of each species in the total , as well as the size distributions within those species were different, as shown in Figure 3.

The absence of small-size (< 40 cm fork length) fish and the greater percentage of skipjack (93% instead of 64% in 2008) could be explained by the fact that the fish were, in large majority (70%), tagged from free schools, when those only constituted about 45% of tagged fish in 2008.

Within all tagged fish, 79 skipjack were implanted with an archival tag (associated with an orange conventional tag). Deploying archival tags in skipjack is challenging due to the rapid deficit in oxygen the animal experiences as soon as it is out of seawater. The induced stress often prevents the fish from staying calm enough to safely undertake surgery. Suitable individuals need to be inserted with the tag and released if possible within 30 seconds! It is expected that some of those skipjack will be recovered, bringing back a good amount of recorded data about their behaviour and movements.

In addition, 492 skipjack and 9 yellowfin received an injection of strontium chloride (see Fig. 4) that will deposit a mark in their otoliths. When these fish are recaptured, scientists can then validate daily increment formation in the otolith and better evaluate the rate of growth in these species.[1] The injected fish were all tagged with a white conventional tag.

During the WP5 cruise, an important biological sampling effort was achieved with 475 fish sampled. Biological sampling during tagging cruises complements the work conducted by fisheries observers on board tuna fishing vessels, and allows an increase in the number of samples collected in the region during the year. This collection contributes to the WCPFC Tuna Tissue Bank by providing biological information and samples that become available to the scientific community to conduct biological and ecological studies of interest to the region.

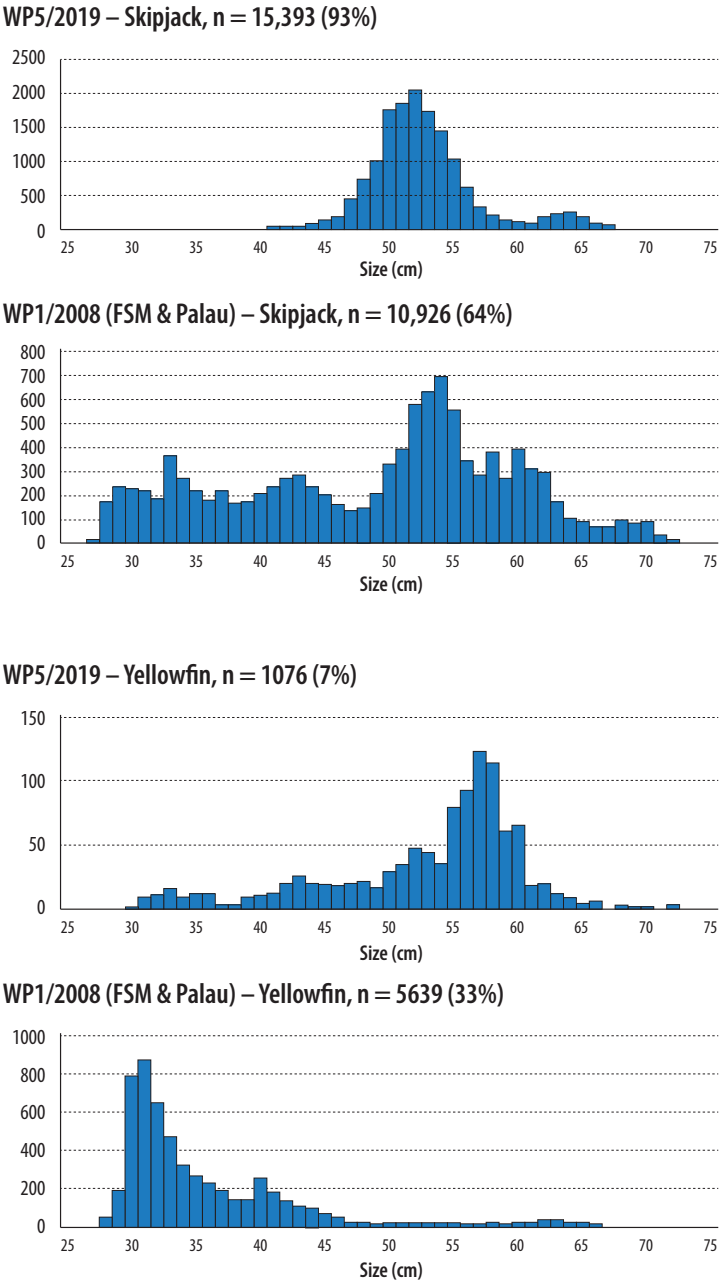

Figure 3. Tagged skipjack and yellowfin size frequency comparisons between 2008 and 2019.

Table1. Number of fish tagged per species and per school association.

School association	Bigeye	Skipjack	Yellowfin	Total
Island or reef	-	54	6	60
Marine mammal or whale shark	26	21	34	81
Drifting FAD	10	2330	460	2800
Anchored FAD	79	498	137	714
Log	31	1181	200	1412
Free school	-	11,309	240	11,549
Total	146	15,393	1077	16,616

[1] See article in Fisheries Newsletter #159 for more information (http://purl.org/spc/digilib/doc/h97cg).

The types of studies in progress that use – and potential studies that could use – data and samples collected during the tagging cruise include:

- Age and growth determination and validation (otoliths, spines);
- Reproduction period, fecundity (gonads);
- Condition index (fat content – Fig. 5);
- Length-weight relationships need to be updated for tuna and established for bycatch species (length and weight measurements);
- Diet studies (stomach);
- Trophic level determination (muscle, liver); and
- Stock structure (fin clips, muscle, otoliths).

Conclusions

The WP5 cruise results, in terms of total tag releases, slightly exceeded the expected number of target releases (15,000) set prior to the experiment. Close to 7000 fish (98% skipjack) were tagged in Palauan waters and over 7500 (90% skipjack) in FSM. Future recovery data from these fish should bring valuable information to their next stock assessment. The expected recovery of some of the skipjacks carrying archival tags will no doubt enhance our knowledge of their behaviour.

News from the Tag Recovery Network

The Tag Recovery Network is growing, with three new staff appointed in November by the SOCSKSARGEN Federation of Fishing and Allied Industries, Inc. (SFFAII) based in General Santos, Philippines, to collect the tags and biological samples from the tagged fish and provide rewards to stevedores and local fishers (Fig. 6).

White-tagged fish are already reported in General Santos but also in Pohnpei (FSM) where local fishers are bringing whole fishes to the National Oceanic Resource Management Authority for data collection and extraction of the otoliths and internal organs (Fig. 7).

On 8 September 2019, in the south of Pohnpei, the SPC tagging team caught a 51-cm skipjack that was tagged with white tag number L01850, injected it with a dose of strontium chloride, and immediately released it. Nearly three months later, on 4 December 2019, the skipjack was

Figure 4. Skipjack tuna receiving an injection of strontium chloride. The fish will also be tagged with a white conventional tag.

Figure 5. Using a fat meter to measure the fat content of bigeye tuna.

Figure 6. From left to right: Caroline Sanchez (SPC tag recovery coordinator), Cyril Villanueva (SFFAII field staff), Joanna Padua (SFFAII administrative staff) and Neil Lloyd (SFFAII field staff).

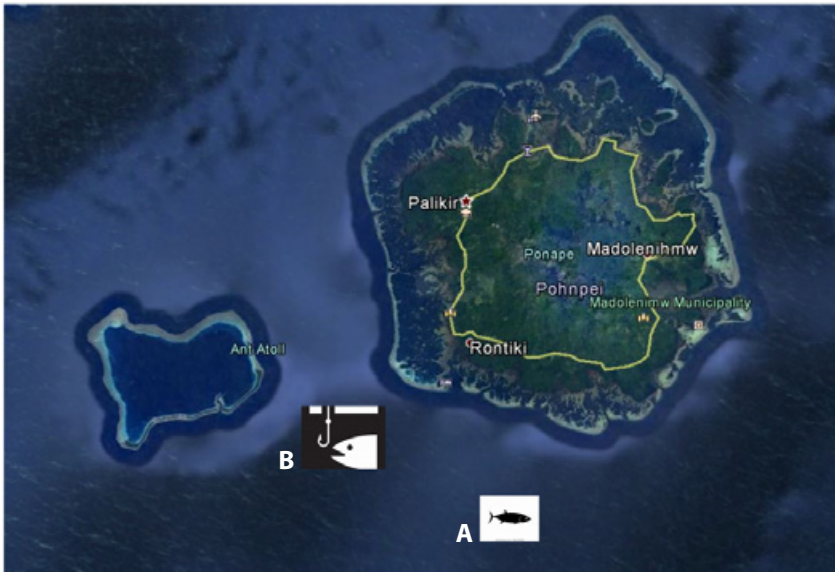

Figure 8. Locations, within the exclusive economic zone of the Federated States of Micronesia, of tag-and-release (A) and re-capture (B) of skipjack (tag L01850).

caught by fishers half a nautical mile from Ant Atoll (Fig. 8). This mature fish seems to have stayed around Pohnpei over the entire period. Its marked otoliths will provide valuable data to fine-tune estimations of the rate at which mature skipjacks grow.

Keep an eye out for tagged fish, but do not remove the tag (Fig. 9) and bring the whole fish (not gilled and gutted) to your closest national fisheries office for your reward. Whole white-tagged fish are purchased at a rate of USD 10/kg (fish weight), and the finder also receives a reward of USD 100. Whole orange-tagged fish are purchased at the same rate but the finder receives a reward of USD 250 instead of USD 100. Observers on board fishing vessels will assist in collecting data and, on arrival at port, taking the fish to the local fisheries authority. Yellow tags, and orange or white tags that have been removed from the fish, have rewards of USD 10 each.

Figure 7. Local fishermen from the Federated States of Micronesia collecting their reward at the National Oceanic Resource Management Authority office in exchange for the whole fish.

Figure 9. White tag left in the flesh of the fish for reward purpose. This tagged fish, which was reported in General Santos, was caught by a Philippine purse-seine vessel fishing in international waters south of the Federated States of Micronesia. The fish spent 101 days at liberty and travelled 627 nautical miles.

If by chance you encounter a white or orange tag on a tuna, please contact:

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Beaching of drifting FADs in the WCPO: Recent science, management advice and in-country data collection programmes

Lauriane Escalle,[1] Joe Scutt Phillips[2] and Graham Pilling[3]

Fishers have long known that pelagic fish species aggregate around floating objects such as natural logs and debris, and have intentionally deployed bamboo rafts with the express intention of attracting species such as tunas. This has been done for decades in coastal areas throughout the Pacific, where anchored fish aggregating devices (FADs) are used by artisanal and recreational fishers to increase food security through higher catch rates and reduced fishing costs (Itano et al. 2004). Anchored FADs have also been used by industrial fisheries (pole-and-line and purse-seine vessels) for several decades, mostly in the western part of the western and central Pacific Ocean (WCPO), to attract and catch tunas. More recently (in the late 1990s), the WCPO purse-seine fisheries began deploying their own drifting fish aggregating devices (dFADs), typically consisting of a bamboo raft with numerous 30- to 80-m appendages of old ropes or nets hanging below. Their use expanded rapidly, given the higher catch rates and fewer chances of unsuccessful sets on dFADs compared with free school sets, and dFADs have become a key component of the purse-seine fishery and responsible for 40% of the total purse-seine catch in recent years (Williams and Reid 2019). This has been facilitated by technological developments, such as the use of satellite buoys. These high-tech buoys packed with solar-powered electronics provide fishers with the position of their dFADs and can indicate the amount of tuna aggregated underneath each one of them.

Purse-seine fisheries represent a very important source of financial income and employment for Pacific Island countries and territories (PICTs), with up to 98% of the national government revenue generated by fishing access agreements in some cases (FFA 2017). While dFADs help stabilise catch rates and make fishing fleets more profitable, and hence generate revenue for PICTs, the now extensive use of dFADs also leads to several issues. dFAD sets present higher rates of catch for juvenile tuna, especially bigeye, potentially affecting the status of tuna stocks; dFADs are also responsible for higher bycatch rates.

The scale of dFAD use in the WCPO is the highest of all oceans, as it has been estimated that between 30,000 and 65,000 satellite buoy-equipped dFADs are now deployed in the WCPO each year (Escalle et al. 2018). This extensive use of dFADs, therefore, also raises concerns about ecosystem impacts, such as the entanglement of sensitive species, and marine pollution, with a high proportion of dFADs being lost at sea. Ultimately, they may reach coastal areas, where they become beached (i.e. wash up on shore) and potentially damage reefs and related ecosystems.

In this paper, we present results from recent scientific research estimating the number of dFAD beaching events in the WCPO, their spatial distribution, and the factors influencing high rates of beaching. We also describe the potential management options that may mitigate marine pollution and beaching events. Finally, we present opportunistic data from dFADs found beached in various areas around the WCPO and highlight the need for more systematic record, with the help of local communities, of information on dFAD and satellite buoys found beached or drifting in coastal areas. The paper concludes with a call for the submission of any information regarding dFADs or satellite buoys found beached or at sea in coastal areas around the Pacific.

Results from scientific research

A large number of dFAD trajectories were recently provided by fishing companies to the Parties to the Nauru Agreement (PNA) through a dFAD tracking programme that aimed to improve the understanding of dFAD use; provide better scientific information on the impacts of dFADs and fishing on them; have a better understanding of the economics of dFAD use; and inform dFAD management. The availability of these data to the Pacific Community (SPC) for scientific studies that help guide dFAD management has, in particular, allowed investigation into the patterns of dFAD beaching events. Using this regional database of dFAD trajectories during the 2016–2017 period, Lauriane Escalle and fisheries scientists from SPC's Oceanic Fisheries Programme identified 1320 beaching events (7% of the dFADs in the database) in the WCPO (Fig. 1; Escalle et al. 2019a) over 30,000 drifting fish aggregating devices (dFADs). The exclusive economic zones (EEZs) presenting the highest number of beaching events were Papua New Guinea (483), Solomon Islands (379), Kiribati (155) and Tuvalu (117). The drivers of beaching events, however, varied between these different areas, as highlighted

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[3] Deputy Director FAME, Oceanic Fisheries Programme, Pacific Community

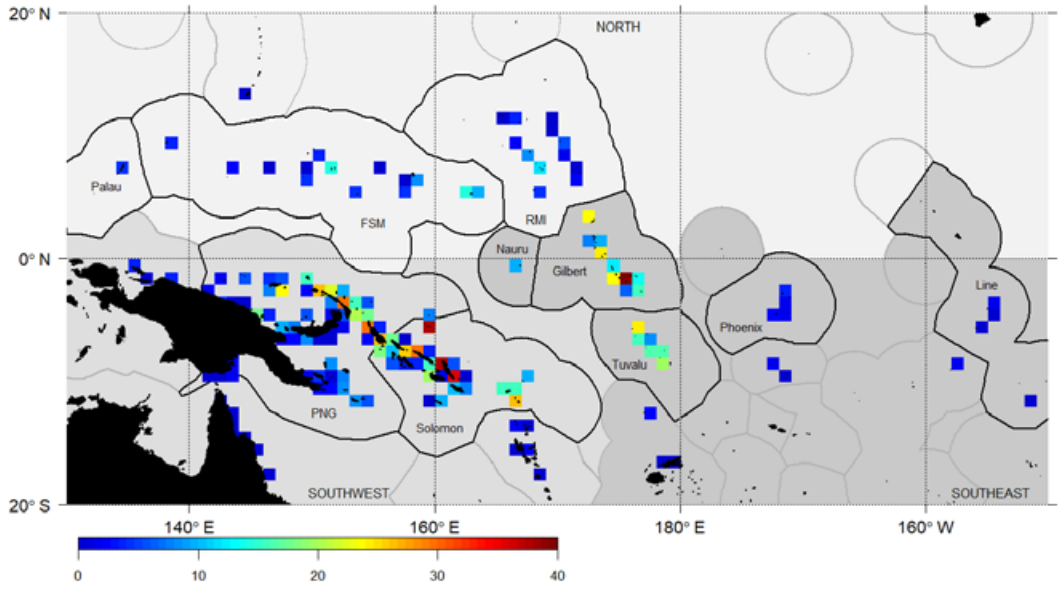


Figure 1. Number of beaching events (1320 in total) per 1° grid cell across 2016 and 2017. Countries that form the Parties to the Nauru Agreement (Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands and Tuvalu) where most dFAD trajectories in the regional dataset occur, are indicated on the map.

using a combination of real dFAD trajectories and of simulations based on ocean currents (Escalle et al. 2019b).

The study found the following.

- Islands within the EEZs of Papua New Guinea and Solomon Islands experienced the highest number of beaching events. Beaching here was mostly driven by oceanographic processes, principally due to the dominant westward current along the equator, but was also due in part to local currents that drive floating objects onto coastlines.
- Kiribati's EEZ, located along the equator, experienced a high number of dFADs drifting through its waters alongside significant levels of beaching, simply caused by its proximity to where fishers appear to deploy dFADs.
- Tuvalu's EEZ is influenced by large-scale ocean circulation and is the area with the highest dFAD density in the WCPO, which explains the relatively high beaching rate of dFADs observed in this area.
- One main limitation in the current assessment of beaching events in the WCPO is the fact that most records come from within the waters of PNA members, as very few data from other countries or outside of EEZs within high seas pockets have been made available by fishing companies to the PNA regional dFAD tracking dataset. In addition, the satellite buoy attached to dFADs is generally deactivated when the dFAD drifts outside of the main fishing area (which means fishers do not receive positional or echo-sounder information for their dFAD). Subsequently, information on these dFADs arriving in coastal areas, including beaching events, is often lacking, meaning our calculation of beaching rates is likely under-estimated.

For more information on dFAD beaching in the WCPO based on data from the PNA FAD tracking programme and cutting edge simulation methods, see https://www.nature.com/articles/s41598-019-50364-0

Potential management options

Management of the dFAD purse-seine fishery by the Western and Central Pacific Fisheries Commission (WCPFC) includes prohibiting all dFAD-related activities (deploying, setting and servicing) during a three- to four-month period (i.e. FAD closure), as well as limiting the number of active satellite buoys that each vessel can follow at any given time to 350 (WCPFC 2018). These measures mostly aim to reduce the impact of dFAD use on tuna stocks.

Specifically, for objectives that aim to reduce dFAD-induced marine and coastal pollution, additional management measures could include:

- limiting the total number of dFAD deployments in the WCPO;
- limiting the number and/or the spatial location of deployments in areas where beaching is linked to deployment strategies (i.e. beaching events in Kiribati's Gilbert Islands);
- using biodegradable materials for dFADs (currently encouraged by WCPFC, with several ongoing trials by fishing companies in the WCPO);
- retrieving dFADs at sea before they reach areas identified as sensitive to beaching; and
- initiating shoreline cleaning programmes, potentially through a financial contribution by fishing companies.

Figure 2. dFADs found beached or entangled in coral reefs in Touho, New Caledonia (top-left, A. Durbano, Association Hô-üt'), New South Wales, Australia (top-right, G. Holmes, The Pew Charitable Trusts) and Pitcairn (bottom photos, Jon Slayer - Protect Blue).

Opportunistic data collection

In addition to the beaching events effectively recorded through the analysis of dFAD trajectories, it has been estimated that around 50% of dFADs are lost at sea (i.e. drifting outside the fishing grounds of fishing companies that own them) (Escalle et al. 2019a). Although some of these dFADs may be retrieved at sea by other vessels, most of them will likely end up as marine pollution and will ultimately disintegrate at sea, sink or beach on coastal areas, potentially quite far from purse-seine fishing areas. Given that the satellite buoy attached to the dFAD is no longer transmitting, these beaching events will remain unnoticed until found by someone.

Hence, to complement the analyses already performed and the data currently available to scientists and managers, the *in situ* record of dFADs reaching coastal areas and their impacts is necessary. In this way, opportunistic communication regarding dFADs found beached in different areas around the WCPO have begun to be reported to SPC in recent years (see Fig. 2). When a satellite buoy is still attached to the dFAD or just by itself, it is possible to check the presence of the buoy in the PNA dFAD tracking database. This could help a) determine whether the dFAD has been used in the WCPO, and b) give access to all or part of its trajectory.

During the fifth western Pacific (WP5) tagging cruise in September 2019 in the Federated States of Micronesia, visits to Yap State's outer islands allowed discussions with local communities regarding beached dFADs and satellite buoys, which are often taken apart so that the batteries and solar panels can be re-used (Fig. 3). On every island visited, local communities claimed to have found dFADs and/or satellite buoys. The data collected during this tagging cruise was purely opportunistic, and unlikely to be systematically repeated in the future. While local communities were interested in collaborating with scientists, the remote nature of these islands precludes any data transmission programme.

Similarly, during a two-week visit in the northern Cook Islands (Manihiki and Rakahanga) to assist the Cook Islands Ministry of Marine Resources gather views to develop a new strategic plan for the pearl industry, 36 satellite buoys and/or dFADs were found on beaches or

Figure 3. dFADs found beached by locals in Ulithi and Lamotreck islands in Yap State within the Federated States of Micronesia. (images: Joe Scutt Phillips, SPC)

in people's garden (Fig. 4). This is a striking number, but while a certain number of satellite buoys and/or dFADs certainly arrived recently on beaches, others may have been collected a long time ago.

This highlights the need for data collection of buoys already gathered by local communities, but more importantly to develop a programme to collect precise information on dFADs and buoys newly beached and/or drifting through coastal areas, as well as their impacts, in the WCPO.

Launching an in-country data collection programme

In-country data collection programmes for beached dFADs and lost dFADs drifting near shore are essential to complement existing databases and assess the actual beaching rates and the consequences of these on coastal ecosystems and local fisheries.

Figure 4. dFADs found beached on Rakahanga, Cook Islands. (images: Ian Bertram and Jeff Kinch, SPC)

Following the arrival of a large number of dFADs in coastal areas, including in PICTs where purse-seine fishing does not occur (e.g. Wallis and Futuna, and French Polynesia), some countries have started programmes to collect such information. This involves distributing posters to inform local communities of what dFADs are, why collecting such data is important, and how to record the appropriate information on them (Fig. 5). For the moment, programmes have been launched or are in the development stage in Cook Islands, Wallis and Futuna, and French Polynesia.

Please send any information regarding dFADs that are beached or in nearshore areas to: rar@mmr.gov.ck ; service.peche@agripeche.wf and drm@drm.gov.pf). Such a programme, accompanied by community awareness, will be expanded to several other PICTs over the next few months.

Acknowledgments

We are grateful to members of the Parties to the Nauru Agreement for access to their dFAD tracking data. We would also like to thank Ian Bertram, Jeff Kinch and the Cook Islands Ministry of Marine Resources for beached dFADs data collection in Rakahanga and Manihiki, local communities in Yap State (FSM), and Boris Colas (SPC) for his work on the communication poster.

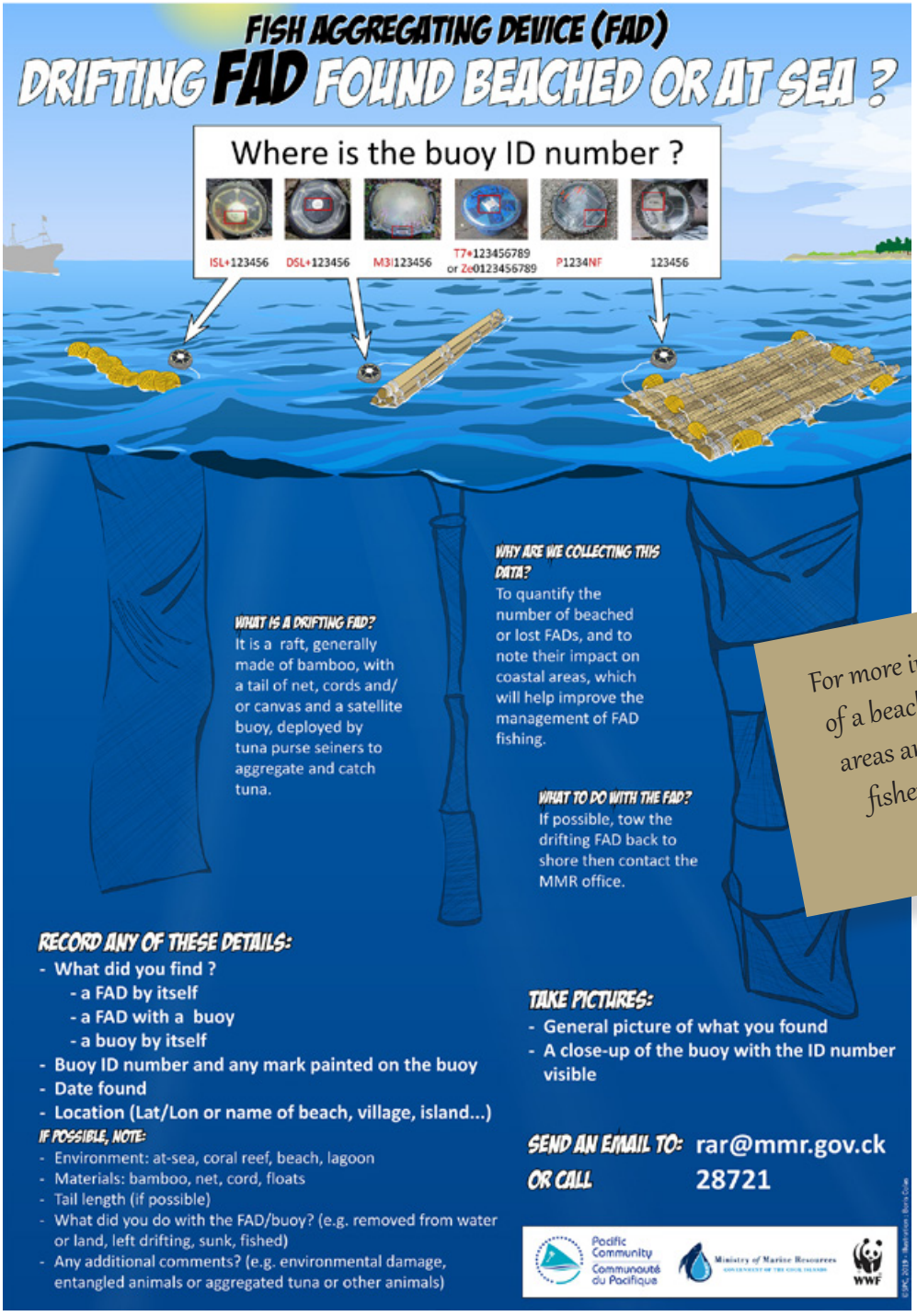
References

Escalle L., Brouwer S., Pilling G. and PNAO (Parties to the Nauru Agreement Office). 2018. Estimates of the number of FADs active and FAD deployments per vessel in the WCPO. WCPFC Scientific Committee. WCPFC-SC14-2018/MI-WP-10. Available at: https://www.wcpfc.int/node/31819

Escalle L., Muller B., Scutt Phillips J., Brouwer S., Pilling G. and PNAO. 2019a. Report on analyses of the 2016/2019 PNA FAD tracking programme. WCPFC Scientific Committee. WCPFC-SC15-2019/MI-WP-12. Available at: https://www.wcpfc.int/node/30938

Escalle L., Scutt Phillips J., Brownjohn M., Brouwer S., Sen Gupta A., Van Sebille E., Hampton J. and Pilling G. 2019b. Environmental versus operational drivers of drifting FAD beaching in the Western and Central Pacific Ocean. Sci. Rep. 9, 14005. Available at: https://doi.org/10.1038/s41598-019-50364-0]

FFA (Pacific Islands Forum Fisheries Agency). 2017. FFA tuna development indicators, 2016 [Brochure]. Honiara, Solomon Islands: Forum Fisheries Agency [https://ffa.int/ tunadev_indicators].



For more information, or to notify the finding of a beached FAD or satellite buoy in coastal areas around the Pacific, contact your local fisheries office and/or send an email to

laurianee@spc.int

Figure 5. A poster on dFADs developed for the Cook Islands.

Itano D., Fukofuka S. and Brogan D. 2004. The development, design and recent status of anchored and drifting FADs in the WCPO. 17th Meeting of the Standing Committee on Tuna and Billfish.

WCPFC. 2018. CMM-2018-01 Conservation and management measure for bigeye, yellowfin and skipjack tuna in the Western and Central Pacific Ocean. Available at: https://www.wcpfc.int/doc/cmm-2018-01/conservation-and-management-measure-bigeye-yellowfin-and-skipjack-tuna-western-and

Williams P. and Reid C. 2019. Overview of tuna fisheries in the Western and Central Pacific Ocean, including economic conditions – 2018. WCPFC Scientific Committee. WCPFC-SC15-2019/GN-WP-01. Available at: https://www.wcpfc.int/node/32051

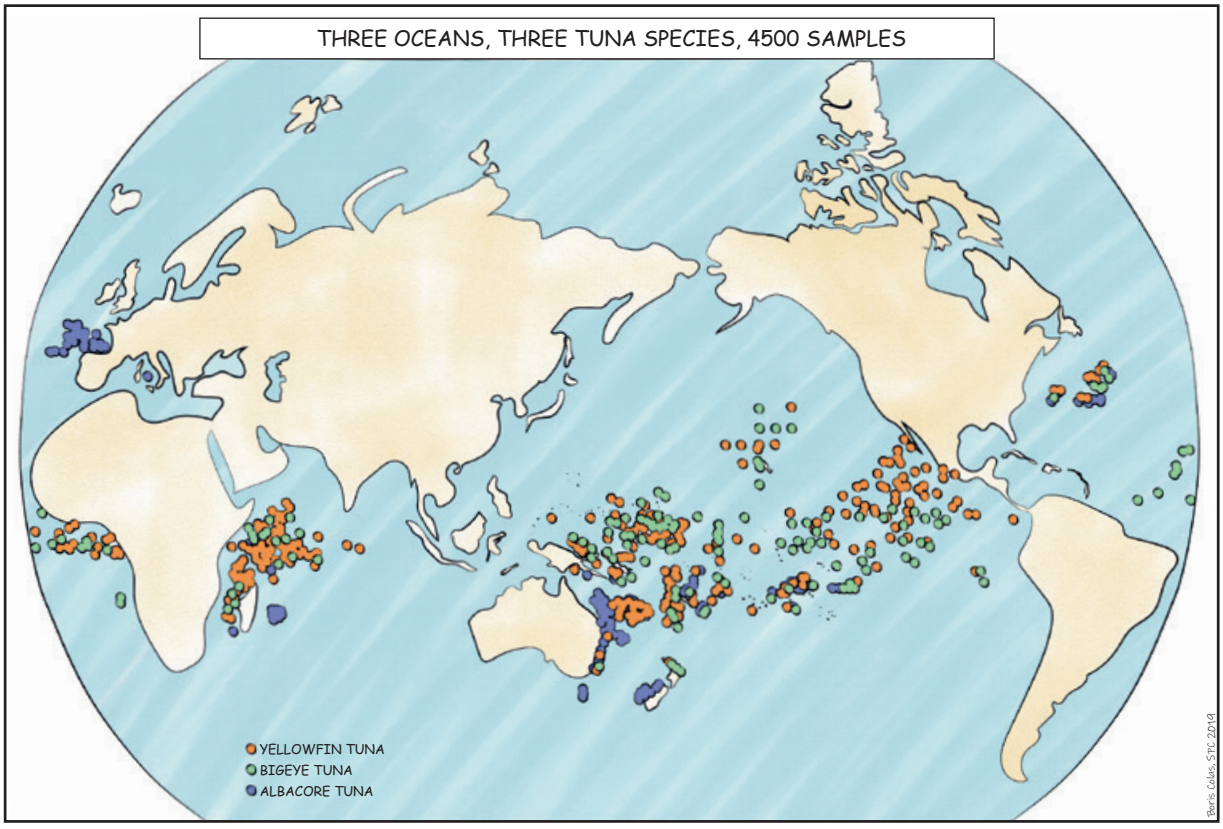
Tuna, the spy who came in from the sea

Anne Lorrain[1] and Valerie Allain[2]

Much appreciated for its flesh, tuna is now also revealing another feature of great interest to scientists (again showing its versatility). Research on the carbon composition of tuna flesh has revealed that, over the past 15 years, deep changes have occurred in the carbon cycle and the phytoplankton underpinning ocean food webs. A multidisciplinary study published in November 2019 (Lorrain et al. 2019) is based on a broad network of international cooperation making it possible to collectively assess 4500 muscle samples from three tuna species caught in the Pacific, Indian and Atlantic oceans between 2000 and 2016. Biological observations on such an extensive spatial and temporal scale are unusual and of prime importance for the validation of climate forecasts and their consequences for food webs.

Tracing the carbon cycle through isotopes

Carbon is a fundamental element that can be inorganic, like that contained in atmospheric carbon dioxide (CO_2), or organic. The human body contains 18% carbon in terms of weight, making it the second biggest component after oxygen, and this carbon can be found throughout the body, e.g. in muscle proteins, fats and DNA. It is therefore present in living beings, the air, the Earth's crust and the oceans. The ocean absorbs more than 90% of the heat associated with climate warming and over 30% of the carbon emissions from fossil fuel burning. The consequences of this on the functioning of the ecosystem and marine organisms through, for example, ocean acidification are not yet fully known. Until now, only some localised observations from certain oceanic regions have provided fragmented information on this topic. This new study, carried out by some 20 international researchers, for the first time provides some elements of overall understanding through analysis of the stable isotopes in the carbon present in 4500 specimens of tuna harvested from the Pacific, Indian and Atlantic oceans between 2000 and 2016 (Insert 1 - tuna map).



INSERT 1 (Illustration: Boris Colas, SPC)

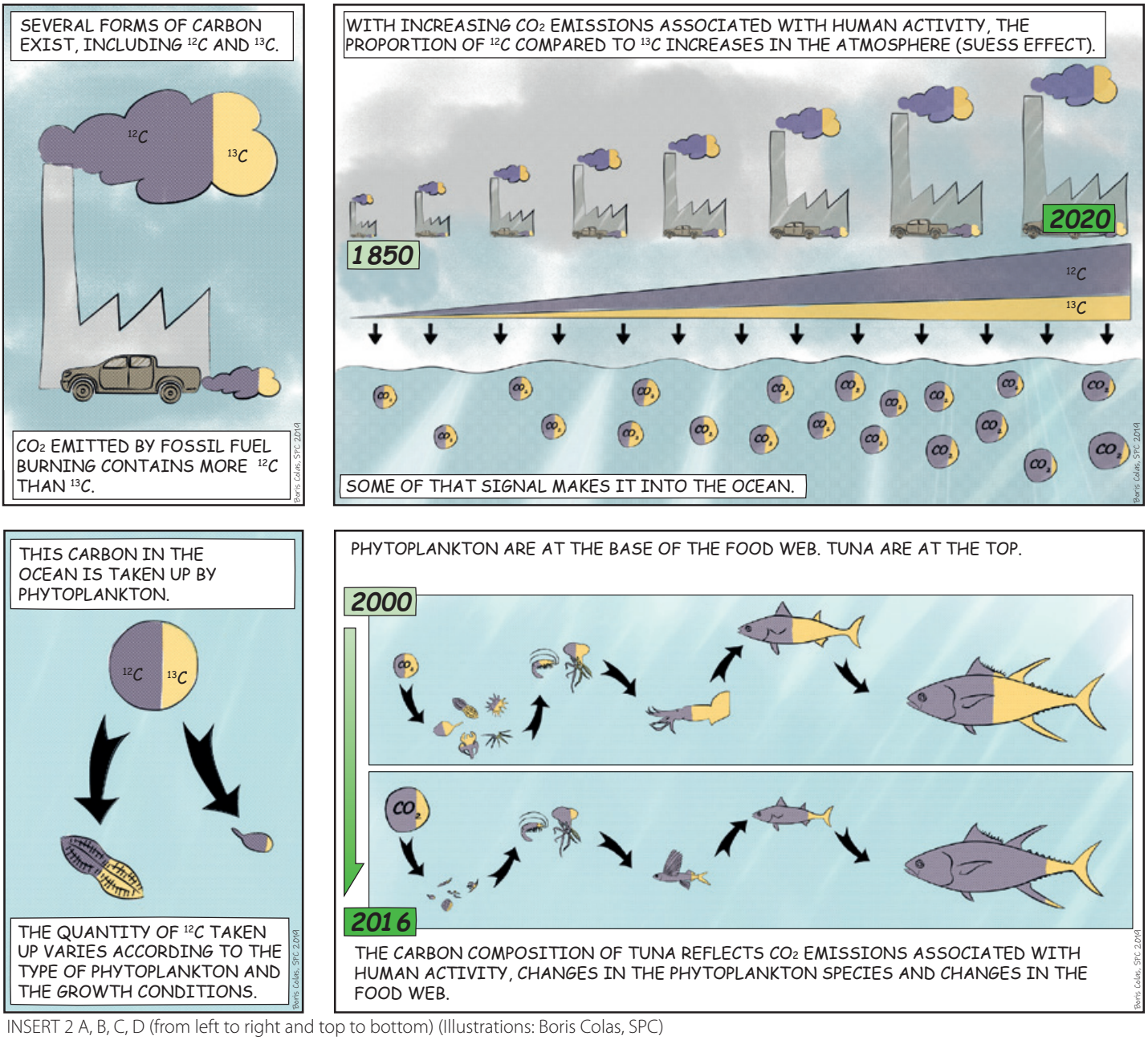
[1] Institut de recherche pour le développement (IRD) and Laboratoire des Sciences de l'Environnement Marin (LEMAR, Université de Brest, IRD, CNRS, IFREMER), France

[2] Pacific Community, Oceanic Fisheries Programme, New Caledonia

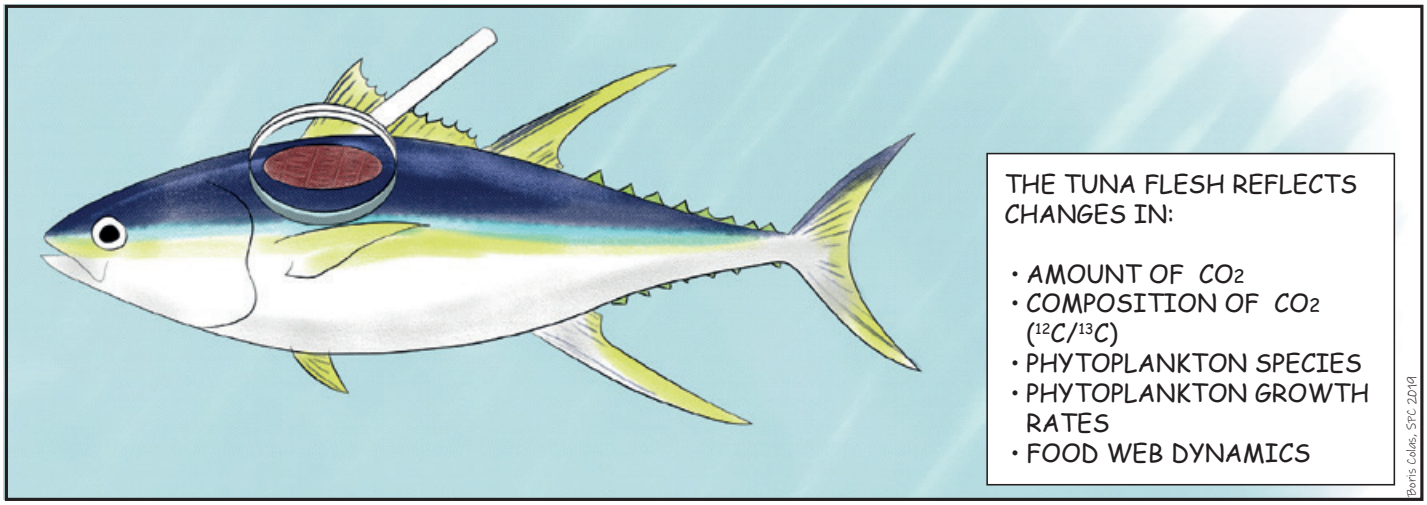
Carbon exists in various forms, called stable isotopes, with special reference to ^{12}C and ^{13}C (articulated as Carbon 12 and Carbon 13, please see Insert 2A). These isotopes do not have the same mass, with ^{12}C being lighter than ^{13}C. Because of this difference in mass, ^{12}C and ^{13}C react differently during chemical, physical or biological change processes. For example, when a process of water evaporation involving dissolved carbon occurs, the light carbon (^{12}C) tends to evaporate more readily and the water vapour contains more ^{12}C than the residual unevaporated water. The distribution of ^{12}C and ^{13}C is not uniform throughout the world, in the atmosphere or in living organisms with a majority carbon content. Measuring their respective abundance levels makes it possible to shed light on these various processes and understand the carbon cycle. For example, it makes it possible to trace atmospheric CO_2 emissions due to human activity.

Fossil fuels at the dinner table

Since the end of the 19th century, the burning of fossil fuels (oil, coal) has released into the atmosphere light carbon enriched with ^{12}C, (or depleted in ^{13}C): this is what is commonly referred to as the Suess effect (Insert 2B). The heavy isotope content reduction in the atmosphere moves by diffusion into the ocean and then travels up the food web to the tunas (Insert 2D). Measuring relative abundances of carbon isotopes (also referred to as measuring isotopic ratios) in tuna muscle makes it possible to trace the proportion of CO_2 emitted by humans and absorbed by the ocean. The reduction in ^{13}C in tuna muscle is five times higher than that expected if it was solely due to the Suess effect. Increasing use of fossil energies is therefore not sufficient to explain the low ^{13}C value observed in tunas.



INSERT 2 A, B, C, D (from left to right and top to bottom) (Illustrations: Boris Colas, SPC)



INSERT 3 (Illustration: Boris Colas, SPC)

But what causes tuna's isotopic composition to fall?

In our study, we sought to determine what other factors could explain the steep decline in ^{13}C in tuna by examining every stage in carbon conversion through the marine cycle, from water composition to tuna.

The carbon composition of tunas is governed by a number of factors, acting synergistically, i.e. (Insert 3):

- the quantity of CO2 present in the oceans, a majority of which is due to the CO2 emissions associated with human activities;
- the types of phytoplankton present in the oceans and their growth rates; and
- the various trophic relationships at play and culminating at the tuna level.

Atmospheric carbon enters the oceans through diffusion and is absorbed by phytoplankton, which need it in order to develop. The proportion of ^{12}C and ^{13}C absorbed is variable depending on the kind of phytoplankton and their growth rate (Insert 2C). Phytoplankton is the foundation of the food web and is consumed by larger organisms, which themselves are in turn consumed by bigger and bigger organisms up to the top predators like tunas. The proportion of $^{12}C/^{13}C$ in phytoplankton is then propagated throughout all levels of the food web and can be changed at each level depending on the organisms concerned. In this way, the changes in $^{12}C/^{13}C$ proportions in the phytoplankton populations find their way through the food webs to the apex tunas (Insert 2D). Changes in the type of trophic relationship (changes in the type of prey or the number of different steps in the food web) can also influence the proportions of $^{12}C/^{13}C$ observed in tuna muscle.

Tuna as climate change sentinels?

Through a modelling approach taking into consideration all the processes set out above and known to have an influence on isotopic values (summarised in Insert 3), we demonstrate that, while all the factors at work can influence the isotopic composition of tuna muscle, the one with the most impact is linked to the kind of phytoplankton occurring in the oceans. These results suggest that deep changes in the phytoplankton population structures at the foundation of the food webs that culminate in tuna have been taking place for the past 15 years. These data are of inestimable value for the calibration and validation of climate models and for projecting the effects of climate change onto ocean productivity. Few biological datasets are in fact available at such spatial and temporal scales.

We also suggest that the phytoplankton communities are constantly shrinking because the smaller species contain more ^{12}C than the larger species such as the diatoms. These changes in populations are not improbable because, with climate warming, changes are being forecast in the way water masses are structured (ocean stratification, in other words less mixing between surface water and deep water), with a reduction in the quantity of nutrients present in surface waters. Faced with the available nutrient quantities, not all phytoplankton species adapt in the same way and, for example, smaller-sized species show higher suitability when the waters are nutrient-poor, which could explain a change in population structure.

Consequences on energy transfers and health?

A change in the phytoplankton communities could have extensive repercussions on trophic webs, for example by reducing the amount of energy and nutrients available for

fish. Research in fact suggests that the smallest phytoplankton species synthesise less of the omega-3 polyunsaturated fatty acids essential for the growth of many species of fish and beneficial for human health. This opens promising research avenues for further exploration, as tunas are a source of the fatty acids essential for human health.

The importance of long-term biological datasets and international collaboration

This multidisciplinary study involving biologists, biogeochemists and physical oceanographers represents a hitherto unprecedented application of the analysis of stable isotopes in the large marine predators such as tunas in order to identify decadal changes in the ocean carbon cycle.

These measurements do however need to be performed on a long-term basis, i.e. over a 30-year period, to be able to confirm that they are indeed linked to climate change and not natural variability.

Whatever the case, these results demonstrate the relevance of using tuna as environmental change sentinels and militate for the introduction and long-term maintenance of biological tissue banks such as the marine specimen bank at SPC (http://www.spc.int/ofp/PacificSpecimenBank, Smith et al. 2017), which contain a real wealth of information.

In addition to the time dimension over more than 15 years, this study is especially robust because of its spatial amplitude and the number of specimens analysed in the three oceanic basins (Pacific, Atlantic and Indian). This upscaling is the fruit of a very broad network of international cooperation, initiated as part of the CLIOTOP (Climate Impact on Top Predators, http://imber.info/science/regional-programmes/cliotop) task force in 2009, which unites more than 12 institutions from around the world (Pacific Community, French Institute of Research for Development, Commonwealth Scientific and Industrial Research Organisation, Duke University, GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Institut Pierre-Simon Laplace, Inter-American-Tropical-Tuna-Commission, Division of Marine Fisheries New Bedford Office, Australian River Institute, Seychelles Fishing Authority, AZTI Tecnalia, New Zealand National Institute of Water and Atmospheric Research).

References

Lorrain A., Pethybridge H., Cassar N., Receveur A., Allain V., Bodin N., Bopp L. *et al.* 2019. Trends in tuna carbon isotopes suggest global changes in pelagic phytoplankton communities. Global Change Biology, 0. [https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.14858 (Accessed 12 October 2019)].

Smith, N., Donato-Hunt, C., Allain, V., McKechnie, S., Moore, B., and Bertram, I. 2017. Developing a Pacific Community Marine Specimen Bank. SPC Fisheries Newsletter, 152: 43–47. [http://purl.org/spc/digilib/doc/4kxdc (accessed 19 December 2019)]

RTMCF3: Working with people in support of sustainable coastal fisheries and aquaculture

Noro, Solomon Islands (image: Francisco Blaha)

The Third Regional Technical Meeting on Coastal Fisheries (RTMCF3) was held at the Pacific Community (SPC) headquarters in Noumea from 5 to 8 November 2019. Continuing the momentum generated at the first two meetings, RTMCF3 brought together over 60 technical fisheries and aquaculture officers from 20 Pacific Island countries and territories (PICTs) to address some of the main challenges and opportunities relating to coastal fisheries and aquaculture in the Pacific.

RTMCF is a highly valuable opportunity for members to engage in technical discussions and share knowledge and expertise on coastal fisheries issues and success stories. RTMCF3 is the first phase of the new and still evolving governance framework, and participants were asked to identify, discuss and agree on clear priority coastal fisheries and aquaculture technical and scientific issues and opportunities. These outcomes and key decisions will be submitted to the 12th Heads of Fisheries (HoF12) meeting in March 2020 for consideration and action and, where required, forwarded to the Regional Fisheries Ministers' Meeting and if necessary, to Forum Leaders.

The agenda and themes for RTMCF3 were developed in consultation with SPC members and partners, with specific priority topics this year having been selected through an online survey of SPC members:

- Science: new technologies, e-data processes and systems;
- Aquaculture: implementation of the Regional Action Plan on Aquatic Biosecurity; and
- Community-based fisheries: scaling-up community-based fisheries management.

Following up on specific actions and initiatives from previous RTMCF meetings, SPC reported on the progress made on implementing earlier RTMCF Action Plans, focusing on recent advances on coastal fisheries and aquaculture data collection and management, including ongoing initiatives on data storage, data dissemination and sharing, and overall data governance. While efforts are underway to simplify data collection in certain Pacific Island countries and territories (PICTs), there is a strong desire to establish a regional process to develop minimum requirements, standards and protocols for data collection. A new action was formulated for SPC to establish this process and for the Heads of Fisheries to identify the development and implementation of this as a priority for funding.

SPC presented the European Union-funded Regional Project for Sustainable Ecosystem Management (PROTEGE). The project is aimed at strengthening regional cooperation for European Overseas Countries and Territories (OCTs) in four areas: sustainable livestock activities, community-based fisheries management (CBFM), sustainable fishery and aquaculture products, and cooperation platforms. Introducing new actions for this year, participants welcomed the possibility of organising technical exchanges between OCTs and other PICTs under PROTEGE and the Pacific European Union Marine Partnership (PEUMP) project. SPC PROTEGE and SPC's Fisheries Aquaculture and Marine Ecosystems (FAME) Division will examine opportunities to initiate such exchanges.

Coastal fisheries report card and indicators

The Coastal Fisheries Report Card[1] provides annual high-level reporting on the current status of Pacific coastal fisheries in relation to the goals, indicators and strategies adopted in the Regional Roadmap[2]. The Coastal Fisheries

[1] https://fame1.spc.int/en/publications/roadmap-a-report-cards

[2] The Regional Roadmap for Sustainable Fisheries, endorsed in 2015 by the Pacific Islands Forum Leaders, set seven clear goals for oceanic and coastal fisheries for the following ten years, as well as indicators that can be used to measure progress.

Report Card, which was initiated in 2015, provides a snapshot to enable fisheries stakeholders and political leaders to monitor progress on implementing the Roadmap. Key improvements in the preparation of the Coastal Fisheries Report Cards for 2018 and 2019 were highlighted during the meeting while acknowledging the existing gaps that need to be addressed. The RTMCF also agreed to confirm the Coastal Fisheries Report Card focal points to ensure all PICTs are covered.

The meeting agreed on the template approach to progress and support national level Coastal Fisheries Report Cards as a system for measuring progress of coastal fisheries management. A draft national Coastal Fisheries Report Card template will be circulated to members for their feedback via the Coastal Fisheries Report Card focal points and RTMCF3 member representatives. SPC will then present a finalised national Coastal Fisheries Report Card template to HoF12 in March 2020 for their input and endorsement.

Innovative technologies to support management

Sharing successful new initiatives to support the management of coastal fisheries and aquaculture is a key feature of this meeting. Members have the opportunity to present informative, new or innovative technical initiatives and technologies for the benefit of others, and this is clearly appreciated. The presentations are available on the FAME meeting webpage[3] and include:

- the implications of Samoa's new trochus fishery for other PICTs;
- updates on CITES and sea cucumbers;
- Aquanetix, the application of online software for farm data collection in Vanuatu;
- the 4FJ and Set Size campaigns in Fiji;
- the development of animated videos and short training movies for awareness raising; and
- the efforts towards sustainability of the demersal line fishery in Tonga.

REEFLEX

Raising awareness about the various fisheries rules is essential to effective management, and SPC has developed a new legal research tool to assist decision-makers, fisheries managers, specialists and researchers, as well as civil society. The REEFLEX web application (access link on the SPC FAME webpage)[4] comprises three tools that allow the user to access laws and policies, and compare legislation for coastal fisheries and aquaculture in Pacific Island countries and territories (PICTs). This is much more than just a database: it allows the user to compare, analyse and understand coastal fisheries and aquaculture governance frameworks for each PICT. As with all such tools, user feedback and collaboration is necessary to fine-tune it as it evolves. SPC and members agreed to identify effective ways to include additional subnational legislation and management plans in the REEFLEX database, in collaboration with national legal officers.

Focused sessions on priority topics

Gathering regional technical fisheries and aquaculture experts together provides the ideal platform to tackle some of the existing challenges in this arena. During facilitated breakout groups, members collaborated to define next steps and potential solutions to the main issues and questions under the three topics of science, aquaculture and community-based fisheries. The resulting actions they identified are available in the "Outcomes" document, which has been published on FAME's meeting webpage.[2]

Science – New technologies, e-data processes and systems

Coastal fisheries generally does not have the same profile as offshore fisheries among PICTs as a contributor toward national GDP, despite the vital importance of coastal fisheries for community food security across the Pacific. Consequently, coastal fisheries data collection is poorly resourced, and there is less management capacity in coastal fisheries than in the oceanic fisheries sector. Fisheries data are essential to underpin the sustainable management of coastal fisheries and aquaculture, yet the region lacks long-term quality datasets for coastal fisheries. Further simplifying existing processes, as set out in RTMCF1 and RTMCF2, will assist in obtaining improved quality data for stock assessments leading to improved fisheries management. The challenge is to ensure that coastal fisheries data collection is standardised and distilled down to the most user-friendly level, while also maintaining data quality for informed fisheries management.

Presenting an overview of the evolution of fisheries data collection, SPC highlighted the progress made since the previous RTMCF meetings and emphasised the need for user feedback on the practicality of these approaches. SPC will continue working with PICTs to establish e-data collection systems that can accommodate the various fisheries data types and surveys, including the use of e-data systems to improve efficiency and robustness of data collection and dissemination and migrating existing coastal fisheries data into the new e-data systems. Meanwhile, in order for monitoring programmes to

[3] https://fame1.spc.int/en/meetings/248
[4] http://www.spc.int/CoastalFisheries/Legislation/main

be sustainable and comparable, it is important that a regional approach to standardised minimum data requirements (e.g. size, weight and reproductive data) is endorsed by the Heads of Fisheries and designated as a priority.

Ensuring community buy-in is crucial and requires training and awareness-raising activities. To this end, SPC will work with countries to inform local communities of the context and importance for fisheries monitoring tools and to increase community involvement in data collection. Existing e-data apps can be used for community-based reporting alongside the development of associated training for communities to implement community monitoring.

Chronic understaffing was identified as an ongoing challenge, along with the necessity to develop technical capacities of existing staff. The "brain drain" that many PICTs experience, combined with a lack of succession planning, severely affects the continuity of monitoring programmes. Added to this is the pressing need for clear and delineated roles for fisheries staff (e.g. separating compliance from science roles). These issues are related to short-term funding arrangements and it is, therefore, important to consider ways to build longevity in funding programmes, through government and donors, for coastal fisheries science and management. This will be raised at the Heads of Fisheries meeting in 2020.

Aquaculture – Implementation of the regional action plan on aquatic biosecurity

Aquatic biosecurity is the key to improving fish production. It aims at maintaining healthy aquatic organisms, reducing the risks posed by pathogens and invasive species, and meeting food safety standards in seafood products. Attention to aquatic biosecurity improves animal production, safeguards human health, and assists PICTs with meeting their international obligations in terms of trade and access to markets (e.g. New Caledonia is approved for export of uncooked prawns to Australia).

Achieving these goals requires political commitment by governments and administrations to the core values of biosecurity. Several different statutory arrangements are in place among PICTs in terms of the allocation of powers and responsibilities among agencies. Government agencies that work in isolation and do not share information, fragmented legislation, and unclear responsibilities can hinder progress in aquatic biosecurity. Members endorsed the draft Regional Action Plan on Aquatic Biosecurity, which was presented by SPC, and this will be presented to the Heads of Fisheries for their endorsement.

Members requested SPC to provide technical assistance, resources and capacity building in aquatic biosecurity planning, implementation and development of protocols. They also advocated sharing national aquatic biosecurity strategies, legislation, policies and plans between PICT governments and administrations, which would be highly beneficial to capture the benefits of effective biosecurity at the national level. Technical assistance and capacity building in aquatic biosecurity in the region should also include actions in support of improved food safety, such as in ciguatera outbreaks, seafood poisoning, and zoonosis from seafood-borne pathogens.

Community-based fisheries – Scaling-up community-based fisheries management

Community-based fisheries management (CBFM) is being implemented in PICTs in line with the 'New Song for Coastal Fisheries'[5], but faces several barriers to scaling up. Currently, it is estimated that 90% of coastal communities in the Pacific Islands region do not have CBFM regimes, despite many PICT governments and administrations having policies in support of CBFM. CBFM is important for food security and livelihoods, especially in the context of increasing human populations across the Pacific, which are dispersed over fragmented geographies. There are many partner agencies and organisations in the region that support CBFM efforts.

A number of local communities in PICTs have made great strides in establishing CBFM, including the adoption of an ecosystem approach to fisheries management. While these initiatives continue to progress, there is still room for improvement. This session dedicated to CBFM involved sharing experiences, what has and has not worked, success stories and lessons learned, with sustainably implementing and scaling-up of CBFM to ensure a wider impact of the CBFM approaches.

A number of actions were proposed (which are detailed in the Outcomes and Agreed Action Plan document, available on the meeting webpage[2]). Members agreed that there needs to be greater support for CBFM in terms of development,

[5] http://coastfish.spc.int/en/component/content/article/49-other-documents/461-a-new-song-for-coastal-fisheries.html

implementation and resourcing. In particular, there is a call for all members, SPC and partners to prioritise a collaborative, coordinated, gender-sensitive and holistic multi-stakeholder approach to CBFM with clear identification of the roles of those involved. It is also vital to recognise that where management strategies lead to catch restrictions, alternative livelihoods for communities will need to be addressed within the programme. A review of CBFM experiences in the Pacific will be led by SPC, focusing on lessons learned and identifying effective approaches in the region.

Priority, new and emerging coastal fisheries and aquaculture issues and opportunities

A presentation by Southern Cross University canvased a new regional project proposal being developed on 'a new era for sea cucumber fisheries'. In close partnership with SPC and other organisations, the project would comprise a regional symposium to assemble recent lessons learned from sea cucumber fisheries; individual support to PICTs on technical capacity in management, awareness tools and monitoring, control, surveillance and enforcement; and monitoring of fisheries performance and a new and modified management regime. The meeting supported the proposal concept to be developed jointly with selected PICTs and requested SPC to provide an updated report to HoF12 on sea cucumber fisheries management and monitoring.

Following this, participants engaged in small group discussions to identify priority, new and/or emerging issues and opportunities in coastal fisheries and aquaculture in the region that are in addition to the topics covered in RTMCF. Priority issues identified for coastal fisheries included: livelihoods (fish and non-fish based); increasing political will; coastal fisheries legislation and management; and external environmental pressures (climate change, coral bleaching and micro-plastics). Priority issues identified for aquaculture included: exploring new species; post-harvest value adding; feed and technology and equipment development; improving the enabling environment (legislation and capacity); and sea ranching. This information will be used to inform SPC and the next RTMCF agenda.

Workshop on coastal fisheries and aquaculture monitoring, control, surveillance and enforcement

After RTMCF3, a one-day workshop was held on monitoring, control, surveillance and enforcement (MCS&E). Coastal fisheries and aquaculture are vital to the livelihoods of many small Pacific Island countries and territories, as well as providing a major source of animal protein. Offshore fisheries MCS&E is often given higher priority due to the significant financial gains from access fees and fines for infringements and, consequently, benefits from more resources to ensure compliance. By contrast, coastal fisheries provide far more employment than offshore fisheries at a national level, but they need to compete for a limited amount of national resources and often, education, public health and infrastructure take priority. The first challenge faced in the development and implementation of an effective coastal fisheries MCS&E strategy is how to prioritise and raise the profile of these fisheries.

Case studies from New Zealand, Kiribati and other Pacific Islands highlighted the necessity to control illegal activity at the initial stage to prevent it becoming a large-scale problem. Recognising the significance of these crimes also encourages a compliance culture within the community. Some countries

also gave presentations on positive experiences in coastal fisheries and aquaculture surveillance and enforcement.

Evidence gathering and correct documentation are fundamental to any successful law enforcement. It is crucial to get the basic details right before confronting larger-scale infringements. As a way of assisting fisheries officers with doing this, a simplified approach to enforcement for coastal fisheries and aquaculture infringements was proposed for members to discuss. The approach includes a number of actions such as awareness raising and education, ongoing training of authorised officers, adoption of a step-by-step incident interview book for inspections, and the use of administrative penalties, such as warnings or spot fines, as well as a database to record coastal fisheries and aquaculture enforcement data and information that could reveal trends in offences over time. Ultimately, it is vital for fishers and enforcement officers to understand the national coastal fisheries and aquaculture legislation and regulations in order to promote compliance.

Feedback

Delegates were asked to rate aspects of the meeting, including the content, organisation and opportunities for feedback. In brief, the majority of delegates rated the meeting content good or excellent (96%), and highly rated the relevance of the meeting for their work (also 96% good or excellent). Participants appreciated the chance to share experiences with people from other PICTs, with 96% agreeing that members were encouraged to share their experiences, with suggested improvements also calling for more opportunities to share success stories. Participants were positive about group work, with 88% rating this as good or excellent. And although more time was allocated this year to group discussions, some members still felt that this was not sufficient and that future meetings could be more focused on group work. Some members commented on the formality of the meeting and requested that future meetings be more informal. Encouragingly, 92% felt that they had gained new knowledge from the meeting. The detailed feedback report will soon be available on the RTMCF3 meeting page and used to improve the format and content of next year's meeting.

The next RTMCF meeting will be held in late October or early November 2020 in Noumea, New Caledonia.

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Participants of the third SPC Regional Technical Meeting on Coastal Fisheries.

Establishing a national FAD programme

One of the most successful initiatives in the Pacific Islands region, which began in the early 1980s, has been the introduction of fish aggregating devices (FADs) to aid in the development of small-scale tuna fisheries (Gillett et al. 2019). FADs, however, have often been deployed on an* ad hoc *basis, when funding, mostly from foreign aid, has been made available. The long-term success in developing the region's small-scale fisheries depends on strong and sustainable FAD programmes, which are needed in most Pacific Island countries. In this article, we detail the main requirements to establish sustainable national FAD programmes.

Current approach to FAD work in the region

Only a few countries in the region have a national FAD programme. Several countries have partial FAD programmes that meet their requirements while other countries have intermittent and unstructured approaches to dealing with the use of FADs to increase fishers' access to tuna and tuna-like species for food security and livelihoods. The common FAD work undertaken by Pacific Island countries and territories (PICTs) is based on the following scenarios:

- No national FAD programme in place. Deployment of FADs is an irregular activity undertaken by the national fisheries department (when funds are made available) in response to requests from fishing communities for FADs.
- FADs are deployed on an ad hoc basis, depending on requests from communities or according to the national fisheries agency's campaign. Funds for these FAD deployments are diverted from other programmes, or opportunistic expenditures.
- Installation of FADs is included in a country's action plan for the coming year. Orders are placed for FAD materials to address requests when received from communities; and/or FADs are earmarked for communities in advance and FAD materials are ordered specifically for those communities to address their immediate requirements. There are usually no long-term plans to install FADs, or to replace FADs when they are lost.
- The Pacific Community (SPC) or regional non-governmental organisations (NGOs) have funds to assist countries with their FAD work to meet certain objectives such as:
  - A possible solution to divert fishing pressure from coral reefs.
  - An alternative activity to supplement the catches of fishers who are excluded from fishing in marine protected areas.
  - A way to alleviate post-disaster stress by increasing access to tuna and tuna-like species for food security while newly planted crops mature.
- Requests for SPC's assistance with FAD work are generally for the following reasons:
  - Training new staff to construct and deploy FADs.
  - Refresher courses for staff previously trained because staff have lost confidence in rigging and deploying FADs.
  - The private sector (game fishers) requests FAD assistance but the fisheries department does not have the capacity to provide this assistance, or it is not part of their mandate.
  - Installation of FADs as part of collaborative projects between NGOs, PICTs and SPC.
  - Trial of new FAD designs.
- Funding support provided by SPC and NGOs to address requests from PICTs for FADs is mainly to:
  - assist a particular PICT that has a structured project focused on small-scale fishing development;
  - assist PICTs implementing marine protected areas where FADs are installed as an alternative fishing ground;
  - facilitate the alleviation of fishing pressure on reef stocks in overfished areas; and
  - provide post-disaster assistance to help small-scale fishers provide nutritious food for communities during times of food shortages while new crops mature, and so fishers can continue their fishing operations offshore around FADs and away from areas where coral reefs have been badly damaged.

Lessons learned

Although there are insufficient data to corroborate the effectiveness of FADs and their impact on the supply of fish for coastal communities generally, several case studies (e.g. Albert et al. 2014; Albert et al. 2015; Bell et al. 2015a and 2015b; Gillett 2018; Sharp 2011) have revealed that FADs are effective in reducing the cost of fishing operations, result in increased catches, and improve safety by providing a focal point for fishing.

Despite the scarcity of data, fishers region-wide overwhelmingly vouch for FADs as a beneficial tool; national fisheries managers also acknowledge that FADs are important for the development of small-scale fisheries. FADs are also recognised as an important way of diversifying and transferring fishing effort in situations where coastal fish stocks have been overfished and where marine protected areas have been established.

The array of ways in which assistance is provided to PICTs by SPC and NGOs for the installation of FADs is, however, far from ideal. In particular, these approaches do not sustain the use of FADs by small-scale fishers. Development and implementation of country-driven, long-term FAD programmes is the solution.

The way forward

The development of effective national FAD programmes will depend on:

- Establishing a specialised section within the national fisheries agency to design and implement all national FAD work. The section can be a stand-alone unit or part of another section.
- Clear "standing orders" to define the duties and operating procedures for the specialised FAD section.
- Allocating a sufficient budget to encompass the full requirements of the national FAD programme (as listed below).
- Shore-based infrastructure, with sufficient space for rigging FADs both near the central fisheries office and at provincial fisheries offices, dedicated office space and use of planning rooms, and secure storage areas for new FAD materials and for constructed FADs ready to deploy.
- Protocols for the procurement and storage of FAD materials, including auditing procedures that ensure there is always a stock of FAD materials within the country at strategic locations to replace lost FADs.
- A specialised FAD team, capable of providing national coverage for FAD services, with the team comprising a team leader and trained technicians.
- Ongoing established training programmes for fisheries officers and fishers in the deployment of FADs, and in safe and effective FAD-fishing methods.
- Office equipment, rigging and construction tools, high-definition deepwater echo sounder (capable of readings of up to 3000 m depth or more), powered deployment vessel or dumb barge (capable of carrying 3-tonne loads), powered boat for FAD site surveys and for towing barge if the barge option is preferred, crane truck with minimum safe working load of 3 tonnes, forklift, safety clothing and equipment as identified.

Storage space for FAD materials (top), specialised FAD staff (middle), and FAD components assembled and ready to be deployed to quickly replace lost FADs (bottom) are some of the elements needed for an effective national FAD programme. (images: William Sokimi, SPC)

- Data collection that is based on the use of recognised systems to record catch, effort and socioeconomic data to determine the impact of FADs.
- Periodically trialling new FAD systems in order to continually improve the longevity of FADs, reduce costs, mitigate any environmental impacts of FADs, and identify the optimum number of FADs needed to meet national needs.
- Consult with stakeholders to establish an acceptable "code of conduct" for the mutual use of FADs by multiple user groups where needed.

- Implement an ongoing public awareness programme to make the public aware of the benefits of FADs for food security and livelihoods, FAD placements, FAD break-offs, cautions, and the performance of particular FADs during the season.

Sustainable financing

The benefits of FADs as part of the national infrastructure for food security warrants the inclusion of national FAD programmes in recurrent budget expenditures; otherwise *ad hoc*, or stop–start, support for FADs will continue and the nutrition of coastal communities will suffer.

PICTs are strongly encouraged to identify the most practical sources of sustainable financing, which might include the use of fishing licence revenues, depending on the national context.

Assistance to establish and operate a national FAD programme can be requested from development agencies, although PICTs should be ready to make the various essential investments listed above using recurrent budget expenditures if funds from donors are unavailable within a specified time frame.

Key messages

Key messages are summarised in two policy briefs produced by SPC (Pacific Community 2012 and 2017), and include:

- Sustainable FAD programmes should be an essential part of investments in national infrastructure and strategies for the food security of coastal communities.
- Although financial and technical support can be sought from donors and/or regional technical organisations and NGOs, a recurrent source of national funding should be earmarked for sustaining FAD programmes.
- Monitoring catches that are made from around FADs, and their impacts on food security, is required in order to demonstrate their value and convince stakeholders that FADs are a good investment for their respective countries.
- End-user engagement will help to secure the support of communities for national FAD programmes, and the co-management required to make these programmes a success.

References

Albert J.A., Beare D., Schwarz A.M., Albert S., Warren R., Siota J. and Andrew N.L. 2014. The contribution of nearshore fish aggregating devices (FADs) to food security and livelihoods in Solomon Islands. PLoS ONE 9(12): e115386.

Albert J.A., Albert S., Andrew N., Blanc M., Carlos A., Luda L., Tofuakalo F., Masu R., Oengpepa C., Oeta J., Posala R., Schwarz A.M., Sibiti S., Siota F., Sokimi W., Tan S., Tawaki A., Teri J. and Warren R. 2015. Nearshore fish aggregating devices (FADs) for food security in Solomon Islands. CGIAR Research Program on Aquatic Agricultural Systems. Penang, Malaysia. Program Brief: AAS-2015-05.

Bell J.D., Albert J., Andréfouët S., Andrew N.L. Blanc M. et al. 2015a. Optimising the use of nearshore fish aggregating devices for food security in the Pacific Islands. Marine Policy 56:98–105.

Bell J.D., Allain A., Allison E.H., Andréfouët S., Andrew N.L., Batty M.J., Blanc M. et al. 2015b. Diversifying the use of tuna to improve food security and public health in Pacific Island countries and territories. Marine Policy 51:584–591.

Gillett R. 2018. Small-scale tuna fishing at Kadavu Island, Fiji. SPC Fisheries Newsletter 156:38–42.

Gillett R., Blanc M., Cartwright I., Batty M., Savins M., Albert J., Idechong N., Tanetoa M., Emberson T. and Sokimi W. 2019. Forty years of small-scale tuna fishery development in the Pacific Islands: Lessons learned. SPC Fisheries Newsletter 157:60–68.

Pacific Community. 2012. Policy Brief #19. Fish aggregating devices (FADs). Noumea, New Caledonia: Pacific Community. 4 p.

Pacific Community. 2017. Policy Brief #31. Sustainable national artisanal FAD programmes: What to aim for. Noumea, New Caledonia: Pacific Community. 4 p.

Sharp M. 2011. The benefits of fish aggregating devices in the Pacific. SPC Fisheries Newsletter 135:28–36.

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Enhancing fishery officers' communications skills

From left to right: Fisheries officers Joseph Teuea and Taatie Eria, from Kiribati, and Amanda Le'ota and Siosi Matanga from Tonga. (image: Céline Muron, SPC)

In December 2019, the Pacific Community (SPC) organised an attachment training programme aimed at reinforcing the strategic communication and information skills of Pacific Island fisheries officers. Five fisheries officers from Tuvalu, Kiribati and Tonga took part in this two-week workshop, learning about and exchanging ideas on how to build and implement an efficient, culturally adequate communication plan, and how to design information tools that address fisheries management issues.

For the vast majority of Pacific Island communities, the lack of access to information tailored to their needs is a barrier to their engagement and participation in decision-making, including decisions related to their marine resources. To address this challenge, SPC is implementing communication, information and outreach activities that target coastal communities through its Fisheries, Aquaculture and Marine Ecosystems (FAME) Division. These activities are part of the Coastal Fisheries Governance Project [1] and the Pacific-European Union Marine Partnership (PEUMP) Programme[2], and are delivered through national governments and relevant local networks and partners.

Reinforcing local capacity is part of the challenge. For the five Pacific Island fisheries officers – Eria Taatie and Joseph Teuea from Kiribati; Amanda Le'ota and Siosi Matanga from Tonga; and Matelina Stuart from Tuvalu – the opportunity to learn innovative approaches and practices during four participatory sessions was provided by SPC's information and communications officers.

Session 1: Assessing the context and analysing the situation

The objective of this session was to analyse the current strategic communications and approaches used in trainees' respective countries, and discuss their comparative strengths and weaknesses. All trainees considered radio programmes and community visits as successful approaches to trigger changes in community behaviour, even if radio may be expensive in some places. Social media (such as Facebook) were also recognised as strong tools to reach coastal communities, but these are not fully used by fisheries authorities in the region.

Session 2: Building social and behavioural change communication

Toky Rasoloarimanana, FAME Communications Officer, used fisheries issues as a way to explain the theory of social

[1] The Coastal Fisheries Governance Project aims to strengthen governance structures and processes for the effective management of coastal fisheries and aquaculture, at the national and subnational level. It focuses specifically on supporting Pacific Island countries and territories in developing legislation and policies, and improving monitoring, control, surveillance and enforcement. This project is funded by the New Zealand Ministry of Foreign Affairs and Trade.

[2] Funded by the European Union and the Government of Sweden, the EUR 45 million PEUMP programme promotes sustainable management and sound ocean governance for food security and economic growth, while addressing climate change resilience and the conservation of marine biodiversity. It follows a comprehensive approach, by integrating issues related oceanic fisheries, coastal fisheries, community development, marine conservation and capacity building under one single regional action.

and behavioural change communication (SBCC). SBCC is the interactive process of any intervention that involves individuals, groups or community members who are developing communication strategies to promote positive behaviours that are appropriate to their settings.[3] Practical exercises allowed trainees to start working on an SBCC strategy for fisheries management in their country.

Source: Adapted from Ryan Long - https://ryanlonglicsw.com/behavioral-coachingpersonal-training/

Why do we need to think "change"?

Coastal marine resources are declining everywhere, and the main reasons for this decline include overfishing, the use of destructive fishing methods (e.g. dynamite, chemicals and poisons) and environmental disturbances, which are all human caused. Establishing regulations to prevent these destructive practices may not be efficient if resource users do not fully understand the cause and effect of their actions. SBCC can be used to shift current ways of thinking and trigger personal behaviour changes that result in positive effects.

Session 3: Social media and video production training

Evlyn Many, the Information and Communications Officer for SPC's Public Health Division, conducted a session on best practices for social media, including defining content types and strategies, and using infographics, captions, hashtags, stories, and user-generated content. Practical exercises included the production of a short interview video for social media.

Session 4: Recording for radio programmes and videos

In this final session, fisheries officers were trained in voice recording. This session included tips on how to use the tone of the voice while speaking on radio awareness programmes.

Matelina Stuart recording the Tuvaluan version of two animated videos of SPC series "Fisher's Tales". (image: Céline Muron, SPC)

As a practical exercise, the recording of a voice-over in a local language for two animated videos of the series "Fisher's Tales" was conducted in a studio under the supervision of a sound engineer.

The attachment training programme also provided an opportunity to develop information and awareness-raising tools that are in line with the communications strategy drafted during the workshop.

Acknowledgements

The authors would like to thank the five participants for their professionalism and enthusiasm during the training, and their respective fisheries authority for allowing them to be away from their office for more than two weeks.

This attachment-training programme was organised with the support of the Pacific Islands Regional Oceanscape Programme (World Bank), the Tobwan Waara Programme, the Technical Cooperation Programme of the Food and Agriculture Organization of the United Nations, the Coastal Fisheries Governance project, and the PEUMP Programme.

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[3] Adapted from Wikipedia : https://en.wikipedia.org/wiki/Social_and_behavior_change_communication)

Fisheries and aquaculture stakeholders from French Pacific overseas countries and territories work together

About 30 participants, including representatives of institutions in New Caledonia, French Polynesia and Wallis and Futuna; the Pacific Community (SPC) Regional Project for Sustainable Ecosystem Management (PROTEGE) team; and thematic-area specialists gathered in Wallis and Futuna from 18 to 22 November 2019 for the first PROTEGE Regional Coastal Fisheries and Aquaculture Workshop. One of PROTEGE's goals is to manage reef and lagoon resources – both locally and regionally – in a more sustainable and integrated manner suited to both island economies and climate change. PROTEGE is an integrated project aimed at reducing human and natural systems' vulnerability to climate change by building adaptation capacity and resilience. It is funded by the 11th European Development Fund for four overseas countries and territories: French Polynesia, New Caledonia, Wallis and Futuna, and Pitcairn.

A single crew going in the same direction to a common destination...

For participants of this first Coastal Fisheries and Aquaculture Workshop, committing to a regional cooperation approach was like everyone taking the same boat. It also meant focusing on personal exchanges between professionals and with local stakeholders on Wallis and Futuna to better understand the wider context of the situation and better grasp the realities in the field.

A powerful symbol of those aspirations was Uvea's last traditional ocean-going canoe, which took workshop participants to the small offshore island of Nukulaelae.

Participants were able to talk with the village chief and island inhabitants about forming an alliance for jointly managing the environment and resources. Such opportunities allowed a discussion about innovative initiatives to unite communities with regard to management issues, without concealing the difficulties of the task, and presenting other possible solutions.

A socially and environmentally responsible workshop

PROTEGE is particularly careful to ensure that project activities are committed to social and environmental responsibility. Organisers and participants took care to respect the islanders' customs and habits. The lavelua, or king, of Uvea and traditional leaders welcomed the delegation on their arrival with a kava ceremony. During the ceremony, traditional leaders learned about the workshop's objectives and shared islanders' needs and questions about climate change, and the status of their marine resources. Customary authorities, the French administration, elected officials, fishers and environmental associations also took active part in several work sessions.

All lunches were prepared by local women's groups from Uvea's various districts. These meals were prepared solely with local products and served on natural or renewable materials such as leaves or gourdes. On site, participants limited the number of printed copies and cut down on travel time through ride-sharing.

Spotlight on workshop objectives and outcomes

Initial efforts between the OCTs helped identify four expected outcomes for the project's Coastal Fisheries and Aquaculture theme:

- Aquaculture techniques that are sustainably integrated into natural settings and suited to island economies are trialled and implemented at pilot scales and then transferred to the rest of the Pacific.
- Participatory management and integrated planning of exploited fisheries resources are continued and strengthened.
- Fisheries and aquaculture products are developed as part of a sustainable development approach.
- Cooperation among OCTs, OCTs and ACP countries is strengthened and made sustainable through operational, coordination and support mechanisms.

A regional launch and strengthening workshop was planned so that the operational implementation of activities was carried out to accomplish these four outcomes starting in late 2019.

Boat trip for workshop participants on the last traditional oceangoing canoe in Uvea. A powerful symbol of cooperation, sharing and tradition. (image: Matthieu Juncker, SPC)

The workshop's goal was to meet three objectives:

- sharing information and obtaining feedback on previous, current and planned activities in each territory;
- strengthening regional cooperation with, as a prerequisite, the territories' being familiar with each other's activities and specific issues; and
- making tangible progress in implementing the regional components of PROTEGE's activities.

All topics from the Coastal Fisheries and Aquaculture theme were addressed, and the crucial role played by climate change in coastal fisheries and aquaculture in the medium term were highlighted. Other topics that were raised included joint management of marine resources, which was discussed with government representatives, along with information about the status of exploited fisheries stocks, setting up coastal fisheries observatories, low-tech aquaculture techniques, and mitigating the impacts of aquaculture and seafood processing.

Even though OCTs had their own separate issues and problems, they consistently highlighted the advantage of having a regional approach to coastal fisheries and aquaculture, something that was still largely lacking in the region. PROTEGE offers an opportunity for OCTs to form partnerships with each other, other Pacific Island countries, and existing programmes and organisations such as the Pacific-European Union Marine Partnership, and the Locally Managed Marine Areas network.

Although the workshop's objectives were met, this event merely marks the beginning of a collaborative effort spanning several geographical levels and including grassroots organisations through to regional government administrations. This work will be implemented in 2020.

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Seaweed farmers in Solomon Islands trained in basic financial literacy

The farming of the seaweed Kappaphycus alvarezii ***is a steadily growing aquaculture production sector, particular in rural coastal communities in Solomon Islands. Although production has varied, Solomon Islands is the largest seaweed producer in the South Pacific, with around 480 tonnes produced in 2017[1]. A major problem identified by the Solomon Islands Ministry of Fisheries and Marine Resources (MFMR) that plagues seaweed farmers is their lack of financial management skills to manage and advance seaweed and other subsistence businesses. In order to boost the financial skills of seaweed farmers on Manaoba Island and those of national fisheries staff, MFMR and the Pacific Community (SPC) – through the Sustainable Pacific Aquaculture Development project (PacAqua) in partnership with the Lotas Development Engineering and Electrics – conducted a basic financial literacy training on Manaoba.***

Interest in the training was so strong that following the initial workshop involving 25 invited farmers, 45 farmers attended and participated in the five-day training that ran between 9 and 13 December 2019. Of these participants, 26 were women who were keen to learn more about financial management concepts. Four MFMR staff were also trained to allow them to share the information during interactions with other farmer groups in the future. The training aimed to build business literacy skills of seaweed farmers so that they could better operate their small businesses. All participating farmers are members of the Manaoba/Hatodea Seaweed Farmers Association.

Manaoba was producing around 100 tonnes of dry seaweed in 2013–2014. Farmers earned around SBD 3000 (~ AUD 530) from the sale of ten 40-kg bags of dry seaweed. During the same period, the number of seaweed farmers grew from 50 to around 90. This has since, however, decreased back to less than 50, as many farmers have stopped producing because of marketing-related constraints. The primary issue is that they no longer have a locally based buying agent on the island. Remaining farmers are struggling and have to take their seaweed directly to Honiara incurring high freight cost. MFMR is currently negotiating with buyers and looking to establish local buying agents to overcome this issue.

A better understanding of how to operate and manage their businesses will greatly contribute to their growth. Prior to the training, many farmers stated that they were unaware of

Mr Silverio Alofi, retired teacher and seaweed farmer, leads discussions during group activities. (image: Avinash Singh, SPC)

[1] Anon. 2018. Solomon Islands Ministry of Fisheries and Marine Resources, Aquaculture Division Annual Report 2107. Solomon Islands Ministry of Fisheries and Marine Resources. 15 p.

financial management practices, budgeting, saving opportunities, and bookkeeping principles. Assessing production costs, managing money and reinvesting in their business were concepts that were foreign to them and, as a result, they did not fully understand how to manage their business operations and could not maximise their profits.

Reeves Tagini, a seaweed farmer from Manaoba, stated that through the training, he developed a better understanding of bookkeeping and record keeping, and said that prior to the training he was unaware as to how much he earned a year. Now he notes his income and expenditures and keep records to formally know his earnings and plan expenditures throughout the year. Mr Tagini also stated that there were no banks on Manaoba, with the closest Bank South Pacific branch located in Auki, around 112 km away. Rural banking was trialled but for reasons unknown to him were not continued. No agents for mobile banking exist in this area. Mr Tagini intends to find out more about how to operate a savings club to help his community as many people found it difficult to save money at home. Because commercial banks are far away, setting their own savings club would allow them to save money, individually and collectively, and if necessary borrow against it in the future.

Another farmer, Magreth Ratu said that many people did not know how to obtain financial skills. The training increased awareness on specific opportunities to improve skills, and how to access funding for development.

Farmers also highlighted that cultural practices such as buying on credit (*kaioni*) or the *wantok* system, prevents them from establishing sustainable businesses. Mere Eke tried to run a second-hand clothes business from income generated from her seaweed farm, but soon found that all of her investments were lost to such traditional obligations. She found it hard to say no to family and friends, and quickly found out the hard way about business failure. She added that after the training, she will be stricter with any credit to family, and will focus on seaweed farming activities.

A lead farmer, David Molia, who has been farming seaweed since 2004, said that if he knew about the financial concepts he learned during the training in his early years of farming, his capacity to manage his business would have been better and he would be in a much better business position now.

Clement Aitorea, lead trainer of the financial literacy training, highlighted that the knowledge gained by farmers here could be applied to their farming business, investments and their daily livelihoods. The training was delivered in the local language and resulted in high participation during lectures and group exercises.

Sylvester Diake Jr, Chief Fisheries Officer of MFMR, said the training "was an eye opener for Manaoba farmers to learn about the business side of farming and we are looking forward to changes in terms of maximising their economic benefits".

A similar training is planned for seaweed farmers on Wagina Island in January 2020. Wagina is the largest seaweed producing area in Solomon Islands.

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

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Participants of the December 2019 financial literacy training on Manaoba Islands, Solomon Islands. (image: SPC)

Tongan *mabe* pearl farmers trained in basic financial literacy

Tonga's* mabe *pearl industry is steadily growing, with around 22 small aquaculture farms operating throughout the country, and the majority of the farms located around Vava'u Island and the remaining in the Ha'apai and Tongatapu islands. In order to boost the financial skills of pearl farmers and national fisheries staff, the Tongan Ministry of Fisheries (MoF) and the Pacific Community (SPC) – through the Sustainable Pacific Aquaculture Development project (PacAqua), in partnership with the Tongan Business Enterprise Centre (TBEC), the training arm of the Tongan Chamber of Commerce – conducted a basic financial literacy training in Vava'u from 25 to 26 September 2019.

In total, 21 participants were trained, including 15 *mabe* pearl farmers from Ha'apai, Nuku'alofa and Vava'u, and 6 national fisheries staff. The training aimed at building the business literacy skills of pearl farmers. With the exception of one farmer who run other tourism-based businesses, all other farmers operate in an informal subsistence manner, without a business license. Most, however, are members of the Tongan National Pearl Farmers Association (TNPFA).

As stated by Mr Sailosi Hemaloto, a pearl farmer from Vava'u, having a better understanding on how to operate and manage a small business will greatly assist pearl farmers in growing their own businesses. Prior to training, many farmers admitted that they did not know how to assess the real costs associated with running their business and, therefore, could not maximize their profits.

Learning to work with a cash book to monitor their cash flow was useful, and understanding how to estimate the cost of time required for the business as part of their investment, helped determine the real operating and production costs.

An additional benefit of bringing farmers from outside Vava'u to the training was that it assisted in developing networks among the farmers and the Pearl Information Centre and Workshop (PICW), with two farmers now given consent by TNPFA to send their raw pearl oysters shells to PICW to process and retail as jewellery. This allows pearl farmers from Nuku'alofa and Ha'apai to link into the strong tourism market during the whale-watching season in Vava'u. It will also benefit new shell crafters who may not have their own farms to access mature shells to develop new jewellery and generate income.

Most *mabe* pearl products are retailed through the PICW building, which is made available by the Tongan government. TNPFA and PICW also benefit from the technical support provided through Australia's University of the Sunshine Coast, with funding support from the Australian Centre for International Agricultural Research. Currently, several volunteers through the Australian Volunteers International programme are helping to improve PICW operations. These volunteers have made an amazing impact through improved designing of *mabe* jewellery, capacity building for local crafters, and marketing pearl products for the tourism market.

Mr Afei demonstrates carving of elegant *mabe* pearl jewellery to participants. (image: Avinsah Singh, SPC)

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

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Are you ready to make a difference in the Pacific aquaculture sector?

Aquaculture is a sector where low supply and strong demand provide an opportunity for farmers, growers, processors, exporters and small businesses in the Pacific Islands region to create new customers and expand current operations.

The Pacific Community (SPC) is now inviting those with an interest in exploring their field to submit proposals for the Sustainable Pacific Aquaculture Development project. Through this project, SPC will provide business mentoring and training, capacity development, and technology transfer in feed, seed and broodstock management to selected enterprises and partners and individuals.

Success stories

Previous recipients of project support are already enjoying success in aquaculture. Ms Katarina Baleisuva, a tilapia businesswoman from Fiji, now operates a successful tilapia hatchery producing all male fingerlings. She identified this area as a constraint for growth of the sector and a business opportunity. The project has enabled her to learn new skills and grow in confidence as a lead farmer. She has recently been voted as president of the newly formed "Tilapia Fiji" association. Ms Baleisuva hopes to inspire more women to engage in aquaculture businesses in our region.

Katarina Baleisuva in her tilapia hatchery. (image: Avinash Singh, SPC)

Another successful recipient, is a Yonki-based (Papua New Guinea) tilapia hatchery and farm business. The family-owned business run by Mr Guna and Ms Lencie Yogomul, received technical capacity building to develop their hatchery and improve farming practices. In addition, both were trained in utilising software from the company MYOB to better manage their business.

Interested in finding out more?

Individuals and enterprises from the following countries are eligible to receive support from the project: American Samoa, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Wallis and Futuna.

If you are a resident of one of these countries, and interested in learning more about how SPC and the Sustainable Pacific Aquaculture Development project can work with you, simply complete a "request for proposal" (RFP) with details about your project.

Copies of RFPs and forms can be downloaded from SPC's website: http://www.spc.int/procurement. For any additional information or clarification on RFPs, send an email request to procurement@spc.int, quoting RFP in the subject line.

Completed proposals should be emailed to p rocurement@spc.int with the heading "RFP 19/105 – Sustainable Pacific Aquaculture Development Project" or by courier to:

Pacific Community (SPC) Procurement Unit –
RFP 19/105 Private Mail Bag, Suva, Fiji

All proposals should reach SPC before 14 February 2020, at 4 pm Fiji time.

No submission shall be made or communication undertaken directly with SPC staff on this procurement.

Note: The Fisheries, Aquaculture and Marine Ecosystems Division (FAME) of the Pacific Community (SPC) has launched the New Zealand Ministry of Foreign Affairs and Trade (NZMFAT) funded Sustainable Pacific Aquaculture Development project (PacAqua). In order to increase and improve economic and nutritional gain from aquaculture in the Pacific, aquaculture will be developed on a business-like footing, be it private sector or community led.

New tilapia hatchery to boost fish production in Papua New Guinea

A shortage of fingerlings has been one of the major constraints limiting the growth of fish farming at Yonki in Papua New Guinea's Eastern Highlands. As a result, many farmers resort to the collection of wild fingerlings for stocking their farms. Unfortunately, these wild fish may have poor genetic quality and many farmers highlight that fish growth is slow. The Papua New Guinea National Fisheries Authority (NFA) and the Pacific Community (SPC), through the Sustainable Pacific Aquaculture Development project (PacAqua), have assisted ASK Sanctuary, an aquaculture enterprise at Yonki Dam, to develop a tilapia incubator hatchery.

Due to the high demand of fingerlings from cage and pond farmers, ASK Sanctuary has taken the initiative to meet these supply shortfalls. It is estimated that over 300,000 fingerlings are required to stock existing and new farms in the area. Mr Guna Yogomul, ASK Sanctuary General Manager, states that "In order to produce more fish, stock our own farm, and consistently supply fish to the market, ASK Sanctuary decided to invest in the incubator hatchery. We realised that in order for fish farming to grow in Yonki Dam, our hatchery will play a critical development role." The hatchery has a current capacity to produce around 240,000 fingerlings a year. Mr Yogomul intends to build more broodstock ponds to increase his fish egg production capacity. He also plans to start producing male-only fish as these fish grow faster and more uniformly. After testing the new system, a successful trial batch of 27,000 fry was produced and stocked into nursery *hapa* in September, followed by around 80,000 fry in early October 2019. Larger batches can now be produced with increased egg collection and handling of fry.

Some challenges faced by the enterprise include theft of brooder fish, limited on-site electricity production capacity of current solar system and batteries, and access to more broodstock to increase production and cash-flow limitations. In addition, breeding and growing tilapia outside the fish's optimum temperature also poses additional technical challenges. Optimal water temperature to grow tilapia ranges from 29°C to 31°C. The water temperature at the hatchery usually varies between 19°C and 23°C, thus slowing down egg development. A basic solar heat loop and additional insulation have been installed into the hatchery water system to raise the average temperature and improve its stability.

NFA and SPC have also assisted with the development of a tilapia farmer cluster at Yonki Dam. Farmers are able to purchase feed and cages from NFA, and NFA and SPC collaborate on identification and means to overcome other common constraints faced by the farmers. Under the PacAqua project, farmers registered under the Yonki cluster will also have access to nursery *hapa*s so that they can acquire fingerlings and rear them in the dam to a larger size suitable to stocking their cages. This will allow experienced farmers to have better control of their stocking and production cycles. It is envisioned that some farmers may also specialise in nursery rearing of fingerlings to supply cage farmers in future.

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

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Guna Yogomul (right) and Johua Noiney, of NFA, observe fish eggs held in the incubator hatchery. (image: Avinash Singh, SPC)

Ecological and socioeconomic impacts of trochus introductions to Samoa – *A project of the Australian Centre for International Agricultural Research*

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Trochus were introduced to Samoa from 2003 to 2006 with the goal of creating a new fishery that would diversify seafood supply for local communities. It took at least 10–15 years for trochus populations to become established on Samoa's reefs. Underwater visual censuses in 2018 showed that populations are now established around both main islands, Upolu and Savai'i, although they are spatially variable. The project estimated that over 1000 fishers now harvest trochus in Samoa, and 300 of them sell the flesh in villages, roadside stalls and markets. Informal networks are used to sell and distribute the seafood in villages. Analyses found the benefits to be inclusive and gender equitable. For a majority of fishers surveyed, trochus is now one of the most harvested reef resources by volume. The project found significant positive impacts to income, local diets and satisfaction of fishers. Further income from trochus could be made through handicrafts from the shells or shell exports. Permitting exports would need to be accompanied by the implementation of a fishery management plan and a robust system of monitoring, control and surveillance. The fishery is a welcomed success story in an era when seafood supply in the Pacific is under threat.

Background

Trochus, which now goes by the scientific name *Rochia nilotica* (Linnaeus, 1767) (World Register of Marine Species), is an herbivorous marine snail that is commercially important in the Pacific Islands region. A century ago, the distribution of trochus was restricted to the western Pacific and Southeast Asia. Starting in the 1920s, trochus broodstock were translocated to reefs of central Pacific Island countries (Gillett 1993). Sometimes, populations failed to colonise naturally, while in other cases, the translocated broodstock bred successfully and created populations on reefs that later yielded lucrative fisheries for Pacific Islanders (Bell et al. 2005). Until recently, trochus did not naturally occur in Samoa (Fig. 1).

Introductions of species from one country to another come with a risk to native populations of fauna and flora and reef systems. This is especially serious when foreign stock from one country is introduced to "enhance" or "restock" populations already native in another country, as the foreign stock can alter the genetic diversity of native stocks in detrimental ways. Alternatively, foreign stock might be introduced to a country where the species does not occur or has never existed. In such cases involving introductions to new localities beyond geographic ranges ("assisted migration"), the risks to other native species and ecosystems need to be weighed against potential benefits to livelihoods. These considerations are especially pertinent today given that Pacific Island countries have been urged to diversify the supply of seafood in the future (Bell et al. 2009).

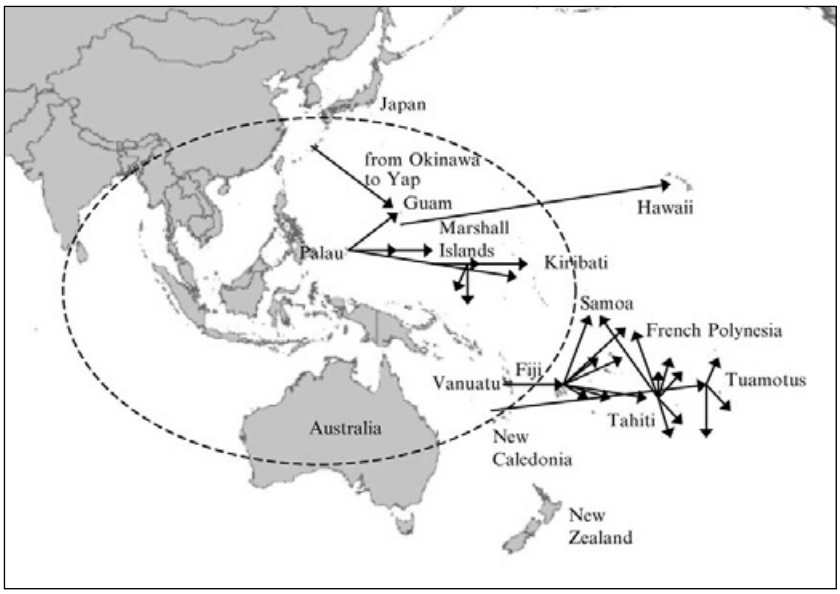

Figure 1. Translocations of trochus among Pacific Island countries. Source: Bell et al. 2005

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An introduction of trochus to Samoa in 1990 was unsuccessful. From 2003 to 2006, a project by Samoa's Ministry of Agriculture and Fisheries (MAF), with expertise and funding from the Australian Centre for International Agricultural Research (ACIAR), introduced trochus from Fiji and Vanuatu to several sites in Samoa. The aim was for the animals to breed naturally to colonise neighbouring reefs and diversify the marine resources available to coastal villages. That project was unable to show that any new populations had been created, although the timeframe was too short to prove ecological success.

The broodstock eventually bred successfully on Samoa's reefs, as evidenced by fishers collecting animals and selling the flesh some years later (Tiitii and Aiafi 2016). Monitoring of local trade by MAF shows a rapid increase in the sales of trochus flesh over the following years (Fig. 2), and underwater surveys at some sites on Upolu Island showed that new populations were establishing one decade after the introductions (Tiitii and Aiafi 2016).

The extent to which wild populations have become established, and the socioeconomic impacts resulting from this, were still uncertain. In addition, fishers are currently benefiting almost solely from the sale of the flesh and are not profiting much from value-adding that could be done to the shells. MAF has not yet allowed exports of trochus, in part because information about the fishery was incomplete; therefore, the full economic value of the animal in Samoa has been largely underutilised.

Figure 2. Fisher with bottles of trochus flesh near Fusi, Savai'i. (image: S.W. Purcell)

Project objectives

Encouraged by the reported success of trochus introductions to Samoa, ACIAR funded a project (2018–2019) coordinated by Southern Cross University (SCU) and MAF. Its four objectives were to: 1) build capacity in value-adding of trochus shells in Samoa; 2) assess the extent of colonisation on Samoan reefs; 3) determine the socioeconomic impacts of the trochus fishery in Samoa; and 4) appraise the potential for exporting trochus sustainably.

Activities

Underwater visual censuses were undertaken at 14 sites around Upolu and 14 sites around Savai'i (Fig. 3). The team counted and measured trochus and other reef gastropods (snails) on belt transects on the reef-front habitat at each site (Fig. 4). An SCU graduate student also studied the association of trochus with habitat features to aid future site selection.

Two capacity-building workshops were held on Upolu and two on Savai'i to train people from neighbouring villages in how to polish trochus shells and make trochus shell jewellery. Equipment from Australia was set up and left in Samoa for further workshops and use by artisans.

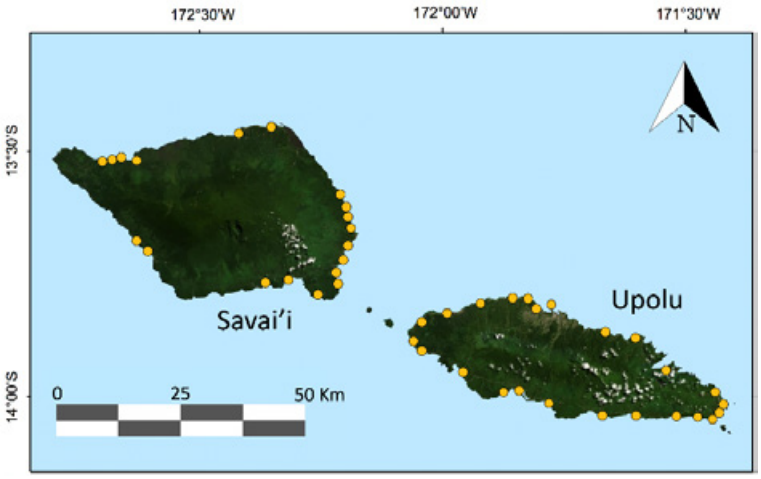

Figure 3. Study sites (yellow dots) in Samoa showing where the underwater survey and socioeconomic surveys occurred.

Socioeconomic surveys of 303 fishers using questionnaire interviews were conducted in 34 villages (Fig. 6). The surveys collected data on the fishing, consumption, sale and trade of trochus in Samoa. Modelling analyses of the data tested gender disparities in these variables and other factors potentially influencing socioeconomic impacts. Lastly, project data were used to assess the

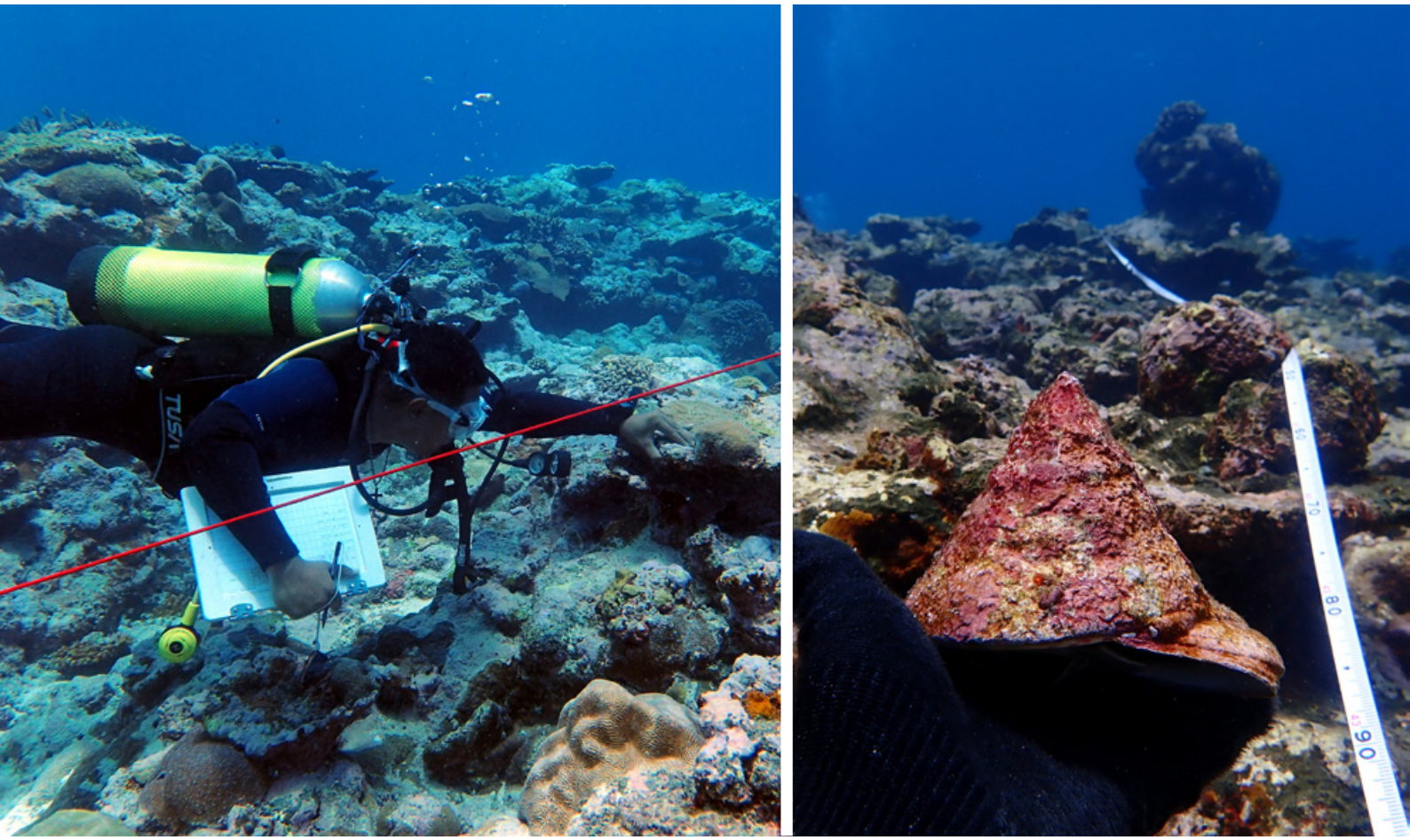

Figure 4. Underwater visual census surveys of trochus in Samoa. (images: S.W. Purcell)

potential volume and value of trochus shell that could be sustainably exported from Samoa, and the management plan for the fishery was reviewed.

Outcomes

Underwater surveys showed that trochus had colonised beyond the initial translocation sites. Two of the three initial translocation sites were not ideal for these populations to thrive. Future translocation and restocking programmes need a better understanding of the habitat requirements of species to be translocated or restocked. The graduate student project determined the specific habitat preferences of trochus, and that it is a generalist species. Reefs in Samoa have been heavily impacted by coral bleaching in the past decade (Fig. 6). Densities of trochus were very high (>500 ind ha^{-1}) at a few sites, and all of the populations contained some large individuals that could be used for jewellery making or shell exports. Large variations in colonisation among sites imply that we should anticipate that the benefits of such translocations will not be even across villages.

Figure 5. Catherine Esau interviewing a young trochus fisher for the socioeconomic survey. (image: S.W. Purcell)

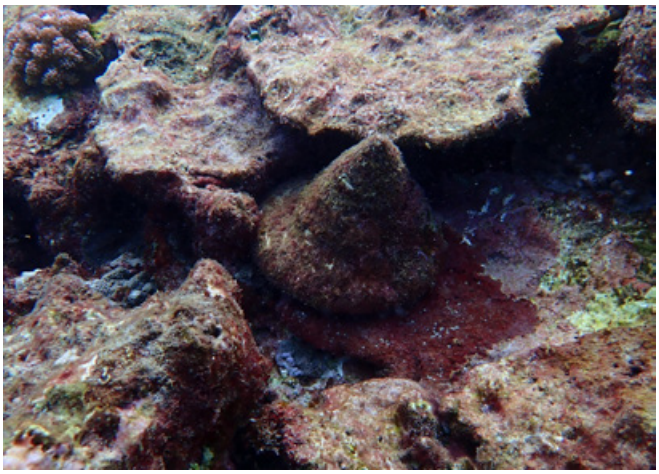

Figure 6. An adult trochus in Samoa next to dead plate corals that have been covered by algae. (images: S.W. Purcell)

Figure 7. A young Samoan fisher with trochus he caught for household consumption. (image: S.W. Purcell)

Our study shows that abundant, exploitable stocks can develop within 15 years, although trochus populations at some sites seem to still be developing. Our analyses did not indicate any negative impacts on native marine snails in Samoa. Trochus are food for a variety of fish and invertebrate species (e.g. wrasses, rays, crabs, octopus, triton and bailer shells), some of which are important for fisheries (Nash 1993). Trochus are grazers, keeping the growth of macroalgae (seaweeds) down to a short turf, and creating space for corals to settle and grow. These translocations of trochus could, therefore, support food webs and the resilience of reefs impacted by coral bleaching.

The fishery is now contributing to livelihood diversification and food security. Young and older fishers and both men and women collect trochus in Samoa, and most of the fishers retained or gave away a majority of their catch for consumption within their villages (Fig. 7). One-third of fishers (both men and women) sold part of their catch using informal markets (mostly roadside stalls). The extra cash resulting from the fishery was spent mainly on other food, school fees and church tithing.

The majority of fishers were satisfied with the income they earned from the new fishery. Most fishers believe that the trochus population is still increasing on the reefs. More than two-thirds of fishers ranked trochus as their top three (out of 15) harvested resources. Fishing was done mainly from paddle canoes or swimming and wading from shore. Our calculations of annual fuel consumption by fishers using motor boats to collect trochus reveal a small carbon footprint for the fishery.

In many respects, the fishery was gender equitable because women and men had similar catch rates, income, satisfaction and perceptions about the fishery. Most fishers agreed with a minimum legal size limit being imposed on the fishery, but some were against the idea of seasonal closures. Finally, we observed an underutilisation of the trochus shells, showing that fishers could significantly increase the income they make from harvesting trochus if opportunities arise for selling the large shells either for handicrafts or for export. Project data showed that around 7 million trochus were harvested across Samoan villages in 2018, including approximately 260 tonnes of trochus legal-sized shell, which could serve in exports to increase the value of the fishery.

Shell jewellery and handicrafts are already popular in Samoa, and products from trochus shells offer a promising new niche. The four one-week-long workshops trained participants from numerous villages on Upolu and Savai'i. Participants learned how to safely use the machines and to grind off the outer layers of the trochus shells to expose and polish the inner pearly nacre (Fig. 8). They made necklaces, earrings and key chains from pieces of trochus. Many of them later sold the jewellery and shells, and were keen to continue making these handicrafts as an alternative livelihood activity. MAF has set up one station at the village of Asau (Savai'i) and is preparing to set up machines at two other stations so that artisans can use them for making handicrafts.

Future activities

The Samoan trochus fishery management plan was reviewed, under the activities of the project, and is set to be implemented soon. Regulations include a "slot" size limit of 90–120 mm shell diameter[4], daytime collection only, the option of a harvest season, and export licences (if exports are allowed).

[4] The shell diameter of trochus is measured across the base of the shell, taking the distance from the outermost tip of the whorl to the farthest edge on the opposite side of the shell. The measurement is also known as the maximum basal shell width.

Figure 8. Participants polishing trochus shells and making jewellery on Savai'i. (image: S.W. Purcell)

MAF has planned to coordinate further training workshops for value-adding of trochus shells. The stations being set up for shell polishing equipment will be managed by MAF, and artisans will pay a small fee that will contribute to maintenance costs and materials.

The success of trochus introductions in Samoa provide yet another example of fishery development of this species. Trochus could offer an important food and income source for other islands yet to have the species, such as the Gilbert Islands in Kiribati. This project gives clearer guidelines for habitat features needed at translocation sites. Further research should use controlled experiments to examine potential ecological effects of trochus, as the introduction of foreign animals to ecosystems is usually scorned by the scientific community.

Even for species with relatively strong potential for local colonisation, such as trochus (Bell et al. 2005), the Samoan case shows that fishable stocks might take at least 15 years to populate. Even longer timeframes could be expected for species with lower rates of productivity (e.g. giant clams and sea cucumbers). Careful judgement and a review of available data should precede any introductions. From a pragmatic viewpoint, resource managers must weigh the potential ecological risks with the potential benefits to livelihoods. The data, thus far, from Samoa suggest that livelihood benefits have been significant, with minimal negative ecological impacts.

Acknowledgements

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References

Bell J.D., Rothlisberg P.C., Munro J.L., Loneragan N.R., Nash W.J., Ward R.D. and Andrew N.L. 2005. Restocking and stock enhancement of marine invertebrate fisheries. Advances in Marine Biology 49:1–370.

Bell J.D., Kronen M., Vunisea A., Nash W.J., Keeble G., Demmke A. and Andréfouët S. 2009. Planning the use of fish for food security in the Pacific. Marine Policy 33:64–76.

Gillett R. 1993. Pacific Islands trochus introductions. SPC Trochus Information Bulletin 2:13–16.

Nash W.J. 1993. Trochus. P. 451–495. In: Wright A. and Hill L. (eds). Nearshore marine resources of the South Pacific. Honiara, Solomon Islands: Forum Fisheries Agency and Institute of Pacific Studies. 707 p.

Tiitii U. and Aiafi J. 2016. Assessment of Samoa's trochus (*Tectus niloticus*) fishery: History, status and recommendations for management. Samoa: the Pacific Community (SPC) and the Samoa Ministry of Agriculture and Fisheries of Samoa. 25 p.

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Progress towards conserving Tonga's coral reefs

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The Kingdom of Tonga's fifth national report to the Convention on Biological Diversity (Anon. 2014) and the report on the status of coral reefs of the Pacific for 2011 (Chin et al. 2011) both list Tonga's coral reef and reef fish fisheries as data deficient, unknown or not considered. While the area of coral reef in Tonga is extensive and many people are reliant on its reef fish fishery, "there has been little scientific monitoring and assessment of most reef areas and many have not been mapped or surveyed" (Chin et al. 2011:197).

In 2002, amid growing concerns over the security of Tonga's marine resources, the Tongan government implemented two-part, community-based marine management under the Special Management Area (SMA) programme. First, through legislative action, each SMA community is granted exclusive access to fishing grounds adjacent to their village. Second, in exchange for this access, a subset of the area must be designated as a permanent no-take zone, termed a fish habitat reserve (FHR). The incentive of exclusive access to fishing grounds in exchange for creating no-take areas has made the SMA programme extremely popular with Tongan coastal communities and, as a result, it has expanded rapidly in recent years. As of December 2019 approximately 50 SMAs have been implemented, 42 of which only since 2014.

While the expansion of the SMA programme has clearly been successful, the paucity of data on Tonga's marine environment made it difficult to determine whether its objectives were being achieved. Ultimately, the success of the SMA programme relies on improving coastal fisheries resources and conservation outcomes, not on creating more SMAs. Determining whether the SMA programme is achieving its aims relies first on having a clear understanding of the state of coastal fisheries resources, and second on being able to attribute changes in these resources to management and not other confounding factors.

Impact is defined as the intended or unintended consequences that are directly or indirectly caused by an intervention (Pressey et al. 2015). Determining impact, however, can be challenging as it involves estimating the counterfactual condition of no action or a different action. Accurately determining impact consists of identifying to what extent observed conditions are the results of the intervention (e.g. SMAs and FHRs), and to what extent environmental or social contextual factors are masking intervention failure or exaggerating successes. Conservation policies and actions, however, are rarely evaluated for their impact (Pressey et al. 2015); few management areas have been evaluated for their past impact and even fewer proposed management areas for their potential future impacts. This trend is equally clear in fisheries management and protected area research in the South Pacific.

From 2016 to 2019 the first stage of a national monitoring programme of Tonga's coral reefs and reef fish fishery was implemented. This project aimed to provide Tonga with crucial information in order to improve the management of its coastal fisheries resources and overall health of its coral reef ecosystem. Ecological surveys of reef fish and benthic community composition were conducted at 270 sites across Tongatapu, Ha'apai and Vava'u, both inside and outside of existing or proposed management areas (Fig. 1).

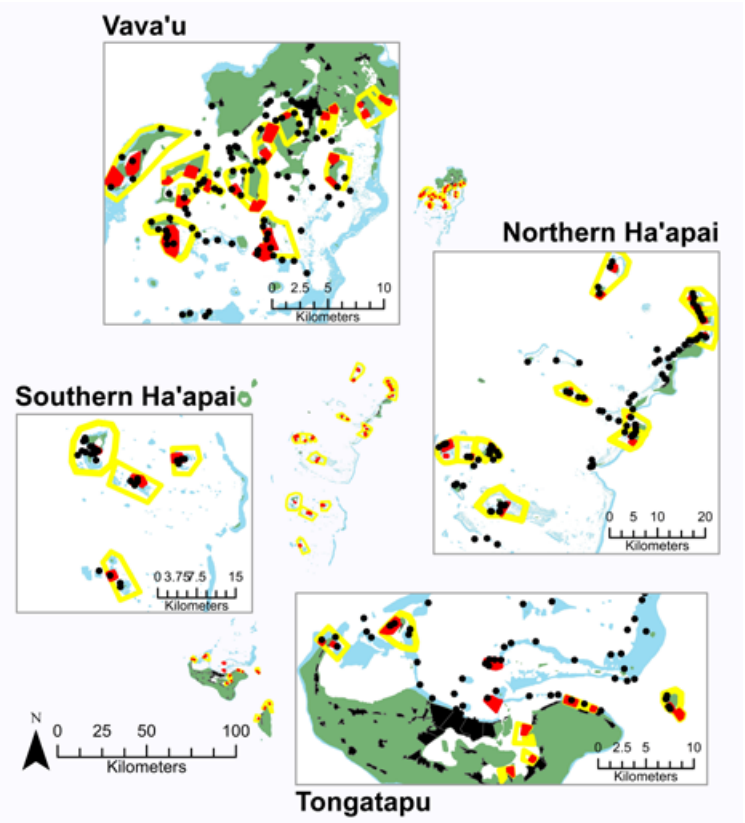

Figure 1. Maps of Tonga's main island groups outlining the current extent of both the Special Management Area programme and the ecological surveys used for this study. Yellow outlines are the Special Management Areas, where only registered members of the community can fish. Red outlines are Fish Habitat Reserves, which are permanent no-fishing zones. Black circles are survey sites and each black outline on land is a village.

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These surveys enabled the production of maps of target species density (Fig. 2) and biomass, reef fish species richness, and coral cover.

In addition, 17 socioenvironmental data layers were built or compiled covering the entirety of Tonga's coral reef ecosystem. These data were not only useful for determining the overall status of Tonga's coral reefs and reef fish fishery, but has also enabled a comprehensive impact evaluation of the SMA programme to be completed. An explicit aim of this project has, therefore, been to use the Tongan SMA programme as a case study for advancing the field of impact evaluation in the community context as well as in the South Pacific. Specifically we: 1) looked back to assess the impact of the oldest established management areas in the country, and 2) used predictive techniques to look forwards at the potential long-term impacts of new or proposed management areas. While some of this work is still unpublished, it is anticipated that it will all be available by mid-2020 (Table 1). A national report is also in preparation, which will provide an overview of the findings written for the general public as well as detailed information on the ecological status of 49 individual SMA communities (Table 1).

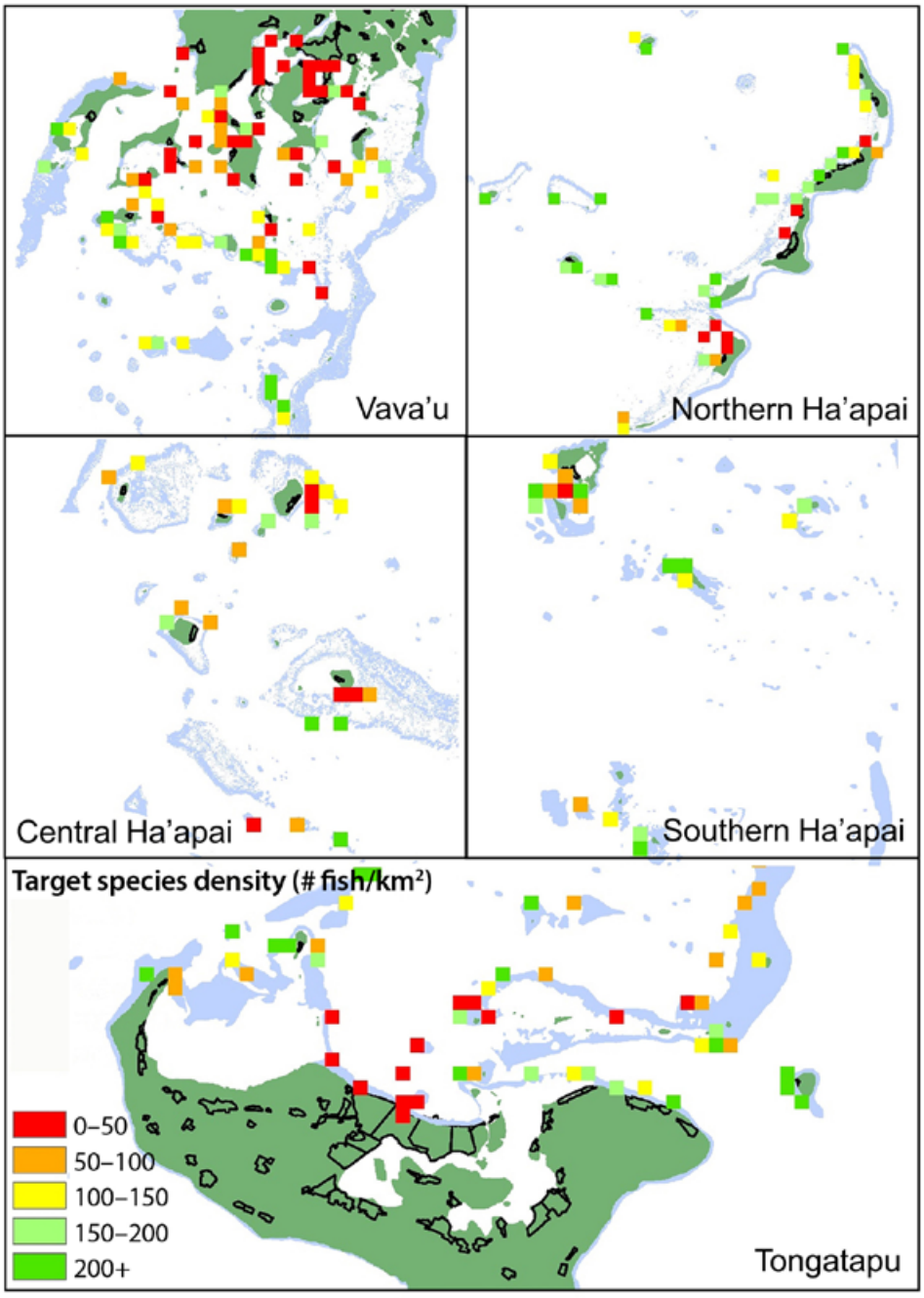

Figure 2. Target species density in surveyed areas.

Table 1. List of completed or ongoing projects with a focus on Tonga's coral reefs, reef fish fishery or Special Management Area programme.

Project	Publishing status	Objectives	Main findings
Ecological and socioeconomic impacts of marine protected areas in the South Pacific: assessing the evidence base	2019	To determine: i) The overall ecological and socioeconomic impacts of marine protected areas in the South Pacific. ii) What factors are associated with positive, neutral and negative impacts in the region. iii) To what extent the protected area evaluation literature from the region has incorporated counterfactual thinking and robust impact evaluation techniques.	Based on 52 identified studies, 42% of measured ecological impacts and 72% of socioeconomic impacts were positive. The proportion of positive impacts was comparable between community-based and centrally governed management areas. There was little evidence of long-term recovery inside periodically harvested closures. Most studies (59%) did not provide any clear consideration of factors beyond the presence of management areas that could have confounded their results. We conclude that counterfactual thinking has yet to be embraced in impact evaluation studies in the region.
Tongan socioenvironmental spatial layers for marine ecosystem management	In review	To provide an open source socioenvironmental dataset covering Tonga's near-shore marine ecosystem. Compiled from various global layers, remote sensing projects, local ministries and the 2016 national census.	The dataset consists of 11 environmental and 6 anthropogenic variables summarised in ecologically relevant ways, spatially overlaid across the nearshore marine ecosystem of Tonga. The environmental variables selected include: bathymetry, coral reef connectivity, distance from deep water, distance from land, distance from major terrestrial inputs, habitat, land area, net primary productivity, salinity, sea surface temperature, and wave energy. The anthropogenic variables selected include: fishing pressure, management status, distance to fish markets, distance from villages, population pressure, and a socioeconomic development index based on population density, growth, mean age, mean education level, and unemployment.
Coral reef annihilation, persistence and recovery at Earth's youngest volcanic island	2019	To examine the destruction, persistence and initial recovery of reefs associated with the hydromagmatic eruption that created Earth's newest landmass, the Hunga Tonga–Hunga Ha'apai volcanic island in the Tongan archipelago.	Despite extreme conditions associated with the eruption, impacts on nearby reefs were spatially variable. Importantly, even heavily affected reefs showed signs of rapid recovery driven by high recruitment, likely from local refuges. The remote location and corresponding lack of additional stressors likely contribute to the resilience of Hunga's reefs, suggesting that in the absence of chronic anthropogenic stressors, coral reefs can be resilient to one of the largest physical disturbances on Earth.
Towards reducing misrepresentations of national achievements in marine protected area targets	2018	To highlight the large-scale misrepresentation, by up to two orders of magnitude, of national marine protected area coverage from two Pacific Island nations in multiple online databases and subsequent reports, including conclusions regarding achievements of Aichi 11 commitments.	Tonga's marine protected area coverage in the World Database on Protected Areas (WDPA) was falsely listed as 10,133.82 km^2 due to the inclusion of a massive 10,000 km^2 paper park, the Ha'apai Conservation Area. In addition, the Phoenix Island Protected Area, one of the largest MPAs in the world (397,447 km^2) was also listed twice in the WDPA.
Incentivising marine management: mechanisms driving the successful national expansion of Tonga's Special Management Area programme	In prep	To identify key characteristics of the SMA programme that have enabled it to successfully avoid two common pitfalls in the expansion of protected areas globally: i) the difficulty of incentivising groups to also manage resources when their livelihoods depend on them, and ii) that many protected areas are situated residually, or in areas with limited value for extractive activities.	Providing immediate incentives (e.g. SMAs as exclusive access zones) that also foster long-term care for natural resources, encourage groups that otherwise may be against management and conservation to implement no-take protected areas (e.g. FHRs). Then ensuring that protected areas occur within the boundaries of these exclusive access zones entices groups to protect areas of greater extractive value than they would likely do so otherwise.

Community-based marine management yields positive impacts for coastal fisheries resources and biodiversity conservation	In prep	To conduct a rigorous ecological impact evaluation comparing the current ecological state of the 15 oldest community-based management areas in Tonga with their estimated counterfactual conditions. We use statistical matching of 11 ecological and socioeconomic variables and a national coral reef baseline dataset constituting 1628 transects.	A two-part approach to marine conservation, whereby communities are granted exclusive access to nearby reefs as an incentive to establish no-take zones, can yield positive impacts on a national level for both coastal fisheries resources and biodiversity conservation. No-take FHRs had significantly greater reef fish diversity as well as biomass, density and length of target species. There was, however, limited evidence of any difference between areas open to all fishing and the SMAs, where community members are allowed to fish.
Predicting impact to assess the efficacy of community-based marine reserve design	2018	Boosted regression trees were used to predict conservation impact to compare recently implemented community-based marine reserves in Tonga to a systematic configuration specifically aimed at maximising impact.	It was estimated that the community-based approach provides 84% of the recovery potential of the configuration with the greatest potential impact. This high potential impact results from community-based reserves being located close to villages, where fishing pressure is greatest. These results provide strong support for community-based marine management, with short-term benefits likely to accrue even where there is little scope for systematic reserve design.
Kingdom of Tonga Special Management Area report 2020	In prep	To provide both a broad overview and detailed synthesis of Tonga's marine resources and the status of the SMA programme. Specifically this document outlines: i) the overall status of Tonga's coral reefs and reef fish fishery, ii) the ecological impacts of the eight oldest SMAs, and iii) detailed baseline data on 41 new SMAs.	i) Both fish abundance and diversity are improving in roughly half of the older FHRs in Tonga. ii) There is little evidence of any recovery inside Tonga's SMAs (outside the FHRs), where fishing is still allowed by the community. iii) The coral reefs and reef fish fishery in Vava'u are in noticeably worse condition than elsewhere in the country. iv) There is extensive evidence of damage to reefs from coral bleaching in Vava'u and northern Ha'apai. v) There is extensive evidence of cyclone damage in southern Vava'u and northern Ha'apai. vi) Poor water quality appears to have damaged or killed many reefs around lagoonal areas in both Vava'u and Tongatapu.

References

Anon. 2014. Kingdom of Tonga's Fifth National Report to the Convention on Biological Diversity. Available at: https://www.cbd.int/doc/world/to/to-nr-05-en.pdf

Chin A., Lison De Loma T., Reytar K., Planes S., Gerhardt K., Clua E., and Burke L. and Wilkinson C. 2011. Status of coral reefs of the Pacific and outlook: 2011. Global Coral Reef Monitoring Network. 260 p.

Fisheries Division, Ministry of Agriculture, Food, Forests and Fisheries. 2010. Community-managed Special Management Areas in Tonga (Brochure 1–2). Available at: http://www.tongafish.gov.to/images/documents/Publications/Brochures/SMA brochure-tonga-En.pdf

Pressey R.L., Visconti P. and Ferraro P.J. 2015. Making parks make a difference: Poor alignment of policy, planning and management with protected-area impact, and ways forward. Philosophical Transactions of the Royal Society B: Biological Sciences, 370(1681). Available at: https://doi.org/10.1098/rstb.2014.0280

Smallhorn-West P. and Govan H. 2018. Towards reducing misrepresentation of national achievements in marine protected area targets. Marine Policy 97:127–129.

Smallhorn-West P., Bridge T., Malimali S., Pressey R. and Jones G. 2018 Predicting impact to determine the efficacy of community-based marine reserve design. Conservation letters. DOI: 10.1111/conl.12602

Smallhorn-West P., Weeks R., Gurney G. and Pressey B. 2019. Ecological and socioeconomic impacts of marine protected areas in the South Pacific: Assessing the evidence base. Biodiversity and Conservation. DOI:10.1007/s10531-019-01918-1

Smallhorn-West P., Garvin J., Slayback D., DeCarlo T., Gordon S., Fitzgerald S., Halafihi T., Jones G. and Bridge T. 2019. Coral reef annihilation, persistence and recovery at Earth's youngest volcanic island. Coral reefs. DOI: 10.1007/s00338-019-01868-8

Fish catches in American Samoa

The Fisheries Division of the American Samoa Department of Marine and Wildlife Resources (DMWR) regularly monitors fish catches of its nearshore fisheries, and the data are used to track the status of fish stocks. The Fisheries Division runs creel programmes that cover commercial and non-commercial fisheries, commercial vendors' receipts, and sportfishing. Creel survey methods follow reviewed and accepted protocols. The pelagic fisheries catch forms a minor part of the data that the United States submits to the Western and Central Pacific Fisheries Commission. The pelagic, bottomfish and coral reef fisheries data form part of the Fishery Ecosystem Plans (FEPs) developed by the Western Pacific Regional Fishery Management Council.

Nearshore commercial fisheries

In 2018, 19 *alia* boats landed 15,014 kg of pelagic fish through trolling, mix bottom fishing-trolling, and longlining. These pelagic fisheries data do not include the catch of purse-seine and longline vessels that offload to the cannery in American Samoa. Yellowfin tuna (*Thunnus albacares*) accounted for 5125 kg, skipjack tuna (*Katsuwonus pelamis*) 3220 kg, albacore (*Thunnus alalonga*) 2270 kg, and wahoo (*Acanthocybium solandri*) 1950 kg. When compared with 2014 pelagic fish landings (18,600 kg), landings have been nearly stable for the last three years, despite the fact that the number of active vessels has declined from 22 in 2015 to 10 in 2018.

Six alia boats landed 6440 kg of bottomfish in 2018. The major species were longtail snapper (*Etelis coruscans*) with 1,720 kg, gray jobfish (*Aprion virescens*) 770 kg, silverjaw jobfish (*Aphareus rutilans*) 680 kg, ruby snapper (*Etelis carbunculus*) 545 kg lbs, humpback snapper (*Lutjanus gibbus*) 410 kg, and redgill emperor (*Lethrinus rubrioperculatus*) 320 kg. The landings of bottomfish have consistently declined since 2015, when 23,100 kg were landed, and the number of active boats has declined from 21 in 2014 to 6 in 2018.

In 2018, four *alia* boats landed 14,060 kg of fish caught by free-dive spearfishing. Twenty-two percent of this catch consisted of blue-lined surgeonfish (*Acanthurus lineatus*), 10% red-lip parrotfish (*Scarus rubroviolaceus*), 7% bluespine unicornfish (*Naso unicornis*), and 6% dark-capped parrotfish (*Scarus oviceps*). Imported reef fish from Samoa amounted to around 2800 kg (20%). The number of spearfishing boats ranged from three to five boats operating each year since 2014.

Recreational and subsistence fisheries

American Samoa's major fisheries include gleaning, thrownetting, spearfishing, handlining, and rod and reel. Cultural practices include fishing for *palolo* (*Eunice viridis*), *atule* (*Selar* spp.) and *ia'sina* (juvenile *Mulloidicthys* spp.). Around 4850 kg of fish were landed and the major catches were *atule* from handlining, octopus from gleaning, blue-lined surgeonfish from spearfishing, and jacks *Caranx* spp. from rod and reel. There was a strong *palolo* rise on October 2018.

Recreational trolling landed 3300 kg of pelagic fish in 2018, while yellowfin tuna accounted for 34%, wahoo 24% and dogtooth tuna (*Gymnosarda unicolor*) 10%. The International *I'a Lapoa* Fishing Tournament landed 2200 kg of pelagic fish, with yellowfin tuna accounting for 56% of this and wahoo 33%.

The commercial invoice system recorded 36,300 kg of pelagic bycatch fish sold from longline vesssels.

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Establishing a community pearl oyster farm in Vatulele Village, Fiji

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Pearl oyster farming has become a vital source of income, improving livelihoods and significantly contributing towards economic development in Pacific Island countries. Because pearl oysters are filter feeders and sequester carbon into their shells, they can be regarded as sustainable elements fostering marine conservation in the region.

Surrounded by the clean pristine waters of Savusavu Bay, the village of Vatulele in Fiji's Cakaudrove Province makes an ideal location for culturing pearl oysters. Efforts to establish a community or private-sector partnership within the village *iqoliqoli* (traditional fishing rights area) are currently underway, with support from the Wildlife Conservation Society (WCS), Pacific Community (SPC) and J. Hunter Pearls Fiji, collaborating to make this a four-way partnership with Vatulele Village over the next two years. The project seeks to explore an integrated production of both round pearls and pearl oyster meat through the aquaculture of blacklip pearl oyster (*Pinctada margaritifera*) by the community. Pearl meat oysters are a new product that will diversify the pearl aquaculture industry, simplifying farming processes and eliminating the need for pearl seeding technicians, which will increase the accessibility for entry into this industry by community groups.

Mother-of-pearl of the blacklip pearl oyster *Pinctada margaritifera*. (image: Bulou Vitukawalu, WCS)

J. Hunter Pearls Fiji is an established company in Savusavu that strives to work with the government and local communities to create a positive pearl aquaculture industry in Fiji that is sustainable, viable and beneficial to local communities. Through this partnership project, WCS will work closely with J. Hunter Pearls, SPC and the Vatulele community to develop business plans to ensure equitable distribution of benefits that will cover future costs of wages, new pearl shell stock, and any other priority community development activities. Additionally, all project partners will support and strengthen the benefits of pearl farming for the community through training, consultations and workshops. J. Hunter Pearls Fiji is the recipient of an award under the New Zealand Ministry of Foreign Affairs Sustainable Pacific Aquaculture project, which is administered by SPC to facilitate and support the establishment of community pearl farms in Cakaudrove Province. This intervention has also been made possible through funding to WCS by the Blue Action Fund, which is supporting a project to expand networks of locally managed marine areas, embedded within or adjacent to larger-scale, multi-use marine protected areas, within which marine resources are sustainably utilised and conserved.

The meat of pearl oysters, lightly steamed and delicious! (image: Sangeeta Mangubhai, WCS)

The pearl oyster farm project is currently in its early stages, with supporting partners assisting in carrying out a series of

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WCS-Fiji staff facilitating discussions with the women's focal group at the workshop in Vatulele Village. (image: Sangeeta Mangubhai, WCS)

Discussions at the project consultation workshop in Vatulele Village's community hall. (image: Fareea Ma, WCS)

The proposed pearl aquaculture site in the pristine clear waters of Vatulele Village. (image: Bulou Vitukawalu, WCS)

Discussions between Justin Hunter (centre) and representatives of the Wildlife Conservation Society, Pacific Community and Vatulele Villagers about potential pearl farm sites. (image: Fareea Ma, WCS)

village workshops and a socioeconomic survey from September to December 2019. These community engagement activities followed a grievance mechanism and a free and prior informed consent process to ensure continued clarity with the community. The initial engagement, which was an awareness workshop followed by a socioeconomic survey, helped to capture the community's existing structure, knowledge, perceptions and expectations of the project. Two project consultation workshops followed suit, with WCS and SPC assisting the community in understanding the business aspects of the project while also helping them set up a Vatulele pearl farm committee and providing options on establishing a legal entity for their community pearl oyster farm. Moreover, two potential sites for the pearl oyster farm have been determined during a site visit. It is envisioned that the second site, which is in close proximity to the village, would be trialled by J. Hunter Pearls in the first quarter of 2020.

The joint aquaculture venture has progressed well over the past few months with a high level of commitment from all project partners and the community. A few community engagements are yet to take place in early 2020, with objectives including officially setting up a legal entity for the community venture, obtaining a license for their pearl oyster farm to operate in marine space, developing a business plan, and finalising the actual growing site for the farm within the licensed area. It is anticipated that the installation of the infrastructure of the pearl oyster farm will take place in mid-2020. The successful operation of this pearl oyster farm project in Vatulele will determine the possibility of replicating it in other community pearl farms in Cakaudrove Province. The pearl oyster farm project is a great opportunity to help support livelihoods through supplemental income within their community and promote the sustainable use of marine resources within their *iqoliqoli*.

Exploring the market potential for Fiji's Rewa River oysters

Jeff Kinch,[1] Moape Yabakiva,[2] Pitila Waqainabete,[2] Unaisi Nalasi,[2] Timothy Pickering,[1] Penina Ravunamoce[1] and Alessandro Romeo[1]

Introduction

As reported on in the previous issue of the *SPC Fisheries Newsletter*[3], the women of Muanaira Village in the Rewa River delta near Suva, Fiji are harvetsing mangrove oysters for sale to relatives and others in Suva and farther afield (Kinch et al. 2019). The main oyster harvested is a species that was introduced into Laucala Bay in the 1970s.

The deployment of spat collectors is one activity conducted to date in an effort to shift the women's efforts from oyster harvesting to oyster farming. Juvenile oysters that had settled onto these collectors were collected in February this year and were counted and graded, and then transferred to plastic mesh baskets hanging on stakes for growing out at a pilot farm site in Laucala Bay. After three months of farming, these oysters were found to have grown rapidly. In May this year, Kinch et al. (2019) conducted a socioeconomic assessment of Muanaira Village and oyster harvesting practices to gain a better understanding of current activities, especially given the opportunities to start farming mangrove oysters to supply Fiji's tourism sector. This has received support from Fiji's Ministry of Fisheries (MoF) and the Pacific Community (SPC) (Jimmy 2019). In August this year, oyster baskets were once again retrieved and again the oysters were graded. New bags of wider mesh size were made, and oysters were placed into the new baskets and returned to the pilot farm (Fig. 1). In December 2019, after 10 months of culture in the mesh baskets, the oysters had reached marketable size (Fig. 2). Their shells measured, on average, 11cm in length and 7cm in width, and were of a regular rounded shape with a nice deep cup. This compares with typical grow-out times of 18 months for oysters grown in farms in New South Wales, Australia. During this same activity in December 2019, the spat catching gear was re-deployed to take advantage of the current spawning season and set up a new batch of oysters in baskets during February 2020.

Figure 1. Muanaira Village Women's Group pilot oyster farm at Laucala Bay near Suva, Fiji. (image: Timothy Pickering, SPC)

[1] Pacific Community
[2] Fiji Ministry of Fisheries
[3] http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/159/FishNews159_45_Kinch.pdf

Figure 2. SPC staff Penina Ravunamoce and Losana Nakabea hold up one of the culture baskets of 10-month-old mangrove oysters, ready for harvesting. (image: Timothy Pickering, SPC)

With such promising results, the women of Muanaira Village are hopeful that these farmed oysters will be more plentiful, easier to harvest, and provide more income in the future (Jimmy 2019). Before more effort is provided for this pilot project, a simple value-chain analysis was conducted in August this year to determine the value of wild harvested oysters and the potential value of fresh farmed oysters sold to hotels or restaurants. The value-chain analysis also looked at other issues such as environmental factors, food safety, and up-scaling production constraints.

The Rewa River Delta

The Rewa is Fiji's largest river, with a total catchment area that is more than a quarter of the total land area of the island of Viti Levu, which equates to approximately 2980 km^2. It discharges an estimated 7900 million m^3/yr of water and approximately 1200 t of sediments (Watling 1985). The Rewa River delta covers and area of 12,062 ha and hosts Fiji's largest and most diverse area of mangroves, the Bonatoa Swamp (Watling and Chape 1992; Gray 1993; Spalding et al. 2010). It also includes other wetland types such as lowland littoral forests, freshwater wetlands, intertidal mudflats, mangrove forests, coastal strand vegetation, estuarine areas, and seagrass beds (Mueller-Dombois and Fosberg 1998). The ecological and environmental services that the Rewa River delta provides includes safe habitat for juvenile and adult marine fauna, the provisions of nutrients to marine food chains through the export or organic matter, the protection of inland areas and settlements from storm damage, salt spray, coastal erosion and inundation due to sea-level rise, and the interception of sediment and nutrient rich runoff from the land, thus maintaining the water quality of the surrounding inshore area (Ewel et al. 1998; Gilman et al. 2006; Polidoro et al. 2010; Marie et al. 2017). The Rewa River delta supports an artisanal fishery that supplies much of the needs of greater Suva (Gray 1993).

Climate change impacts

For Muaniara Villagers, the projected impacts of climate change include increased coastal erosion, contamination of groundwater by saltwater incursion, cyclones and storm surges, heat stress, and drought (Barnett 2011). Overall, climate change threats to the Rewa River watershed and delta include greater intensity of flood events, an increase in the magnitude of storm surges, and more frequent droughts (DBR Pty Ltd 2012). Previous flood events for the Rewa River have resulted in the damage of between 50 and 70% of all crops grown in the the delta (Chaudhury 2015).

The annual mean tidal range for the Rewa River delta is 1.1 m, with a range of neap tides of 0.9 m and spring tides of 1.3 m. Sea level rise is projected to increase by 39 cm by 2090 (IUCN 2013). With this level of projected sea level rise, mangroves in the Rewa River delta will be able to keep up with sustainable rates of sediment replenishment if space is still available landward (Ellison and Stoddart 1991; Ellison and Strickland 2010). Lata and Nunn (2012) offer a different scenerio, whereby sea level rise for the Rewa River delta will actually be 1.2 m by 2100. If this scenerio was to eventuate, then most of the Rewa River delta's mangroves could be lost as early as 2060 (IUCN 2013). In addition, sea surface temperature is expected to increase 1.9°C by 2090 (IUCN 2013).

The most immediate impact of climate change for Muanaira Villagers will, therefore, be on their livelihoods.

Value of wild harvest and farmed oysters

To determine the current value of wild harvested oysters for Muanaira Village, an assessment was conducted on the number and weight of oysters required to fill certain units of sale that are used by the women of Muaniara Village.

To prepare wild harvested oysters for shucking, oysters are first simmered in hot water for 30 minutes. Each cooked and shelled oyster weighs approximately 90 g (n = 100), and a women can shuck six oysters per minute (Fig. 3). As oysters are shucked, they are collected in a container (Fig. 4) and then counted as they filled various units of sales:

- 100 oysters = 500-g margerine container (weighing 0.42 kg);
- 200 oysters = 20 cm x 20 cm ziplock plastic bag (weighing 0.83 kg); and
- 300 oysters = 2-L ice cream container (weighing 1.32 kg).

From these measurements, it was determined that one cooked wild harvested oyster was worth FJD 0.16.

To determine the value of sale of the potential fresh farmed oyster, 14 hotels and restaurants in Suva were contacted, with 11 providing information. None of the hotels or restaurants that were contacted were currently selling oysters on their menus, although several had served local wild-harvested oysters in the past (the native oyster assumed to be *Saccrostea mordax*) or had imported them from New Zealand (Pacific oyster, *Crassostrea gigas*), but there was continued issues with consistency of supply and concerns over food safety. Only five hotels and restaurants knew that local oysters could be bought locally.

All of the hotels and restaurants that responded stated that they would buy fresh farmed oysters from Muaniara Village.

Figure 3. Shucking oysters at Muaniara Village. (image: Alessandro Romeo, SPC)

Figure 4. Shucked oysters at Muaniara Village ready for packaging. (image: Alessandro Romeo, SPC)

Seven said they would pay at a higher price if the oysters were certified safe to eat, two said they would not. Currently, only one hotel said that it serves freshwater mussles (*Batissa violacea*), mainly on Fijian-theme nights or buffets. Other hotels and restaurants serve imported green-lip mussels (*Perna canaliculus*) from New Zealand.

From discussions with various hotels and restaurants, it was determined that they would sell a half dozen fresh oysters for between FJD 20 and 30. Within the food industry, a ratio of one-third is usually used to determine the cost of a meal and the price that it will be advertised for on the menu. Using this ratio, it was determined that women from Muanaira Village could sell one fresh farmed oyster for around FJD 1.00–1.50, and possibly FJD 2.00 for one fresh farmed oyster. It was also

Figure 5. Introduced oyster species, *Crassostrea bilineata*. (image: Timothy Pickering, SPC)

estimated that there was a possibility of supplying at least 1800 fresh farmed oysters each week, just to the 11 hotels and restaurants alone that responded.

Genetic testing

Kinch et al. (2019) noted that there were two species of oysters harvested by the women of Muaniara Village: a local species (assumed to be *Saccostrea mordax*) and an introduced species (originally thought to be *Crassostrea iredalei*). To determine what species of oyster were actually being harvested, 40 oysters were sent to the James Cook University in Australia for genetic testing. Results of the this testing determined that there was, in fact, three species of oysters being harvested by women of Muaniara Village: two native *Saccostrea* species (non-*mordax* lineage), and an introduced species identified as *C. bilineata* (Strugnell 2019; Fig. 5). As noted in Kinch et al. (2019) the introduced species is easily identified as it has a distinct black muscle scar.

From further sampling at the Suva Market, it appears that the introduced oyster has spread widely and can be found in multiple areas of Bau District (Avinash Singh, SPC Aquaculture Officer, pers. comm.).

Food safety testing

To determine if the wild-harvested oysters were safe to eat, 20 oysters were sent to the University of the South Pacific's Microbiology Laboratory for testing of *Salmonella* spp. and faecal coliform bacteria (*Escherichia coli*). The results showed that *E. coli* was present at 430 most probable number (MPN) per 100 g of oyster[4], but *Salmonella* spp. was not[5]. Unfortunately, the levels of *E. coli* detected in the wild harvest oysters means that any fresh farmed oysters will need depuration before sale. *E. coli* is destroyed when wild-harvested oysters are soaked overnight in freshwater and then cooked before shucking.

Under European Union legislation, fresh farmed oysters based on the Food and Agriculture Organization and the World Health Organization's Codex Alimentarius[6], which is the international standard-setting body for food safety. Based on the Codex Alimentarius, there are three zones

[4] ISO Method 16649 – 3: 2015. See: https://www.iso.org/standard/56824.html
[5] ISO Method 6579 – 1: 2017. See: https://www.iso.org/standard/56712.html
[6] http://www.fao.org/fao-who-codexalimentarius/about-codex/en/#c453333

classified for the aquaculture of shellfish based on the presence and amount of *E. coli* in the aquaculture area (Table 1). Fiji's Food Safety Act 2003 (Government of Fiji 2003) and Food Safety Regulation 2009 (Government of Fiji 2009) are aligned with the levels detailed in the Codex Alimentarius.

As the results of the testing show levels of *E. coli* fall within Group B, any fresh farmed oysters from Laucala Bay must undergo a mandatory purification process before sale. Purification processes for shellfish are also defined in the Codex Alimentarius.

Kinch et al. (2019) noted that for the Laucala Bay area, previous research by Morrison et al. (1996, 2001, 2006) and Collen et al. (2011) had noted that contamination of trace metals and persistent organic pollutants were relatively low. In addition to regular testing for *Salmonella* spp. and *E coli*, oysters grown at Laucala Bay should also be regularly tested for heavy metals, especially cadmium, mercury and lead.

Discussion

From the value-chain analysis, it is possible that farming oysters could be commercially viable with potential to supply domestic and possibly export markets. There are already some small-scale exports by Muaniara Villagers sending wild harvest shucked and cooked oysters to relatives living in Australia, New Zealand, the United States of America and the United Kingdom. This is also similar to the small-scale exports of freshwater mussel (*Batissa violacea*) meat exported by Fijians of Indian descent to relatives in Australia and New Zealand (Kuridrani-Tuqiri 2015).

For both local sales and commercial exports, however, there will be a need for a suitable quality assurance programme. To assist with this, it will be necessary to develop food safety protocols and a quality assurance programme that is specific to fresh farmed oysters. A depuration facility will also need to be established. Even though Muanaira Village have running water and power, the location and operation of a depuration facility will need some consideration. Training on hazard analysis and critical control points and food safety would also need to be conducted. It is possible that there is an oligotrophic reef site offshore within the Muanaira fishing rights area that could be used to hold oyster baskets for a short period, so that oysters can depurate without the need for onshore infrastructure. This is a subject for follow-on research.

When women of Muanaira Village and other villages begin farming oysters to market their farmed oysters, there will be a need for support institutions to assist them with long-term planning or financial development. In general, there are difficulties in getting women involved in projects due to social and traditional obligations as women typically tend to the necessary chores of the household and village, and their knowledge and skills are often left out of decision-making processes. Results of the survey in May this year (Kinch et al. 2019), and again in August, show that women from Muaniara Village are essentially occupied with household chores, child care, gardening, church activities and the making of utilitarian items and handicrafts. Subsequently, selling, setting prices and ensuring a profit margin will be a challenge. Decisions will need to be made if they are to meet all traditional obligations and social expectations in their everyday village activities, as well as compete in the market economy.

Another important component will be transportation because, at present, Muanaira Villagers use fibreglass dinghies with outboard engines to access the Bailey Bridge Market or take buses or taxis to meet relatives to sell their oysters to them. Appropriate packing and transport will also need to be considered for delivering oysters that are ordered by restaurants and hotels.

Because the introduced oyster is found in other areas in Bau District, there is the potential to have other villages establish pilot farms in "cleaner" waters. These areas could be identified by physical surveys based on discussions with women selling *C. bilineata* and visiting their home villages in Bau District. It is also possible to identify potential areas by observing *chlorophyll a*. Areas of high concentrations of *chlorophyll a* are shown in red (Fig. 6). This area coincides with Laucala Bay and the wider Bau District.

Table 1. Codex Alimentarius classification for the three aquaculture of shellfish zones. Values for 100 g of flesh and interstitial fluid.

Group A	Group B	Group C
• 80% of the results < 230 colonies	• 90% or more of the results < 4600 colonies.	• Less than 90% of the results < 4600 colonies.
• No result is greater than 700 colonies.	• No result is greater than 46,000 colonies.	• No result is greater than 46,000 colonies.
• Oysters grown or extracted from these areas can be marketed without any purification treatment.	• Oysters grown or harvested in these areas must undergo a mandatory purification process before sale.	• These oysters must undergo two months (minimum) of culture in an area classified as A or B before being commercialised.

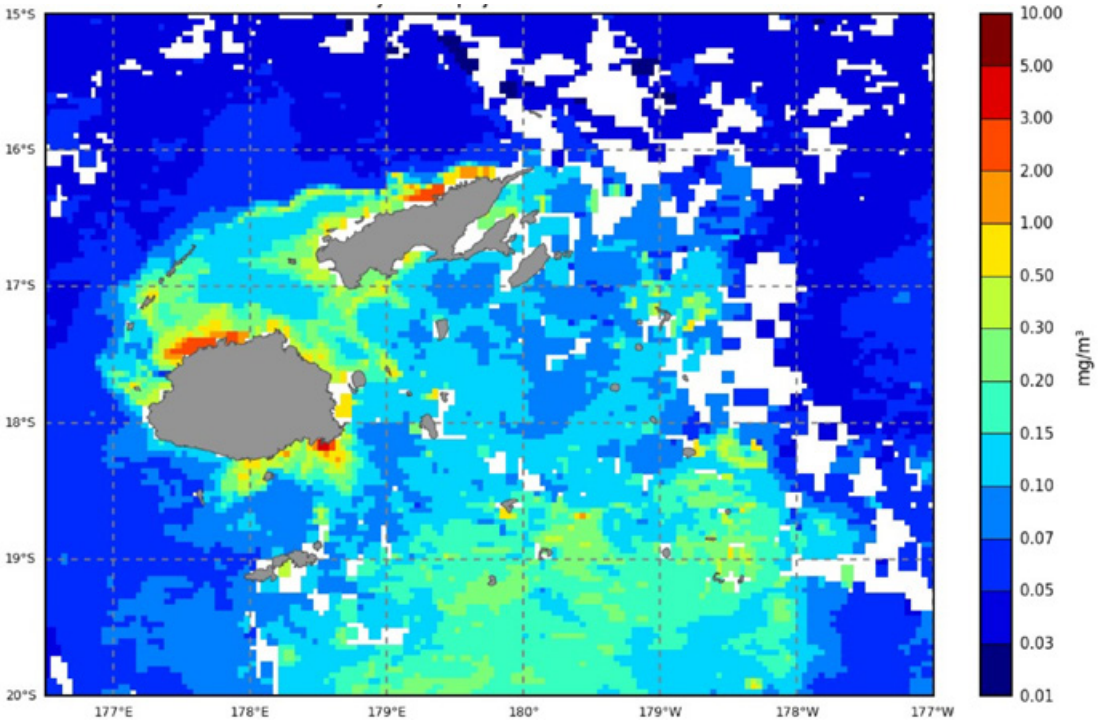

Figure 6. October 2019 chlorophyll a levels for Fiji. Source: Pacific Community 2019 (http://oceanportal.spc.int/portal/app.html#climate)

If there were economies of scale with several villages farming oysters, it would be easier to have a private sector partner support the villages that are farming oysters. This private sector partner could assist with overseeing production through a small-holder cropping model and be responsible for establishing a shore-based depuration system based in Suva that could be used to depurate oysters irrespective of harvesting area. They would also be responsible for packaging, marketing and transport. Monitoring water quality in grow-out areas and conducting regular testing would also be the responsibility of the private sector partner. Another option would be to investigate the potential for a cooperative style community-based depuration system, whereby oyster farmers incur extra costs that would hopefully be recouped by consumers willing to pay a higher price for a "safe" product. The Nature's Way Cooperative[7] in Fiji is an example of a company that seeks to ensure equitable disbursement of rewards to contributors. This process would, however, still require substantial coordination by an external partner. In either case, appropriate benefit-sharing would need to be worked out.

As noted above, climate change impacts will become an increasing emerging issue for people of the Rewa River delta. One of the recommendations stemming from the International Union for the Conservation of Nature's 'Mangrove Ecosystems for Climate Change Adaptation and Livelihoods' (MESCAL) project, which ran from 2009 to 2013, was to enhance livelihood options so that less pressure is exerted on the mangrove system and associated resources (Tuiwawa and Tuiwawa 2013). Farming oysters could assist with this livelihood diversification, and improve economic benefits and living standards for women and their families of Muauaira Village (and for other villages around Fiji) if economies of scale were achieved and a suitable private sector partner was in place.

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References

Barnett J. 2011. Dangerous climate change in the Pacific Islands: Food production and food security. Regional Environmental Change 11(1):229–237.

Chaudhury M. 2015. A review of climate change impacts, adaptation practices and policies, and relevant institutions in Fiji. Washington, D.C.: World Resources Institute.

[7] See: http://www.fao.org/3/a-an427e.pdf

Collen J., Atkinson J. and Patterson J. 2011. Trace metal partitioning in a nearshore tropical environment: Geochemistry of carbonate reef flats adjacent to Suva Harbor, Fiji Islands. Pacific Science 65(1):95–107.

DBR Pty Ltd. 2012. Strengthening the capacity of developing member countries to respond to climate change, Fiji: National Report. Suva: Asian Development Bank.

Ellison J. and Stoddart D. 1991. Mangrove ecosystem collapse during predicted sea-level rise: Holocene analogues and implications. Journal of Coastal Research 7(1):151–165.

Ellison J. and Strickland P. 2010. Recent stratigraphy and pollen analysis of Lomawai and Kubulau mangrove areas, Fiji. Suva: World Wide Fund for Nature.

Ewel K., Twilley R. and Ong J. 1998. Different kinds of mangrove forests provide different goods and services. Global Ecology and Biogeography Letters 7(1):83–94.

Gilman E., van Lavieren H., Ellison J., Jungblut V., Wilson L., Areki F., Brighouse G., Bungitak J., Dus E., Henry M., Sauni Jr. I., Kilman M., Matthews E., Teariki-Ruatu N., Tukia S. and Yuknavage K. 2006. Pacific Island mangroves in a changing climate and rising sea. United Nations Environment Programme Regional Seas Reports and Studies, No.: 179. Nairobi: United Nations Environment Programme.

Government of Fiji. 2003. Food and Safety Act 2003. Suva: Government of Fiji.

Government of Fiji. 2009. Food Safety Regulations 2009. Suva: Government of Fiji.

Gray A.J. 1993. Fiji. In: Scott D.A. (ed.) A directory of wetlands in Oceania. Slimbridge, UK and Kuala Lumpur, Malaysia: International Waterfowl and Wetlands Research Bureau and Asian Wetland Bureau (AWB).

IUCN (International Union for Conservation of Nature). 2013. Impacts of projected climate change on mangrove and coastal ecosystems and community livelihoods in Solomon Islands, Vanuatu, Fiji, Tonga and Samoa. Suva: International Union for Conservation of Nature.

Jimmy R. 2019. Fiji's Muanaira women's group sees promise in pilot mangrove oyster farm. SPC Fisheries Newsletter 159:12.

Kinch J., Vitukawalu B., Nalasi U., Waqainabete P. and Bermudes M. 2019. Socioeconomic aspects of oyster harvesting in the Rewa River Delta area, Fiji. SPC Fisheries Newsletter 159:45–54.

Kuridrani-Tuqiri N. 2015. Value chain analysis of freshwater mussel or kai (*Batissa violacea*) fishery in Fiji. Suva: International Union for Conservation of Nature.

Lata S. and Nunn P. 2012. Misperceptions of climate-change risk as barriers to climate-change adaptation: A case study from the Rewa Delta, Fiji. Climatic Change 110:169–186.

Marie A., Miller C., Cawich C., Piovano S. and Rico C. 2017. Fisheries-independent surveys identify critical habitats for young scalloped hammerhead sharks (*Sphyrna lewini*) in the Rewa Delta, Fiji. Scientific Reports 7:17273. doi:10.1038/s41598-017-17152-0

Morrison R., Narayan S. and Gangaiya P. 2001. Trace element studies in Laucala Bay, Suva, Fiji. Marine Pollution Bulletin 42:397–404.

Morrison R., Harrison N. and Gangaiya P. 1996. Organochlorines in the estuarine and coastal marine environment of the Fiji Islands. Environmental Pollution 93:159–167

Morrison R., Gangaiya P., Garimella S., Singh S., Maata M. and Chandra A. 2006. Contamination of Suva Lagoon. p: 146–155. In: Morrison R. and Aalbersberg W. (eds.). At the crossroads: Science and management of Suva Lagoon. Suva: University of the South Pacific.

Mueller-Dombois D. and Fosberg F. 1998. Vegetation of the tropical Pacific Islands. New York: Springer.

Polidoro B., Carpenter K., Collins L., Duke N., Ellison A., Ellison J., Farnsworth E., Fernando E., Kathiresan K., Koedam N., Livingstone S., Miyagi T., Moore G., Ngoc Nam V., Ong J., Primavera J., Salmo S., Sanciangco J., Sukardjo S., Wang Y. and Yong J. 2010. The loss of species: Mangrove extinction risk and geographic areas of global concern. PLoS ONE. 5: e10095.

Spalding M., Kainuma M. and Collins L. 2010. World atlas of mangroves. Washington, D.C.: Earthscan.

Strugnell J. 2019. Genetic barcoding of Fijian rock oyster species in order to provide species identification. Report to the Pacific Community, Noumea, New Caledonia.

Tuiwawa M. and Tuiwawa S. 2013. A rapid biodiversity assessment, socioeconomic study and archaeological survey of the Rewa River mangroves, Viti Levu, Fiji. Suva: International Union for Conservation of Nature.

Watling R. 1985. Mangrove Management Plan for Fiji. Suva: Government of Fiji.

Watling D. and Chape S. 1992. National state of the environment report. Suva: International Union for Conservation of Nature.

Creel surveys increase understanding of fisher patterns across three atolls in Kiribati

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Introduction

The Pacific Community's (SPC's) Coastal Fisheries Program (CFP) provides technical support to Pacific Island countries and territories (PICTs) to help ensure that subsistence, artisanal and small-to-medium-scale commercial fisheries are sustainable. In mid-2019, a team from CFP worked with staff of Kiribati's Ministry of Fisheries and Marine Resource Development (MFMRD) to undertake intensive creel surveys of local fishers across three atolls. Creel surveys provide data on fishing patterns and allow fisheries managers to document changes to fishing habits as well as changes to fisheries resources more generally. The creel surveys were carried out to complement the national-level household income and expenditure survey (HIES), which was being conducted throughout Kiribati in 2019. The HIES is a multi-purpose survey that has traditionally been conducted in the Pacific Islands region to assist with estimating overall gross domestic production per household, the costs of a basket of goods to revise the consumer price index and, more recently, to assist with analyses of food security and poverty, and provide input into various social development goal indicators. In light of the poor statistics for coastal fisheries production in the Pacific Islands region, Bell et al. (2009a) supported by Gillett (2016) and Gillett and Tauati (2018) suggested that a well-conducted HIES can provide basic information on the composition, quantity and estimated value of coastal fisheries production.

The Statistics for Development Division (SDD) of SPC developed a new standardised HIES for the Pacific Islands region in 2011, utilising a 12-month continuous rolling survey to capture seasonal fluctuations in income, expenditure, production and consumption patterns (Sharp et al. 2018). There are also additional questions on coastal fisheries resources in what has been termed as a "fisheries-friendly" HIES (Gillett 2016; Gillett 2018). The creel surveys carried out by SPC and MFMRD staff will be used to compare and contrast fisheries data collected through HIES questionnaires and help improve its accuracy at local scales. This process can then be repeated multiple times throughout a year to further improve estimates of fisher behaviour.

Data collected during the creel surveys in Kiribati focused on catch and fishing effort, fishing methods, and fisher demographics, as well as fishers' perceptions of change in their fishery over the preceding five years. Surveys were conducted daily through visiting fishers' home villages and from random encounters with fishers returning from their fishing trips. Surveys were undertaken for six weeks spread across the three atolls of Tarawa, Abemama and Onotoa. In addition to fisher interviews, biological sampling of common food fish was conducted, focusing on otoliths for the ageing of fish, gonads for reproductive information and tissue samples for analysis of genetic connectivity.

Here we report on the results of our creel surveys that highlight the coastal fishing practices and perceptions of fishers about the health of their fisheries across the three atolls, all of which are subject to very different levels of fishing pressure.

Fisheries background

Kiribati's fisheries consist of industrial tuna fishing, artisanal coastal reef and pelagic fishing, and subsistence fishing. Historically, 17% of fishers fish commercially full time, 22% fish commercially part time, and 61% fish only for subsistence purposes (Fisheries Division 1995). Data collected in 2014 suggest that small-scale artisanal fishing consists of approximately 30–40% of coastal fisheries catch (Table 1), with a greater proportion of fishers fishing commercially (Campbell and Hanich 2014; Gillett 2016; Ram-Bidesi and Manoa 2008). While subsistence fishing is the predominant source of fish protein across Kiribati, the increase in commercial fishing is likely due to an increase in ice production across the outer islands, cold-storage facilities for local sales and exports, and inter-island trade and shipments to Tarawa. Additionally, a growing demand due to an increasing human population and depletion of local fish stocks in Tarawa has also contributed towards this trend. Estimates of average per capita consumption in Kiribati since 2000 has varied between surveys, ranging from slightly over 62.2 kg (Bell et al. 2009b) to possibly over 200 kg (Gillett 2009) per capita per year. Other studies have proposed the following estimates of fish per capita per year: 87.9 kg (Fisheries Division 2008), 74.0 kg (Rouatu et al. 2015) and 106.9 kg using PROCFish/C data (Awira et al. 2008). These figures are relatively high in comparison to regional Pacific or global

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consumption levels, with coastal production being estimated in tonnes by Gillett (2016) at 19,000 tonnes.

Table 1. Coastal fishery production for 2014.

	Coastal commercial (t)	Coastal subsistence (t)	Total (t)
Kiribati	7600	11,400	19,000

Source: Gillett 2016

A considerable proportion of the population on the outer atolls of the Gilbert Group of Islands (e.g. Abemama and Onotoa) also rely on agriculture (predominantly copra) for income. The Kiribati government has recently introduced a copra subsidy scheme resulting in a price increase to AUD 2.00/kg. This price is comparable to the mean price of ~AUD 2.50–3.00/kg for fish, hence providing a similar level of income in the outer islands.

Historically, fishing techniques used by fishers in Kiribati include bottom handlining, trolling, pole-and-line fishing, mid-water hand-lining, spearing, trapping, netting and reef gleaning (Fisheries Division 1995). Fishing craft includes traditional canoes driven by sail or paddle, plywood canoes powered by outboard motors, and outboard-powered skiffs (fiberglass or aluminium). In the outer islands especially, customary obligations relating to the sharing of fish catches among family and church groups is practiced. Small-scale commercial fishing is concentrated around Tarawa where there is a large population, ice and cold-store facilities, and a cash-oriented economy.

Survey locations

Creel surveys were carried out for six weeks, with two weeks at each atoll: Tarawa, Abemama and Onotoa (Fig. 1). Atolls were chosen according to population size and accessibility, with the population gradient ranging from high, medium and low, respectively.

Survey methods

Regular fishers were initially identified, using MFMRD's contacts and by visiting known landing sites. Most fisher interviews were conducted as fishers were encountered along the road and around common fish markets. On Abemama and Onotoa, fishers who were identified as regularly fishing were

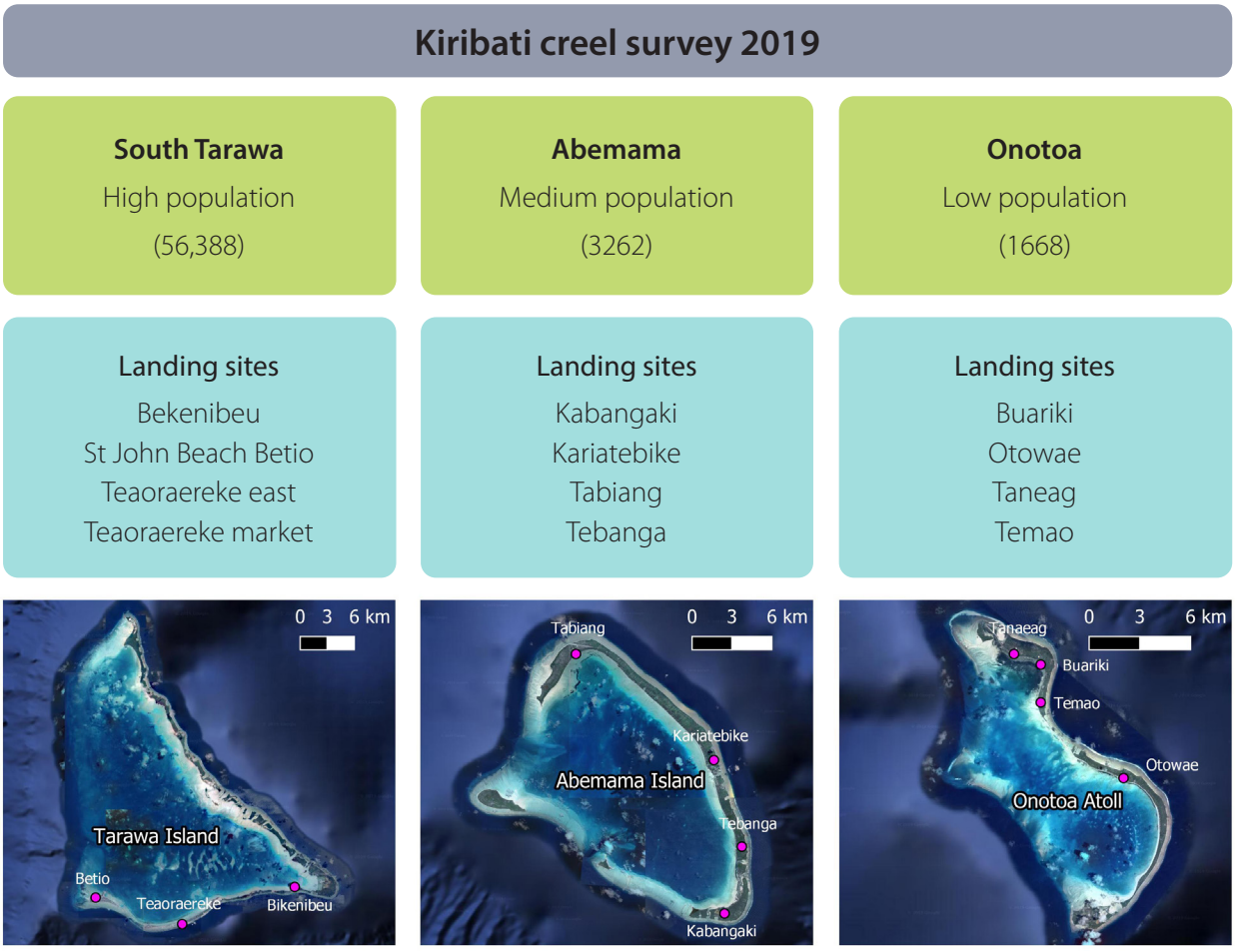

Figure 1. Locations where creel surveys were conducted. Landing sites were surveyed continuously over a two-week period.

Figure 2. Ministry of Fisheries and Marine Resource Development staff conducting creel surveys using Tails. (images: Pauline Bosserelle, SPC)

continuously checked by a survey team staying at community sites to conduct interviews at predefined times.

For each fisher or group of fishers encountered, the protocol was as follows:

- Creel survey interview inclusive of effort for this particular fishing trip;
- Documenting fishing habits and perceptions of the fishery through interview questionnaires (this was only done once when the lead fisher was first met);
- Sampling the catch (i.e. taxonomic identification, length and weight information); and
- Identifying any probable future fishing trip in order to follow up with the fisher or group of fishers.

Interviews were conducted using tablets (Fig. 2). Standardised creel survey forms (Anon 2016), were incorporated into the commonly used Tails application (Hunt 2019, 2016) as a stand-alone creel survey module. The Tails application was originally designed for artisanal tuna fishers but has been updated to include a coastal reef fisheries section. Fishers that were interviewed were provided with ice to ensure there was no loss of income through quality degradation of the catch during the time taken to interview and measure catches.

When a fisher or fishing group was encountered, the lead fisher was interviewed and asked questions relating to the fishing trip, including

- the vessel name,
- the number of fishers that took part in the fishing trip,
- the fishing method(s) used,
- locations fished (fishing area or zone), and
- fishing time (total hours fished).

Historical fishing patterns and perceptions of the state of resources were only documented once, during the initial interview. Questions asked included;

- Demographics: age of fisher, gender, village name of fisher;
- Usual fishing habits: main fishing method, fishing frequency, areas fished; and
- Perception: perceived change in the fishery over the last five years (including catch number, sizes).

While interviews were being conducted, the catch was measured using a camera-based system that records the length and weight of each individual fish (Fig. 3). Analysis of the pictures taken was done using SPC software called "Analyze picture". The length, to the nearest half centimetre (0.5 cm), and weight, to the nearest gram (g) unless damaged, was recorded.

Fishing activity across atolls

In total, 179 interviews were conducted across the three atolls, corresponding to 198 individual fishing events (i.e. there can be more than one "event" in a single fishing trip). A total of 48 fishing trips corresponding to 48 fishing events were recorded in South Tarawa, while in Abemama, 51 fishing trips corresponding to 52 fishing events occurred, and in Onotoa 78 fishing trips were recorded corresponding to 98 fishing events. Among the 102 fishers interviewed (29 in Tarawa, 34 in Abemama and 39 in Onotoa), 29 (8 in Tarawa, 7 in Abemama and 14 in Onotoa) were surveyed on multiple occasions while the remaining 73 were only interviewed once. Among the 198 events, 77 were identified as artisanal fishing activities, while 118 were identified as subsistence fishing activities, and the remaining 3 were not defined.

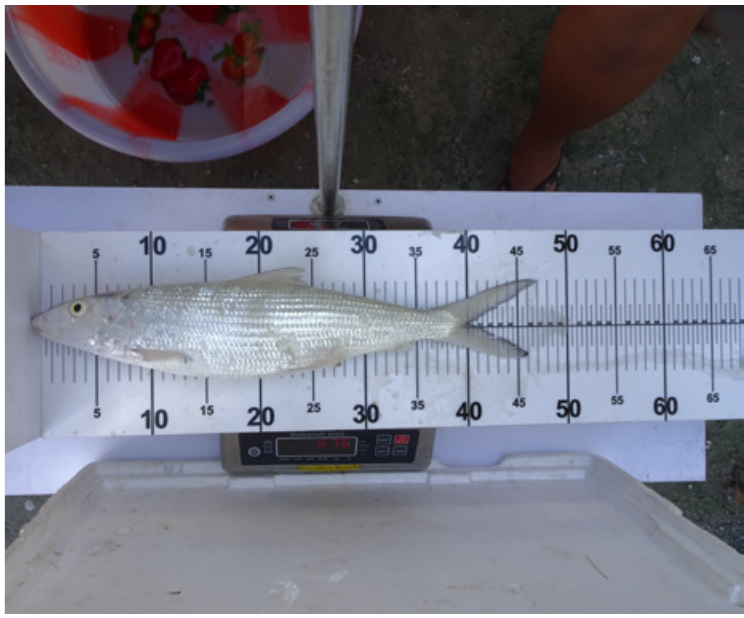

Figure 3. Catch measurements. Left: staff measured the catch using a camera-based system. Right: length and weight of each individual fish were recorded. (images: Pauline Bosserelle, SPC)

Tarawa

Tarawa Atoll has an estimated population of 120,100 (National Statistics Office 2016). Kiribati's capital, which is South Tarawa, had a population of 56,400 in 2016.

Commercial fishing

Kiribati's largest and most economically valuable fisheries are its tuna fisheries, and Kiribati has some of the richest tuna fishing grounds in the world. The country's large exclusive economic zone supports a large oceanic tuna catch by foreign vessels fishing under access agreements with the Kiribati government. Industrial-scale commercial fishing activities in Kiribati are currently exclusively oceanic, and are conducted almost entirely by foreign interests. Purse-seine fishing vessels make up the predominant part of Kiribati's oceanic tuna fisheries and provide over 60% of fishing access fee revenue. Purse-seine vessels tend to concentrate their fishing activities in the Gilbert and Phoenix Islands within Kiribati and primarily target skipjack tuna, which represents approximately 70–85% of the purse-seine and pole-and-line catch (MFMRD 2011). Kiribati also licenses a significant foreign longline fleet, which primarily targets bigeye, yellowfin and albacore tunas, and other oceanic fish species (Campbell and Hanich 2014).

Tuna is not only a major source of government revenue but also a key source of protein (Gillett 2009). Selling frozen traded tuna from the longline and purse-seine vessels is mostly organised by women and is very common at roadside markets.

Artisanal fishing

Due to its high population density, the demand for fish consumption on Tarawa is significantly higher than in the other outer atolls that were surveyed. Despite the lack of organised landing sites for tuna (Banks 2012), artisanal fishers were catching significant amounts of oceanic tuna for local markets and immediate consumption. A significant number or fishers were also targeting flying fish. While these types of fishing activities were not the focus of this survey, the catch level for these is likely to increase due to overfishing pressure in Tarawa Lagoon and other inshore fisheries. Increases in tuna fishing effort are also effective at reducing fishing effort on local reefs. Our survey mainly focused on fishers targeting lagoon and reef fish resources (Fig. 4).

Among the 43 artisanal fishing events recorded, three main fishing methods were used (one event was identified as "unknown" characterised by multiple indistinct fishing activities):

- handlining (bottom fishing) was the most common method, with 25 fishing events;
- gillnetting was the second most common method, with 14 fishing events that mostly targeted bonefish; and
- spearfishing, which was only sporadically practiced, with three fishing events recorded.

Subsistence fishing

In Kiribati, households fish either commercially on a full-time or part-time basis, or for subsistence.

From our observations, subsistence fishing predominantly occurs in shallow waters and lagoon flats, mostly without boats, using a gill net, spear, scoop net at night, or by collecting and targeting both fish and invertebrates. Only four fishing events were recorded for South Tarawa because subsistence activities during our survey indicated a focus on fishing as a means of generating cash. The three main fishing methods used for these events were:


Figure 4. Typical artisanal catch from Tarawa. Left: Bonefish (*te ikari*) sold at Teaorereke market. (image: Pauline Bosserelle, SPC). Right: Mixed reef fish catch. (image: Chris Molai, SPC)

- gillnetting (two events);
- handlining/bottom fishing (one event); and
- spearfishing (one event).

Fishing habits and perceptions

Across South Tarawa, 29 fishers were interviewed about their fishing habits and perceptions of the health of the atoll's fisheries. These interviews revealed that in terms of roles, men engaged in fishing while women were involved in the processing and marketing of catches.

Most fishers who were interviewed fish continuously throughout the year, subject to weather conditions or the need for gear repair or maintenance. The average number of trips per week was 4.7 ± 0.3. Among artisanal fishers, sharing a vessel is common practice. On many occasions, boats are operated by multiple crews of fishers, working to different schedules to maximise boat use and/or to maximise community benefits and thus lower working costs.

The average age for fishers on Tarawa was 35 ± 2 years, and experience ranged from none to having over 36 years of experience. Most fishers, however, had from 0 to 15 years of fishing experience while only 4 fishers had more than 15 years of experience. Both fishing events and fishing habits data indicate that most fishers target the lagoon while a much smaller number of fishers handline on the outer reef.

Most fishers in South Tarawa (52%) perceive that the quantity and sizes of fish are comparable to five years ago. A not insignificant number (39%), however, of the remaining respondents perceived catch quantities and size of fish to be smaller than before (Fig. 5). Overall, based on discussions and interviews with fishers there were limited concerns about current fishing practices and pressure on coastal fisheries resources.

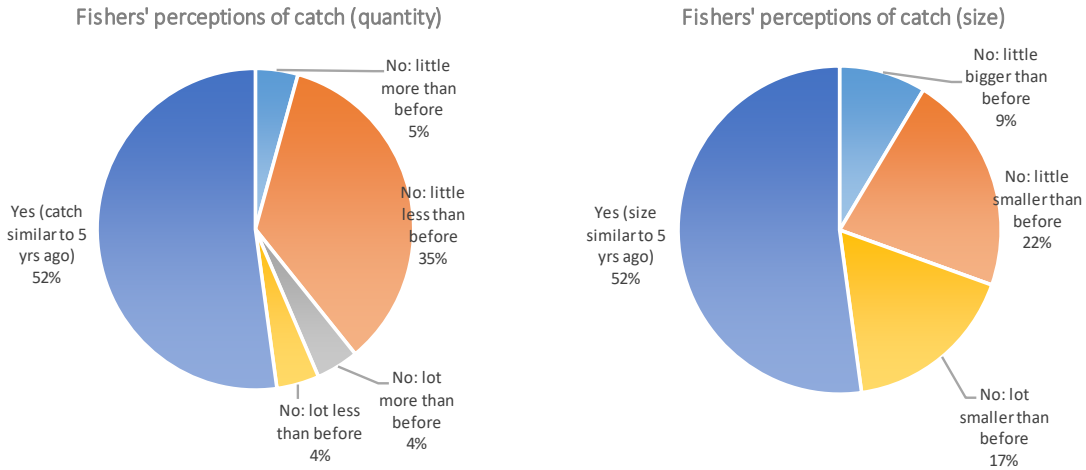

Figure 5. Summary of fishers' perceptions of catch quantity and size of fish catches compared with five years ago at Tarawa Atoll. In total, 29 fishers were interviewed regarding their fishing habits and perceptions.

Abemama

Abemama Atoll is located 153 km to the southeast of Tarawa, just north of the equator. The atoll has approximately 16 km^2 of land area and is bordered by a lagoon on its western side (Awira et al. 2008). The population is approximately 3262 (National Statistics Office 2016).

Artisanal fishing

Socioeconomic survey work conducted at Abemama Atoll as part of the PROCFish programme by SPC in 2004 revealed that fisheries provide the first source of income for one-quarter of all households, and the second source of income for 28% of households on Abemama (Awira et al. 2008). Trade of copra is also a major activity on the island, and balances activities due to competitive prices between coconut and fish. On Abemama, the fish shop operated by the island council only supports the local market. The main freezer complex has been out of order for over a year, further reducing marketing possibilities. Nevertheless, a portion of the island catch (e.g. giant clams, lobsters, salted fish, peanut worms and bivalves belonging to the genera *Anadara* and *Gafrarium*) is regularly sent to Tarawa by freight (plane and ship) for family consumption and/or the market (Fig. 6). The island is a local source of peanut worms (Sipuncilidae, *te ipo*) and giant clams (*Tridacna* spp.), which represent valuable commodities on Tarawa.

While fishing activities occur everywhere on the island, we surveyed the villages of Kariatebeike, Kabangaki, Tebanga and Tabiang where fishing is a major activity. Significant amounts of reef fish are caught and landed by fishers for local consumption. We also noted that marketed fish were sold quickly within the community due to high local demand. Of the 52 fishing events recorded for Abemama, 11 were recorded as artisanal fishing activities, which consisted of: gillnetting (five events), handlining or bottom fishing (five events), and trolling (one event).

Gillnetting was conducted exclusively within the lagoon while handlining and trolling were conducted on the outer reef.

Subsistence fishing

Due to limited market access on the island, most of fishers' catches were for household consumption, with 40 subsistence fishing events recorded out of a total of 52 fishing events. Fishing activities were strongly influenced by tides, which created difficulties in accessing lagoonal fishing grounds and returning to shore around low tide for the canoes. The following subsistence fishing methods are practiced on Abemama:

- Gillnetting (19 events);
- Handlining (11 events);
- Collecting (5 events);
- Trolling: (2 events);
- Unknown representing a mixed of method with undifferentiated catch (2 events); and
- Spearfishing (1 event).

Our interviews highlighted that most fishers use gill nets relatively close to shore in predominantly shallow water on lagoon flats, and that all subsistence activities, with the exception of one trolling event, took place in the lagoon. Fishing for invertebrates is limited to reef habitats and some intertidal and soft benthos habitats. Fishers target sheltered coastal areas and passages, which connect the lagoon

Figure 6. Drying peanut worms (*te ipo*) (left). Buckets of locally caught marine products waiting to be sent to Tarawa by plane (right). (images: Pauline Bosserelle, SPC)

with the open ocean. Most invertebrate species – bivalves, Strombus and sea worms (Sipuncilidae) – were gathered by hand. Subsistence fishers often used dugout canoes with or without a sail.

Fishing habits and perceptions

In Abemama, 34 fishers were interviewed regarding their fishing habits and perceptions of the health of the fisheries, with seven interviewed for more than one fishing activity. Only one woman who was gleaning for invertebrates was interviewed, but as in South Tarawa, their major role is in processing and selling catches.

Similar to South Tarawa, most of the fishers interviewed fished year round unless there was a need for gear repair, maintenance, logistical issues or bad weather. For example in May 2019, there was a fuel shortage on the island and artisanal fishers using motorised boats were unable to fish. The average number of trips per week was 3.3 ± 0.3.

The average age of fishers on Abemama was 39 ± 2 years and their fishing experience ranged from none to over 36 years' worth. While the number of fishers in each of the first three age categories (0 to 5 years; 6 to15 years and 16 to 25 years) was almost the same, it decreased in the last two categories (26 to 35 years and over 36 years). With the exception of artisanal hand-lining and trolling, the rest of the fishing activities were conducted within the lagoon. Activities take place mostly during the day and a few occasion at night.

Fishers perceptions' were more contrasting than in South Tarawa, with the majority of fishers surveyed indicating that they had noticed changes in their catches since five years ago, with 58% of respondents claiming that the quantity and size of fish caught were less and smaller than before (little less/smaller + lot less/smaller). Only, 21% and 27% of respondents did not see any change in catch quantity and size, respectively (Fig. 7). During discussions and interviews, some fishers expressed concerns over their fishing resources and fishing grounds, including concerns over foreign vessels illegally fishing at night on the reef, and the overexploitation of resources by the extensive use of gillnetting and the harvesting of juvenile fish.

Onotoa

Onotoa is a low-lying atoll with a land area of 15.6 km^2. The population of Onotoa in 2015 population was 1393 (National Statistics Office 2016). Onotoa's population has declined by 1.6% over the last decade with most people moving to urban areas. There are seven villages on the atoll, with Tabuarorae, an islet, located at the southernmost end of the atoll and the villages of Aiaki, Otowae, Temao, Buariki, Tanaeang and Tekawa, on the eastern end of the atoll (Ministry of Internal and Social Affairs 2008).

Artisanal fishing

The fishing centre on the island was in constant operation, creating a market for local fishers both for local consumption and for export to South Tarawa through the company Central Pacific Producers Limited using an interisland cargo vessel for shipping. While many fish species were sold on the local market (Fig. 8), including reef fishes and tunas, the export trade mainly targeted large emperors (*Lethrinus olivaceus* and *L. xanthochilus*), large snappers *(Lutjanus gibbus*), and moray eels (Muraenidae), which command a higher price in South Tarawa. The fishing shop in Buariki Village was identified as a focal landing site for this survey, with other sites in the villages of Otowae, Tanaeag and Temao.

Due to the opportunity to export and the availability of ice, the small-scale artisanal fishery was important on Onotoa. Fishers tended to operate in local community groups or

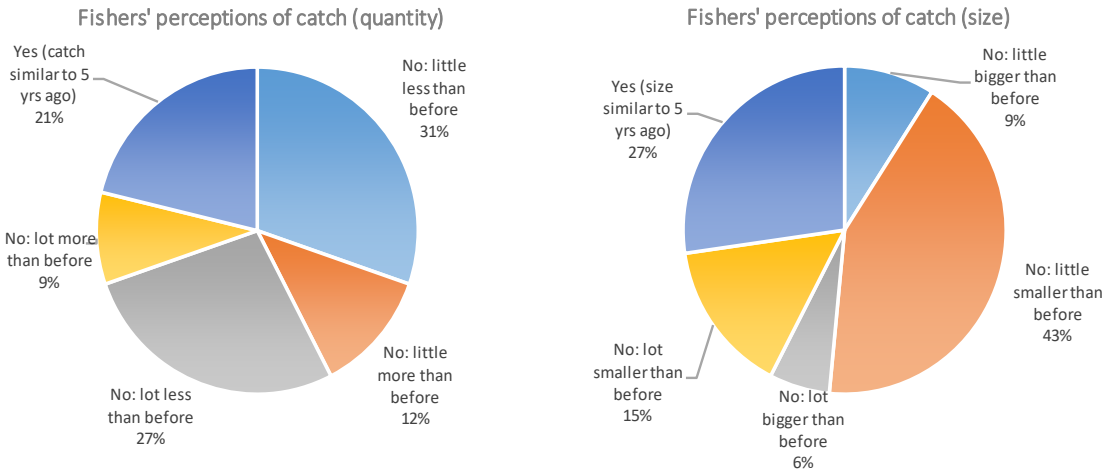

Figure 7. Summary of fishers' perceptions of catch quantity and size of fish catches compared with five years ago at Abemama Atoll.

Figure 8. Example of catch on Onotoa. Left: Artisanal reef fish catch for local market. Right: Drying moray eel from one subsistence fisher. (images: Pauline Bosserelle, SPC)

church groups using motorised boats (owned by either the community or fishing shop) for their fishing. There were 23 fishing events recorded across 5 different fishing activities as follows:

- Handlining: 14 events;
- Spearfishing: 3 events;
- Trolling: 3 events;
- Gillnetting: 1 event;
- Collecting: 1 event; and
- Unknown: 1 event characterised by eel trapping.

Artisanal fishing activities took place in the lagoon and outer reef, with a slightly lower proportion for the latter.

Subsistence fishing

Although the artisanal fishery was important, most fishing activities remained dedicated to subsistence purposes. Subsistence fishing occurred at all surveyed communities but was predominant, if not exclusive, in the village of Otowae (in the southern part of Onotoa). As on Abemama, fishing activities were strongly influenced by tides due to difficulties in accessing lagoonal fishing grounds and returning to shore around low tide with canoes. In total, 74 fishing events were recorded across six fishing activities as follows:

- Handlining: 35 events;
- Unknown: 15 events, mostly characterised by eel trapping specific to Onotoa (Fig. 8);
- Spearfishing: 11 events;
- Trolling: 6 events;
- Gillnetting: 5 events; and
- Gleaning: 2 events.

Subsistence fishers on Onotoa usually fish alone using a dugout paddling or sailing canoe, mostly in the lagoon.

Fishing habits and perceptions

On Onotoa, 39 fishers were interviewed regarding their fishing habits and perceptions of the health of the fisheries there. Gender roles were similar to those at South Tarawa and Abemama, with men involved in the actual fishing, while women marketed and processed catches. In contrast to the other two atolls surveyed, many more fishing trips involving at least two activities were made, with eel trapping often done in conjunction with other fishing activities. Eel traps were baited and/or checked at the same time as other fishing activities such as handlining or spearfishing.

Fishing is a year round activity, subject to bad weather or a need for gear repair and maintenance. The average number of declared fishing trips per week is lower than that for Tarawa and Abemama at 3.0 ± 0.2.

The age of fishers ranged from 21 to 71 years, with an average of 48 ± 2 years, representing an older average compared with South Tarawa and Abemama. Fishers' experience ranged from 6 to over 36 years, with about twice as many fishers having 6–15 years of experience than the above categories (16–25 years; 26–35 years and over 36 years). Overall, fishing activities occur primarily in the lagoon and during the day although there is a small portion of artisanal reef fishing activities that occurr on the outer reef at night.

Similar to Abemama, fishers' perceptions were more contrasting (Fig. 9), with a majority of fishers agreeing that the quantity (51%) and size (44%) of fish caught was (a little or a lot) lower than five years ago. And with these same questions, 28% and 24% of respondents, respectively,

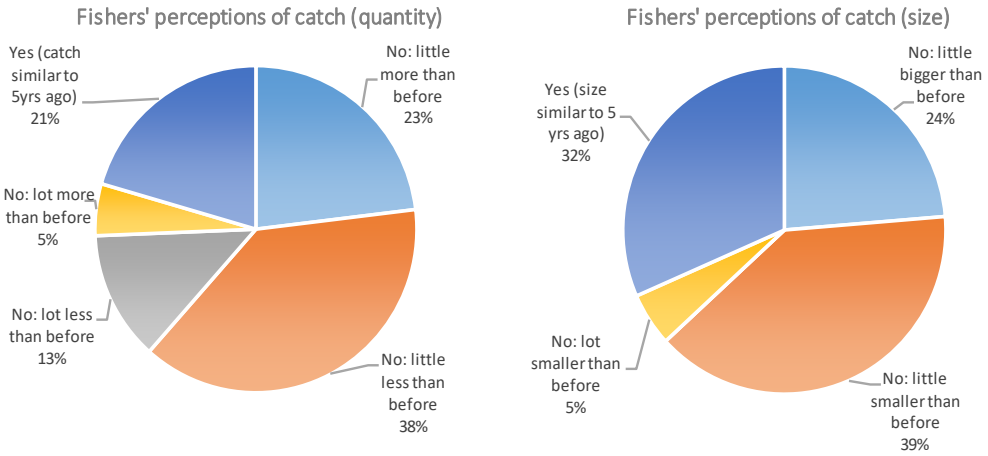

Figure 9. Summary of fishers' perceptions of catch quantity and size of fish catches compared with five years ago at Onotoa Atoll.

considered that catch quantity and size had increased. There was limited concern over the increasing pressure on marine resources due to market availability.

Conclusions

Our creel surveys demonstrated that fishing patterns in the Gilbert Islands of Kiribati are island-specific and largely influenced by the size and density of the resident human population, with greater population size creating greater demand. The greater population size of South Tarawa, which is home to the capital and is the main population centre, has created an export market for other atolls with regular plane and ship access to South Tarawa to sell their products or send seafood to families. While other factors such as habitat quality, abundance of marine resources, alternative income opportunities, and market availabilities also play an important role in fisheries dynamics, population pressure is the primary driver.

While subsistence fishing activities occur across all three atolls, it is more prevalent in the outer islands where there are limited opportunities for commercial sales. Artisanal fishing is a result of a high local demand and driven by people who have other income sources such as from employment or copra trade (i.e. only in the outer island).

Creel surveys enabled different fishing patterns across the three atolls to be identified; however, as with any surveys conducted across widely dispersed and remote locations there are limitations to how much these results can be extrapolated to other atolls and/or other times of the year. This survey complements and enhances the results of the Kiribati HIES survey but multiple creel surveys need to be conducted throughout the year to provide a more comprehensive calibration of the HIES outcomes. Creel survey interviews were conducted on an opportunistic basis and with a focus on fish. Hence, there are very few insights into invertebrate fisheries, which are a significant component of coastal fisheries. While some fisher groups were re-encountered, many were not, which makes averaging through time difficult and unreliable. In addition, interviews and observations were based on a short time period of two weeks and on specific atolls, which is unlikely to be representative of patterns throughout the year. A second "snapshot" creel survey conducted in Abemama at the end of 2019 has confirmed this, with strong differences in fishing activities between the two survey periods.

Our results have provided valuable information on fishing activity across Kiribati, although we stress the importance of surveying fishing activities regularly over annual time frames if the aim is to obtain a more realistic understanding of what is being caught, when it is being caught, how it is being caught, and what happens to it after it has been caught. There are intra-annual fluctuations in fishing patterns that result in significant differences in what and how much is being extracted from local reef systems and these can only be captured through regular sampling programmes. Increased knowledge of atoll fisheries will result in a much more realistic evaluation of fishing pressure leading to more appropriate management measures to ensure the continued and sustainable use of marine resources. Regular surveys also allow for real-time tracking of significant changes to fish stocks such as changes in catch composition or size structure, or reductions in catch per unit effort. Identifying such changes then provides a trigger for further investigations of the status of that particular species.

Increasing human population levels – combined with limited livelihood opportunities and the projected impacts of climate change needs – requires strong and informed management to ensure the sustainable use of marine resources. While Kiribati as a whole should have the capacity to

provide enough protein resources for the entire population, the scattered nature of this country of archipelagos provides a complex setting for achieving this. Creel surveys can assist with providing the knowledge to support management and ensure sustainability but they have to be done appropriately and on a continued and regular basis.

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References

Anon. 2016. Creel and market surveys: A manual for Pacific Island fisheries officers. Pacific Community, Noumea, New Caledonia. 123 p.

Awira R., Friedman K., Sauni S., Kronen M., Pinca S., Chapman L. and Magron F. 2008. Kiribati country report: Profiles and results from survey work at Abaiang, Abemama, Kuria and Kiritimati (May to November 2004). Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C/CoFish). Noumea, New Caledonia: Secretariat of the Pacific Community. 313 p.

Banks R. 2012. Accompanying developing countries in complying with the implementation of Regulation 1005/2008 on illegal, unreported and unregulated (IUU) fishing. Country Evaluation Report. EuropeAid/129609/SER/Multi. GOPA Consultants' Consortium, Republic of Kiribati.

Bell J., Bright P., Gillett R., Keeble G., Kronen M., Passfield K. and Ryan C. 2009a. Importance of household income and expenditure surveys and censuses for management of coastal and freshwater fisheries. SPC Fisheries Newsletter 127:34–39.

Bell J.D., Kronen M., Vunisea A., Nash W.J., Keeble G., Demmke, A., Pontifex S. and Andréfouët S. 2009b. Planning the use of fish for food security in the Pacific. Marine Policy 33:64–76. Available at: https://doi.org/10.1016/j.marpol.2008.04.002

Campbell B. and Hanich Q. 2014. Fish for the future: Fisheries development and food security for Kiribati in an era of global climate change, Project Report: 2014–47. Penang, Malaysia: WorldFish.

Fisheries Division. 2008. Fisheries Division Annual Report 2006. Ministry of Fisheries and Marine Resources Development, Tarawa, Kiribati.

Fisheries Division. 1995. Fisheries Division Annual Report 1994. Ministry of Natural Resource Development, Bairiki, Tarawa, Kiribati.

Gillett R. 2009. Fisheries in the economies of the Pacific Island countries and territories. Capacity Development Series. Mandaluyong City, Metro Manila, Philippines: Asian Development Bank. 484 p.

Gillett R.D. and Tauati M.I. 2018. Fisheries of the Pacific Islands: Regional and national information. Food and Agriculture Organization Fisheries and Aquaculture Technical Paper no. 625. Apia, Samoa. 400 p.

Hunt A. 2019. 20,000th Tails logsheet uploaded. SPC Fisheries Newsletter 157:8.

Hunt A. 2016. Mobile phone data collection app for artisanal fisheries makes debut in Funafuti, Tuvalu. SPC Fisheries Newsletter 149:2.

MFMRD (Kiribati Ministry of Fisheries and Marine Resources Development). 2011. A draft strategic framework for institutional strengthening in fisheries managements and development. Kiribati MFMRD, Pacific Islands Forum Fisheries Agency and Secretariat of the Pacific Community.

Ministry of Internal and Social Affairs (Kiribati). 2008. Onotoa Island 2008 Socioeconomic profile. 40 p.

National Statistics Office. 2016. 2015 Population and housing census, Volume 1: Management and housing census. National Statistics Office Ministry of Finance Bairiki, Tarawa, Republic of Kiribati. 196 p.

Ram-Bidesi V. and Manoa P.E. 2008. A preliminary review of coastal fisheries policy and planning in the Pacific Islands. School of Marine Studies University of the South Pacific, Suva, Fiji Islands.

Rouatu I., Leport G., Pascal N., Wendt H. and Abeta R. 2015. Economic valuation of marine ecosystem services of Kiribati: A report to the Marine and Coastal Biodiversity in Pacific Island countries (MACBIO) Project. Suva: GIZ/IUCN/PREP.

Sharp M., Buffiere B. and Menaouer O. 2018. Household Income and Expenditure Surveys (HIES) in the Pacific region. Presented at the 2018 Pacific Statistics Method Board Meeting, Nadi, Fiji.

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