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FAME
Fisheries, Aquaculture and Marine Ecosystems Division

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Cover picture: Sea cage operations in the Marshall Islands. (image: Ryan Murashige, ©Aquaculture Technologies of the Marshall Islands)

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# When a FAD meets a wave buoy

Figure1. Left: Adrien Moineau and William Sokimi connect the wave buoy to the FAD; Right: the low-profile wave buoy is attached to the FAD and starts sending data. (images: ©SPC)

*On 4 March 2021, the Fisheries, Aquaculture and Marine Ecosystems (FAME) Division and the Geoscience, Energy and Maritime (GEM) Division of the Pacific Community (SPC) collaborated with the French Institute of Research for Development (IRD) and local authorities to connect a wave buoy to a fish aggregating device (FAD) deployed off the west coast of New Caledonia. Two days later, Tropical Cyclone Niran hit the coast of New Caledonia, and the wave buoy recorded wave heights of over 7 m. Two months later, the buoy continues to send FAD position data, and wave height, length and direction data, which are useful for oceanographical purposes. The experiment, which will be replicated in several other Pacific Island countries and territories, is already considered a success.*

## Adding a weather buoy to a FAD

A monitoring wave buoy is an instrument that floats on the ocean's surface and records wave height, direction and position, and transmits these data via satellite to a shore-based station for analysis.

The New Caledonia experiment aimed to measure the wave height for coastal hazard real-time monitoring. The instrument measured a wave height of 7.1 m when Tropical Cyclone Niran passed through, which was significantly higher than the modelled forecast of 5.8 m.

The first two months of this trial have shown that:

- national fisheries agencies responsible for FAD programmes can collaborate with national meteorology authorities to install wave monitoring buoys on FADs;
- a wave buoy can record and transmit wave events during the passage of a significant tropical cyclone;
- the buoy provides the GPS locations of the FAD's surface floats, which describe a standard shape and swing radius, and allows a lost FAD to be tracked for recovery; and
- the buoy provides valuable data for safety-at-sea of fishers and other ocean users.

## The benefits for fisheries agencies

The main benefits of linking a wave buoy to a FAD for fisheries agencies are the possibilities to:

- monitor a FAD position in real time;
- understand how the FAD mooring reacts to currents and winds;
- get a more accurate estimate of the anchor position; and
- track the FAD in case of mooring line failure.

The wave buoy is small and light (5 kg) and does not create any drag on the FAD system. It includes a GPS system with real-time iridium data transmission, which is capable of sending data every hour.

A FAD with a mooring rope length of 1920 m was deployed on 22 December 2020 at a depth of 1500 m. The predicted swing scope (the radius of the circle that the surface floats can form around the anchor position) was 1200 m.

Figure 3. Two months of FAD surface float positions (yellow dots), showing two main trends in relation to the estimated FAD anchor position: a southeast zone when the nearshore oceanographic current actively pushes towards this direction; and a northwest zone when the oceanographic current ceases and the usual southeast trade winds are active, pushing the mooring line towards the northwest.

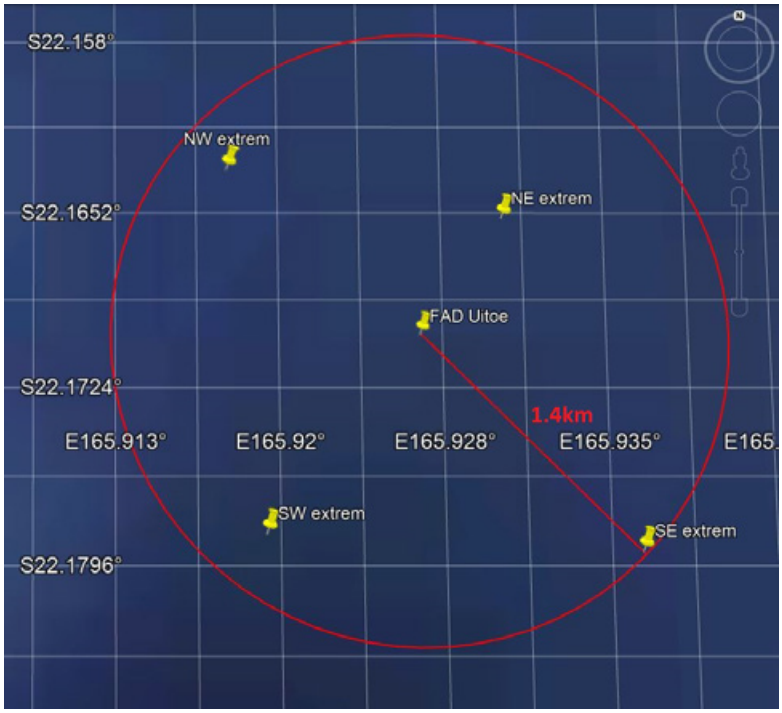


Figure 2. Extreme radius position observed for the FAD.

Over a period of two months, the FAD's recorded position revealed that the FAD's surface floats could be positioned up to 1.4 km from its deployed location and a maximum of 2.5 km was recorded between two positions (Fig. 2). The anchor is, therefore, probably 200 m away, in a southeast direction, from its estimated landing position. This could be another benefit of the position data provided by the wave buoy: determining the exact position of the FAD anchor.

During the passage of Tropical Cyclone Niran, the GPS tracking system on the buoy indicated that the FAD had swung 900 m northeast from its last recorded position, just an hour before.

| WAVE HEIGHT | | DIRECTION | PERIOD | SPREAD |
|---|---|---|---|---|
| 2.1 m | MEAN | 132 ° | 5.6 s | 39 ° |
| | PEAK | 129 ° | 6.0 s | 25 ° |

| WIND SPEED | DIRECTION | SURFACE |
|---|---|---|
| 19.4 kt | 114° | choppy |

| WAVE HEIGHT | | DIRECTION | PERIOD | SPREAD |
|---|---|---|---|---|
| 1.1 m | MEAN | 187 ° | 7.2 s | 36 ° |
| | PEAK | 188 ° | 9.3 s | 25 ° |

| WIND SPEED | DIRECTION | SURFACE |
|---|---|---|
| 3.9 kt | 148° | glassy |

Figure 4. Two sets of ocean state measures provided by the wave buoy.

## Benefits for ocean users

The main benefits of the information provided by the wave buoy to ocean users are the possibility to get ocean weather observation data in real time with the sea state (safety at sea); and know the current FAD location.

Data provided by the wave buoy can also be tailored for navigational safety purpose in various places such as inter-island channels, lagoons, passes, and favourite fishing spots. Ocean state data are crucial information and can be used as a safety parameter for ocean users and fishers at their favourite FAD site.

Figure 4 gives an example of sea state data recorded at two different times. Case 1 (choppy seas, 20 kt of wind and 2 m wave height) is certainly not ideal to be out at sea fishing from a small boat, while case 2 (smooth glassy seas, 3.9 kt of wind and 1 m wave height) seems to be the perfect conditions to go out fishing!

## Benefits for the oceanographical and meteorological agencies

The main benefits of linking a wave buoy to a FAD for meteorological and oceanographical agencies are the possibilities to:

- access observation real-time ocean data for wave prediction and coastal inundation warning;
- provide more accurate "sea bulletins";
- collect extreme weather event data during tropical cyclones;
- improve global numerical wave models by comparing observed and predicted wave data;
- understand nearshore oceanographic current patterns; and
- follow nearshore sea temperature evolution in real time.

Ocean sea surface temperature (SST) is a crucial parameter for monitoring upcoming coral bleaching events. Corals are vulnerable to bleaching when SST exceeds the temperatures normally experienced during the hottest months of the year by +1.0°C. SST is one of the parameters monitored for potential cyclone genesis during cyclone seasons.

Figures 5–8 give three examples of the type of information provided by the wave buoy, and their possible uses.

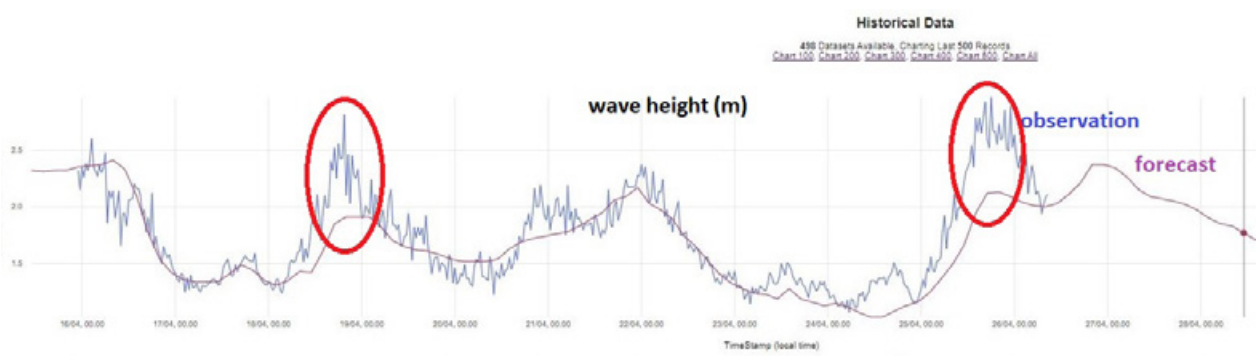


Figure 5. Difference between wave heights observed and wave heights predicted with the Météo France wave model.

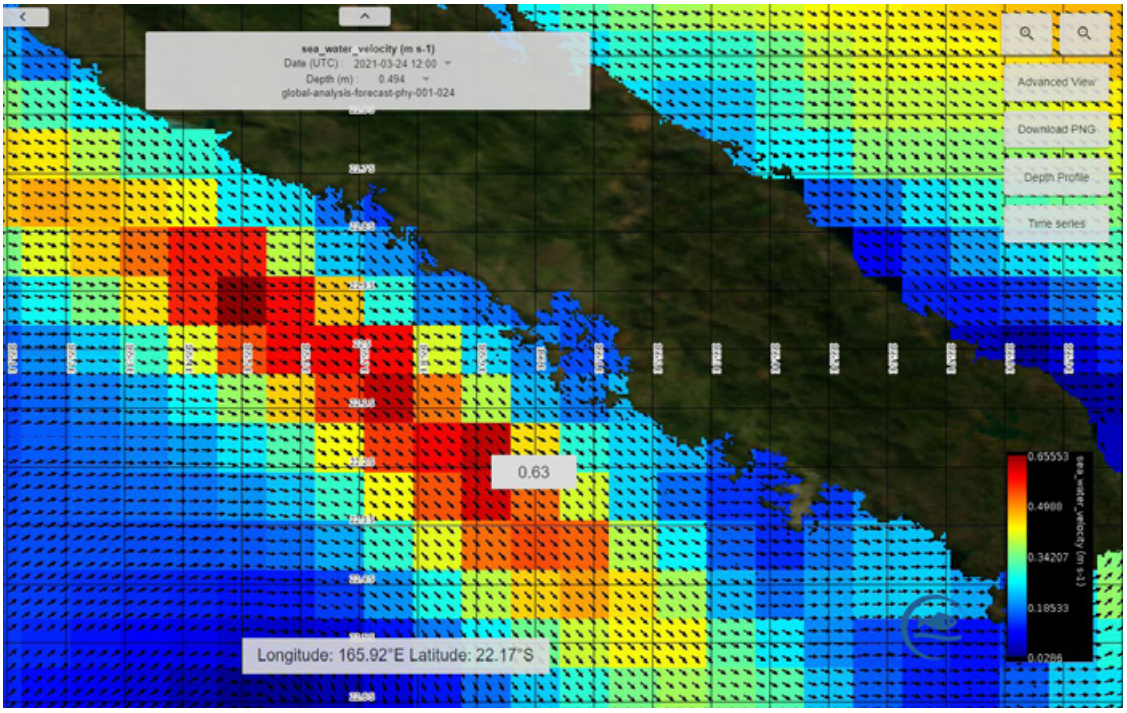


Figure 6. FAD positions recorded in the northwest of the FAD mooring zone by the GPS embedded in the wave buoy confirmed the occurrence of a strong oceanographic current of 0.6 kt towards the southeast, predicted by a MERCATOR[3] numerical model.

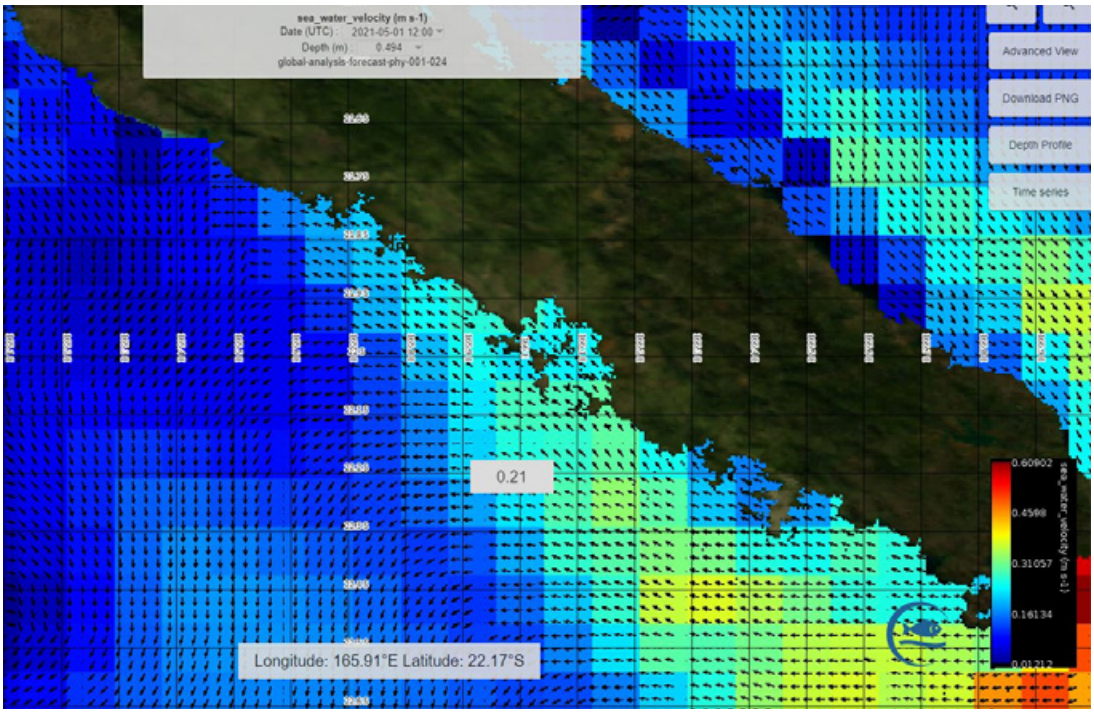


Figure 7. FAD positions recorded in the northwest of the FAD mooring zone by the GPS embedded in the wave buoy confirmed the occurrence of a weak oceanographic current of 0.2 kt towards the northwest, predicted by a MERCATOR[3] numerical model.

[3] https://view-cmems.mercator-ocean.fr/GLOBAL_ANALYSIS_FORECAST_PHY_001_024

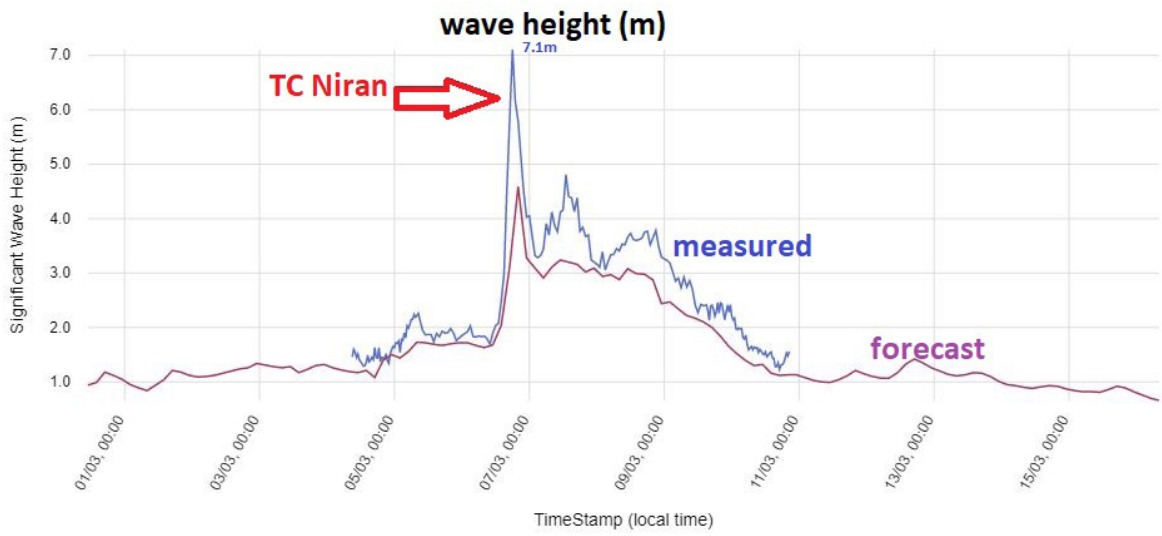


Figure 8. Difference between wave heights observed and wave heights predicted with the Météo France Wave Model during the passage of Tropical Cyclone Niran.

## Other possible benefits for climate observations

Small wave buoy systems, as the one used in New Caledonia, can be equipped with ocean parameters sensors to record ocean temperature, pH, current and other data, providing real-time data to monitor anomalies such as warm water events that provoke coral bleaching.

Using the existing Pacific Islands FAD network, a great ocean observation network could be put in place relatively easily. All moorings are already in place (the FADs), they just need the addition of small wave buoys.

## Regional collaboration benefit

The Pacific Ocean represents 20% of the global ocean area. There are more than 300 platforms providing wave observations globally but less than 1% are in installed in the Pacific Small Island Developing States.

Recently, projects focused on tailored early warning system for coastal communities' inundation forecast in the Pacific Islands region have been able to increase this thin number of ocean observation equipment deployed in the Pacific.

More regional and multi-sectoral partnerships, such as the ones that allowed this FADs or swell buoy to take place, are needed to extend the area surveyed, increase the benefits to a wider range of stakeholders and, in the end, improve the safety of coastal populations and ocean users.

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# The influence of the natural climate variability of La Niña and El Niño events on tunas. Natural until when?[1]

El Niño is the warm phase of the El Niño Southern Oscillation (ENSO) climate pattern, originating from the tropical Pacific Ocean but influencing the world's climate. This phenomenon, which occurs every three to seven years, leads to physical and ecological impacts throughout the Pacific basin, with important connections to other oceanic basins. A typical El Niño event was first scientifically described (Bjerknes 1966)[2] as being triggered by a weakening of the trade winds leading to an eastward expansion of warm equatorial waters accumulating in the western equatorial Pacific, a region called the warm pool, with a sea surface temperature above 29°C. These warm waters reach the eastern Pacific first, and then propagate poleward along the coasts of North and South America where they replace the typically colder and more productive surface waters. The name El Niño (which refers to the Christ child in Spanish) was first linked to the time of year (around December) during which the warm waters reach the Peruvian coast with dramatic consequences on the anchovy population. When the situation reverses – with strong trade winds exceeding their average intensity and pushing the warm equatorial waters far to the west – the productivity of coastal Peruvian and Californian waters reaches a maximum intensity as does the productivity in eastern and central equatorial waters. This cold phase of ENSO is called La Niña.

We now know that the profound changes driven by ENSO – at the scale of the whole Pacific Ocean – have an impact on many ecosystems and marine resources, including changes in the distribution of tunas. El Niño or La Niña directly affect the horizontal movements and vertical distributions of the main exploited tuna and tuna-related species (e.g. skipjack, yellowfin, bigeye, albacore, swordfish and marlins). Purse-seine tuna catches and tagging data in the central western Pacific have clearly demonstrated a spatial shift in skipjack abundance that follows the eastward extension of the warm pool during El Niño, or conversely a concentration in the west during La Niña. These large east–west displacements of skipjack in the equatorial region associated with ENSO can be simulated with the spatially explicit ecosystem and fish population dynamics model SEAPODYM, which is used by the Pacific Community's Oceanic Fisheries Programme. Model results are consistent with observed changes in purse-seine fishing grounds and tagging data (Fig. 1). These results suggest that the eastward extension and westward contraction of tunas and tuna-like fish and their fisheries during El Niño and La Niña phases, are driven by changes in temperature, prey distribution (under the influence of currents), and dissolved oxygen concentration. However, not all ENSO events are equal. Despite several classical phases of development, each ENSO event is unique in terms of its intensity and impact, and the sequence of cold, neutral and warm phases. The complexity of these patterns is the focus of intense research efforts because it is the key to improving our predictive capacity for climate and for ecosystem and fisheries management. Analyses of the spatial patterns of El Niño events reveal two main types – an eastern Pacific El Niño and a central Pacific (sometimes called Modoki) El Niño. The largest El Niño event in 2015–2016 was a central Pacific event, and despite it being a strong one (Fig. 1), it did not significantly impact primary production in eastern Pacific waters as had other western Pacific El Niño events. To add to this complexity, the interannual natural ENSO variability is modulated by another natural climate signal, the Interdecadal Pacific Oscillation (IPO), which seems to be responsible for multi-decadal regimes dominated by higher frequencies of El Niño or La Niña events.

Through its various applications since the 2000s, the SEAPODYM simulations consistently pointed to a positive effect of El Niño events on skipjack larvae recruitment, and the spatial redistribution of juvenile and adult fish. Unfortunately, there are no sufficient and direct abundance surveys, such as eggs and larvae sampling, to monitor large-scale variability of tropical tuna species' larval densities. However, this variability propagates through the population structure and can be detected (with some delay) in the exploited stock, either through the analysis of catch rates and size frequencies of catch, or inferred from model and stock assessment analyses based on these datasets. The skipjack link between ENSO and larvae recruitment is confirmed by an independent estimate of recruitment (Fig. 2) of the Western and Central Pacific Fisheries Commission, which uses the standard stock assessment model MULTIFAN-CL. In that case the recruitment series is estimated from catch and tagging data, without any oceanographic information.

[1] Summarised and updated from: Lehodey P., Bertrand A., Hobday A., Kiyofuji H., Mc Clatchie S., Menkes C. E., Pilling G., Polovina J. and Tommasi D. 2020. ENSO impact on marine fisheries and ecosystems. In: McPhaden M.J., Santoso A. and Cai W. (eds). El Niño Southern Oscillation in a Changing Climate. Book Series: Geophysical Monograph Series. https://agupubs.onlinelibrary.wiley.com/doi/10.1002/9781119548164.ch19

[2] Bjerknes, J. 1966. A possible response of the atmospheric Hadley circulation to equatorial anomalies of ocean temperature. Tellus 18(4):820–829. doi: 10.3402/tellusa.v18i4.9712

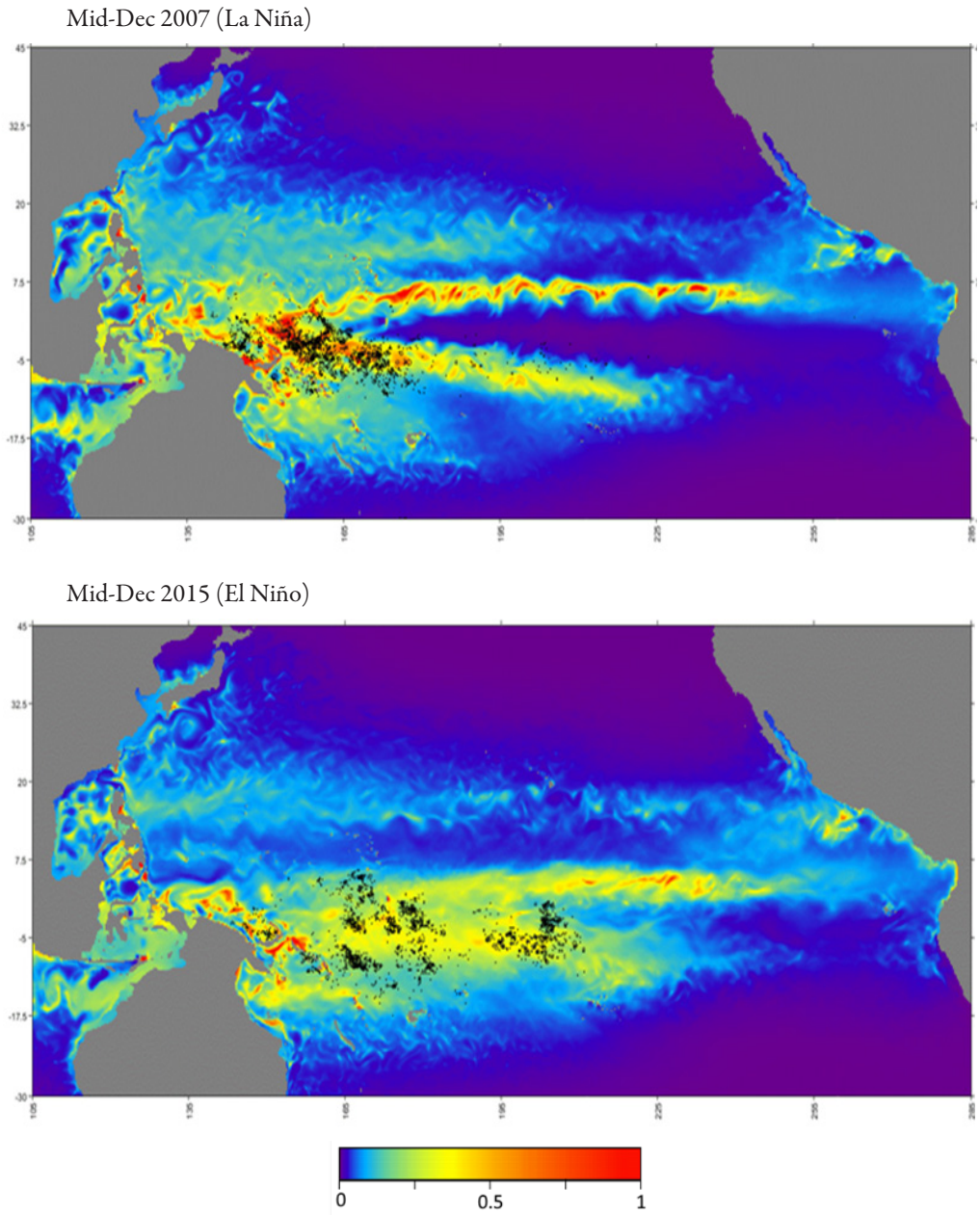


Figure 1: Impact of ENSO on distribution of Pacific skipjack tuna population and fisheries. Biomass distribution of skipjack tuna predicted with SEAPODYM (t per km$^2$) and observed catch (black circles) during typical La Niña and El Niño situations.

It is worth noting that the correlation between the series of skipjack recruitment and the ENSO indicator (SOI: Southern Oscillation Index) is achieved after the recruitment series has been detrended (i.e. the increasing linear average trend is removed to keep only the interannual variability). Is this tendency due to the influence of climate change? Increasing amplitudes of El Niño events since the 1980s in the central equatorial region has been reported, and the last El Niño event (2015–2016) generated an unprecedented warm temperature anomaly in this region. Its extreme intensity has been attributed in part to unusually warm water conditions in 2014 and to long-term background warming. Also, unlike in previous strong El Niño events, the 2015–2016 event was not followed by a strong La Niña phase, depriving this region of a strong subsequent recovery of the equatorial upwelling and high productivity associated with it. However, given the relatively limited period of modern observations of climatic and oceanographic conditions, it is possible that such an extreme event, and the absence of a subsequent La Niña event is still within the range of natural variability that occurred for ENSO in the last few centuries. The latest projections of ENSO under the International Panel on Climate Change business-as-usual emission scenarios suggest more frequent and more extreme and eastern Pacific El Niño events, and extreme La Niña events associated with the mean-state changes under greenhouse warming. These

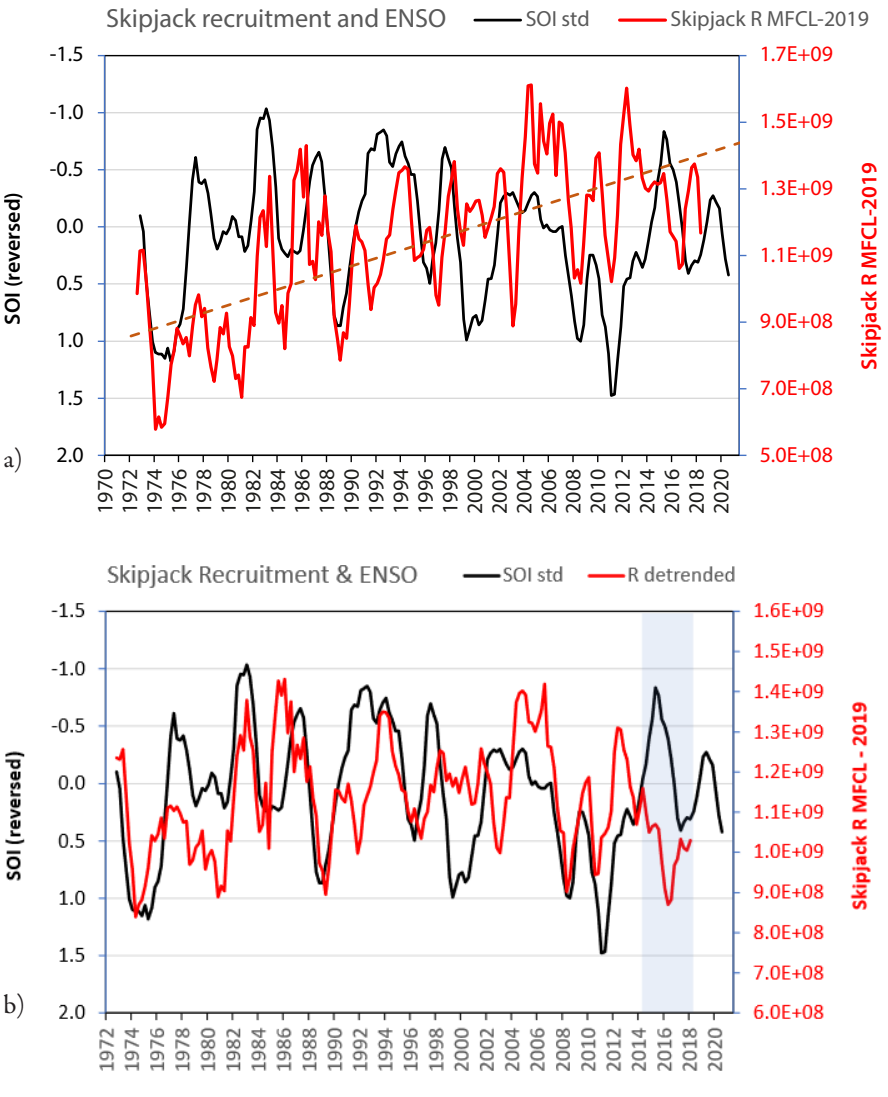


Figure 2. The impact of ENSO on Pacific skipjack tuna recruitment. Comparison of skipjack tuna recruitment index estimated in 2019 with the model MUTIFAN-CL for the Western and Central Pacific Fisheries Commission stock assessment study and the Southern Oscillation Index (SOI reversed axis). A high negative (positive) SOI index indicates El Niño (La Niña). The series are presented before (a) and after (b) detrending of the recruitment time series. Note that typically, standard stock assessment models hardly estimate the last years of recruitment (shaded area) due to the absence of information on what will become the future adult stock.

projections, however, still include many uncertainties due to model biases.

New simulations are currently being carried out with SEAPODYM to analyse recent changes in the dynamics of tuna populations and fisheries, and to compare these results with stock assessment results. The focus of the analyses is not just on the highly tropical skipjack species that seem to thrive in a warming ocean, at least so far, but also more sub-tropical to temperate tunas, especially albacore. This species might have the most to lose from the warming of the ocean, which would impact its subequatorial spawning grounds. The recent La Niña that has been experienced in recent months will also provide another good benchmark to test the model's predictive skills.

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# First year of data collection on beached drifting FADs in Wallis and Futuna

A fish aggregating device (FAD) is a human-made anchored or drifting object that is intentionally placed in the ocean to attract pelagic fish, such as tuna. A drifting FAD (dFAD) typically consists of a bamboo raft with a 50-m appendage of old ropes or nets hanging below it, and is equipped with a solar-powered satellite buoy, and often an echosounder, so that fishers can track the dFAD's position and assess the tuna aggregated underneath it.

In high-seas waters, the purse-seine fishery deploys thousands of dFADs each year to aggregate and catch tuna. These dFADs eventually drift into coastal waters where they become marine pollution, and may damage coral reefs, or entangle threatened marine species (Banks and Zaharia 2020; Escalle et al. 2019).

In early 2020, the Wallis and Futuna fisheries department, with support from the Pacific Community (SPC) Oceanic Fisheries Programme, launched a project to collect data on beached dFADs and/or dFADs that had drifted into the coastal waters of Wallis and Futuna from elsewhere in the Pacific. Information regarding dFADs found in Wallis and Futuna are important for quantifying and better understanding the impacts of dFADs locally and in the Pacific in general. Results from this programme will support sustainable fisheries management and help protect the environment through scientific advice to governments and regional management bodies (e.g. the Western and Central Pacific Fisheries Commission).

Following an awareness and communication campaign in Wallis and Futuna, the public was invited to report any dFADs they found to the fisheries department (Service de la pêche, DSA Wallis et Futuna). In just the first year of this programme, 159 distinct dFADs and/or satellite buoys have been reported. The majority (93) were unattached satellite buoys, 43 were dFADs without buoys attached, and 22 included the dFAD with a satellite buoy attached (Fig. 1). Most dFADs were reported from the east side of Wallis Island (Fig. 2 and Table 1).

Most of the retrieved dFAD components were recycled as hammocks, nets for chicken pens, moorings, or anchored FADs. Some satellite buoys have been taken apart as well, with the components re-used locally, while others have been kept alongside houses or brought to the fisheries department. A project to re-purpose some satellite buoys was implemented with a high school

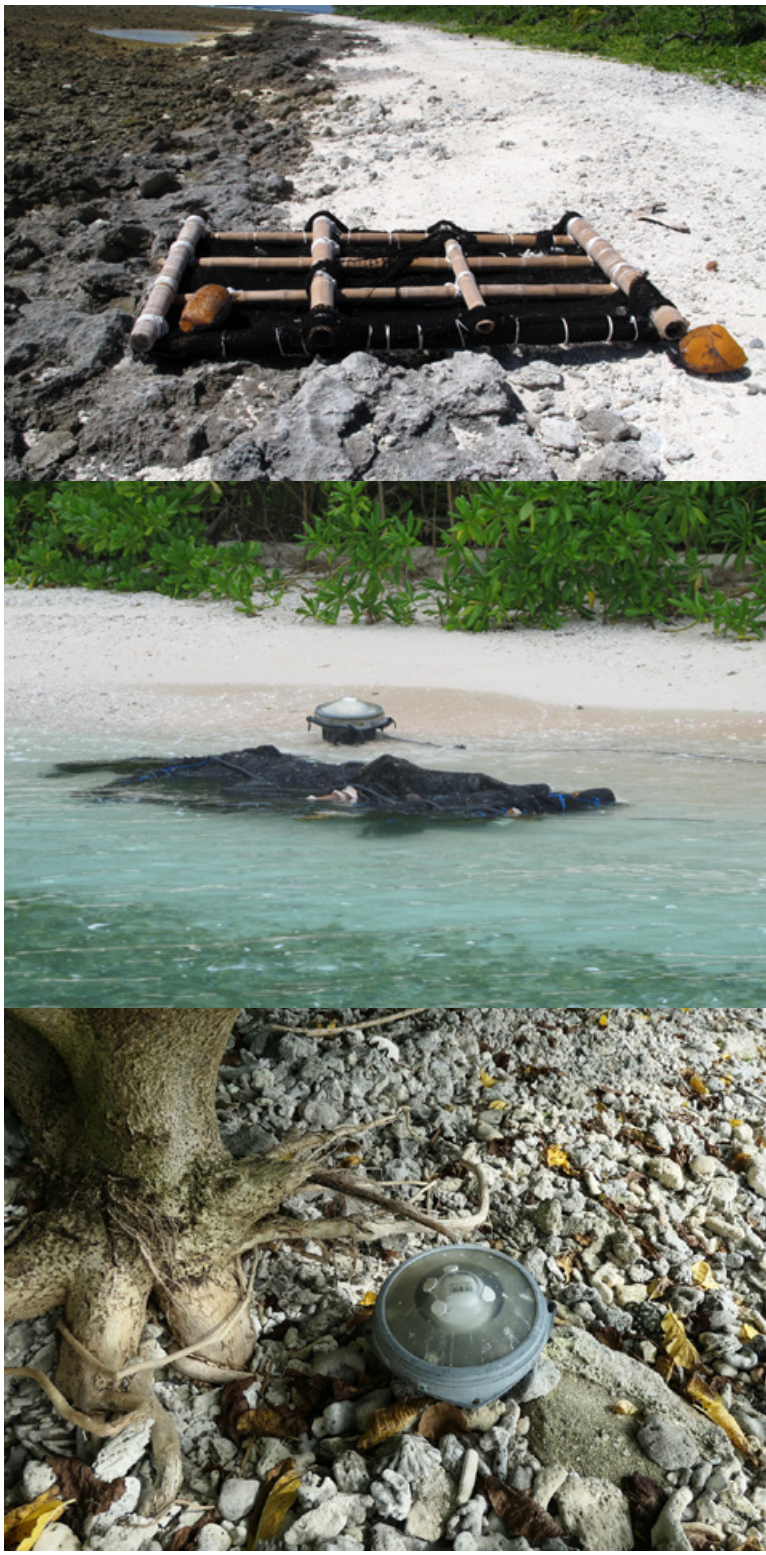

Figure 1. A dFAD found beached (a), a dFAD with a satellite buoy recently stranded (b), a detached satellite buoy found in Wallis and Futuna (c). (images ©SPC)

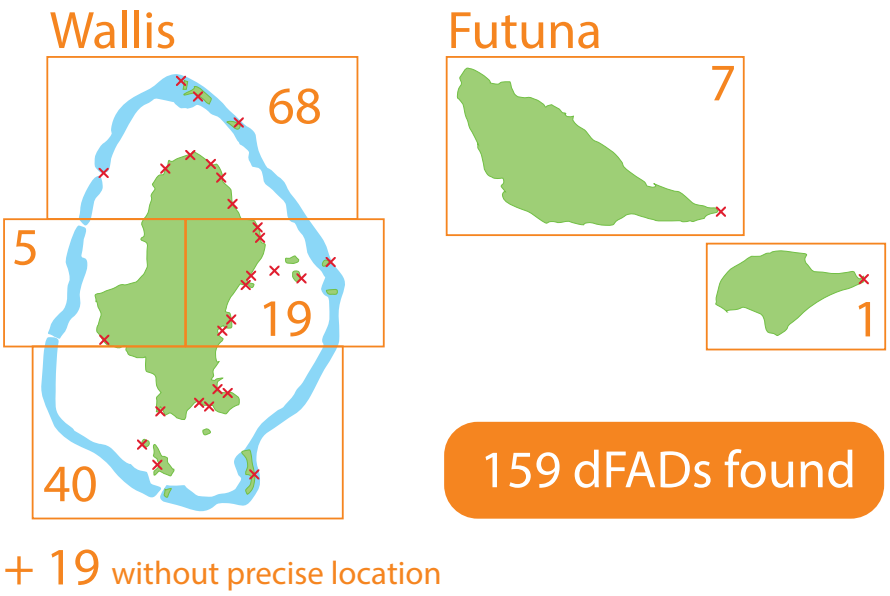


Figure 2. Known positions of 159 dFADs and buoys found beached in Wallis and Futuna over the course of the programme. Note: dFADs and buoys may have been found in previous years but reported to the fisheries department since the beginning of the programme.

class. Students transformed buoys into outdoor solar lamps and phone chargers for the Mata Utu high school (Fig. 3).

While the impact on the environment is difficult to fully assess, it can be noted that no animals were found entangled in the nets of the beached dFADs. Some dFADs, however, were found caught on corals (Table 1), although the degree of damage could not be assessed. When still drifting in the lagoon or ocean, dFADs can aggregate fish and be used by local fishers; one fisher reported that he had caught a Spanish mackerel on a dFAD.

In terms of marine pollution, most of the dFADs found consisted of a bamboo raft with various plastic components attached (PVC tubes, ropes, nets, buoys, tarps). These dFADs were rarely found completely intact with both the raft and the netting hanging below it (10% of the findings) (see Fig. 1). Typically, only the raft of a dFAD was found. Rafts were found either intact (50% of the findings) or damaged (40% of the findings), which could indicate they had been drifting a long time before reaching Wallis and Futuna. The satellite buoys – made of solar panels and electronic components – were present in most of the findings (72%).

Figure 3. Mata Utu high school students re-purposed washed-up dFAD satellite buoys into autonomous outdoor solar lamps for the main entry of the school, or used as phone chargers. (images: ©Mata Utu High School)

The programme is continuing in Wallis and Futuna, with the population still encouraged to report any dFAD or satellite buoy found beached or drifting close to shore. The data collected are part of a wider regional data collection effort (see box below), intended to be the basis for scientific analyses to guide sustainable management of the purse-seine dFAD fishery in the Pacific.

Table 1. Location of dFADs found in Wallis and Futuna.

| Status | Location | Number found |
|---|---|---|
| Picked up previously | House or garden | 77 |
| | Wharf | 6 |
| Found along the coast | Beach | 41 |
| | Reef flat | 6 |
| | Rocky shore | 3 |
| | Mangrove | 1 |
| | Effluent | 1 |
| Found at sea | Drifting in the lagoon | 9 |
| | Ocean | 5 |
| | Coral reef | 10 |
| **Total** | | **159** |

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## Regional database of dFADs found in coastal areas

The data currently available to quantify beached dFADs have been shown to be under-estimates, given the frequent deactivation of dFADs when drifting outside the intended fishing area (see Escalle et al. 2020b), and do not contribute information regarding ecosystem impacts. Hence, data collected locally is the key to precisely assessing beaching rates and impacts.

In the Pacific region, data collection programmes on dFADs reaching coastal waters and/or beaching have also started in the Cook Islands and French Polynesia in 2020, as well as in the Federated States of Micronesia and the Republic of the Marshall Islands in 2021 (Escalle et al. 2019, 2020a). These programmes involve local communities reporting their findings to fisheries officers, who enter data onto forms and in their country or territory's database. Data are then transferred to SPC, where staff compile all the data into a regional database. In parallel, other initiatives have also led to additional data on beached dFADs being included in the regional database, for instance through data collection at Palmyra Atoll since 2009 (The Nature Conservancy) or in Hawaii since 2015 (Center for Marine Debris Research) (Escalle et al. 2020a). Opportunistic data collection has also been reported to SPC since 2018, including through SPC's existing data collection networks, and includes reports from Australia, New Caledonia, Pitcairn Islands, Samoa, Tuvalu and Vanuatu (Escalle et al. 2020a).

Relevant quantification of the occurrence of dFADs beaching or drifting nearshore, as well as an assessment of resulting ecosystem impacts, will be possible through continued data collection over several years and covering the largest area possible. Collaboration with several Pacific Island countries and territories is key to the success of the database and will help guide sustainable management of dFAD fishing in each country and the whole Pacific.


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# What is the nutritional value of reef fish and mud crabs?

Thanks to long-term efforts made by the Pacific Community, the Food and Agriculture Organization of the United Nations and the University of Wollongong, a Pacific Nutrient Database (PNDB) and its accompanying user guide were made public in December 2020. The PNDB gives access to the nutritional values of the main foods consumed in the Pacific Islands region, including marine foods that are essential for food and nutrition security of coastal communities. The PNDB is designed to facilitate the use of data, primarily derived from household income and expenditure surveys, to conduct poverty, nutrition and food security-oriented analysis in the Pacific region. Through its concordance with international classification and food groups, the database facilitates rapid and comparable consumption-oriented analysis, which will guide evidence-driven policy to support vulnerable populations, such as those who live in poverty and/or are food insecure.

At a national and regional level, the PNDB is an instrument that will support the establishment of a consumption baseline to work towards alleviating the triple burden of malnutrition – the coexistence of undernourishment, nutrient deficiencies and obesity – that is hampering the development of Pacific people and their economies. It will also support the derivation of an evidence base to alleviate poverty, achieve food security and improve nutrition.

In the context of Pacific food systems, which fisheries are central to, the PNDB includes 55 different marine-based foods, belonging to four main categories:

1) Fresh, chilled or frozen fish (13 species or groups of species)
2) Fresh, chilled, frozen seafood, such as crustaceans, molluscs and other shellfish, and sea snails (20 species or groups of species)
3) Dried, salted, pickled or smoked fish and seafood (3 groups of products)
4) Other preserved or processed fish and seafood-based products, such as canned fish, caviar, roe and fish pie (19 groups of products)

For each of these marine-based foods, the PNDB provides edible portion conversion factors that enable, for example, the conversion of whole fish into a quantity that is an average edible amount. PNDB then provides conversion factors for this 100 g of edible fish and other foods to allow for the estimation of dietary energy consumption (kcal) and access to nutrients. The PNDB includes information access to 22 macronutrients and micronutrients, including iron, calcium and vitamins A, B, C and E for these 55 marine-based foods (and 800+ other food items). Table 1 gives an example of the information available in the PNDB.

Finally, the PNDB includes pre-assigned food classifications, such as Pacific Guidelines for a Healthy Living,[1] the FAO/WHO Global Individual Food consumption Data Tool,[2] FAOSTAT,[3] the Household Dietary Diversity Score,[4] and the United Nations Harmonised System.[5] All of these allow the production of statistics on the consumption of fish, and other foods in the database, by these food classifications, which aim to inform the improvement of Pacific Island diets and to answer questions such as "What is the nutritional value of coastal fisheries?".

The PNDB User Guide can be download at:
http://www.fao.org/publications/card/en/c/CB0267EN/
and the PNDB dataset is available here:
https://microdata.pacificdata.org/index.php/catalog/755

The PNDB content can be explored and downloaded via the user-friendly PDH.stat Data Explorer. Various tools also allow users to connect to the dataset via Excel, Stata, R, Python and PowerBI. See Pacific Data Hub User Guide.

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[1] http://purl.org/spc/digilib/doc/sgg28
[2] http://www.fao.org/gift-individual-food-consumption/en/
[3] http://www.fao.org/faostat
[4] http://www.fao.org/nutrition/assessment/tools/household-dietary-diversity/en
[5] https://unstats.un.org/unsd/tradekb/Knowledgebase/50097/Trade-Statistics-Coding-Systems

Table 1. Nutritional values of 25 marine-based foods.

| | Edible portion (%) | Inedible portion (%) | Water (g) | Energy (kcal) | Energy (kJ) | Protein (g) | Total fat (g) | CHO available (g) | TDF (g) | Na (mg) | Mg (mg) | K (mg) | Ca (mg) | Fe (mg) | Z (mg) | Retinol (µg) | β-carotene equiv. (µg) | Tot. vitamin A equiv. (µg) | Thiamin (mg) | Riboflavin (mg) | Naicin (mg) | Vitamin B12 (µg) | Vitamin C (mg) | Vitamin E (mg) | Cholesterol (mg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fresh. chilled or frozen fish | | | | | | | | | | | | | | | | | | | | | | | | | |
| Spanish mackerel. "Walu" | 67 | 33 | 75.00 | 112.00 | 470.00 | 20.90 | 3.10 | 0.000 | 0.000 | 137.00 | 32.00 | 158.00 | 7.00 | 0.50 | 0.60 | 17.00 | 0.00 | 17.00 | 0.760 | 0.080 | 2.700 | 0.550 | 0.00 | 0.40 | 41.00 |
| Sardine | 65 | 35 | 72.90 | 105.64 | 442.00 | 19.70 | 2.90 | 0.000 | 0.000 | 665.00 | 46.00 | 352.00 | 725.00 | 3.95 | 3.10 | 106.00 | 0.00 | 106.00 | 0.019 | 0.073 | 7.390 | 0.500 | 0.00 | 0.46 | 129.00 |
| Snapper | 85 | 15 | 75.30 | 110.66 | 466.31 | 20.13 | 3.20 | 0.340 | 0.000 | 78.00 | 34.00 | 502.00 | 18.00 | 0.58 | 0.53 | 31.00 | 0.00 | 31.00 | 0.110 | 0.020 | 6.980 | 0.700 | 0.20 | 0.26 | 44.00 |
| Sweetlip. painted | 43 | 57 | 78.00 | 84.00 | 352.00 | 19.80 | 0.20 | 0.500 | 0.000 | 84.00 | 37.00 | 339.00 | 39.00 | 0.40 | 0.60 | 29.00 | 0.00 | 29.00 | 0.010 | 0.090 | 3.100 | 2.110 | 0.00 | 0.70 | 47.00 |
| Tuna. albacore | 58 | 42 | 68.00 | 150.00 | 628.00 | 26.40 | 4.70 | 0.300 | 0.000 | 35.00 | 41.00 | 431.00 | 9.00 | 1.00 | 0.50 | 20.00 | 0.00 | 20.00 | 0.050 | 0.030 | 2.100 | 0.700 | 0.30 | 0.50 | 53.00 |
| Tuna. skipjack | 58 | 42 | 64.70 | 178.58 | 748.72 | 25.63 | 8.20 | 0.570 | 0.000 | 31.00 | 36.00 | 381.00 | 3.00 | 1.70 | 0.53 | 78.00 | 0.00 | 78.00 | 0.050 | 0.030 | 6.800 | 0.700 | 0.30 | 0.26 | 53.00 |
| Tuna. yellowfin. bigeye | 70 | 30 | 74.03 | 109.00 | 456,05 | 24.40 | 0.49 | 0.000 | 0.000 | 45.00 | 35.00 | 441.00 | 4.00 | 0.77 | 0.37 | 18.00 | 0.00 | 18.00 | 0.118 | 0.115 | 18.475 | 2.080 | 0.00 | 0.24 | 39.00 |
| Fish. reef. not further specified | 89 | 11 | 76.00 | 110.00 | 458.00 | 19.50 | 3.30 | 0.300 | 0.000 | 73.00 | 40.00 | 370.00 | 19.00 | 0.70 | 0.60 | 31.00 | 0.00 | 31.00 | 0.060 | 0.070 | 3.000 | 2.300 | 0.70 | 0.80 | 51.00 |
| Fish. pelagic/ocean. not further specified | 79 | 21 | 70.89 | 150.80 | 631.71 | 21.02 | 7.17 | #N/A | 0.000 | 83.03 | 33.28 | 401.10 | 21.10 | 1.09 | 0.74 | 45.07 | 0.00 | 51.68 | 0.076 | 0.108 | 6.473 | 1.155 | 0.27 | 0.49 | 53.76 |
| Fresh. chilled. frozen seafood e.g. crustaceans. molluscs and other shellfish. sea snails | | | | | | | | | | | | | | | | | | | | | | | | | |
| Beche de mer/sea cucumber | 80 | 20 | 83.00 | 53.00 | 221.00 | 12.80 | 0.10 | 0.000 | 0.000 | 716.00 | 119.00 | 37.00 | 87.00 | 1.20 | 0.20 | 0.00 | 0.00 | 0.00 | 0.000 | 0.030 | 0.000 | 0.000 | 2.00 | 0.00 | 0.00 |
| Crab. coconut | N/A | N/A | N/A | 97.00 | 405.85 | 22.00 | 0.90 | 0.000 | 0.000 | 395.00 | 40.00 | 310.00 | 49.00 | 0.20 | 3.40 | N/A | N/A | 2.00 | 0.000 | 0.060 | 2.100 | 3.200 | 0.00 | 1.70 | N/A |
| Crab. mud | 20 | 80 | 77.70 | 97.50 | 407.94 | 19.95 | 1.90 | 0.000 | 0.000 | 372.00 | 40.00 | 325.50 | 116.00 | 1.40 | 4.30 | 199.00 | 232.00 | 110.00 | 0.025 | 0.115 | 2.750 | 5.100 | 2.50 | 2.00 | N/A |
| Octopus | 79 | 21 | 81.00 | 73.00 | 306.00 | 16.40 | 0.70 | 0.100 | 0.000 | 280.00 | 29.00 | 286.00 | 16.00 | 0.60 | 1.60 | 43.00 | 0.00 | 43.00 | 0.030 | 0.090 | 2.200 | 19.000 | 0.00 | 0.70 | 90.00 |
| Seaweed | 100 | 0 | 93.50 | 9.00 | 36.50 | 0.60 | 0.30 | 0.000 | 1.900 | 810.00 | 51.50 | 163.00 | 56.00 | 8.00 | 0.00 | 0.00 | 593.50 | 49.50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.00 | 0.30 | 0.00 |
| Sici-shell. meat | N/A | N/A | 71.00 | 116.00 | 486.00 | 26.60 | 0.90 | 0.000 | 0.000 | 714.00 | 66.00 | 116.00 | 2.00 | 2.30 | 1.50 | 0.00 | 107.00 | 9.00 | 0.000 | 0.000 | 0.700 | 0.000 | 0.00 | 0.00 | 0.00 |
| Trochus | N/A | N/A | N/A | 81.00 | 338.90 | 14.70 | 2.40 | 0.000 | 0.000 | 714.00 | 66.00 | 116.00 | 2.00 | 2.30 | 1.50 | N/A | N/A | 11.00 | 0.000 | 0.100 | 1.400 | 57.050 | 0.00 | 0.40 | N/A |
| Squid. not further specified | 67 | 33 | 79.25 | 85.41 | 360.16 | 17.95 | 1.45 | 0.095 | 0.000 | 290.00 | 47.50 | 206.00 | 13.40 | 0.95 | 1.16 | 0.00 | 0.00 | 0.00 | 0.075 | 0.040 | 3.350 | 1.250 | 2.50 | 1.73 | 186.00 |
| Prawn/shrimp. not further specified | 75 | 25 | 76.13 | 92.24 | 390.54 | 20.44 | 1.17 | 0.000 | 0.000 | 249.00 | 44.00 | 233.50 | 89.00 | 1.56 | 1.31 | 27.00 | 2.50 | 27.42 | 0.015 | 0.045 | 6.555 | 1.450 | 1.00 | 1.81 | 150.50 |
| Crayfish / lobster. not further specified | 68 | 32 | 74.87 | 94.86 | 398.60 | 20.00 | 1.03 | 0.908 | 0.000 | 133.00 | 40.98 | 296.75 | 59.43 | 0.97 | 4.53 | 7.50 | 29.50 | 10.46 | 0.059 | 0.067 | 3.771 | 2.308 | 1.75 | 0.97 | 63.25 |
| Dried. salted. pickled or smoked fish and seafood | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fish. dried. salted | 100 | 0 | 43.00 | 185.00 | 776.00 | 42.00 | 1.50 | 0.400 | 0.000 | 1730.00 | 60.00 | 47.00 | 174.00 | 1.70 | 1.20 | 0.00 | 0.00 | 0.00 | 0.060 | 0.310 | 4.600 | 12.000 | 0.00 | 2.40 | 90.00 |
| Fish. smoked | 100 | 0 | 66.00 | 152.00 | 634.00 | 27.20 | 3.70 | 2.100 | 0.000 | 593.00 | 40.00 | 368.00 | 2.00 | 0.00 | 0.60 | 28.00 | 0.00 | 28.00 | 0.060 | 0.000 | 8.300 | 0.610 | 0.00 | 0.40 | 98.00 |
| Other preserved or processed fish and seafood-based products | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fish finger. crumbed. purchased frozen | 100 | 0 | 55.00 | 224.00 | 938.00 | 11.60 | 11.30 | 19.100 | 1.000 | 320.00 | 25.00 | 219.00 | 35.00 | 1.00 | 0.50 | 410.00 | 0.00 | 410.00 | 0.070 | 0.050 | 1.500 | 0.800 | 0.00 | 1.50 | 31.00 |
| Sardines. canned. not further specified | 100 | 0 | 64.07 | 192.52 | 805.30 | 20.37 | 12.30 | 0.167 | 0.100 | 489.33 | 52.00 | 346.67 | 460.33 | 3.20 | 2.27 | 23.67 | 0.00 | 23.67 | 0.010 | 0.263 | 9.033 | 9.533 | 0.00 | 2.13 | 91.33 |
| Tuna. canned in brine | 79 | 21 | 75.00 | 109.00 | 457.00 | 22.10 | 2.20 | 0.000 | 0.000 | 390.00 | 30.00 | 272.00 | 8.00 | 1.00 | 0.90 | 15.00 | 0.00 | 15.00 | 0.000 | 0.100 | 7.400 | 3.800 | 0.00 | 0.60 | 43.00 |
| Tuna. canned in oil | 80 | 20 | 57.00 | 290.00 | 1212.00 | 20.80 | 23.20 | 0.000 | 0.000 | 417.00 | 27.00 | 270.00 | 5.00 | 0.60 | 0.80 | 19.00 | 0.00 | 19.00 | 0.000 | 0.090 | 8.100 | 4.800 | 0.00 | 0.60 | 33.00 |

# Pacific Fisheries Leadership Programme navigates COVID-19 through online learning

The Pacific Fisheries Leadership Programme (PFLP) is an adaptive professional, leadership development programme. It was initiated by the New Zealand Ministry of Foreign Affairs and Trade, after consulting Pacific leaders on how New Zealand can support Pacific Island countries and territories achieve the goals of the Regional Roadmap for Sustainable Pacific Fisheries (FFA and SPC 2015). A review demonstrated that a key challenge in achieving the goals of the Roadmap is the lack of leadership skills within emerging leaders. The overall goal of the programme is to "increase economic and food security benefits from well-managed and sustainable fisheries and aquaculture in the Pacific" (MFAT 2015). To achieve this goal, the long-term goal of PFLP is to create "a regional pool of current and emerging leaders that are capable and confident to address Pacific fisheries priorities and strengthen regional fisheries leadership and cooperation" (FAME MEL 2020).

So far, PFLP has trained 98 participants from 14 different Pacific Island countries, of which 47% are female (PFLP 2020). COVID-19, however, has impacted the delivery of this programme. Travel restrictions have hindered face-to-face delivery of the course content, leading PFLP to adapt rapidly. COVID-19 has affected almost all forms of education and capacity development programmes, leading to a switch to online learning to ensure continuation of content delivery (OECD 2020; Li and Lalani 2020). Consequently, the digital divide between people has increased, with the United Nations Educational, Scientific and Cultural Organization reporting that more 826 million students do not have access to required technologies, and more than 706 million do not have access to the internet at home (Amporo and Nabbuye 2020; Burns 2020).

In this context, the following question was asked: "How effective is e-learning in the case of PFLP?" This was the main question of preliminary research on the effectiveness of this "new way" of teaching and learning. To assess the effectiveness of online teaching and learning within PFLP, a framework was created based on existing literature. The framework illustrates two overarching themes: individual learning and group-based learning.

Individual online learning allows for the assessment of participants' response to the course, learning outcomes and preliminary behavioural changes, which can be compared to those achieved through face-to-face learning. Face-to-face group learning highlights participant engagement, interaction and motivation, and how these differ from those achieved through individual online learning.

Figure 1. Pacific Fisheries Leadership Programme cohort 2. (image: ©PFLP 2020)

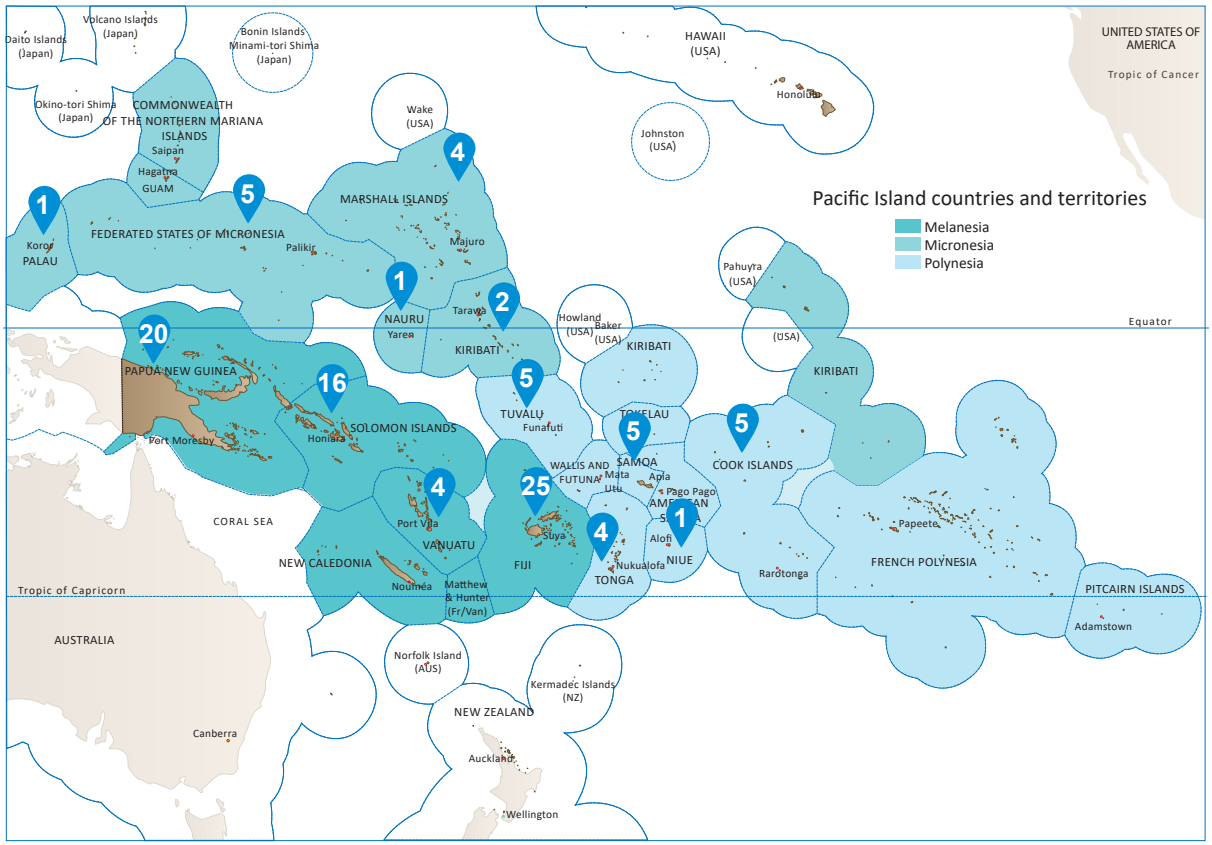


Figure 2. Distribution of Pacific Fisheries Leadership Programme participants. (image: ©SPC)

In total, 19 participants were interviewed, both face-to-face and online. Additionally, four PFLP staff members were interviewed to gain an additional perspective of the difference between the two modes of learning. These data were triangulated with data from participant feedback surveys.

The research revealed the advantages and disadvantages for both types of learning. With regard to face-to-face learning, it was clear that participants were able to build stronger relationships with one another and with the facilitators. Participants stated that they created groups on social media in order to keep in contact and share experiences and challenges. These strong relationships will be beneficial to address the multitude of challenges that the Pacific fisheries sector is facing (Bell et al. 2011; FAO 2020). In addition, overall motivation was higher and participants were highly engaged during face-to-face learning because they were removed from their work environment and had limited distractions. The distances that some participants need to travel, and the time away from the office, often makes it impossible or extremely difficult to attend courses outside their home country.

In terms of online learning, the course became more accessible to fisheries officers within the region. It was not necessary for them to be out of office for a prolonged period of time, and long distances were not an issue. Having the course online also allowed them to continue working while increasing their leadership capacity. Furthermore, online learning enabled facilitators to adapt the course quickly according to participants' needs. With online learning, however, there is little to no interaction among participants or with the facilitators, resulting in rather weak relationships. Moreover, engagement throughout the online session was rather limited, with many participants dropping in and out of sessions. This was mainly due to arising work priorities that they needed to be attended to or unstable internet connections.

Nonetheless, all interviewed participants stated that the course content was highly relevant to them and they learned many new aspects of leadership.

> "It's really eye-opening for myself as trying to in progress in terms of the leadership in my work and the content of the training was very good."
>
> PFLP online participant

It became clear that the individual learning of participants was at least as effective in the online session as it was in the face-to-face session. As indicated above, however, group-based learning has been heavily impacted by the online nature of the course. This aspect was not effectively addressed in the online session and has restricted participants from building strong relationships. The group experience was mainly impacted by the two external factors of work priorities and unstable internet connections. Similar trends have also been observed in other capacity development programmes from SPC, and is not solely an issue concerning PFLP.

Resulting from the disadvantages and advantages of both types of learning, a hybrid model seems highly suitable when travel restrictions are lifted. Implementing a hybrid version would mean taking the advantages of both modalities to maximise effectiveness. For instance, PFLP participants could attend the first few sessions in person to engage and interact with each other and start building strong relationships. After a few days, participants could return to their home countries and continue their learning remotely. This would ensure that they are not out of the office for a prolonged period of time, while having had the opportunity of interacting with other participants. The issues surrounding unstable internet connections could be supported by PFLP in the form of data packages.

This hybrid mode of delivery would be almost ideal considering it would combine the advantages of both modalities. However, high travel costs will prevail, and the benefit of the travel needs to be justified. In addition, travel restrictions do need to be lifted in order for this to occur. As long as travel restrictions are still in place in the Pacific Islands region, it is important to continue delivering the programme online. Participants have stated the high relevance of the course. Ultimately, efforts need to continue in order to achieve the goals of the Regional Roadmap for Sustainable Pacific Fisheries. Under current circumstances, continued adaptation and tailoring of content towards participants' needs will ensure increased effectiveness of online learning.

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# Teen Tuna Tok: Pacific youth-inspiring conversations with fisheries scientists and experts

***Pacific youth who want to enter the fields of science, research, marine biology or fisheries sometimes have a tough time finding role models in the region. Knowing that they grow up in the middle of the largest ocean in the world, fish and ocean-related topics are part of their culture and heritage. For teenagers and young adults, having a role model or a person who inspires them are hugely important, so that they can build their own personalities and develop their own set of values. During this time of the COVID-19 pandemic, it is more important than ever to continue inspiring youth in order to to strengthen their confidence and belief that they can achieve the success they are seeking.***

## The Teen Tuna Tok initiative

As a joint initiative of the Pacific Community (SPC) and the Pacific Islands Forum Fisheries Agency (FFA), a social media campaign has been launched to initially connect Pacific youth to world-class fisheries experts and scientists for the celebration of World Tuna Day. This celebration, occurring every year on 2 May, is an opportunity to raise awareness about the importance of tuna.

To prepare for this event, Pacific youth were asked to prepare and record on video, questions for tuna scientists on three main topics: tuna and their biology, climate change and tuna, and the importance of tuna to the Pacific. This call for video entries was announced through social media (Facebook and Instagram) a month before the celebration day.

Three weeks later, SPC and FFA received entries from teens from the Federated States of Micronesia, Kiribati, Marshall Islands, Papua New Guinea and Tonga.

## The content

Surprisingly, participants aged 12 to 7 mostly asked questions about the risk of tuna becoming extinct or overfished, such as :

1) Why are tuna such fast swimmers? Why do they migrate from one place to another?
2) What are other ways, other than farming, to prevent tuna from becoming extinct?
3) How can we prevent tuna from becoming extinct?

SPC and FFA experts were pleased to see that tunas are of great interest to young people in the Pacific, and were surprised to see how concerned they are about the future of tunas. Indeed, it is not yet a commonly known fact that the western and central Pacific Ocean is currently the only ocean region where all four key tuna species can be found in healthy populations, being neither overfished nor experiencing overfishing. So, doing their best to avoid the usual expert jargon, FFA and SPC scientists and fisheries experts

shared stories, visual metaphors and used simple words to engage and awaken the youth to the importance of tunas to the people of the Pacific, and to the world.

"Teen Tuna Tok has been a great opportunity to share the science and create what we hope, will be an ongoing dialogue with Pacific youth," stated Neville Smith, Director of SPC's Fisheries, Aquaculture and Marine Ecosystems Division.

For the scientists who are used to talking with their peers, it was a refreshing exercise and a great reminder of their own motives. For the teenagers, these conversations were a good learning experience in scientific enquiry, as they allowed the youth to process the concepts in their own terms. The best conversations happen when both sides are truly interested in what the other has to say and there is room for the unexpected.

Check the Teen Tuna Tok video playlist here, or search "Teen Tuna Tok" on YouTube.

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# Human rights law in coastal fisheries and aquaculture in the Pacific

***The Pacific Community (SPC) has produced a comparative analysis of national legislation on gender and human rights requirements in coastal fisheries and aquaculture in six countries: Fiji, Kiribati, Samoa, Solomon Islands, Tonga and Vanuatu.[1] The analysis highlights the opportunities for the governments of Pacific Island countries and territories to implement human rights principles in coastal fisheries and aquaculture legislation, and to identify existing barriers to their effective implementation. The key findings of the study have been summarised in a Policy Brief that is available in English and French.[2]***

***The conclusions and recommendations of the analysis incorporate feedback provided by national participants and partners during SPC's Regional Workshop on Gender, Social Inclusion and Human Rights in Coastal Fisheries and Aquaculture in July 2020. This virtual event was an occasion for participants to gain an enhanced understanding of gender and human rights issues in order to improve mainstreaming into national policies, laws and actions. As a result, a similar analysis is currently being conducted by SPC for the Federated States of Micronesia, Marshall Islands and Palau.***

## Key finding and challenges

Coastal fisheries are vital to Pacific Island communities, providing both food and livelihoods. Like other economic sectors, coastal fisheries face several challenges in the protection the human rights. This study analyses the progress made by six Pacific Island countries in protecting the human rights of small-scale coastal fishers and fish workers, and highlights opportunities to improve domestic legislation.

Under human rights law, governments must ensure the right to a safe and healthy environment by promoting the sustainable management of natural resources, as well as the right to participation in public affairs, without discrimination. They should also guarantee access to markets, as well as safe work and social security for coastal fishers and fish workers who are typically self-employed or operating in the informal sector. Government should increase sea safety training and develop comprehensive policies and legislation underpinned by the constitutional recognition of people's rights at work.

Community-based fisheries management systems help to ensure local communities' access to coastal marine resources, facilitate public participation in resource management, and promote sustainable fishing. However, some human rights challenges persist in certain customary practices. In some cases, such practices may exclude or sideline women and other vulnerable groups from land tenure arrange-

[1] See: Graham A. and D'Andrea A. 2021. Gender and human rights in coastal fisheries and aquaculture. A comparative analysis of legislation in Fiji, Kiribati, Samoa, Solomon Islands, Tonga and Vanuatu. Noumea, New Caledonia: Pacific Community. 108 p. Available at: http://purl.org/spc/digilib/doc/zz6mn

[2] See: Graham A. and D'Andrea A. 2021. Gender and human rights in coastal fisheries and aquaculture law – SPC Policy Brief #36. Noumea, New Caledonia: Pacific Community. 4 p. Available at: http://purl.org/spc/digilib/doc/z9dso

ments or from participation in local resource management. In other cases, families that are banned from a community are deprived of their livelihoods and, therefore, denied their right to food.

On the positive side, laws and court decisions within Pacific Island countries are increasingly recognising that custom is bound by certain fundamental rules, such as the principle of non-discrimination, which are constitutionally protected. Expanding constitutions to recognise the right to food would further allow individuals and communities to legally challenge any practice that denied them this right. International human rights law thus provides guidance to governments on how to proceed without undermining indigenous peoples' rights to marine resources and local conservation efforts.

## Recommended priority actions

Achieving sustainable development for both men and women working in the coastal fisheries sector will require Pacific Island countries and territories to review their laws, policies and programmes to ensure they respect and protect economic, social and cultural rights, and do not jeopardise the rights of local communities that depend on coastal marine resources for their livelihood. Training should be provided to judiciary, civil society and customary institutions in order to raise awareness of human rights and social inclusion issues. To ensure that human rights are effectively recognised and put into practice, Pacific Island governments are encouraged to monitor the implementation of human rights law for small-scale coastal fishers and fish workers through existing national mechanisms.

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Suva market, Fiji. (image Ariella D'Andrea ©SPC)

# Sea cage finfish aquaculture for Pacific Island countries and territories

## Worldwide expansion

The farming of marine finfish species has expanded greatly worldwide since the 1970s. A main constraint has been the supply of fingerlings, but the supply of hatchery-reared fingerlings, from both intensive technological efforts and simpler grassroots methods, has advanced and driven production in what is often a very profitable (and risky) undertaking.

Sea cage aquaculture of temperate and subtropical species such as Atlantic salmon (*Salmo salar*), sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) in the Mediterranean produced around 3 million tonnes (t) worldwide in 2020. Tropical marine finfish species such as milkfish (*Chanos chanos*) and barramundi (*Lates calcarifer*) produced 0.5 million tonnes in the same year.

Most of the salmon production comes from complex, vertically integrated companies investing in fingerling supply and industrial sea cage farming, with large boats and advanced technology. Marine farms that specialise in tropical species often involve smaller operators in complex value chains. A dominant constraint for both approaches is the supply of fish feed. Plastic cages made from polyethylene pipe are now common in many areas because they are light, durable, able to withstand heavy weather (if moored correctly), and can be assembled at remote sites. The cost of these materials has come down considerably as previously innovative manufacturing techniques have become commonplace.

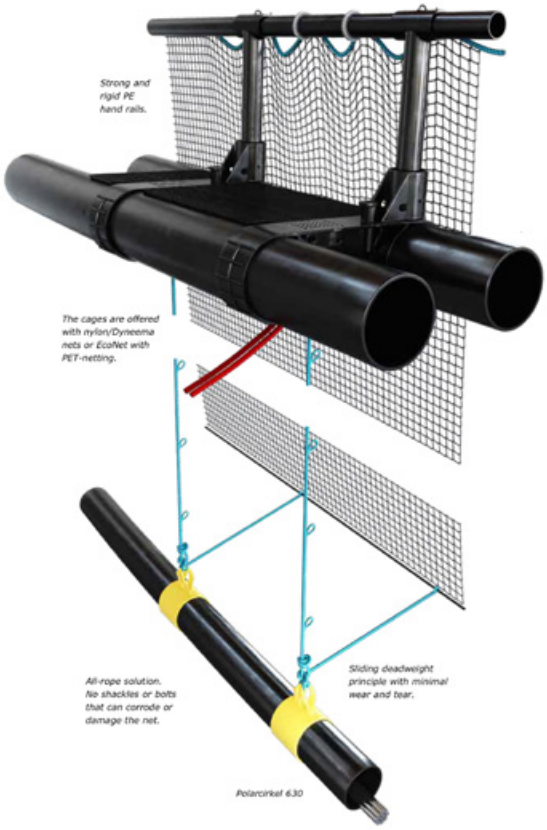
Increasingly though, sea cage farming sites are becoming harder to find in many locations around the world. Conflicts with coastal residents and recreational users, and increased public scrutiny of environmental impacts of marine farms, all reduce the availability of appropriate sites. Appropriate sites are what many Pacific Island countries and territories have in abundance, but sea cage farming of hatchery-produced marine finfish is only occurring in a few locations in the region.

## Pacific efforts

Pond culture of marine species, wild caught as fry, has had a long history in many Pacific Islands. Hawaii has milkfish ponds that were constructed several centuries ago, and Cook Islands, Fiji, Kiribati, Kosrae, Nauru, Tuvalu and Yap all have histories of stocking naturally occurring ponds with milkfish or other marine species for use when sea and weather conditions prevent fishing.

Milkfish is an excellent species for tropical finfish aquaculture because their nutritional requirements are low, they have a wide distribution, and a wide range of environmental tolerances. There has been a 60% increase worldwide in milkfish production from 2008 to 2018; the majority from

Rabbitfish grown in sea cages, Touho, New Caledonia. (image: ©Matthieu Juncker)




Example of a round plastic sea cage and its cross section manufactured by AKVA Group. (source: https://www.akvagroup.com/pen-based-aquaculture/pens-nets/plastic-pens)

Indonesia and the Philippines and the majority from sea cage farming. Coastal ponds were previously used in both countries, but productivity was not as high, and required increased utilisation of coastal land resources, which resulted in reduced water quality through pollution or development of agriculture or housing.

Extensive pond methods used in some Pacific Island countries and territories, notably Kiribati, are also trending toward more intensive cage farming based on the hatchery supply of fingerlings. With support from Taiwan and China, Kiribati has a milkfish hatchery facility capable of producing 2 million fry per year from just 200 broodstock, and is moving towards intensive cage farming.

Marine finfish hatcheries are also operating in French Polynesia, the Marshall Islands and New Caledonia. New Caledonia's ADECAL[1] is producing red emperorfish (*Lutjanus sebae*), locally called pouatte, and two species of rabbitfish (*Siganus* sp.) or picot. The development effort in French Polynesia involves the hatchery production and cage rearing of orbicular batfish (*Platax orbicularis*), or paraha peue, for the domestic market, and 60 t or more could support economic production. The Marshall Islands has achieved hatchery production of Pacific threadfin (*Polydactylus sexfilis*), a fish of high value in Hawaii where they are called moi.

## Hatchery production of fingerlings

A marine finfish hatchery is a complicated operation, and needs to be supported by trained staff, specialised equipment and feed. Water quality must be maintained at high levels and temperature kept as stable as possible. Live feed of different types must be produced, and broodstock often held for long periods of time before they are in a reproductive condition to be successfully manipulated to spawn.

Two broad strategies are used in relation to the application of technology. The extensive approach principally lacks a high degree of temperature regulation for conditioning broodstock, and feeds larval fish with "greenwater" cultures of mixed, naturally occurring microalgae and zooplankton. This method forms the strategy for milkfish fingerling production in Kiribati and underpins the industry in Southeast Asia.

A more expensive and intensive approach involves the operation of indoor recirculating aquaculture systems with controlled temperature and lighting. This approach is used in New Caledonia. The increased investment allows for more frequent maturation of broodstock by establishing broodstock groups subjected to different artificial seasons and thus an increased production of eggs at a time to suit

[1] Agence de Développement Économique de la Nouvelle-Calédonie (New Caledonia Economic Development Agency)

planned production. Finfish larvae in this type of operation are fed from monocultures of intensively reared zooplankton (principally rotifers and brine shrimp), enriched by feeding the zooplankton with intensively cultured microalgae containing fatty acids important to larval development (n-3 fatty acids EPA DHA). Copepods are also used for live feed, although they are hard to culture but can be used to feed larvae with smaller mouths.

Good larval nutrition early in the fish's life is crucial in both extensive and intensive approaches; it aids in swim bladder development and inflation, which is an important energy stage for larval marine finfish that need adequate energy reserves to avoid significant larval mortality. From the hatchery, the use of land-based nursery systems for small fingerlings can increase survival rates after transfer to sea cages. Land-based nursery systems (overwhelmingly in recirculating aquaculture systems) are becoming increasingly important for many marine finfish producers who are rearing bigger fish because the risks of predation, disease and weather are reduced. The bigger the fish when placed in sea cages, the closer they are to harvest size so there is less time for something to go wrong.

## Sea cage aquaculture

### *Sea cages*

Marine sea cage farming was initially developed in sheltered coastal sites around the world. As technology has advanced, marine farms have been moving to open ocean sites. Open ocean sites may reduce conflict with other users of coastal areas, and have more stable water quality, particularly with regards to oxygen. Open ocean aquaculture requires heavy and expensive gear, however, in order to operate successfully.

The Pacific Islands have a plethora of accessible coastal locations, and many of these are fantastic sites for marine finfish farms. Compared to ponds that have been used in Pacific Island locations, sea cages utilise as little as $^{1}/_{300}$ of the area for the same amount of biomass production. Biomass densities of up to 40 kg/m$^3$ are routine for milkfish farming in Asia.

Small cages made from plastic drums and wood have been used in several Pacific Island countries, including Papua New Guinea, Solomon Islands and Tuvalu, for the grow-out of wild harvested or imported marine finfish fry; they have been susceptible, however, to cyclone damage. The increase in milkfish production in Southeast Asia has resulted in improved availability of both square but predominately circular sea cages, framed with polyethylene pipe. They are relatively light and flexible (thus resilient with respect to wave action), can be constructed onsite with relatively simple workshop tools, and the pipes joined by plastic welding techniques.

Sea cage operations in the Marshall Islands. (image: Ryan Murashige, ©Aquaculture Technologies of the Marshall Islands)

Sea cages are generally moored in a grid system designed to dampen the forces of weather. The longitudinal axis of the grid is positioned across the direction of greatest wave action and current flow in order to maximize water exchange; routinely, a minimum depth of 10 m or so is required. A properly moored sea cage marine farm can withstand wind speeds of up to 150 km/hr.

## *Feeding and operation*

Feeding fish is one of the most significant operations for sea cage farming, and many fish feed best in the early mornings when they have more appetite and are much less likely to let feed float down to the bottom uneaten. This is also a time when staffing can be more challenging. Feed can also be a major cost (often the major cost) of sea cage farming. Therefore, ensuring that the amount of feed given to fish is efficiently converted to fish growth (or weight) is important.

Feeding is often automated, especially in locations where labour costs are high, or for offshore sites where access may be difficult. Feed is delivered as a percentage of the total biomass in the cage each day. For Pacific Island marine farms, feeding can be an onerous task, a small circular sea cage of 10 m in diameter – such as the ones used in the Marshall Islands – can hold a total biomass, at an ethical density, of well over 3000 kg of fish. For moi this could mean feeding up to 90 kg daily into one cage as the fish approach their harvest weight. Transporting the feed to the site and manually feeding this amount, for a production cycle of around 120 days, places a heavy demand on logistics and labour. One 10-m circular sea cage may require an input of 9 t of feed or more for one production cycle, and there are at least 10 cages in Majuro Atoll.

Given the quantities of feed needed for sea cage farming, easy access to pelleted feed is important. So, despite the availability of sites, marine farms can be restricted to locations that have access to agricultural feed mills that produce feed for pigs and chickens, such as in Fiji and New Caledonia. Kiribati and the Marshall Islands partially offset this challenge by producing onsite "wet" pellet feeds that incorporate some locally produced nutrition sources such as coconut and trash fish, but imported ingredients are often still required to achieve efficient growth.

Sea cage farm maintenance through the production cycle involves keeping the nets clean to maximize water exchange through the cage, and keeping the net intact to prevent stock from escaping. Most marine farm sea cages have a double net, the outer net being a predator-preventer net. Sea cages attract seals in temperate zones and sharks in the tropics. Treatment for disease is also a major task, and fish often need to be bathed in freshwater within a cage with a waterproof liner to remove parasites or heal an injury caused by fungal infections.

## *Will sea cage farming become viable in the Pacific?*

Sea cage farming production is an activity that could provide jobs and income in many Pacific Island locations. But the biggest challenge for a sea cage farming project is to produce fish at a price that is competitive with the domestic price of fish available from local coastal and oceanic fisheries. At present, there are only a few places in the Pacific Islands – such as New Caledonia and French Polynesia – where capture fishery prices can be higher than finfish aquaculture production costs. A second option is to produce fish that have a high value in overseas markets, such as the moi farmed in the Marshall Islands for high-paying markets in Hawaii, but this requires direct and reliable access by air, and only a few locations in the Pacific have this type of access. The third option is the use of low technology to reduce the cost of production, but it comes with increased risks and puts a limit on scale.

The demand for marine fish in overseas markets, however, is increasing and Pacific Island coastal fish stocks are under severe pressure. Both factors will continue to drive up fish prices, a trend that is unlikely to be reversed. This demand could also increase the likelihood that sea cage farming will become viable in more places around the Pacific and contribute, along with other aquaculture sectors, to food security in the region.

Milkfish sea cage farming in Kiribati is intensifying, with new links to high demand in China. Red emperorfish and rabbitfish production will move to 40 t annually in New Caledonia as this project looks to validate its costs at a commercial scale, while moi production in the Marshall Islands is affected by the COVID-19 crisis, which has reduced the link to high-paying markets in Hawaii.

This type of work could be something for many young Pacific Islanders, both men and women, to work towards, and could provide opportunities to earn money while maintaining a connection to the ocean. While there are environmental impacts of marine finfish cage farming, their impact can be managed. Thanks to the efforts of the teams mentioned here and to the experience gained from other aquaculture projects, Pacific Island countries and territories could promote an industry in line with what they have done so well for centuries: using the bounty of the ocean for the benefit of their people.

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# The potential and issues surrounding local ecological knowledge in fisheries science and management

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Indigenous rangers from the Yuku Baja Muliku Traditional Owners in Cape York, Australia. (image: © Andrew Chin)

***The Fish and Fisheries Lab (www.fishandfisheries.com), based at James Cook University in Australia, teaches several undergraduate and masters level subjects about fisheries management. One of the most popular subjects is "Managing Tropical Fisheries", where students learn about the importance and complexity of tropical fisheries, and how they need very different management approaches compared to more traditional industrialised fisheries such as cod or swordfish. As part of the course, students are required to submit an essay on a complex area of tropical fisheries. Many students submit well written, well researched, and insightful essays that we felt are worth sharing. This essay by Rachel Mather was the pick of the essays submitted in 2020, and we are pleased to share it with you through the*** **SPC Fisheries Newsletter.** ***Well done Rachel.***

***Dr Andrew Chin – Course Coordinator***


## Abstract

The cumulative body of ecological knowledge held by local communities and developed through extensive interaction with the ecosystem, and shared over generations, is referred to as local ecological knowledge (LEK). This knowledge may be held by indigenous groups, and those who rely on an ecosystem for their livelihoods, such as commercial fishers. The LEK held by fishers often includes detailed information about the biology and abundance of economically or socially important species, and how their population size and distribution are influenced by interannual, seasonal and diel changes in the environment. This information is of considerable value to fisheries scientists and managers, particularly in data-poor fisheries where the collection of such data through scientific field surveys may not be viable. This paper outlines several examples of the application of LEK in fisheries science and management, and describes the challenges and considerations associated with this.


## Introduction

### *Local ecological knowledge*

Local ecological knowledge (LEK) refers to the cumulative body of knowledge held by local communities about an ecological system, gained through a history of close interaction with the environment (Zukowski et al. 2011). This includes traditional ecological knowledge (TEK), which refers to the local knowledge held by indigenous communities. TEK can be thought of as an integrated system of knowledge, belief and practice – ecological information is embedded within an understanding of resource management systems and techniques, and is in turn nested within a social system with norms and worldviews influencing how the community perceives their relationship with the environment (Butler et al. 2012; Schafer and Reis 2008). These integrated systems of TEK are cumulative and dynamic, founded upon observations and practical experience, transmitted across generations and adapted through time (Schafer and Reis

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2008; Zukowski et al. 2011). However, LEK also refers to the knowledge held by other resource users, such as commercial fishers who rely on a local ecosystem for their source of livelihood, spend a considerable amount of time on the water, and require a detailed understanding of the ecosystem (Mackinson and Nottestad 1998; Maurstad 2002).

LEK knowledge differs from Western science and management knowledge (SMK) in several ways, and while it is often dismissed by scientists for not conforming to Western scientific standards and norms, the potential for both knowledge systems to complement one another in environmental management is gaining recognition (Pita et al. 2016). The primary difference between LEK and SMK is the method of obtaining and sharing knowledge (Maurstad 2002). SMK is obtained through systematic observation following the scientific method, usually with the aim of quantifying natural phenomena and identifying statistically significant patterns or trends. This information is then compiled and published in academic journals to be accessed by scientists and managers. LEK is based on long-term observations, and is adapted and strengthened with each generation, through its applications within livelihood systems. LEK is often shared orally among peers or across generations (Maurstad 2002). Given its significance to livelihoods (e.g. enabling access to a food source for isolated communities, or giving a competitive edge to commercial fishers), those who hold LEK may be selective when it comes to sharing this knowledge, and outsiders may not be granted access to it (Maurstad 2002).

These knowledge systems also differ in spatial and temporal scale. SMK typically aims to understand ecological processes across a large spatial scale but a relatively short time frame (Butler et al. 2008; Zukowski et al. 2011). Conversely, LEK is able to provide detailed knowledge about localised systems, often over multigenerational timeframes that are generally inaccessible using scientific methods (Butler et al. 2012; Zukowski et al. 2011). Furthermore, LEK is often qualitative rather than quantitative, which may pose some challenges when integrating this knowledge with SMK (Zukowski et al. 2011).

### *Potential of LEK in fisheries science and management*

Communities that are reliant on fisheries for their livelihoods will often have extensive ecological knowledge of the ecosystems where they fish, as a result of close observation of factors affecting fish distribution and fishing success (Mackinson and Nottestad 1998). This knowledge may include critical information about the biological and ecological characteristics of economically or culturally important species, such as juvenile and adult habitat preferences, migration patterns, spawning or feeding grounds, and changes in stock status (Butler et al. 2012; Mackinson and Nottestad 1998; Zukowski et al. 2011).

With this information, LEK has the potential to improve the overall understanding and management of fished ecosystems. Its integration into fisheries management would be particularly beneficial for data-poor fisheries such as tropical artisanal fisheries, which are often underreported and take place in remote areas where the collection of detailed scientific data to support management may not be feasible (Silvano and Valbo-Jørgensen 2008). LEK has also provided valuable insights into other data-poor fisheries such as the recreationally targeted Murray crayfish in Australia, and long-term population trends in Arctic whales (Johannes et al. 2000; Zukowski et al. 2011). In these scenarios, fishers' LEK has been demonstrated to be an accurate and reliable source of information that may otherwise be missed by outsiders such as fisheries scientists and managers. In addition to providing an alternative source of information about fished ecosystems, the incorporation of LEK into fisheries science and management can help to engage resource users to produce a greater sense of environmental stewardship, build trust and understanding between fishers and managers, facilitate co-management and improve compliance (Butler et al. 2012; Schafer and Reis 2008).

This paper considers several examples of the contribution of LEK to fisheries science and management, in order to understand the potential and limitations of these knowledge systems, along with the challenges and considerations associated with their application in the management of environmentally, economically and socially sustainable fisheries.

## Examples of LEK in fisheries science and management

Presented in this section are some examples of the application of LEK in fisheries, demonstrating its value and reliability as an information source, the factors driving its application, and the consequences of overlooking LEK in favour of traditional scientific methods.

### *Reliability of fishers' LEK*

One of the primary reasons LEK is overlooked by fisheries scientists and managers is the widespread perception that this knowledge is unreliable because it does not adhere to scientific conventions. However, a study by Zukowski and colleagues (2011) suggests that fisher LEK can provide reliable information to improve fisheries management. The study gathered LEK through face-to-face interviews, mail and telephone surveys, and catch data through logbooks and diaries. This information was then compared with scientific data on the size and sex ratios of Murray crayfish, collected via field surveys in the Murray River in Australia (Zukowski et al. 2011). The authors found no significant difference between the LEK data obtained through fisher interviews, and the scientific data obtained through catch cards and field surveys. Thus, it was recommended that fishery management could be improved by LEK to identify ecosystem changes, which could then be verified through scientific surveys and used to inform proactive management decisions.

The authors also noted that where fishers' knowledge differed from scientific knowledge, this did not necessarily indicate a lack of reliability of LEK. Instead, these differences may be the result of differences in methods, experience, and spatial or temporal scales used when collecting the data, pointing out that LEK is often based on much longer-term observations than scientific data (Zukowski et al. 2011).

### Value of fishers' LEK

In addition to providing reliable information, fishers' LEK has been shown to provide scientists and managers with new information that may be overlooked or beyond the scope of scientific surveys (Bergmann et al. 2004; Maurstad and Sundet 1998). Lavides and colleagues (2010) used LEK to infer reductions in finfish diversity in Bohol, Philippines, where fish provide an important protein source and long-term time-series data for marine biodiversity are scarce. Based on information gathered from local fishers, the authors identified 21 species that had disappeared from catches, with two species recommended as a priority for further monitoring, including the giant grouper (*Epinephelus lanceolatus*) and the "highly vulnerable" African pompano (*Alectis ciliaris*) (Lavides et al. 2010). The use of scientific field surveys to collect such information would be expensive, and data would still be limited to a short time-scale with no historical baseline.

In their study on artisanal fishing areas in the Patos Lagoon, Brazil, Schafer and Reis (2008) highlighted the value of LEK for providing information that is new to fisheries scientists and managers. Through interviews with local fishers, 124 fishing areas were identified and geo-referenced, 80% of which were previously unregistered and known only to fishermen. This information is important for managers as it indicates the extent of fishing pressure within the lagoon, and how fishers may interact with nursery or spawning areas, in turn influencing population dynamics of the stock and showing which areas may require protection. It may also be used in conjunction with total catch and gear-type information to produce yield models to help inform management strategies (Schafer and Reis 2008).

### Consequences of overlooking fishers' LEK

The LEK held by fishers can provide critical information on how the abundance and behaviour of target species may be influenced by habitat and interannual, seasonal, lunar and diel environmental variation (Johannes et al. 2000). Fisheries scientists and managers who overlook this information may put these resources at risk, compromising both the health of the ecosystem and the livelihoods of those who rely on them, as demonstrated in five examples presented by Johannes and colleagues (2000). One such example was that of the declining spawning runs of bonefish, an important source of food security in Kiribati. The construction of causeways blocking migration routes, and overfishing by gill nets during spawning runs, had caused a significant reduction in successful spawning of the species. While this was evident to older fishermen around the atoll, interviews based on a questionnaire, conducted by the Fisheries Department with younger fishers, failed to bring this issue to light, and thus fisheries managers were unaware of the impending demise of the stock. Johannes conducted less-structured interviews with well-respected older fishermen, which revealed that a single spawning run remained, and that this too was in decline. Upon recognising the dire condition of their vital resource, the villagers of North Tarawa initiated an informal protection effort for the spawning run. Almost a decade later, in 1999, catch per unit effort and average size of bonefish were both on the rise, owing to the culmination of each island's LEK compiled by collaborating fisheries scientists, despite the shortcomings of formal fisheries management (Johannes et al. 2000). Current regulations on the harvesting of bonefish in Kiribati, both formal and informal, vary among islands. For example, a complete ban on harvesting and possession was implemented in Kiritimati in 2008, while bylaws in North Tarawa prohibit splash fishing of bonefish, although enforcement of both regulations remains a challenge (Campbell and Hanich 2014). Unfortunately, the IUCN Red List estimates that since 1999, Kiribati's bonefish stocks have declined by roughly 30% as growing human populations have led to further overfishing and pollution, along with increased fishing pressure from an emerging recreational catch-and-release fishery (Campbell and Hanich 2014; Jansen and Bakineti 2020)

### Incorporating fishers' LEK with SMK

Despite its potential for information and perspectives new to fisheries science and management, the integration of LEK with SMK remains in its infancy in most fisheries (Zukowski et al. 2011). Butler and colleagues (2012) studied the progression of this integration in the Torres Strait, providing insight into the factors driving this development in fisheries science and management. Earlier studies identified three main factors initiating this process: depleted fishery stocks, limited scientific knowledge, and ownership of resources by local communities (Johannes et al. 2000). However, surveys conducted with fisheries managers and scientists in the Torres Strait revealed that LEK had only been applied to the turtle, dugong, lobster and hand-collectable fisheries, and that only two of the seven species exploited by these fisheries matched these criteria (Butler et al. 2012). Instead, co-management characteristics and a species' cultural value were proposed as the primary drivers of LEK integration. In particular, turtles and dugong are recognised as cultural keystone species in the Torres Strait, playing an important role in islanders' livelihoods while also receiving significant international conservation interest. It was revealed that the integration of LEK with science and management for these species has driven co-management between indigenous and government stakeholders. In turn, this has catalysed the co-management of other species with less cultural importance, for example the establishment of community-based management of hand-harvested beche-de-mer and trochus in the Torres Strait (Butler et al. 2012). These findings

reveal the value of finding common ground, such as cultural significance, between managers and stakeholders to catalyse co-management efforts.

## Challenges and considerations

### *Quality of LEK information*

Several challenges arise in the incorporation of LEK with SMK for the benefit of fisheries science and management, and as a result this remains "the exception, rather than the rule" (Zukowski et al. 2011). The first challenge is mistrust of TEK by many scientists who consider it to be "anecdotal knowledge", and of lesser value than information gathered by trained scientists according to scientific convention (Mackinson and Nottestad 1998; Silvano and Valbo-Jørgensen 2008). Because LEK does not meet the indicators used in Western society to establish validity (e.g. replicable studies, statistical significance and formal peer review), fisheries managers may be hesitant to make decisions based on information that cannot be substantiated in this way.

LEK has been demonstrated as a reliable source of valuable fisheries information, and should not be excluded from management on the basis that it is not "scientific". However, it should be noted that both fishers' and scientists' knowledge are fallible and subject to bias, and should be verified when possible (Johannes et al. 2000). This may be achieved through field surveys in some situations, although LEK cannot always be reproduced; for example, when gauging historical baselines. In such situations, information should be corroborated by more than one individual, for example when mapping spawning locations using LEK, Ames (2003) required the independent identification of a site by two or more fishers. Furthermore, Ames (2003) checked that the depth and substrate at each site was conducive to the known biology of the species. Finally, given the long time-span of much LEK, timelines should be established using supporting information to determine the approximate timing of significant events and changes within the fishery (Ames 2003).

It should be noted that discrepancies between SMK and LEK do not necessarily mean one is wrong, but may be a product of how the data are collected (e.g. over a different spatial or temporal scale, or using different gear and techniques), shining an alternative perspective on the situation (Silvano and Valbo-Jørgensen 2008). Rather than dismissing LEK as incorrect, researchers should strive to understand the cause of the discrepancy in order to better understand the ecosystem.

### *Ethical considerations*

There is also the ethical challenge of how LEK may be applied, and with whom it may be shared. Fishers may be hesitant to share their ecological knowledge with scientists and managers for a number of reasons, including fears that competitors may gain access to this information, or that fisheries managers will close off areas that are heavily fished, and therefore economically important (Maurstad 2002; N. Rynn, professional net fisherman, pers. comm. 27 November 2020). There may also be cultural limitations on who has the rights to access TEK in some communities; for example, outsiders may be restricted, while in many indigenous Australian cultures it is law that certain knowledge, known as "men's business" and "women's business" must not be shared across gender groups.

Indigenous rangers like those from the Yuku Baja Muliku Traditional Owners in Cape York, Australia, have extensive and valuable knowledge about the fish populations in their rivers and sea country. (image: ©Andrew Chin)

By gathering, recording and publishing fishers' LEK, which has traditionally been shared orally among exclusive groups, the nature of the knowledge system is changed. Once included in published scientific works, fishers no longer have control of this information (Maurstad 2002). This may be particularly harmful to communities where such information is held and traded as social currency, or where fisheries are regulated largely on the basis of social norms. As described by Maurstad (2002), outsiders with access to this information are less likely to adhere to these norms, leaving local fishers at a competitive disadvantage and changing the dynamics of the local social-ecological system. Thus, fisheries researchers must be mindful not to put fishers and their communities at a disadvantage when

sharing their LEK with managers or the public. Maurstad (2002) states that the best way to achieve this is to ensure that fishers are actively engaged in cooperative management, rather than simply being consulted.

## Conclusion and recommendations

By including LEK in fisheries science and management, we have the potential to improve the quality and detail of ecological information used to inform management decisions. Through gathering and applying LEK, we also have the opportunity to increase engagement with fishers and facilitate co-management, improving compliance and ultimately improving both environmental and social outcomes. The incorporation of LEK with SMK for culturally important species can help put the co-management networks in place to facilitate its incorporation with other species in the future.

While the value of LEK in fisheries is clear, just as with scientific knowledge, quality assurance of information should be conducted and multiple lines of evidence sought. Additionally, it is important for researchers to communicate effectively and build mutually beneficial relationships with fishers, in order to obtain the most accurate information and apply it in the most effective way possible (Mackinson and Nottestad 1998). Failure to consider the interests of the fishers sharing their LEK, whether cultural or commercial, may result in negative outcomes for the fishers and their community, and is likely to create further distrust of scientists and managers in the future. It is recommended that a social scientist be included in the team when collecting LEK to maximise engagement with fishers while ensuring research is conducted in an ethical manner.

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# Dynamics of a South Tarawa Atoll fisher group, Kiribati

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## Introduction

The Republic of Kiribati consists of three main island groups, the Gilbert Islands (or Tungaru Group), Line Islands and Phoenix Islands. While Kiribati's exclusive economic zone encompasses 5 million km², its total land area is just slightly more than 810 km² (Lovell et al. 2002). Tarawa is the largest of 16 atolls that make up the Gilbert Islands group (Fig. 1).

Tarawa's reef perimeter is approximately 107 km² and is open to the west where the reefs are permanently submerged. The lagoon area encompasses 375 km² and has many reefs within it, with the shallowest areas being on the eastern and southern margins (Lovell et al. 2002). Inner reef habitats are divided into the atoll rim, lagoon floor, and patch reefs and shoals. Because the western margin of the atoll is submerged, there is a continual exchange of sea water between the lagoon and the ocean. In contrast, the southern and eastern atoll rim consists of a relatively narrow outer reef flat, a series of low islets, and a wide lagoonal sand flat with limited ocean exchange. Causeway construction has further reduced this exchange by obliterating most passages along South Tarawa and several along the eastern rim on North Tarawa. These differences in oceanic to lagoon water exchanges have created a lagoon with marked northwest to southeast gradients in water characteristics, including productivity and composition (Paulay and Kerr 2001).

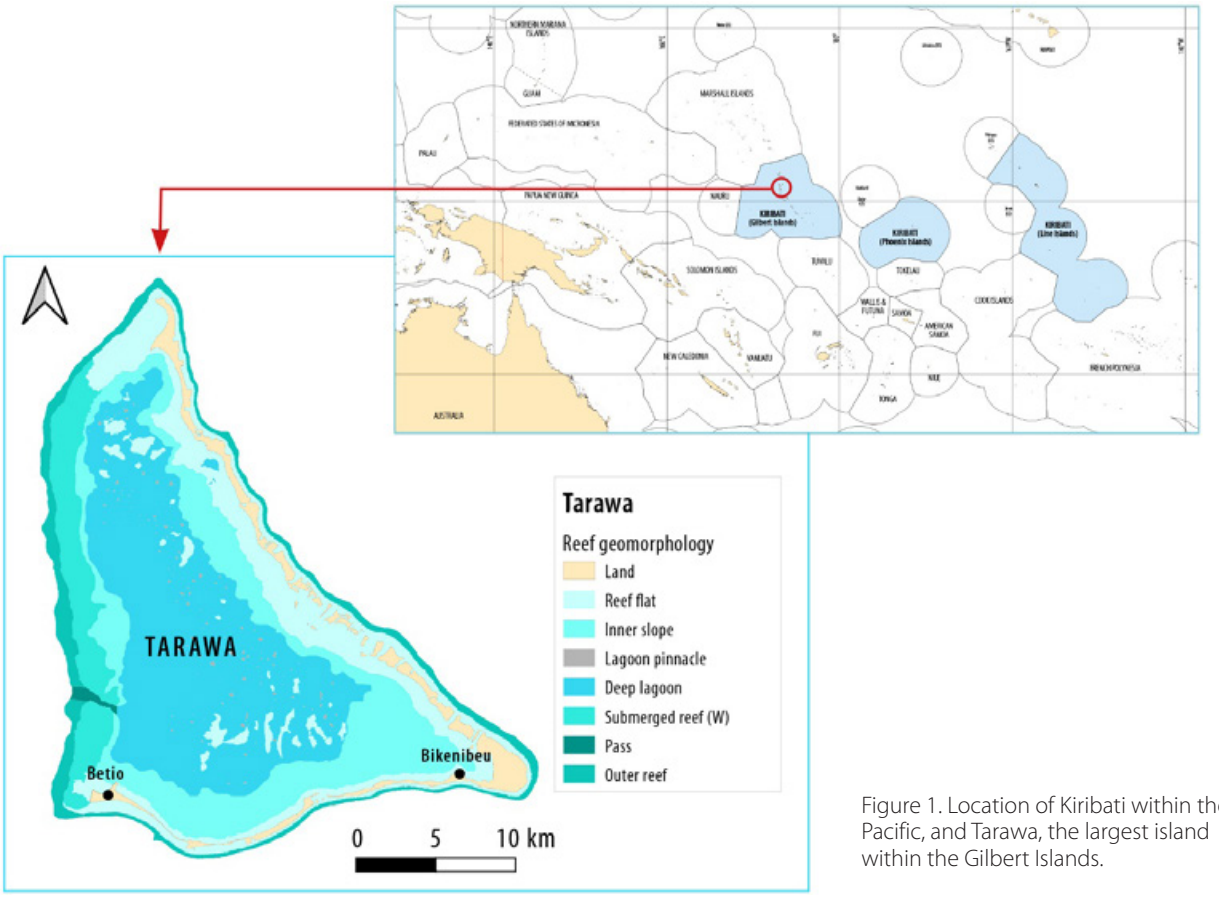



Figure 1. Location of Kiribati within the Pacific, and Tarawa, the largest island within the Gilbert Islands.

[1] National Fisheries Authority, Papua New Guinea
[2] Pacific Community
[3] Ministry of Fisheries and Marine Resources Development, Kiribati

Kiribati is one of the poorest countries in the world and is ranked 134th in the United Nation's Human Development Index (United Nations Development Programme 2021). Its economy was previously dependent on the revenue brought in from phosphate mining on Banaba Island, which ended in 1979. Since then, Kiribati has made up most of its income revenue from fisheries through foreign vessel fishing licenses, most notably for tunas, which are transshipped at Betio on South Tarawa (Barclay and Cartwright 2007; Gillett 2016; Zylich et al. 2014).

South Tarawa is also the main residential area in Kiribati, home to nearly half of Kiribati's total population. South Tarawa's population has grown exponentially in the last century. In 1931, there were 3031 people on South Tarawa. The 2015 census estimated the population on South Tarawa to be 56,338 (National Statistics Office 2016), and the 2020 provisional census data estimated a current population of 63,439 people (National Statistics Office 2021). The people of South Tarawa live on a series of atolls linked by causeways, some 30 km in length, with the widest point being only 300 m, and covering an area of approximately 15.75 km$^2$. South Tarawa has a very high population density of 2557 people per km$^2$, with some areas, such as Betio, having over 15,000 people per km$^2$.

The population increase on South Tarawa is a physical representation of rural–urban migration that dominates interisland movement and reflects the inequalities between rural and urban areas. South Tarawa has many "pull" factors, such as employment and education opportunities, and greater access to goods and services. Because of this huge rural–urban migration, South Tarawa continues to face many development challenges. These challenges include severe overcrowding in both formal and unplanned settlements, increased pressure on freshwater reserves, high levels of pollution in the lagoon as a result of increased solid and human waste, and conflict over land.

The fisheries of South Tarawa have also changed greatly in recent decades as human development and fishing effort have increased to meet the increased demand for food (Beets 2000). Previous assessments have documented declines in abundance and generally negative trends in yield and catch per unit effort (Cross 1978; Yeeting 1986; Mees 1988; Mees et al. 1988).

As part of the Pacific Community's (SPC) assistance to member countries, and in order to gain a better understanding of fisheries dynamics in Kiribati, a number of creel surveys were conducted across three atolls in the Gilbert Islands in 2020: Tarawa, Abemama and Onotoa (see Molai et al. 2020). This article focuses on Tarawa because it is the most densely populated atoll in the group by a factor of 13. During surveys on South Tarawa, we encountered one fisher group in particular at Bikenibeu that was consistently engaged in commercial fishing. During a 14-day period from 25 May to 7 June 2019, the authors sampled their catches daily. This group (referred to as the "study group" hereafter) also kept a detailed logbook of their expenditures and catches of which, copies were made with their permission. The period of the logbook encompassed the period 2 March to 7 December 2019.

## Monitoring landings from an artisanal fisher group

For the 14-day sampling period, the study group was visited every morning on their return from fishing the previous night. In total, 10 fishing days were sampled. There were no fishing activities on Sundays, therefore no fish were landed on Monday mornings. In addition, fishing did not occur on two other occasions, once because of inclement weather and the other because there were not enough eskies (portable ice chests or coolers) available because the existing eskies were still full from the previous fishing trip, meaning not all fish from that trip had been sold. This study group targeted reef fish from the outer reef areas at night through handlining. Fishing was conducted at three locations in Tarawa Atoll:

- southwestern end (n = 4);
- northwestern end (n = 4); and the
- northeastern end (n = 2).

Sampling the catch of this study group consisted of short interviews with lead fishers from each fishing event, and sampling the whole landed catch for species identification, length and weight.

## Number and weight of fish landed

During the 14-day sampling period, 1322 fish weighing a total of 965 kg were landed with an average of 132 fish ± 16 (SE) or 96.5 ± 14.8 (SE) kg of fish caught per fishing trip. Of note, the amount of fish caught was relatively consistent for most fishing trips but a number of trips showed greater variability (poor or rich days). This could have been influenced by a number of factors, including the location targeted (in this study, comparisons were not made due to the reduced number of fishing trips), tides, moon phase, weather conditions, fisher knowledge and experience. As examples, surveys conducted in late 1985 in Betio, Bairiki-Nankai and the Bikinebeu-Ananau causeway showed that ocean fishing in December declined due to bad weather, with a subsequent shift to reef fishing, which increased during the Christmas and New Year period due to increased demand (Mees and Yeeting 1986). In rough weather, more lagoon fishing is conducted, while in calm weather greater fishing effort is on oceanic species.

During the 14-day period of our survey, catches varied from 32 fish (42.1 kg) to 187 fish (205.8 kg) (Fig. 2).

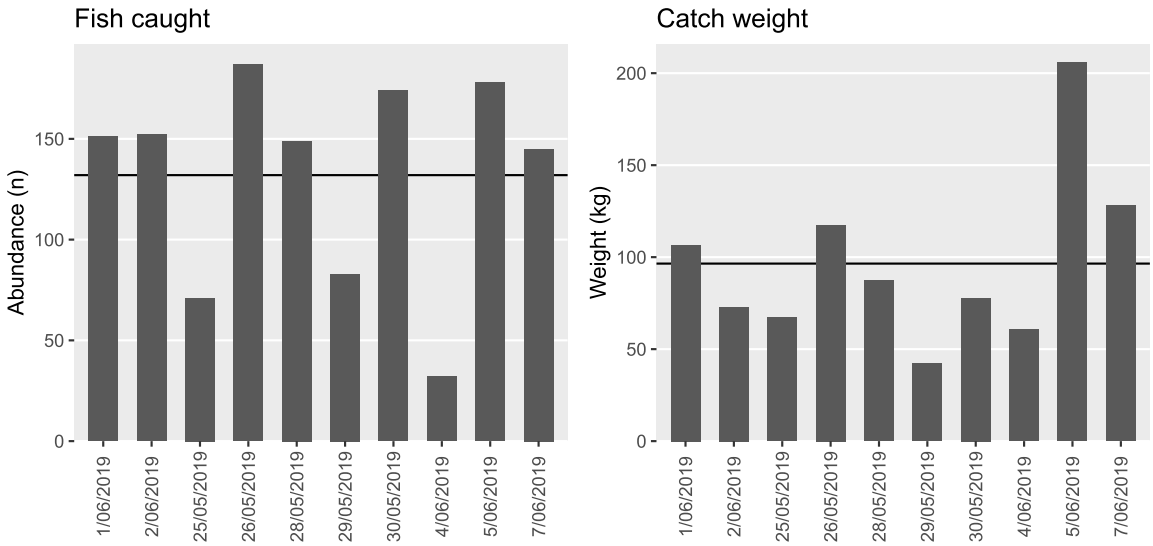



Figure 2. Landed catches across the survey period (May–June 2019).
Left: overall fish catch, right: overall catch weight. Dark horizontal lines correspond to the overall mean.

## Fish families represented

Among the nine fish families found in the catches (Table 1), the most common were the families Carangidae, Lethrinidae and Lutjanidae. While these three families were almost equally represented in terms of the number of fish caught (around 30% each), the Lethrinidae family made up more than half of the weight of fish landed (59%) (Fig. 3).

Table 1. Families represented in the catches (n= number of fish caught)

| Family | n |
|---|---|
| Albulidae – bonefish | 3 |
| Balistidae – triggerfish | 7 |
| Carangidae – jacks and scads | 398 |
| Holocentridae – soldierfish and squirrelfish | 28 |
| Lethrinidae – emperors | 454 |
| Lutjanidae – snappers | 386 |
| Priacanthidae - bigeyes | 12 |
| Serranidae – groupers | 11 |
| Sphyraenidae – barracudas | 23 |

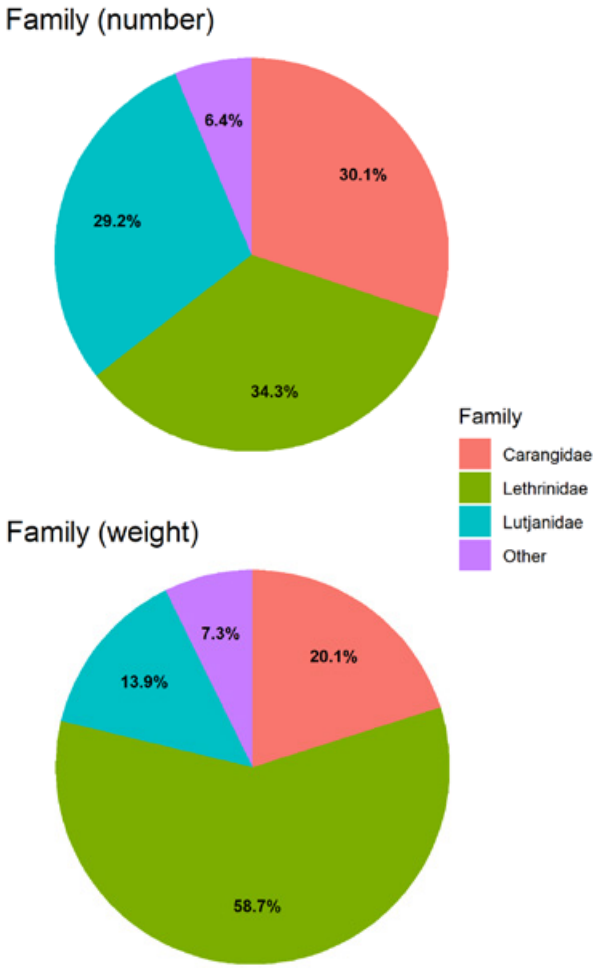



Figure 3. Fish families represented in the catch.
Top: catch in number; bottom: catch in weight.

## Dominant fish species

In total, 43 fish species were recorded in the catches, with 17 species represented by at least 10 individuals (Fig. 4). The top five species caught were the spangled emperor (*Lethrinus nebulosus*), scads (*Selar* spp.), paddletail or humpback red snapper (*Lutjanus gibbus*), bigeye trevally (*Caranx sexfasciatus*) and longface emperor (*Lethrinus olivaceus*). These five species had more than 100 individuals landed during the sample period.

## Proportion of the catch above size at maturity

To evaluate the status of the populations of species caught by this study group, the proportion of fish caught that were above or under the reported length at maturity (i.e. the length for which 50% of individuals in a given species are mature) was evaluated. This evaluation was done for species that had over 30 measurements. As there are no reported sizes at sexual maturity published for fish in Kiribati, we used sizes at sexual maturity taken from the literature (Table 2). We note however, that because sizes at sexual maturity can vary across locations (Longenecker et al. 2017; Prince et al. 2020), these values should be used with some caution.

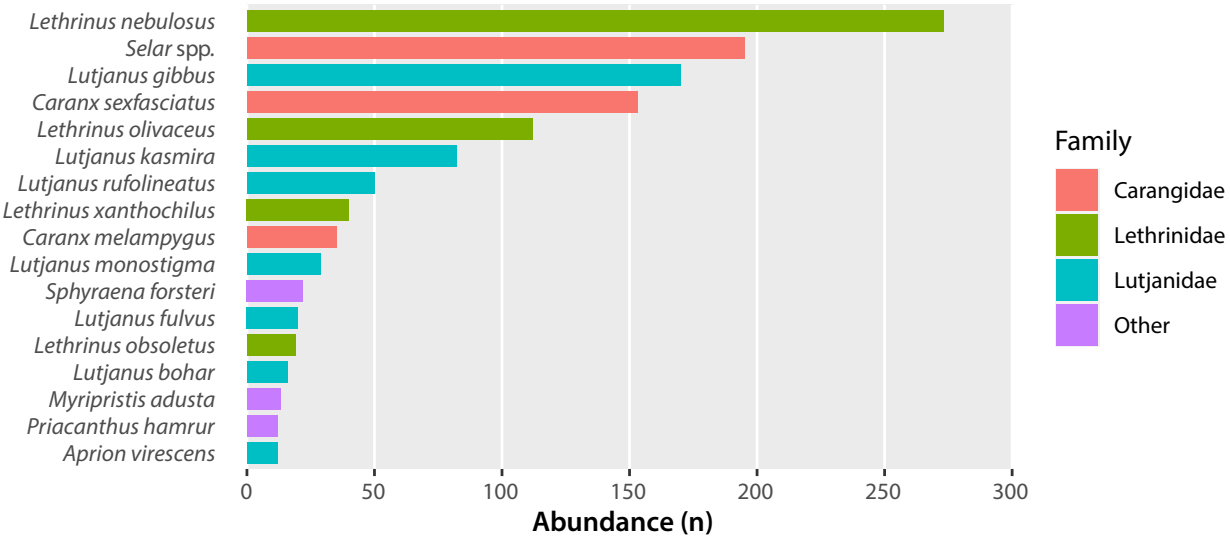
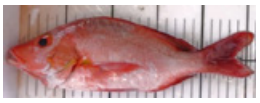



Figure 4. Fish species caught. Abundance corresponds to the total number of individuals encountered in the different catches across the 14-day sample period.

Back from a fishing trip, Tarawa, Kiribati. (image: Jeff Kinch, ©SPC)

Table 2. Species size reference table and associated literature. Sizes are expressed as fork length (FL) or in total length (TL) in centimetres and mean sizes are associated with standard error (SE), the number of individuals measured is also provided (n).

| Scientific name<br>Common name | Species photos | Maturity (cm FL) | References used, Location | Legal size (cm FL) | n | Mean size (cm ± SE FL) |
|---|---|---|---|---|---|---|
| *Caranx melampygus*<br>Bluefin trevally | | 35 (TL) | (Sudekum et al. 1991)<br>Hawaii | | 35 | 32.91 ± 0.85 |
| *Caranx sexfasciatus*<br>Bigeye trevally | | 50 | (Van Der Elst 1993)<br>South Africa | | 153 | 30.99 ± 0.48 |
| *Lethrinus nebulosus*<br>Spangled emperor | | 39.5 | (Ranatunga and Rathnayaka 2019)<br>Sri Lanka | 55 | 271 | 40.49 ± 0.23 |
| *Lethrinus olivaceus*<br>Longface emperor | | 40.9 | (Prince et al. 2015)<br>Palau | | 112 | 47.22 ± 0.55 |
| *Lethrinus xanthochilus*<br>Yellowlip emperor | | 30 | (Prince et al. 2015; Taylor et al. 2018)<br>Palau; American Samoa | | 40 | 40.55 ± 0.47 |
| *Lutjanus gibbus*<br>Paddletail snapper |  | 25 | (Moore 2019; Taylor et al. 2018)<br>New Caledonia; American Samoa | 25 | 170 | 25.37 ± 0.28 |
| *Lutjanus kasmira*<br>Common blue-stripe snapper | | 20 | (Rangarajan 1971)<br>Andaman Sea | 15 | 82 | 18.9 ± 0.21 |
| *Lutjanus rufolineatus*<br>Yellow-lined snapper | | 16.4 | (Taylor et al. 2018)<br>American Samoa | | 50 | 17.87 ± 0.10 |
| *Selar* spp.<br>Scads | | 21.5 | (Roos et al. 2007)<br>Reunion Island | | 183 | 25.47 ± 0.11 |

The nine species considered for their size at sexual maturity (Fig. 5) were:

- four species (longface emperor, yellowlip emperor, yellow-lined snapper, scads) with a high dominance of mature individuals (85–100%);
- two species (spangled emperor, paddletail snapper) with a slight dominance of mature individuals (50–65%);
- one species (common blue-stripe snapper) with a slight dominance of immature individuals (50–65%); and
- two species (bluefin and bigeye trevally) with a high dominance of immature individual (75–99%)

## *Proportion of the catch above the legal size established in 2020*

Of the more than 30 species collected, only three – spangled emperor, paddletail snapper and common blue-stripe snapper – were associated with a minimum harvest size regulation in Kiribati (Ministry of Fisheries and Marine Resources Development 2020) (Fig. 6).

All of the spangled emperors that were caught were under the legal size, while almost all common blue-stripe snappers were above the minimum harvest size. Catches of paddletail snapper were more balanced, with slightly more individuals above or equal to the legal catch size than under it.

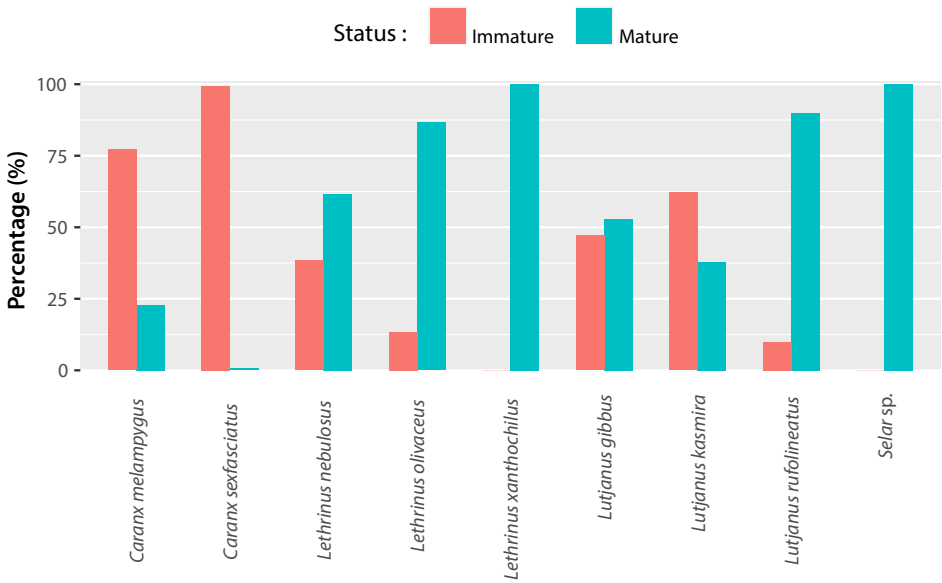



Figure 5. Proportion of estimated mature and immature individuals caught during the two-week sample period.

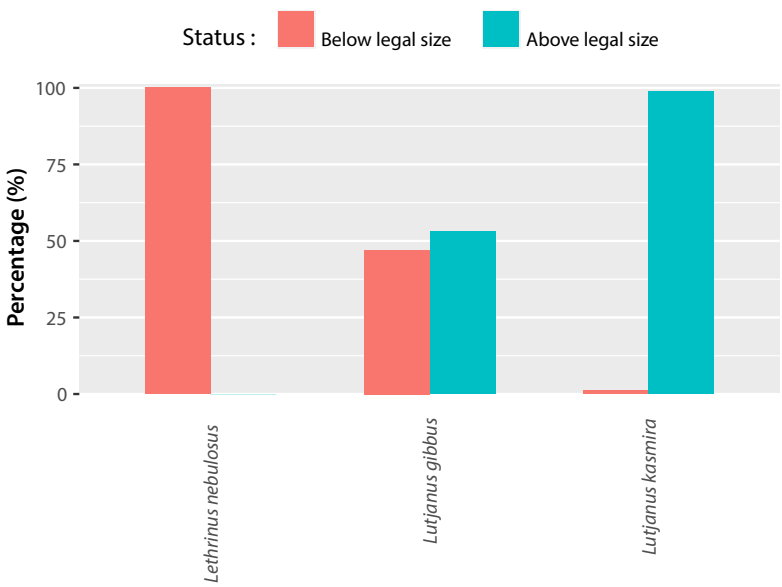



Figure 6. Proportion of individuals above or below legal size caught during the 14-day sample period.

## Comparison of study group catches with other 2019 fisher group catches and historical handlining catches in Tarawa

As noted above, target species in South Tarawa have greatly changed over recent decades. The introduction of new technologies, such as monofilament gill nets and boats with outboard engines, also coincided with a significant decline in the use of traditional fishing methods. With high historical incidences of ciguatera from fish caught on the outer reefs of Tarawa Atoll (Cooper 1964; Tebano 1992; Lovell et al. 2002), fishing effort outside the lagoon has primarily targeted tunas or flying fish. Gibson (1976) noted that the most preferred fish species consumed at Bikenibeu in the mid-1970s was, in order of preference, tunas, bonefish, wahoo and mullet. Later catch surveys conducted in early 1981 in Betio, Bairiki-Nanakai, Bikenibeu, Teinainano and Buota showed the most important targeted fish species was bonefish, with an emerging market for the export of spangled emperor. At Bikenibeu, the top five species caught at this time, in order of importance, were bonefish, mullet, paddletail snapper, Pacific silver-biddy and convict surgeonfish (Marriott 1981). During the early 1980s, there was an economic downturn that resulted in increased fishing effort, a growth in entrepreneurism among artisanal fishers, and the acquisition of more efficient gear types (Marriott 1982).

Over time, target fisheries have changed across South Tarawa, with greater specialisation among fisher groups and village localities. Snappers (Lutjanidae), emperors (Lethrinidae) and groupers (Serranidae) dominated handline catches in the early 1990s. A survey conducted from April 1992 to February 1994 recorded 54 species and 1793 individuals caught from 46 fishing trips. Paddletail snapper was reported to be the most abundant species caught (40% of total number of fish caught), followed by orange-striped emperor (18%). Trevallies and squirrelfishes were also an important part of landings. Fishing effort using handlines was significantly greater in the northern and western ends of Tarawa Lagoon than in southern and eastern sites (Beets 2000). Later, Ram-Bidesi and Petaia (2010) noted that fishers on South Tarawa were targeting schools of paddletail snapper prior to their spawning run.

Creel surveys have been conducted in South Tarawa since 2013 by the Research and Monitoring unit of the Coastal Fisheries Division of Kiribati's Ministry of Fisheries and Marine Resources Development (MFMRD). In total, 67 handlining catches were recorded by MFMRD. These records were retrieved from MFMRD's database and compared to the 2019 landings from the study group we monitored (Table 3).

Table 3. Number of historical handlining landings in South Tarawa.

| Historical MFMRD landings | |
|---|---|
| 2013 | 9 |
| 2014 | 19 |
| 2015 | 7 |
| 2016 | 3 |
| 2017 | 12 |
| 2018 | 9 |
| 2019 | 8 |
| Total (past) | 67 |
| **2019 landings** | |
| **Study group 2019** | **10** |
| **Other groups surveyed in 2019** | **18** |

A typical handline catch, Tarawa, Kiribati. (image: Jeff Kinch, ©SPC)

### *Comparison of number and weight landed in the past*

The average landing based on the two-week sampling period of the monitored study group tended to be approximately 30% higher than the average landings of other fisher groups monitored during the 2019 survey (Fig. 7). Historical landings recorded by MFMRD in South Tarawa tended to be around 50% lower for the same fisher groups encountered in this study in terms of number of fish landed, landed weight and species diversity. Although MFMRD's historical landing data were lower for the same fisher groups encountered in this study, when all landing were pooled for all fisher group landings recorded by MFMRD, there were some similarities with regards to year. In terms of weight, catches were similar between 2013, 2014 and 2019 while the number of fish caught was closer to those of 2013, 2014 and 2016 (Fig. 7). While this comparison gives some insights into the range of catches through time, the significant disparities in the number of landing surveys completed and/or fisher groups surveyed, as well as seasonal differences, these comparisons cannot be considered definitive or complete.

### *Comparison of families' representativeness across years*

In comparison with the study group, catch composition was well represented across years for the Lutjanidae and Lethrinidae families. The Carangidae family was less represented with the exception of years 2015 and 2019. In 2019, the catch was more diverse with other families well represented in catches (Fig. 8).

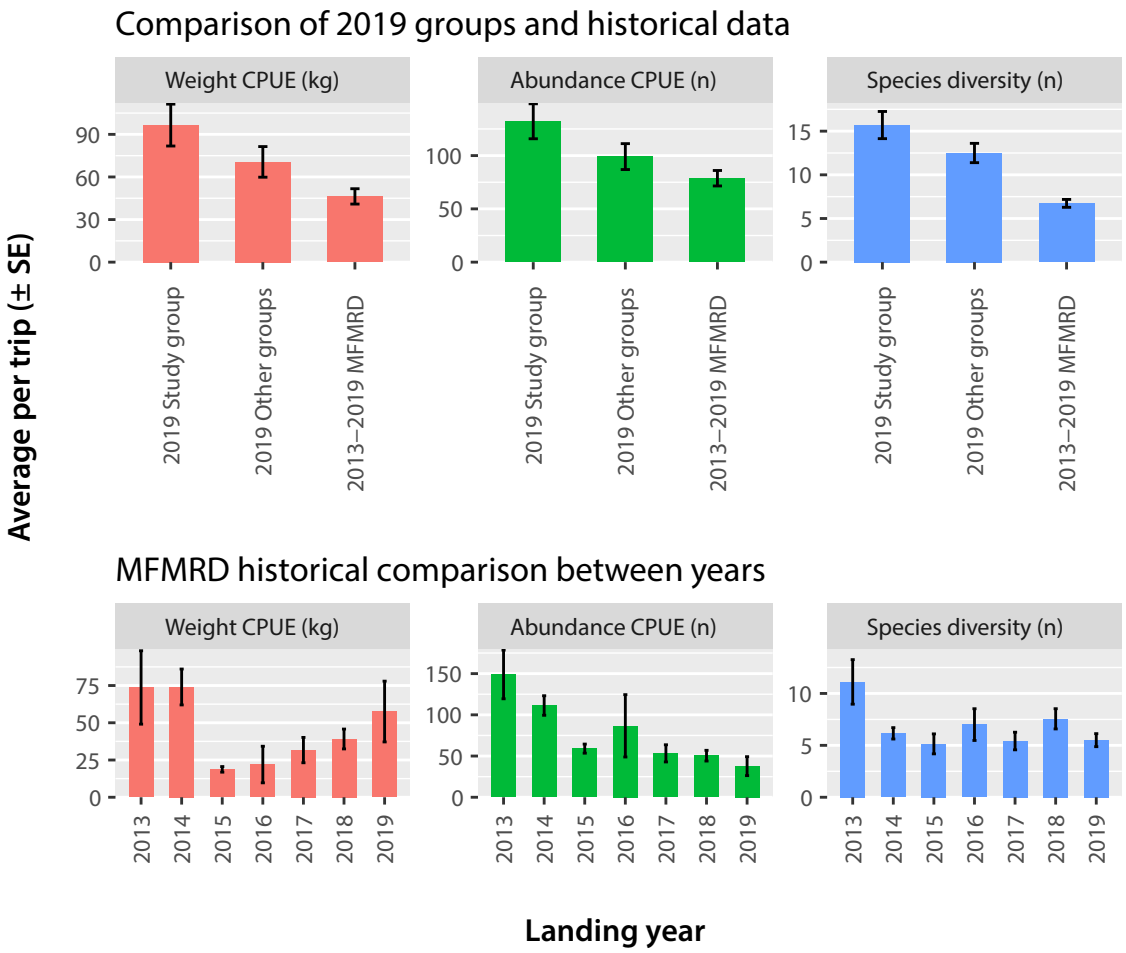



Figure 7. Comparison of catch of study group and historical data (per landing).
Top: The study group against 2019 other groups and MFMRD historical data pooled; Bottom: MFMRD 2013–2019 historical average catch details per year.

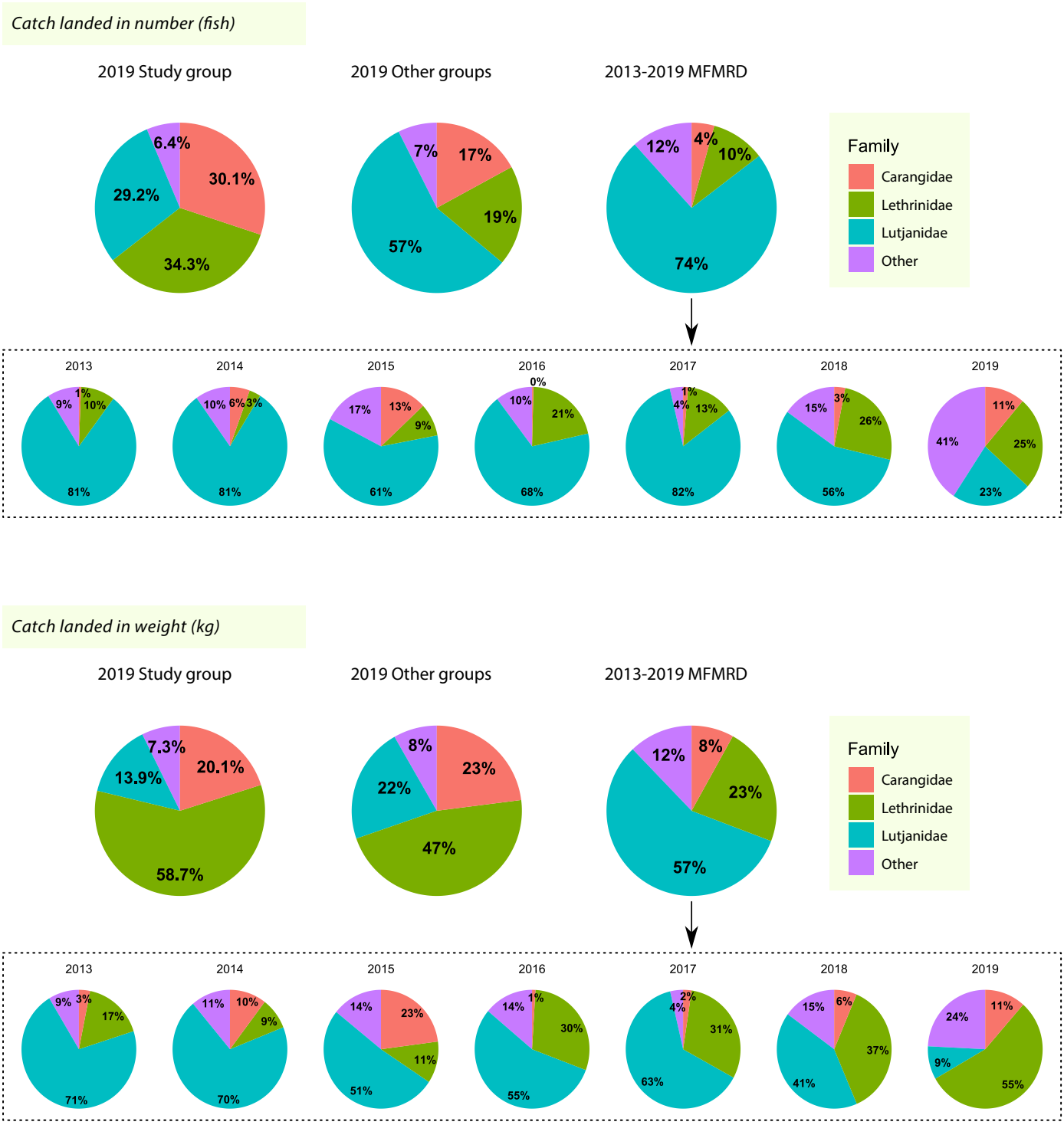



Figure 8. Catch composition, by family, for the study group, the 2019 Other groups and MFMRD historical data (pooled and by years). Top: catch in number; bottom: catch in weight.

On a more general trend, Lutjanidae tended to be dominant in the number of fish landed and overall weight of fish caught. However, the proportion of the Lethrinidae catch by weight was better represented, suggesting larger fish from the Lethrindae family were being caught, as opposed to more fish being caught from that family.

## Comparison of mean size of top species

The mean size of fish common to the study group, 2019 other fisher groups, and MFMRD's historical catch data were also compared (Fig. 9). The mean size varied across the different groups studied and the importance of the variability tended to be linked to larger species.

The longfaced snapper displayed the greatest differences between the groups compared. The 2019 study recorded the highest mean size, followed by the study group and the MFMRD historical data. For some species – spangled emperor, blacktail snapper (*Lutjanus fulvus*), paddletail snapper and one-spot snapper (*Lutjanus monostigma*) – MFMRD historical data recorded a slightly greater mean size, which might suggest a possible effect of fishing pressure on these species but, the lack of sufficient data makes it difficult to make accurate comparisons.

Paddletail snapper had the highest number of records in the historical catch data, although there was significant variability in the mean size of this species across years (Fig. 10). In 2016, the lowest mean size recorded was 7.5 cm lower than the highest mean sizes recorded in early 2019.

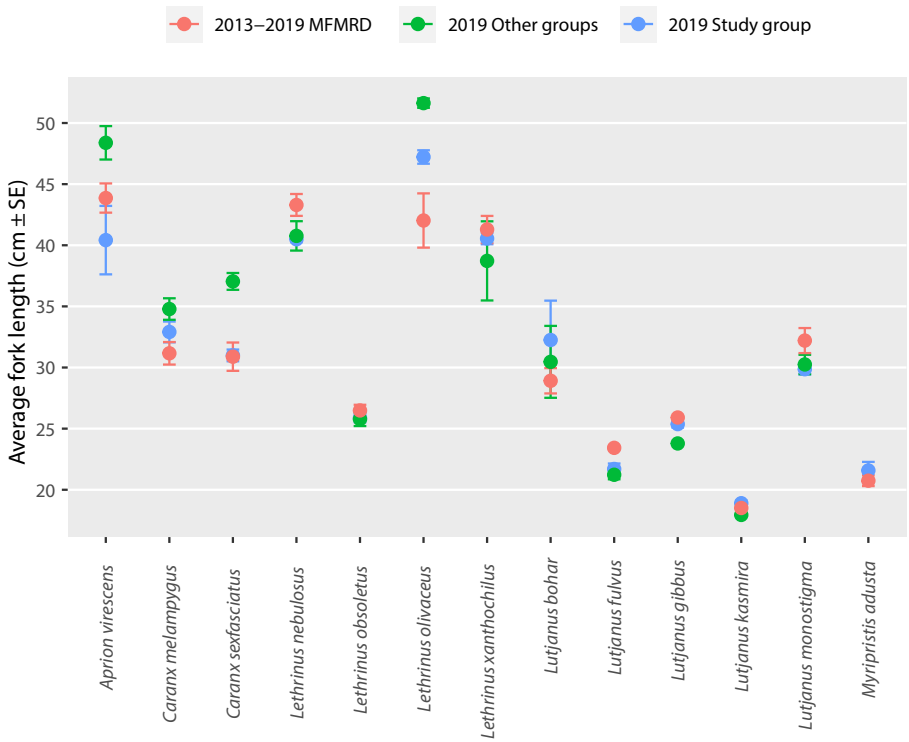



Figure 9. Mean size (±SE) of 13 fish species in the 2013–2019 historical catch data (all years pooled), this study group catch, and the 2019 other fisher groups catch.

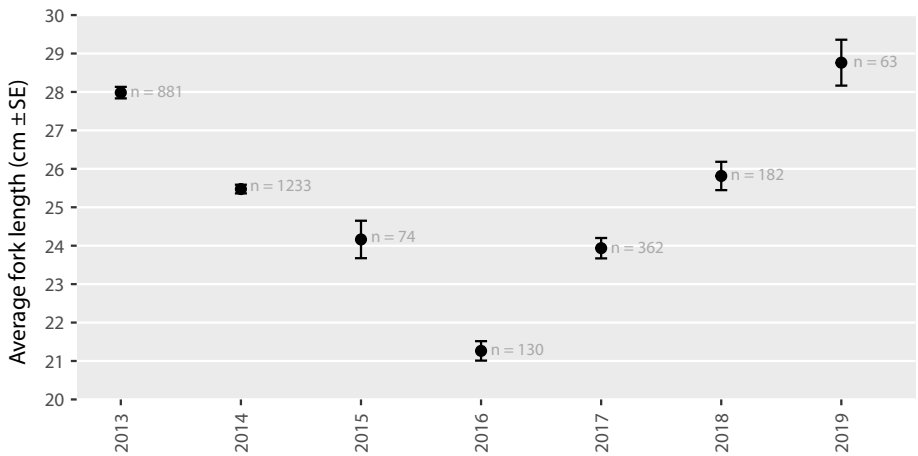



Figure 10. Mean size (± SE) of *Lutjanus gibbus* in the 2013–2019 MFMRD historical catch by years.

## Socioeconomics

The artisanal fisheries sector on South Tarawa is divided into full-time commercial, part-time commercial and subsistence fisher groups. In 1982, 130 households were surveyed in Bikenibeu and of these, 72% were fishing households with 14% being full time commercial fishing households, 13% being part-time and 66% subsistence fishing only (Marriott 1982). The study group that we monitored would be regarded as being full-time commercial because fishing is their main income-earning activity and they fish specifically to sell. The leader of this study group was from another island in the Gilbert Group but married to a woman from Bikenibeu. At the time of monitoring, they were running two vessels. Operations of these two vessels were dependent on having working engines and enough fishers to fish. Over the extended period that was recorded in the logbook, 15 fishers were engaged, with 6 of these being considered regular full-time fishers and another 3 being part-time fishers, and the remaining 7 being taught the fishing processes and deciding if they would participate more frequently.

The simplest and most common form of handlining used by the fishers on South Tarawa is a line of a certain length (usually between 20- and 40-lb breaking strength), a sinker (lead, chain or any other weight), a cast snood and at least one hook. The study group described in this paper had a preference for size 7, 8 and 10 hooks, which cost between AUD 0.10 and 0.20 each. Sinkers cost AUD 0.30 each, while a roll of 25-lb fishing line was AUD 4.80, and hand reels were between AUD 4.50 and 5.00, depending on size. Generally, only one baited hook is used for each fishing line, although more than one hook (but not more than three) is also used. Hooks were sometimes rigged with a fluorescent tube over its shanks.

Women's roles in the fishing sector of South Tarawa are mostly limited to gleaning in the lagoon, as well as selling fish on the roadside or in markets (Tekanene 2006). The study group we monitored had two full-time women selling fish. One woman was the wife of the study group leader and the other was her relative. Both women took a portion of the profit from each day's sales.

During the period 2 March to 7 December 2019, 210 fishing trips were recorded (Table 4). In general, three fishers fished each night although on a few occasions only two fishers went. Expenditures were included fuel, bait (mostly tuna or flying fish), provisions (e.g. tobacco, flour balls, coffee and sugar); gear replacement (mostly hooks and sinkers), and ice to keep fish fresh. Batteries were also purchased for torches and a hand-held GPS.

For each fishing trip approximately 70 kg of gutted fish was sold, earning approximately AUD 225.00, which once deducted from operating costs (fuel, ice, bait, provisions and gear) was then shared among the study group as follows:

- the leader took one to two shares: one for the boat and one as a fisher if he went fishing;
- the fishers each received one share; and
- the women marketing the fish also received one share.

Fish usually sold for AUD 1.50/lb, though on some occasions fish were sold for AUD 1.00 to AUD 1.20/lb when it was necessary to sell them quickly for fear of spoilage. On one occasion, high-valued fish were sold for AUD 1.90/lb. The local profit-sharing systems operating among fisher groups on South Tarawa tend to favour those who own the fishing assets and hence command the means of production for themselves and others. Fishers' shares ranged from negative

Table 4. Study group expenditures and income from 2 March to 7 December 2019. Numbers in the table are expressed as average (Av.) ± standard error (SE)

| Activity | Boat 1 (n = 131) | Boat 2 (n = 79) | Average (n = 210) |
|---|---|---|---|
| Av. no. fishers | 3 | 3 | 3 |
| Av. fuel used per trip (L) | 39.66 ± 0.89 | 32.94 ± 0.97 | 37.13 ± 0.70 |
| Av. fuel cost per trip (AUD) | 54.45 ± 1.23 | 45.10 ± 1.32 | 50.93 ± 0.96 |
| Av. bait cost per trip (AUD) | 8.40 ± 0.27 | 7.85 ± 0.38 | 8.19 ± 0.22 |
| Av. ice cost per trip (AUD) | 10.00 ± 0.03 | 10.00 ± 0.25 | 10.05 ± 0.10 |
| Av. provisions cost per trip (AUD) | 9.70 ± 0.09 | 9.60 ± 0.06 | 9.69 ± 0.06 |
| Av. gear cost per trip (AUD) | 8.00 ± 0.33 | 6.40 ± 0.39 | 7.42 ± 0.26 |
| Av. gutted fish weight sold per trip (kg) | 74.37 ± 3.13 | 61.42 ± 2.79 | 69.49± 2.25 |
| Av. amount earned per trip (AUD) | 240.40 ± 9.64 | 202.25 ± 9.04 | 226.04 ± 7.01 |
| Av. ice cost for marketing per trip (AUD) | 8.00 ± 0.64 | 9.40 ± 0.65 | 8.82 ± 0.47 |
| Av. earnings for women marketing fish (AUD) | 22.45 ± 0.98 | 18.60 ± 0.87 | 21.00 ± 0.70 |
| Av. earnings per fisher (AUD) | 23.35 ± 1.47 | 19.00 ± 1.48 | 21.72 ± 1.08 |

Table 5. Study group expenditures and income from 25 May to 7 June 2019. Numbers in the table are expressed as average (Av.) ± standard error (SE).

| Activity | Boat 1 (n = 10) |
|---|---|
| Av. no. fishers | 3 |
| Av. fuel used per trip (L) | 40.50 ± 2.57 |
| Av. fuel cost per trip (AUD) | 55.75 ± 3.45 |
| AV. bait cost per trip (AUD) | 5.90 ± 0.67 |
| Av. ice cost per trip (AUD) | 10 .00 ± 0.00 |
| Av. provisions cost per trip (AUD) | 9.60 ± 0.00 |
| Av. gear cost per trip (AUD) | 5.35 ± 1.55 |
| Av. gutted fish weight sold per trip (Kg) | 83.23 ± 11.86 |
| Av. amount earnt per trip (AUD) | 277.10 ± 38.92 |
| Av. ice cost for marketing per trip (AUD) | 7.20 ± 1.93 |
| Av. earnings for marketing woman (AUD) | 23.50 ± 2.16 |
| Av. earnings for fisher (AUD) | 30.85 ± 6.32 |

AUD 10.90 to an extreme high of AUD 108.25 but averaged AUD 21.72 across all trips recorded in the logbook. The two women sellers earned, on average, AUD 21 per fishing trip with a range of AUD 3.00 to 77.00.

In the case of the detailed catch monitoring from 25 May to 7 June 2019, only one boat was in operation (Table 5). During this period, the study group's overall catch and profitability was slightly higher than that observed across the average of the logbook period (see Table 4).

Fish selling commences as soon as the fishing boat returns from fishing, which could be between 5.30 and 7.00 am. In general, people on South Tarawa are buying fish for their next meal as many people lack the ability to store fish appropriately. A lack of suitable storage means most fish is cooked the same day that they were bought.

## Conclusion

The analysis presented in this study details the importance of understanding better what species fisher groups are targeting, when, why and how. This is particularly important for places such as South Tarawa because if fisheries resources continue to decline, fishers will be left with limited options for income, and there will be an impact on general food security. In South Tarawa, the rate of unemployment is already high with employment opportunities restricted to working in the government public service, the service and retail sector or working on foreign merchant and fishing vessels. South Tarawa's growing population and the associated increasing demand for seafood, changes in fishing technologies, the development of organised fishers' groups, and a lack of alternative livelihood options, means that the fisheries resources of Tarawa Atoll are, and will continue to be, increasingly exploited to sustain growing usage needs. When combined with climate change, South Tarawa is facing multiple and simultaneous threats to its liveability and survival (Donner 2010; Story and Hunter 2012; Campbell and Hanich 2014). It has been predicted that future periodic storm surges caused by increased storm activity associated with climate change could cause up to 25–54 % of South Tarawa to become inundated by 2050 (Campbell 2000). For Bikenibeu, where this study was centred, it has been estimated that a sea-level rise of 0.5 m would cause almost all of the shoreline on the lagoon side, and a small part of the ocean shoreline, to be submerged, resulting in 51% of the total shoreline breached and 71% of the land area of Bikenibeu to be flooded (He 2001)

The Government of Kiribati recognises the importance of the long-term protection of its fisheries resources as detailed in the National Fisheries Policy 2013–2025 (Ministry of Fisheries and Marine Resources Development 2013). The National Roadmap for Coastal Fisheries was also endorsed in 2019 (Ministry of Fisheries and Marine Resources Development 2019) and a set of fishing regulations adopted in 2020 (Ministry of Fisheries and Marine Resources Development 2020). The data presented in this study also highlight the importance of sampling from different fisher groups because having a suitable sampling range allows for the detection of changes to fisheries resources and effort over time. For fish species that are heavily targeted, it is suggested that regular monitoring programmes be conducted that systematically collect the necessary information to inform decisions regarding management in a timely and effective way. Of particular importance are data that allow for better comparison of sizes of fish caught and overall fishing effort. Having this level of information would assist MFMRD to set suitable and relevant size limits as per their Fisheries (Conservation and Management of Coastal Marine Resources) Regulations 2020 (Ministry of Fisheries and Marine Resources Development 2020). For example, the newly implemented size limits imposed for spangled emperor will not have the required purpose of ensuring sustainability as none of the individuals recorded in this study were above the legal size.

Recent efforts to improve the legal frameworks for managing fisheries in Kiribati, raising awareness, strengthening monitoring, control and surveillance are crucial (Teemari et al. 2020). Ongoing monitoring (e.g. Molai et al. 2020; Andrews et al. 2020) is required to help inform management and overall wider fisheries development initiatives for South Tarawa and Kiribati as a whole. Such monitoring programmes, however, remain a great challenge as does the enforcement of regulations.

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# An assessment of plastic waste generation from fishing vessels in the western and central Pacific, and potential measures to improve onboard waste management

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***This article is based on the executive summary of a report[2] commissioned by the Pacific Islands Forum Fisheries Agency (FFA) to gain an understanding of the situation regarding plastic waste that is dumped into the western and central Pacific Ocean from fishing vessels. Given the current situation with the COVID-19 pandemic, this desktop study reviewed the existing literature on the subject to gain insight about waste management practises onboard fishing vessels. Fishing boat officers and/or company personnel were surveyed when possible, and the extensive experience of the authors in the fields of fishing vessels and waste management were also relied on to make an overall assessment of the current situation regarding waste disposal on vessels in the Pacific.***

***The ultimate aim of the study was to provide possible strategies and actions that could be taken at both the national and regional level to eliminate all plastic waste disposal at sea. The authors have endeavoured to address this central point through a thorough and careful analysis of the information available. It is essential to bear in mind from the outset, the reason why an attempt was being made to determine the amount of waste that is dumped in the ocean: to prevent it.***

## Estimates of waste generation by fishing vessels

Estimates of waste generation by fishing vessels is only ever amenable to broad estimates, as the amount changes every day and there are many variables, including vessel size, crew numbers, type of fishing, length of voyage, vessel condition and operating standards on board.

Similarly, given that waste management practises onboard vessels vary widely, it is not realistic to make any meaningful estimate of the amount of waste being dumped unless an extensive, real-time study of several vessels during whole fishing trips is conducted. To make a broad sweeping claim regarding the amount of waste dumped from all fishing vessels might discourage those operators who are doing their best to deal with waste problems onboard, while making those – if any – who dump everything over the side, actually look better.

Faced with this conundrum, and mindful of the ultimate purpose of this study, the authors have taken the approach of trying to estimate the amount of waste that certain vessels might generate.

The full report differentiates between: 1) operational and maintenance waste that is related to crew and vessel size and condition, and days at sea; and 2) fishing operations waste that is directly related to the type of fishing and total fishing effort. Using existing literature, observer reports and the authors' varied experience, some broad estimates have been made that might allow a determination of a vessel's expected waste generation. These estimates are of a conservative nature and are applicable to a broad range of vessels.

The study did not look at the issue of lost and discarded fishing gear, as this was not part of the terms of reference. The issue could, however, be addressed through recommendations and standards that are already in place, such as of the International Convention for the Prevention of Pollution from Ships (MARPOL)[3] and the International Maritime Organization (IMO).[4] The strategies and actions proposed below take account lost or discarded fishing gear and allow for the integration of measures to combat this problem into the proposals, through the marking of fishing gear.

Our estimate of waste generated by the different tuna fishing fleets in the western and central Pacific Ocean (WCPO) is as follows.

**Longline vessels.** For the 1700 active vessels in the WCPO:

- Plastic liners in bait boxes: 402–935 tonnes; median: ~ 670 tonnes per annum.
- Cardboard: 2958–6879 tonnes; median: ~ 4920 tonnes per annum.
- Using 60% as a proxy based on observer reports: **between 241 and 560 tonnes of plastic waste from bait alone is being dumped at sea every year, while the figure for cardboard is between 334 and 776 tonnes.**

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[2] Leney A., Blaha F. and Lee R. 2021. An assessment of fishing vessel plastic waste generation in the WCPO region – And potential measures to improve waste management in the fleet. Honiara, Solomon Islands: Pacific Islands Forum Fisheries Agency.
[3] https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx
[4] https://www.imo.org/en

Salt bags for brine stored in a purse seiner. (image: © Francisco Blaha)

**Purse-seine vessels.** For the 253 vessels in the FFA register:

- Salt bags for brine making: 210 tonnes, equivalent to 2,800,000 individual bags.
- Using a 37% proxy: **77.7 tonnes of woven plastic salt bags (equivalent to 1,036,000 individual bags) are dumped into the ocean every year.**

**Operational and maintenance waste:**

- Longline vessels: 1000 tonnes produced, 600 tonnes dumped into the ocean every year.
- Purse-seine vessels: 220 tonnes produced, 80 tonnes dumped into the ocean every year.

## Existing international frameworks and guidelines

Having determined some idea of the type and scale of the problem regarding the waste generated on fishing vessels, the study then looked at the practicalities of dealing with those quantities and types of waste. The current institutional frameworks that exist – under MARPOL, the Western and Central Pacific Fisheries Commission (WCPFC) conservation and management measure (CMM) 2017-04,[5] and IMO agreements – are looked at in detail to determine if a good framework and clear guidance already exists. It is clear that all of the institutional frameworks, guidance documents, standards and agreements that might be needed by ship operators to address the issue of onboard waste management are, in fact, already in place.

## Waste reception capacity at Pacific ports

The study examined the potential to off-load waste at several Pacific Island ports. The picture is grim: of the five fishing ports in the region that were looked at, only one – Suva in Fiji – has access to a landfill facility that is in any way compliant with any desirable standards. The other four nations – the Federated States of Micronesia, Kiribati, Marshall Islands and Solomon Islands – struggle with their own local waste management to varying degrees, and their landfill facilities are mostly already overwhelmed. Adding foreign commercial waste to existing domestic waste is not a viable solution, where that is avoidable. While some fishing vessels do operate out of Pacific Island ports as a home base (e.g. one company in the Marshall Islands and another in Noro, Solomon Islands) and have to dump their waste in local dumpsites, the majority of fishing vessels are actually foreign-based, and materials that are now waste were once provisioned onto those vessels either at overseas ports or from carrier vessels.

[5] https://www.wcpfc.int/doc/cmm-2017-04/conservation-and-management-measure-marine-pollution

## Waste disposal for the distant-water fishing nations vessels

Taking a conventional solid waste management approach of investigating "reverse logistics" pathways,[6] and following the internationally accepted principle that the country to which a fishing vessel belongs is also responsible for the waste that vessel produces (in this case, the flag state or de facto home port). The carrier fleet provides an excellent opportunity to improve waste management at sea. Carrier vessels are typically larger than fishing boats, and have adequate deck space for taking waste back to an appropriate port to be dumped. Because the actual waste takes up less space than the products that originally generated that waste, there is clearly an opportunity to involve the carrier fleet in a formal waste management function.

It is fully accepted that the carrier fleet fills its holds with fish that take up some of the space of supplies that were carried out. But while longline vessels consume vast numbers of boxes of bait, and purse-seine vessels take on many tonnes of 50-kg sacks of salt, there is space on decks and in dry holds to store carefully managed waste that can be taken back to shore. Carriers have the potential to have small compactor baling machines onboard that can compress waste, increase the density, and thus reduce the stowed volume of waste. And some vessels have IMO-compliant incinerators that are much safer for both ship and crew than rusty oil drums with holes that are common on the decks of many fishing vessels. Oil drum incinerators are undesirable from a ship safety point of view and are a known health hazard to crew as they generate carcinogenic smoke in significant quantities.

In short, if the waste produced by fishing boats is to be professionally addressed, then it must become part of the everyday operation of running a tight ship, and waste needs to be managed and stowed for off-loading at the appropriate place and time. Good ship operators are already doing this, and all the guidance that is needed to help other operators improve their onboard waste management exists in great detail under the MARPOL and IMO frameworks. The logistical problems are quite easily solved, and there is no shortage of guidance on how to address them; the major challenge at present is the indifferent attitudes toward proper waste management.

On this note, the full report provides some simple and practical advice on onboard waste management that is derived from the direct experience of the authors in this field, one of which spent several years at sea during which one of his tasks was to manage the waste onboard, ensuring that nothing went over the side except food waste.

## Economic incentives for improved waste management

Having determined that, for the carrier-supplied fleet at least, there is a clear alternative to dumping waste in the ports of Small Island Developing States (SIDS), and that commercial and financial considerations are a significant driver in how waste is managed onboard. The report takes a brief look at the economic incentives that currently exist and may drive how waste is managed on fishing vessels. It can be clearly seen that the economic incentives are entirely aligned to encourage poor waste management and ocean dumping. This is an important insight, and one recognised by the IMO, and several MARPOL documents call for the creation of incentives to improve waste management. The report quotes a ground-breaking recent economic analysis[7] from the British government to support the conclusions reached here. Improved waste management will incur additional costs, but this is simply part of the cost of running a responsible business and cannot be used as a justification to pollute the natural environments of small Pacific Island nations. Currently, the "avoided cost" (i.e. financial benefit) of poor waste management is, de facto, a subsidy from island nations to those businesses that evade their responsibilities under MARPOL. In fact, a "secondary market" in waste may appear whereby carriers charge fishing vessels to take their waste away, thus allowing those vessels to fulfil their waste bond requirements.

## Strategy to eliminate the dumping of waste at sea

With all of the above now providing some clarity to the waste management situation onboard fishing vessels, we reach the heart of the matter: How might any dumping of waste from fishing boats cease? From the above, strategic points can be developed and enumerated, and resulting actions that can be taken to implement these strategic points can become clear.

The resulting strategic points are as follows:

1) Either waste is dumped into the sea, or it is returned to port at some point, and in some form. MARPOL does not allow the dumping of any solid wastes considered in this study to be dumped into the ocean, including incinerator ashes, thus:

   ***All vessels should return with some quantity of waste to be off-loaded at port.***

[6] "Reverse logistics" differs from traditional waste management in that it adds value back into the chain by recovering and repurposing products, whereas waste management focuses mainly on disposal.

[7] The Economics of Biodiversity: The Dasgupta Review February 2021: https://www.gov.uk/government/publications/final-report-the-economics-of-biodiversity-the-dasgupta-review

2) If something is to be managed, then it will need to be measured. Therefore, the questions are: How much? and How do we measure it? There are two separate waste streams to consider: fishing operations waste, and operational and maintenance waste. The first is related to fishing effort while the second is related to crew and vessel size, and the number of days at sea, thus:

   ***A measure of expected waste generation by vessel is required.***

3) The overall framework of institutional and technical standards and guidelines already exists with MARPOL and IMO. The overall aim must be to ensure that those vessels that do not currently have good waste management practices, must change their current practices, thus:

   ***Under the FFA Harmonised Minimum Terms and Conditions, all licensed fishing vessels must comply with MARPOL, whether the flag state is a Party or not.***

4) There is actually an economic incentive to operate a vessel with poor waste management; an economic incentive must be created to improve waste management, thus:

   ***An economic incentive to follow MARPOL requirements must be created.***

5) Measures must be simple to implement where possible for both FFA and fishing companies. Onerous and complex reporting systems that require significant additional effort and cost to report, monitor and enforce are unlikely to be adopted, thus:

   ***Simple metrics must be used, and effort must focus on a small number of key ports and/or locations.***

6) The issue of onboard waste management is fundamentally a logistical challenge; all of the materials that become waste were put on the ship either in port or during a carrier transshipment, thus:

   ***Existing reversed logistical pathways must be used.***

7) Pacific Island ports already have a domestic waste crisis and are, in very large part, unsuitable places to take foreign waste generated by overseas business operations. Therefore, aside from local-based fishing vessels, vessel waste needs to be returned to originating home ports, thus:

   ***Wastes from vessels of distant-water fishing nations should not be off-loaded at Pacific Island ports.***

Managing waste on small islands is a real challenge, Majuro, Marshall Islands. (image: ©Alice Leney)

8) Larger vessels are much better placed to have better waste management systems because they have more space, can operate small compactors to increase waste density, can operate safe and compliant incinerators, and can handle and stow larger waste containers, thus:

   *Carrier vessels must accept waste from fishing vessels.*

9) There must be a long-term element to the strategic actions that is aimed at changing, over time, the culture onboard those fishing vessels that do not currently have good waste management systems in place, thus:

   *Easy waste management measures should be imposed at the start, and the bar should be raised over time.*

10) Ship owners and operators who can show that they have MARPOL-compliant systems already in place, and already take waste management seriously, must be recognised. Those who do not must be held accountable, thus:

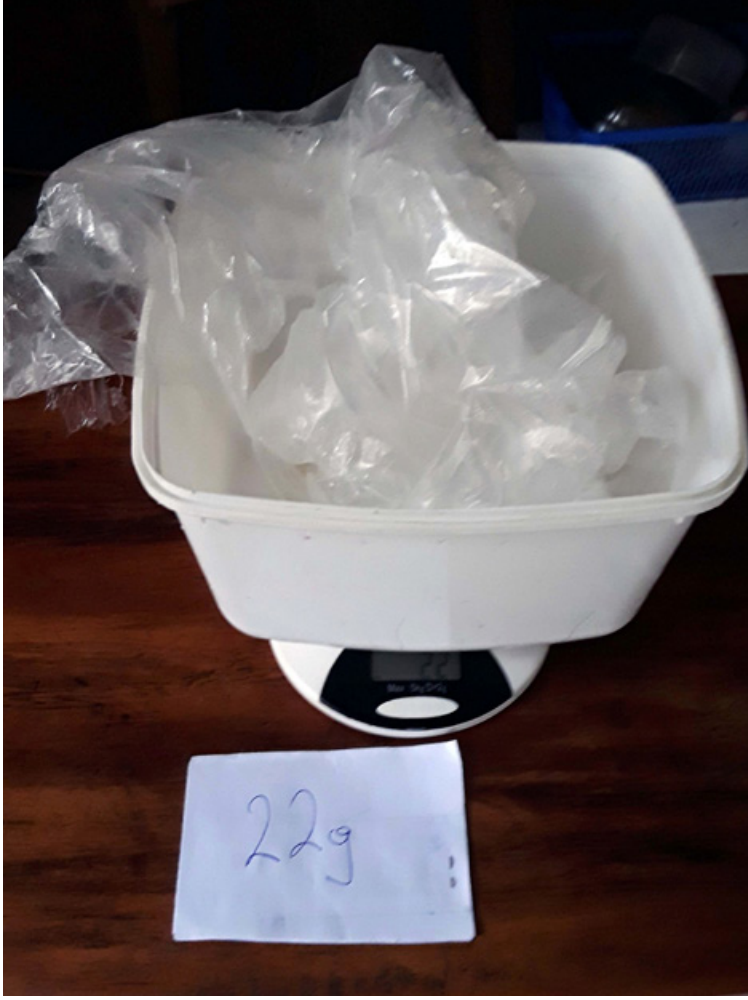
   *Good businesses should be rewarded, and poor operators should be targeted.*

These strategic points rest on two fundamental pillars: 1) simple ways to measure and monitor onboard waste to know that change is occurring; and 2) the development of incentives to reward those already doing the right thing, encourage change in those who need to, and sanction those who resist.

## Proposed actions to take

From this strategic analysis, and a close look at the realities of dealing with waste onboard ships, the report recommends a divergence from the MARPOL method of measuring waste by volume in cubic metres, to that of weight in kilograms. The reasons for this are elaborated on in the report, and the key considerations are provided by strategic points 5 and 9. Measurement must be as simple as possible and consistent with reasonable estimates because reasonable estimates are the bedrock of waste measurement. This approach meets the requirements of the first pillar on which the strategy rests.

For the second pillar, the heart of the proposed actions is the FFA Harmonised Minimum Terms and Conditions that require demonstrated effort to comply with WCPFC CMM 2017-04 as well as MARPOL requirements. Alongside this, using the widely used waste management principal of extended producer responsibility, a "waste bond" is proposed, whereby a vessel must show that a reasonable quantity of waste is disposed of onshore in an acceptable manner to avoid sanction.




Weighing plastic liners from a standard bait box used by tuna longliners. (image: © Robert Lee)

This waste bond would be held in escrow in some conventional form[8] to ensure that good operators are not penalised, but poor ones are. Greater detail of this proposal is provided in the report, but in essence the following "action points" are proposed.

### A. Provide, as part of licensing (under the Harmonised Minimum Terms and Conditions), vessels with a simple electronic template for a Garbage Record logsheet

Some work will need to be conducted to develop a suitable electronic Garbage Record logsheet template, that will minimise the quantity of information required to be recorded so that it is as simple as possible to fill out and check. This would be similar to vessels that presently do electronic reporting. For example, the garbage categories used in MARPOL can be simplified significantly for the purposes of this action: there is no need to identify so many categories.

Weight in kilograms should be entered into the Garbage Record logsheet, which could consist of a simple MSExcel spreadsheet. The logsheet should be uploaded regularly to a shared database managed by either the Secretariat of the Pacific Regional Environment Programme

[8] There are a range of potential financial mechanisms by which businesses operate escrow arrangements, for example "trust accounts" and "bank guarantees" to name but two.

(SPREP), the Pacfic Community or FFA. Each ship would have a specific identity, just like with electronic catch and effort logsheets. Each uploaded logsheet, with new information added, would replace the previous one, allowing to gather an annual total for each fishing vessel. This is consistent with strategic points 1, 2 and 5 described earlier.

**B.** Set up a database for Garbage Record books/logsheets.

An electronic repository for the standardised Garbage Record Books is needed on the servers of SPREP, SPC or FFA, or "in the cloud", on which vessels can upload their data. This is an electronic reporting task and complements action point A.

**C.** Require all FFA-licensed vessels to provide a garbage management plan.

This plan should be as simple as possible and consistent with representing the realities of waste storage on the vessel in question. A concise template plan should be drafted to assist standardisation and encourage simplicity, and to avoid recording any unnecessary information. Carrier vessels should be expected to include provisions in their plans to take waste from fishing vessels during transshipments. Carriers will be expected to show compaction capacity and/or large waste holding capacity.

Standardising plans will help ensure that only the important information is in the plan (e.g. how waste is contained and stowed, any compaction measures, scrap metal separation, description of any incinerator used). There is no need to describe recycling capacity, waste type and separation. A template should be drafted and field tested on a small number of suitable candidate companies and vessels that are prepared to assist in this endeavour, so as to develop the simplest plan but one that fits the purpose. This is consistent with strategic points 3, 5, 6 and 8.

**D.** Develop a formula for calculating expected waste generation per vessel.

The goal here is to identify a small number of vessels that have good waste management systems, learn what works best, and use that information to develop a simple formula based on vessel size, number of crew members, days at sea, fishing type and fishing effort. This current report can provide some guidance to for how to go about this, but because it is a desk-top study, it is not ideal. The use of existing observers to collect data for such a study is ideal, and training could be easily provided to them for this purpose.

This action can be combined with action point C so that the same field testing of a management plan can be used to collect data. The study period need not be too long, the intention is to determine a number for a reasonable quantity of expected waste generation, and feed into the development of onboard systems. Good measurements will provide good data to help vessel owners determine waste stowage requirements for an expected voyage length.

Vessel owners could be encouraged to participate in such a study by being given a waiver from having to post an initial waste bond, if that approach was subsequently taken. This is consistent with strategic points 2, 9 and 10.

**E.** Require all onboard incinerators to meet IMO standards.

Any waste incineration that takes place onboard should be done so in a proper incinerator that is made for the purpose, and not in a non-compliant device that is a potential health and safety hazard. Incinerators that are IMO-compliant are larger, more complex and expensive. It is expected that these will mainly be used on carrier vessels. This will concentrate monitoring effort on a smaller number of vessels, especially as incinerated waste is harder to measure.

This action requires that vessels submit pictures and specifications of their installed incinerator, at the same time as – and as part of – their waste management plan. Non-compliant incinerators could cause rejection of the plan. A date should be set as to when a vessel must comply. MARPOL standards for incinerators are extant;[9] this action requires no additional effort to develop standards. This action is consistent with strategic points 3, 4, 8 and 10.

**F.** Develop a waste bond system that is payable at the time of licensing.

The action points above will feed into the development of a waste bond. With a reasonable estimate of the amount of waste expected to be generated, consistent with ship operations and size, the amount of waste bond that should be posted can be determined. Many factors that must be considered when setting the bond amount, including practical, economic and political factors. The waste bond would be held in escrow, possibly using a conventional commercial mechanism, and rolled over annually for each license period, or as required. Those vessels that consistently fail to manage their waste may lose their bond.

Action points A to E could be conducted over the course of a year, so that by the end of the first year the formula for expected waste will have been developed, and templates for Garbage Record books and management plans have been field tested. The study of a select small number of vessels that currently have good waste management systems can be conducted using a cohort

[9] Resolution Mepc.244(66) 2014 Standard Specification for Shipboard Incinerators

of waste-trained observers. At the start of a new licensing period, vessels will be required to post a waste bond that will be fully refundable when, at the end of the period, the expected amount of waste has been off-loaded. Vessels that are being re-licensed can roll-over their waste bonds. Non-compliant vessels will lose their bond and be required to pay another. Fishing vessels that pass their waste on to a carrier vessel can be deemed to have effectively fulfilled their responsibility, thus transfering that liability to the carrier vessel. Carriers will also be required to have waste bonds as part of their licensing conditions, and will acquit those responsibilities at the point of off-loading waste to a port, and recorded in their Garbage Record book.

The amount of a waste bond to be paid could be set at the end of each permit period, using a sliding scale that rewards good operators, and puts pressure on the worse ones by increasing the level of their bond.

Vessels that can demonstrate full compliance with MARPOL and produce records and plans to support that compliance, including pictures of the current waste management situation on the vessel, may not be required, at the discretion of FFA, to post a waste bond. This rewards businesses that are already making the required effort to manage their waste responsibly. This is consistent with strategic points 4 and 10.

**G.** Communicate the new waste regime to FFA stakeholders.

If the above action points are adopted and implemented, then the rationale for following them needs to be communicated to key stakeholders during the development stage. This could be refined and spelled out in at least two briefing papers: one that is more detailed along the lines of an executive summary that might go to key stakeholders, and one that is a factsheet that can be more widely circulated to those who are less interested in the details but need to know about the coming changes to licensing conditions.

## Subsidiary actions

### *Strengthening enforcement and reporting of WCPFC CMM 2017-04*

The MARPOL requirements described above must be viewed in the light of WCPFC CMM 2017-04, which expressly addresses waste from fishing vessels. The section of this report that discusses this alignment clearly demonstrates that these proposals to drive as much waste as possible back along the logistical pathway provided by the carrier fleet is the cheapest option for both SIDS and distant-water fishing nations and Flag State operators.

CMM 2017-04 explicitly recognises that WCPFC members, cooperating non-members and participating territories (collectively referred to as CCMs) should follow MARPOL; it also explicitly recognises that SIDS are challenged through an inability to provide adequate facilities for receiving and managing waste from ships in their ports; and explicitly states that[10]:

*CCMs shall cooperate, consistent with national laws and regulations, directly or through the Commission, and in accordance with their capabilities,* ***to actively support*** *SIDS and territories* ***through the provision of adequate port facilities*** *for receiving and appropriately disposing of waste from fishing vessels*. [emphasis added.]

It is incontestable that it will be far cheaper for both SIDS and Flag States to drive waste back through the logistical chain to ports that do have adequate facilities to accept commercial wastes from fishing vessels. The cost of building landfills and other waste management facilities in SIDS is not only immense, but a long-term programme of improvement completely unsuited to the vagaries of short-term commercial considerations.

Through the waste bond system proposed, which would of course also apply to carrier vessels and any other FFA-

Standard bait box used by tuna longliners showing the plastic liner. (image: © Robert Lee)

[10] WCPFC CMM 2017-04 Adoption Point 8

licensed vessels, the carrier fleet can actively participate in ensuring that waste only goes to ports that have adequate facilities. As carriers take on the waste from fishing vessels – even from vessels belonging to a different Flag State to the carrier – a secondary market will spring up whereby carriers are paid by the fishing vessels to take their waste away – just as vessels would normally pay to have their waste disposed of in port.[12]

The Garbage Record book/logsheet will record transshipment to a carrier as a transfer of ownership just as it does with fish, and so fulfil fishing vessels' obligations to dispose of their waste correctly under the conditions of the waste bond. The cost will be up to the market and will also be influenced by the amount at which the waste bond is set: if set too low, the market will not function. Carriers will then in turn pay to dispose of the waste at a port with adequate facilities. This proposal is using market mechanisms to enact point 8 of the CMM, and at a far lower cost than that of financing waste management facilities and landfill construction in SIDS.

Similarly, the action points recommended in this report will help address CMM points 9[12] and 10[13]: the loss and recovery of fishing gear. The proposed Garbage Record book/logsheet to be developed could easily incorporate a lost fishing gear component; if fishing gear were both marked (as required by the Harmonised Minimum Terms and Conditions) and logged as lost, then this study proposes using a waste bond as an incentive to those vessels that recover lost fishing gear, in line with strategic points 9 and 10 above.

### *Inclusion of CMM 2017-04 and MARPOL issues as part of electronic monitoring objectives*

Electronic monitoring is set to be further deployed in the region and already plays a role in pollution monitoring, despite the political, logistical and operational problems discussed. Therefore, the potential of incorporating issues related to waste offloading to the present scope of electronic monitoring is consistent to both areas of compliance.

Off-loading fish to a carrier vessel or at a home port should be accompanied by off-loading of waste, and thus could be easily verified through video footage. Video observers should not be expected to look through large quantities of footage for incidents of waste being dumped overboard during normal ship operations. This is consistent with strategic points 5 and 6.

## Strengthening existing requirements of marking fishing gear and using biodegradable fish aggregating devices

The IMO Action Plan[14] suggests that fishing gear should be marked with the deploying vessel's identifiers, and this should also apply to FADs. If this measure was enacted, it would be possible to reward those who collected discarded fishing gear by using the waste bond money of those who lost the gear.

There is a large area of potential study and policy development to consider when working out a sliding scale to sanction those who lose large amounts of fishing gear at sea. For example, the loss of a FAD that was built with only biodegradable materials, designed to break down over time in the ocean, and not entrap bycatch of any sort might not incur penalties; the loss of a FAD made of plastic components, on the other hand, would. A waste bond could provide the source of funds. Such work would need to be conducted after the effort to develop an initial waste bond level.

## Conclusion

If the above proposals were to be accepted and acted upon, there are many details to be worked out; but the proposals developed here are offered as a workable way forward to address what has been, until now, somewhat of an intractable problem. These proposals show a clear way forward using the principals of waste management and economic incentives that have been tried and tested, and proven to be successful, albeit in quite different fields. They could, however, well work in this one too.

[11] If a fishing vessel is not already paying to have its waste disposed of in port, then it is clear why the WCPFC states in CMM 2017-04 Preamble: "convinced that certain activities associated with fishing may affect the Western and Central Pacific marine environment ... and impacts on marine ecosystems".

[12] CMM 2017-04 Adoption Point 9: "CCMs are encouraged to develop communication frameworks to enable the recording and sharing of information on fishing gear loss in order to reduce loss and facilitate recovery of fishing gear."

[13] Ibid, Point 10: "CCMs are further encouraged to develop frameworks or systems to assist fishing vessels to report the loss of gear to their Flag State, relevant coastal States, and the Commission."

[14] Resolution Mepc.310(73) Action Plan to Address Marine Plastic Litter from Ships

# How to draft effective coastal fisheries and aquaculture legislation

*Alex Sauerwein,[1] Ariella D'Andrea[2]* and Jessica Vapnek[3]*

## Introduction

With the endorsement of the regional policy "A new song for coastal fisheries – pathways to change: The Noumea strategy" in 2015 (Anon. 2015), Pacific Island countries and territories (PICTs) have committed to updating and strengthening their laws and regulations to ensure sustainable, accountable and participatory management of marine resources. Since then, fisheries agencies around the region have been leading the effort to review their national legislation and identify gaps in their coastal fisheries and aquaculture regulatory frameworks. Given the limited number of legislative drafters in many countries, fisheries officers are often tasked with preparing a first draft of the laws or regulations required to manage coastal fisheries. Some have requested guidance from the Pacific Community (SPC) (Box 1).

This brief guide provides an overview of how to draft legislation to manage small-scale coastal fisheries and aquaculture. It reviews what legislation is, and explains where officials should start when preparing a piece of legislation. It also provides tips for drafting comprehensive and clear legislation, as well as clues for better compliance with the legislation once enacted.

## Box 1: Assistance and training

SPC has been providing technical assistance to PICTs to develop sound coastal fisheries legislation since 2017 under the Effective Coastal Fisheries Management Project, through the New Zealand Ministry of Foreign Affairs and Trade. In 2019, the first SPC Short Course in Preparing and Drafting Coastal Fisheries Legislation was held in Noumea, New Caledonia, in collaboration with Solon Law (www.solonlaw.uk). Plans to organise a second one in 2021 were thwarted by the COVID-19 pandemic. Instead, SPC is now developing an online course targeting the Pacific region with the expert support of the University of California, Hastings College of the Law (www.uchastings.edu).

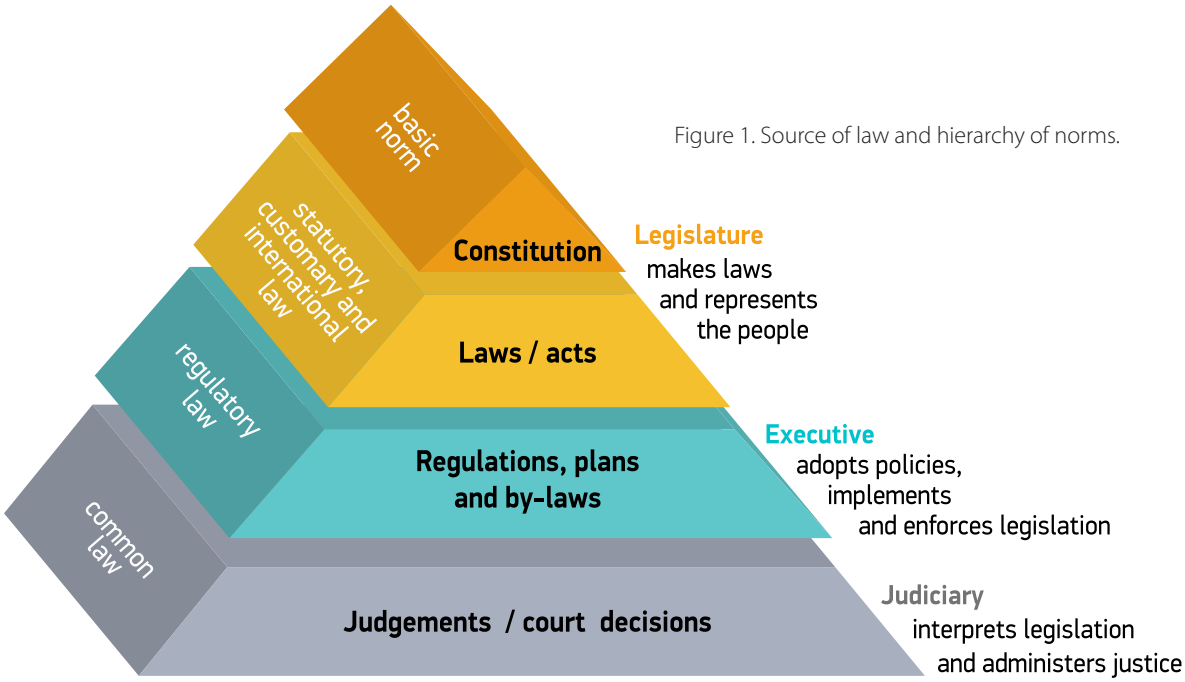



Figure 1. Source of law and hierarchy of norms.

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## What is legislation?

Legislation is a type of binding legal instrument passed by a legislature or by the executive. Common examples are laws and acts passed by a parliament or congress, as well as other regulatory instruments (such as regulations, decrees, orders, and bylaws) issued by a cabinet, minister, or agency. Laws and acts are called primary legislation while other regulatory instruments are called subsidiary legislation. Primary legislation outlines broad principles and goals, and sets up structures, powers and procedures. Subsidiary legislation fills out the details of whatever is established in the primary legislation. Subsidiary legislation – also called secondary or subordinate legislation – is invalid if it contradicts or goes beyond the scope of the primary legislation (Fig. 1). Legislation is different from policies and plans, which are not normally binding, although management plans are considered to have the force of regulations in some jurisdictions.

Imagine parliament passes legislation to accomplish the goal of preserving local fisheries (e.g. a Local Fisheries Act). This would be the primary legislation. The act may delegate authority to the ministry or department in charge of fisheries, or to a local governing body. To accomplish the stated goal of the primary legislation, the delegated body (the ministry or department) may create subsidiary legislation, such as regulations, to do things like impose permit requirements or prohibit fishing during certain seasons to allow fish to spawn (e.g. Bonefish Fishery Regulations). Details are placed in the subsidiary legislation to allow for rapid changes in response to scientific or other developments (e.g. to open or close a fishing season based on a stock assessment). Otherwise, any changes would have to go through parliament again (to change the primary legislation), which would be time consuming.

The legislation mentioned above is statutory law, meaning it has been formally approved and written down. In contrast, customary law refers to the customs established by longstanding practice within a community that are widely accepted as legally binding on its members. Customary law is generally orally held and transmitted within the community. Although many PICTs have pluralistic legal systems that recognise customs as a source of law alongside statutory law, this guide focuses only on statutory legislation, both primary and subsidiary. We now turn to how to word such statutory legislation in a clear and effective way to ensure that it is properly understood and consistently applied.

## Steps to start drafting legislation

### *Step 1: Understand the political background and policy objectives*

The political background refers to the reason the legislation is being drafted. For example, a recent Fisheries Act may require a governing body to draft regulations to curb fishing during a certain season or area. This could be because a popular practice is negatively affecting fisheries in a particular community (e.g. fishing during spawning season, or in a spawning area). It is important to keep this political background in mind when drafting, to ensure that the legislation targets the relevant issue and advances the policy objectives (Box 2). Furthermore, the political nature of new

### Box 2: Ask "Why?"

A common question asked during stakeholder consultations is why a certain regulation or legal provision is being adopted. Resource management legislation should be based on science. Although it is unusual to explicitly mention the justification for each provision in statutory law, the overall policy or management objective being pursued should be clearly stated at the beginning of the act or regulations or in the associated policies and plans.

Participants to a short course in preparing and drafting coastal fisheries legislation in Noumea, New Caledonia, 10–14 June 2019.

## Box 3: Voluntary guidelines and standards

Organisations such as the United Nations and its specialised agencies like the Food and Agriculture Organization (FAO) may produce guidance on the subject matter of the legislation. In fact, FAO has produced the Code of Conduct for Responsible Fisheries and Voluntary guidelines for sustainable small-scale fisheries. Tools like these are not mandatory, but they are an invaluable resource when drafting national legislation. This is because the guidance represents the consensus of many countries, including one's own. In addition, these organisations have the resources to conduct high-level comparative research, which strengthens the persuasive power of these voluntary guidelines and standards.

legislation is important because implementing it will affect people's lives. Industry players, local fishing communities, or environmental groups may have strong opinions about the legislation, depending on how they are affected. While the legislation is being prepared, it is critical to involve and consult all affected groups, or stakeholders – both because taking their interests into account helps to achieve the intended policy objectives and to avoid catching them by surprise when the legislation is enacted.

### *Step 2: Define the scope*

It is important to consider the scope of the legislation before beginning to prepare it. "Scope" means the intended impact of the legislation – broad or narrow. For example, the legislation may target all domestic waters, a portion of those waters (such as a certain reef area or a community-managed area), or a particular marine species or fishery. The scope of the legislation must be clearly defined so that authorised enforcement officers understand the intent behind the legislation and appreciate exactly what (and whom) it targets. The scope is also important to ensure that parameters are imposed on the government, since government action may affect people's rights and freedoms.

### *Step 3: Choose the right provisions*

The next step is to sketch out the main content or types of provisions the legislation will include to achieve the policy objectives. For example, the legislation may outline management measures that restrict access to fishing grounds (e.g. licensing or registration), prohibit the use of certain fishing gear or methods (e.g. explosives or poisons), or put limitations on catches (e.g. size or quantity restrictions). Perhaps the legislation will empower local communities to adopt community-based fisheries management plans or to appoint honorary fish wardens to conduct surveillance in the area.

Before delving into the content, however, it is good practice to become familiar with the relevant guideposts, such as any international treaties the country may have signed, international or regional standards and guidelines that apply to the country (Box 3), other existing national legislation on the subject, and (in common law jurisdictions) any applicable court cases interpreting relevant existing legislation.

### *Step 4: Implement safeguards*

It is important to include safeguards in legislation to prevent decision-makers from exercising too much discretion, which can lead to corruption. There are several tools that can help ensure that decisions are made in a consistent manner. First, legislation should clearly define the criteria for making decisions, for example to issue or revoke a licence. Second, legislation should require decision-makers to consult with or seek approval from another relevant agency. Third, legislation should require decision-makers to justify and

## Box 4: Ten guiding principles for clear drafting

| | |
|---|---|
| **Active** *vs* passive | Prefer verbs to nouns and choose active over passive phrases |
| **Clear** *vs* ambiguous | Clearly identify the subject and avoid ambiguity |
| **Coherent** *vs* illogical | Group related ideas into organised sections and subsections |
| **Concise** *vs* wordy | Use short, simple sentences, and get to the point |
| **Consistent** *vs* inconsistent | Use defined terms consistently |
| **Inclusive** *vs* biased | Be socially inclusive and avoid gendered language (see Tip #2) |
| **Modern** *vs* archaic | Avoid old-fashioned language |
| **Positive** *vs* negative | In most cases, use positive rather than negative statements |
| **Simple** *vs* complex | Use the simplest word that conveys the meaning |
| **Singular** *vs* plural | Prefer singular over plural form |

document their decisions in writing for future scrutiny so that they can be held accountable. Fourth, legislation can require reports detailing the decision-making process, so that the process is transparent and freely available for stakeholders wishing to understand it. Fifth, stakeholders should be allowed to challenge or appeal official decisions and to submit complaints about actions stemming from the legislation.

### *Step 5: Check for legislative processes or requirements*

Sometimes countries have specific legislative drafting, approval and adoption requirements. Even if non-lawyers are drafting legislation that government lawyers will later review, it is important to draft the legislation properly from the outset. This means finding and following any drafting or procedural manuals or other applicable requirements. It is also important to understand and follow the process of drafting, proposing and shepherding legislation to approval. For example, the country may have embraced a specific drafting style, or a particular format or structure for the legislation. A piece of legislation may need to be brought to a vote in the legislature, or approved by the cabinet, or submitted to an agency for input or sign-off. These are all important considerations to note before drafting the legislation, to avoid delays and ensure proper approval.

## Box 5: The "universal he" and "man" words*

| Avoid | Use |
|---|---|
| Businessman | Businessperson; business executive; entrepreneur |
| Cameraman | Camera operator |
| Chairman | Chairperson; chair |
| Fisherman | Fisher |
| He | They |
| His | Their |
| Mankind | Humankind |
| Manning | Working; staffing; running; crewing |
| Policeman | Police officer |
| Workman | Worker |

* Suggestions in this table are based on Revell and Vapnek 2020.

## Tips to draft clear and effective legislation

### *Tip #1: Be clear, concise and consistent*

Legislation should be drafted so that it is clear, concise and consistent. This ensures that once enacted, it will be effective and enforceable. The legislation should give effect to government policy, promote good governance, and minimise corruption and abuse. When drafting legislation, use words consistently and be specific.

**Use plain language** rather than legalese. For the sake of clarity, sentences should be short and get straight to the point, using simple terms and phrases with clear meaning. Long and convoluted sentences could confuse the reader. Ten guiding principles are proposed in Box 4 for clear drafting.

**Only use necessary words.** Courts and those enforcing legislation will read every word of the legislation and assume that each word has meaning. For this reason, drafters of legislation should think carefully about each word and only include those that are necessary to accomplish the intended outcome.

### *Tip #2: Use gender-neutral expressions*

Gender-neutral or gender-silent drafting is the best practice for inclusive legislation. As a simple matter of fairness and equality, all persons covered by a law should be able to imagine themselves in it. Language shapes perceptions, which can continue, deepen, or counteract power and status imbalances among the genders. Internationally, there is a growing recognition of non-binary gender identities and the need to address masculine bias in language. Avoid masculine or feminine pronouns where possible, even if it means repeating the noun. Generally, replace gendered terms with gender-neutral or silent synonyms (Box 5).

### *Tip #3: Specify the who, how, when, where and what*

It is important to clearly specify all aspects of a particular obligation or prohibition. This also helps the drafter advance policy goals. For example, legislation may specify that parrotfish may not be caught and kept. The what – catching parrotfish – is clear. But for this legislation to be enforceable, it also needs to specify:

**The who:** Legislation should specify who is not allowed to catch this fish (e.g. only commercial fishers, recreational fishers, subsistence fishers). Further, the legislation should specify who is responsible for enforcing the legislation.

**The how:** Legislation should specify how catching the fish is prohibited (e.g. from a boat, on foot, with certain specified gear or methods). This is important so that people who will be affected by the legislation will understand exactly how it works.

**The when:** Legislation should specify when its provisions are enforceable (e.g. only during certain months, year-round, during spawning season, at night). This will put stakeholders on notice of when they may engage in an activity.

**The where:** Legislation should specify where the target prohibition applies (e.g. only in the lagoon, on the reef slope, in a marine reserve, in certain islands, or throughout the country). Explain the requirements in sufficient detail so that people will be able to comply with the legislation.

**The what:** As stated above, the "what" is clear in the example – landing parrotfish. It is important to clearly define the subject of the legislation and the action(s) in question so that those enforcing the legislation know what to enforce, and so that those affected by the legislation are on notice regarding the expected behaviour.

### *Tip #4: When to use must, may and may not*

Legislation confers benefits and imposes restrictions. The words must, may and may not are used to accomplish these goals, but there are differences.

**Must** is most effective when it is used to impose a duty to act. For example, The aquaculture operator must provide a production report to the director every six months. A drafter of legislation should use the word must in place of shall because shall could be misconstrued (e.g. to mean a future action), whereas must is clear. Use must when you want a person to have an obligation to act in a prescribed way.

**May** is used to grant discretion or authority to a person. For example, The minister may issue a fishing licence means the minister has the authority to issue or not issue a fishing licence. Use may when you want a person (usually a government official empowered in the legislation) to have the discretion to decide whether and how to act.

**May not** is used to prohibit an action. For example, People may not fish in the bay during the summer months. In this example, people do not have permission to engage in the prohibited action. Use may not when you want to deny a person (usually an official) the power to act or you want to prohibit a person from engaging in an action.

### *Tip #5: Clearly define terms*

Defining terms is a very powerful tool when drafting legislation because it gives the drafter the ability to control the meaning of the words, which can determine how the legislation is applied. Clearly defining terms is also important because it helps stakeholders understand the intention of the legislation and, more importantly, it allows the legislation to be enforced as intended. If the targets are defined too narrowly or too broadly, the legislation can miss certain people or things, or cover too many people or things. For example, when drafting legislation on a place called "the bay", include a definition that clearly identifies what and where the bay is and what water is included (consider using GPS coordinates). This means the legislation can simply refer to the bay, but all parties will know what that means.

**Include a definitions section.** Remember to include a list of definitions at the beginning or end of the legislation. Do not gloss over common words under the assumption that local parties will know what they mean – always define a word or phrase that does not already have a legal significance. At the same time, only define terms that are actually used in the text and need to be interpreted in a specific way to achieve the objectives of the legislation (no need to define everything!).

## How to ensure compliance and effective implementation

### *First clue: Identify enforcement officers*

When drafting legislation, identify the authorised officers who will enforce the legislation, including how they will be appointed and what their duties will be. In addition, specify the powers the authorised officers will have. For example, Agents may enter boats or premises to perform inspections, take photographs, samples, or measurements, and seize items not in compliance with this legislation. In some cases, community officers or local fish wardens can be appointed, or there are general provisions for participatory surveillance (e.g. citizens can report a breach to an officer). When giving powers to government officials or community wardens, it is important to consult the constitution, which may impose limits on how governments can infringe on people's rights; for example, to not have the government enter their home without authorisation.

### *Second clue: Spell out offences and penalties*

Legislation should clearly define offences, which are actions that constitute a breach of the law, and penalties, which are the punishments associated with each offence. Punishment should be proportional to the breach. For example, a

minor infraction would not call for a year's imprisonment or a million-dollar fine. Depending on the jurisdiction, a punishment may be applied by a court, or by an administrative agency (through a police officer or fishery management officer). Court-imposed sanctions might include imprisonment, whereas administrative sanctions might include monetary penalties, such as spot fines, or other sanctions, such as licence revocation or suspension. Legislation should clearly identify the punishment. For example, *A person in violation of this law may face a fine of up to $500 or the revocation of the fishing licence*. This puts people on notice before they engage in the prohibited activity and provides clear guidance to the officers who enforce the legislation. It is important to spell out in the legislation the consequences for violations because this leads to better compliance. It also prevents constitutional challenges if people allege that penalties were not properly established or clearly stated.

### Third clue: Recognise existing rights and situations

Legislation is normally written for the future, meaning that it typically affects only events taking place after its entry into force. Nonetheless, legislation frequently affects existing rights or situations. For example, if the legislation establishes a new requirement that all aquaculture farms must be licensed, then all farms that have been operating (legally) without a licence under the previous regime will become illegal as soon as the new legislation comes into force. To avoid this unfair situation, the legislation should include transitional and savings provisions. Transitional provisions are provisions that explain how the new law will bridge the past and current situations (i.e. situations that are ongoing at the time of entry into force). For instance, there may be a grace period for people to take the necessary action to comply with the new rules. On the other hand, savings provisions are provisions that extend the validity of the old rules that would otherwise be immediately changed or repealed by the new law. Taking the example above, a transitional provision might allow people who started fish farming operations before a given date to keep applying the old rules for a certain time period. This type of provision is known as a "grandfather" clause in some jurisdictions. For a savings clause, an example might be that when repealing an old Fisheries Act, the new legislation states that the existing subsidiary regulations will remain in force under the new act until new regulations are adopted.

### Fourth clue: Consider implementation capacity

When drafting legislation, make sure that the new provisions can be implemented with the available resources. To become operational, coastal fisheries legislation must be put in practice by trained fisheries officers who understand they have an important educational role. Consider the capacity of the country's fisheries agency, or how to secure funding for additional monitoring, control and surveillance (MCS) operations that may be required under the new law. This might include staff, training and equipment. Inspections and MCS operations should be planned, and standard operating procedures developed to streamline implementation. Resources are also needed to ensure that adequate forms and data collection systems are available (e.g. for fisheries officers to record fishing activities by licensed vessels or registered fishers or boats). In certain cases, fisheries agencies may rely on community-based fisheries management (CBFM) or local authorities for the control of local fishers and small boats.

### Fifth clue: Foster awareness and participation

Community awareness and participation are key to the success of new legislation. As mentioned in Step 1, consultation with stakeholders – including the local communities affected by the legislation – is essential before and during the legislative drafting and adoption process. In this way, the legislation will be more effective because it is adapted to the local context. Legislation that reflects community concerns and considers traditional knowledge will be better understood and accepted by people in the area, thereby promoting buy-in. In turn, local awareness of the legislative goals can promote compliance. Community outreach is also important in order to provide people with accurate information on the new rules. If the legislation allows for adoption of CBFM plans or other co-management arrangements, consider including such provisions in those plans. Say, for example, the legislation is needed to protect a certain fish species that is overfished in some areas. Rather than banning all fishing of that species nationally, which may lead to local pushback and less effective implementation, it may be wise to address the issue under a CBFM plan (Fig. 2). This helps to promote ownership of the rules by local communities, which in turn fosters compliance.

## Conclusion

To summarise, when preparing statutory legislation, it is important to follow the five steps outlined above:

1. Understand the political background and policy objectives of the legislation being drafted.
2. Define the scope of the legislation so it is not too broad or too narrow.
3. Choose the right provisions to accomplish the stated goals, bearing in mind the defined scope.
4. Be sure to implement safeguards to prevent corruption.
5. Always check for special legislative processes or requirements that might affect the legislation.

Figure 2. How to establish a community-based fisheries management (CBFM) plan.

Drafting effective legislation can be accomplished by considering the five tips we have addressed here:

1. Be clear, concise, and consistent, and use plain language.
2. Use gender-neutral expressions and avoid exclusionary language so all readers can envision themselves in the legislation.
3. Specify the who, what, when, where and how.
4. Respectively use must, may or may not when imposing a duty, granting authority or making a prohibition.
5. Clearly define terms and include a definitions section so the legislation is always interpreted the way it was intended.

Remember that legislation must be complied with to be effective and follow the five clues provided to maximise compliance:

1. Consider the roles and powers of enforcement officers.
2. Clearly define the offences and penalties for violation.
3. Take into account existing rights so that the legislation is not challenged or ignored.
4. Crucially, do not ignore the financial and human capacity to implement the legislation.
5. Finally, involve stakeholders in the drafting process so they can have a hand in shaping the legislation and can understand how it will affect them once it is enacted; this will foster ownership, buy-in, and ultimately, compliance with the new legislation.

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Fisherman landing his daily catch, Nauru. (image: Ariella D'Andrea, ©SPC)

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