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Unloading bycatch from a tuna longliner, Noro, Solomon Islands. Image: Francisco Blaha, www.franciscoblaha.info

Editorial

Climate change is usually associated with increasing temperatures and rising sea level. But these are only two of its many consequences, even if they are perhaps the most dramatic. Johann Bell and Tarûb Bahri, in their article on page 43, discuss the likely consequences of climate change for industrial and coastal fisheries of the Pacific Islands region, as well as for aquaculture.

For industrial fisheries, it is predicted that the four main tuna stocks – albacore, bigeye, skipjack and yellowfin – will be 'relatively' unharmed by climate change because of their ability to move to favourable areas. But, this shift will particularly affect those small island States that are highly dependent on licence fees from industrial fleets, and in which the local population depends heavily on coastal marine resources for food security.

The consequences of climate change on small-scale fisheries are mostly linked to the increase in sea surface temperatures, which will drive many target species to higher latitudes, and will damage or destroy vast areas of reefs, thereby considerably reducing their productivity. In the Pacific islands, most small-scale catches come from coral reefs, and many communities have few sources of animal protein other than those derived from the sea, thus making coastal populations particularly vulnerable to climate change.

In reading the various articles in this issue, I couldn't help but notice that almost all of the topics covered – tuna fisheries science and management, shark survival, identification of alternative marine resources, recruitment of juvenile eels, rock oyster aquaculture – cannot be addressed without taking into account the impact of climate change. A challenge that requires an urgent and effective response.

Aymeric Desurmont
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Feature article

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Cutting edge science at the 14th meeting of the WCPFC Scientific Committee

Representatives from countries across and beyond the Pacific Islands region met this past August in Busan, Korea for the 14th Regular Session of the Scientific Committee (SC) of the Western and Central Pacific Fisheries Commission (WCPFC). During meetings of the SC, delegates review the latest science relevant to the management of migratory species in the Western and Central Pacific Ocean (WCPO), and make formal recommendations to the WCPFC meetings held in December each year. The SC is an important meeting for the scientific team of the Oceanic Fisheries Programme (OFP) of the Pacific Community (SPC), in part because OFP is the WCPFC's scientific and data management services provider. The papers and presentations for this meeting by OFP scientists (over 45 papers by OFP authors for the 14th meeting) provide the backbone for important discussions on the scientific aspects of the world's largest tuna fishery. It is also the key pathway through which OFP's work translates into concrete outputs for Pacific communities. The OFP team was heavily involved in presentations and working groups for all four themes reviewed by the SC: data and statistics, stock status, management issues, and ecosystems and bycatch mitigation.

SPC, in collaboration with the Pacific Islands Forum Fisheries Agency, provided the latest tuna catch information for the WCPO. The provisional tuna catch for 2017 was estimated to be just over 2.5 million metric tonnes, with a delivered value of over USD 5.8 billion. While this catch level was the lowest in the last six years, it still represented nearly 80% of the total Pacific Ocean catch and over 50% of the global tuna catch.[1] OFP also presented estimates of bycatch within the longline fishery at the regional level, based on the invaluable information collected by regional observers onboard these vessels. Catch was estimated for 45 species or species groups, covering the full range of finfishes, billfishes, sharks and rays, marine mammals and sea turtles that have been recorded in longline observer data. This work represents the first estimates of such a wide range of species catch, although further improvements in the spatial coverage of available observer data and data inputs would help OFP's ability to estimate these.

Following the new stock assessment of bigeye tuna in the WCPO last year[2] and recommendations for further work, OFP scientists worked with the Commonwealth Scientific and Industrial Research Organisation in Australia to increase the amount of information on the age of larger bigeye tuna. This further improved our understanding of bigeye growth. SC14 agreed that this updated information on growth should now be a key input into OFP's bigeye stock assessments, which are used to provide advice. OFP presented an update to the 2017 stock assessment, incorporating this new information. As seen in 2017, the resulting advice was more positive than in previous years, but was tempered by additional SPC analyses suggesting that under some future conditions, the bigeye stock may decline under allowed levels of fishing.

OFP also presented a new assessment of the South Pacific albacore stock, which further improved on the previous assessment in 2015. The main conclusion is that while the adult stock has been reduced to around half its unexploited level, it is comfortably within biologically safe limits. However, although there have been reduced longline catches in the last four years, and at the same time some improvements seen in catch rates in the fishery, catches in 2017 increased by around a third compared with 2016. Given the new assessment, SPC has been asked to examine what may happen to the stock and fishery in the future if those catch levels continue.

In discussions of management issues, OFP presented work to support the 'harvest strategy' approach for tuna stocks. This approach focuses on longer-term objectives for the fisheries and stocks, and aims to move away from annual short-term decision-making. This effort is ongoing, and OFP's work supported SC's decisions on the work to be done on skipjack and South Pacific albacore in the next couple of years. The harvest strategy approach needs to bring managers and scientists together to discuss and drive the work, and a proposal to set up a new annual meeting to help this process had the general support of SC14 participants.

In collaboration with the Parties to the Nauru Agreement (PNA), OFP scientists presented two analyses of the use and potential impacts of fish aggregation devices (FADs). Tropical purse-seine vessels make use of artificial floating FADs that attract tuna and improve fishery catches; but these devices have potential negative ecosystem impacts.[3] PNA's fascinating FAD tracking dataset, which provides the position of a FAD at irregular intervals as it is dropped into the water and drifts through the Pacific, provides new insights

[1] More information on the catch and patterns of fishing are available at: https://www.wcpfc.int/node/30997.
[2] See http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/153/FishNews153_23_Hampton.pdf
[3] See, for example, Leroy et al. 2013. A critique of the ecosystem impacts of drifting and anchored FADs use by purse-seine tuna fisheries in the Western and Central Pacific Ocean. Aquatic Living Resources 26:49–61. Available from: www.alr-journal.org/articles/alr/abs/2013/01/alr120033/alr120033.html

into this method of fishing. SPC's analyses highlighted the number of FADs in the WCPO (up to 70,000 FADs were estimated to be in the water in 2017), the rate at which FADs may be 'lost', and how often they may end up beached on the shores of Pacific islands. A discussion of the findings led to recommendations from SC on increasing the use of biodegradable FADs, better measures for FAD control and retrieval, and reducing the number of FADs deployed.

In addition to SPC's work, contributions were also presented by scientists who work across the Pacific on: assessments for Pacific bluefin tuna and North Pacific swordfish by the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC); assessments of sharks by ISC and the Marine Areas Beyond National Jurisdiction project; potential bycatch mitigation measures by scientists from the United States, Japan and New Zealand; and ongoing research on bird interactions by the Agreement for the Conservation of Albatrosses and Petrels.

Next year's proposed assessments for SPC include skipjack, the tuna stock contributing the largest catch in the WCPO, striped marlin in the southwest Pacific, and oceanic whitetip shark. Further work for OFP this year includes the WCPFC's Technical and Compliance Committee (TCC) meeting, and the Commission meeting to be held in Hawaii in December 2018, where recommendation by SC and TCC are reviewed and translated into actual management measures and regulations.

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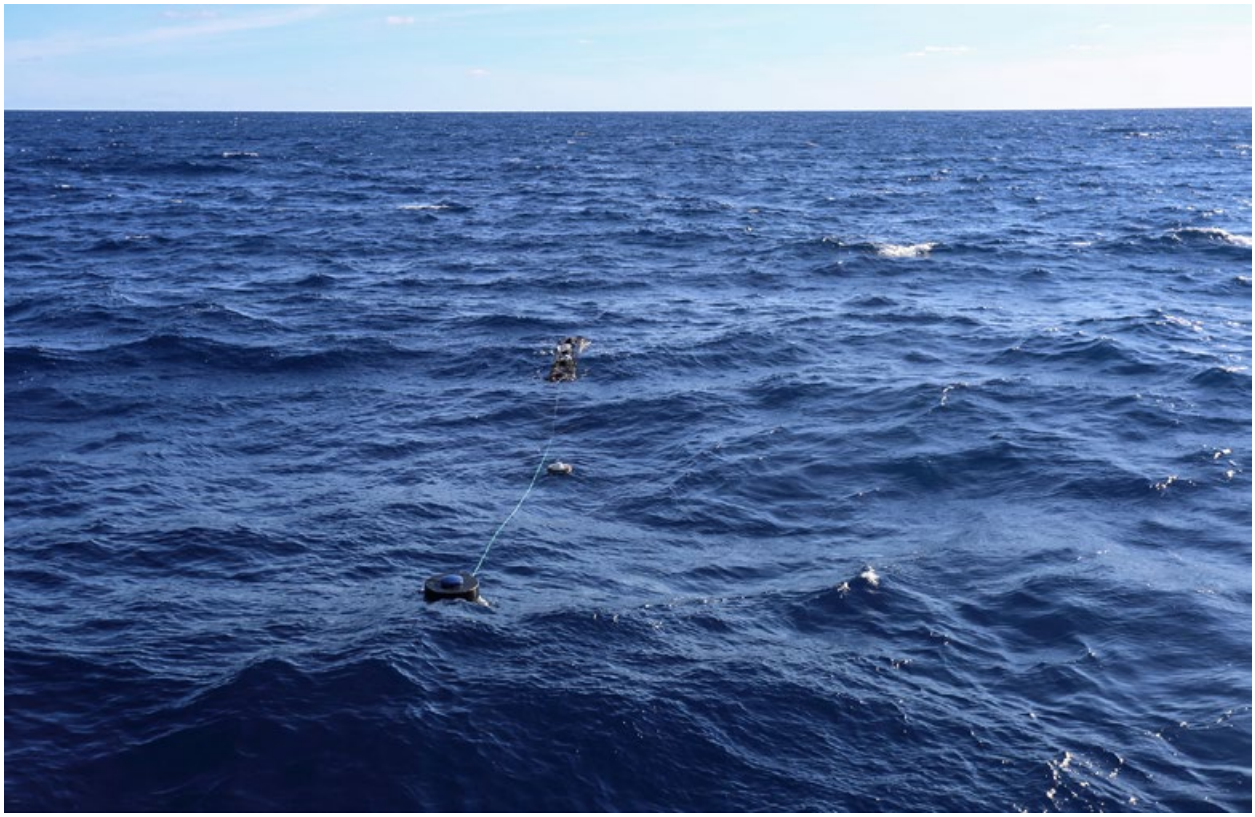

It is estimated that up to 70,000 drifting fish aggregating devices are in use in the western and central Pacific Ocean. Their environmental impact and ways to reduce it were discussed during the 14th WCPFC Scientific Committee meeting.
Image: Fabien Forget

Managing the world's largest tuna fishery

The Pacific Ocean represents 48% of all the world's oceans combined[1] *and supports some of the largest fisheries. In addition, it is home to some of the most abundant populations of tuna species such as albacore, skipjack and yellowfin, and billfish species such as marlin and swordfish. Collectively, these fish are often referred to as highly migratory stocks because of the great distances they swim, often crossing ocean provinces and the boundaries of multiple countries. In the western and central Pacific Ocean (WCPO),*[2] *several countries fish commercially for these species in what has become a multi-billion-dollar industry. But like most natural resources, fishery resources are finite, and if not managed responsibly, they can face the threat of overexploitation.*

Management of these fisheries is achieved through the Western and Central Pacific Fisheries Convention, an international fisheries agreement that seeks to ensure the long-term conservation and sustainable use of highly migratory fish stocks in the WCPO. The Convention, which covers an area that is nearly 20% of the Earth's surface, has established a governing body known as the Western and Central Pacific Fisheries Commission (WCPFC), which comprises representatives from countries that have ratified the Convention, including many Pacific Island countries and territories (PICTs) and distant-water fishing nations, whose vessels often travel large distances to fish in the WCPO.

The Convention faces a number of significant challenges in meeting its objectives of long-term conservation and sustainable use of highly migratory species, not least of which is resolving the competing objectives of countries that fish in the region. A defining characteristic of the WCPO is the extent to which the region comprises the exclusive economic zones (EEZs) and other territorial waters under national jurisdiction. Many small island developing States of the Pacific have long-held aspirations for developing their own domestic commercial fisheries and retaining a greater share of the benefits from the multi-billion-dollar fishery that takes place in their waters. At the same time, the well-established fleets of the industrialised countries continue to grow and become more efficient with the advent of new and better fishing technology. Such growth in the number of fishing vessels in both small and large fleets, coupled with higher productivity in some fleets, poses real threats to the sustainability of WCPO tuna resources.

Recognising these threats to the long-term sustainability of tuna resources, WCPFC agreed to a work plan for the adoption of harvest strategies for the four target tuna species: skipjack, yellowfin, bigeye and South Pacific albacore. The 'harvest strategy approach' establishes rules for the management of the fishery and provides a more formal decision-making framework to align the year-to-year management more closely to the longer-term objectives of sustainability, profitability and economic viability. A first step in developing a harvest strategy is, therefore, to identify an agreed set of management objectives for the fishery, and this has been an area of significant debate in recent meetings of the WCPFC.

Once the basic management objectives have been agreed on, work can begin to define the decision rules, or strategy, for management. Ideally, harvest strategies should be tested before implementation to determine if they can achieve the stated objectives and meet the desired outcomes. Obviously, it is not possible to carry out these tests on real world subjects. There simply are not enough fish stocks or sufficient time to test the many different harvest strategies that need to be investigated before selecting the one that works best, not to mention the significant damage that a fish stock, and the fishing sector, may suffer if a strategy performs poorly. Instead, a simulation modelling framework is used to evaluate the potential performance of many alternative strategies, from which the one that performs best can be selected. The modelling framework is often compared to a flight simulator where a pilot can practice flying an aeroplane under many different simulated situations before flying a real plane with real passengers.

The work required to develop and implement a harvest strategy is considerable, and relies heavily on scientific analyses to provide rigorous, evidence-based advice on management approaches. The Pacific Community (SPC) is the scientific services provider to the WCPFC, and has been tasked with conducting the necessary analyses to support the development of harvest strategies for the four key tuna species. Funding support for the work has come from WCPFC and the European Union, but the vast majority has been undertaken with support from the New Zealand Aid Programme. The work falls into two broad categories. The first involves a comprehensive stakeholder engagement programme that will ensure that all WCPFC members are: 1) fully informed about the process, 2) aware of recent developments, and 3) able to actively contribute to developing the strategies that will impact their fisheries. The second component involves the development of the modelling framework, which requires significant technical expertise and specialist modelling skills.

[1] See, for example: https://www.oceanicinstitute.org/aboutoceans/aquafacts.html
[2] See https://www.wcpfc.int

Purse seiners anchored for transhipment in Majuro, Marshall Islands (top) and longliners from French Polynesia's domestic fleet unloading their catch. The development of a harvest strategy approach for western and central Pacific Ocean stocks and fisheries will aim at giving all stakeholders a clear and long-term vision of the future of their fishery.
Images: Francisco Blaha and Aymeric Desurmont

The stakeholder engagement programme began in earnest in July of this year with a dedicated national harvest strategy workshop held in Tarawa, Kiribati, which was organised in collaboration with the Ministry of Fisheries and Marine Resources Development.[3] Subsequent national workshops are planned for other PICTs as well as the continued use of existing international meetings of fishery managers, which take place throughout the year all over the Pacific.

Work is also underway to develop the simulation modelling framework. While some significant steps have already been taken, considerable work remains to be done. The WCPO tuna fisheries are characterised by highly mobile fish stocks with complex seasonal and spatial movement patterns and stock structure, and are exploited by many different fishing fleets employing a variety of different fishing gear. The scale and complexity of the challenge is significant and places considerable demands on computing facilities and processing power. In this respect we are grateful to the University of Wisconsin for generously providing access to their remote computing facilities, which significantly increases the available processing power for running computationally intensive simulation models.

The development of a harvest strategy approach for WCPO stocks and fisheries is a major undertaking. The combination of highly migratory fish stocks moving across multiple national boundaries, and fished for by a diverse range of fishing fleets and fishing practices operating at an ocean basin scale, coupled with the varied and sometimes conflicting objectives of stakeholders, make this one of the most difficult management challenges in the world of fisheries today.

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[3] See article by Finlay Scott on page 6 of this issue.

First workshop on harvest strategies for improved fisheries management

Staff members of the Oceanic Fisheries Programme of the Pacific Community (SPC) – Robert Scott, Graham Pilling and Finlay Scott, accompanied by Chris Reid from the Pacific Islands Forum Fisheries Agency (FFA) – recently gave a two-day national workshop on the 'harvest strategy approach' to fisheries management in Tarawa, Kiribati.

Fisheries managers are required to make decisions that juggle multiple, sometimes conflicting, objectives such as maintaining stock sustainability while also improving economic performance. The harvest strategy approach attempts to improve fisheries management by ensuring that year to year, management of the fishery supports the achievement of long-term fishery objectives. In 2014, the Western and Central Pacific Fisheries Commission (WCPFC) agreed to establish a harvest strategy for key fisheries and stocks in the western and central Pacific Ocean (WCPO).[1]

An important component of the harvest strategy approach is stakeholder engagement, which involves talking to WCPFC members to explain the process of developing a harvest strategy as well as gathering relevant information from them that will guide the process. Because the harvest strategy will influence fisheries management at a national level, it is essential that stakeholders have the freedom to discuss country-specific interests. To help with this, dedicated in-country workshops are planned in order to explain and discuss the harvest strategy approach in detail and how it relates to the specific interests of the country.

The first of these dedicated national workshops was given in Tarawa, Kiribati on 24 and 25 July 2018, and organised with the Ministry of Fisheries and Marine Resources Development (MFMRD). The workshop was as informal as possible and questions and free discussions were actively encouraged. The group responded to this and kept up high levels of energy and concentration throughout the two days.

Day one of the workshop was open to all government departments. This meant that people that would not otherwise be present at international fisheries meetings could be involved. This was important because successful fisheries management crosses many different sectors. As well as MFMRD, participants were from the Ministry of Environment, Lands and Agricultural Development and the Ministry of Information, Communication, Transport and Tourism Development. MFMRD gave an interesting talk on Kiribati fisheries to set the context, and the main concepts of the harvest strategy approach were introduced. The discussion focused on the higher level, broad-scale objectives for the future development of commercial fishing operations within Kiribati. Group exercises to identify and prioritise key objectives for Kiribati fisheries prompted lively discussions. The intention was not to set objectives for Kiribati, but to help understand how national objectives might feed into a harvest strategy approach undertaken at the broader WCPFC level.

Day two of the workshop was an MFMRD-focused question-and-answer session that covered the harvest strategy approach in more detail. The day was deliberately less structured than the first and led to very productive discussions about the different elements of a harvest strategy and how they relate to Kiribati fisheries. There were additional discussions on the anticipated timeframe of the process and what issues remain to be addressed. The interactive nature of discussions meant that participants could engage with SPC and FFA staff members without having to adhere to a formal structure or endure a long series of presentations.

The organisers greatly enjoyed running the workshop and learned a lot from the participants, and would like to thank them for their continued energy throughout the two days and for provoking some stimulating discussions. The aim is to continue these workshops in as many WCPFC member countries as time and budget allows.

The workshop was supported by the New Zealand-funded Pacific Tuna Management Strategy Evaluation project, which provides support for the development of the harvest strategy approach for WCPFC.

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[1] See article by Robert Scott, p. 4 of this issue.

Wallalis wobbling in whirly weather! A scientific mission thrown off course by heavy seas

Wallalis is the name of a survey at sea that was recently conducted in Wallis and Futuna's exclusive economic zone (EEZ). This two-week trip aboard a scientific vessel was designed to describe the pelagic ecosystem around this island country and to learn more about the physical, chemical and biological environment of offshore waters where seabirds, tunas and other large marine predators are found.

Figure 1. RV *Alis* rocked by bad weather at the main wharf on Wallis. Image: Gildas Roudaut

An ambitious plan to explore a previously unknown zone

Wallis and Futuna has no oceanic fisheries industry but would like to know more about potential resources in its offshore waters, which up to recently have not been explored much.

The Pacific Community (SPC) and the French Institute of Research for Development (IRD) offered to conduct a survey at sea to gather information about micronekton – small fish, squid and molluscs that large marine predators eat. We made a request to the French oceanographic fleet in 2016 for a research vessel to be made available to use. The request was accepted and the mission was scheduled for July 2018.

Because it is difficult to get time granted to a project on a research vessel, the research team – consisting of six scientists specialising in acoustics, micronekton, chemistry, phytoplankton and electronics – developed an ambitious programme to make the best possible use of the two-week period. Given the lack of data on micronekton in this area, the goal was to explore the EEZ from north to south and from east to west in order to produce a map of micronekton diversity and abundance. The team wanted to explore both the northern part of the EEZ on the Pacific Plate, which is characterised by deep water, and the southern part of the EEZ on the Australian Plate, which is shallower. We also wanted to explore very deep areas such as trenches and seamounts, which often have high biodiversity and are biologically rich. We identified 19 sampling stations of interest off the coasts of the islands of Wallis and Futuna, and at each station, physical (e.g. temperature, currents), chemical (e.g. nitrates, phosphates) and biological (phytoplankton, zooplankton and micronekton) measurements would be taken with the help of the ship's crew, who would set the instruments in the water.

The weather was the master of the ship

Due to rough seas and high winds, we quickly had to scale down our ambitious plans because although we were on a research vessel with costly equipment – the latest in acoustic technology – and a team of specialists and professional seafarers who were ready and waiting, going to sea in such weather and sea conditions would have made working conditions quite difficult. Winds averaged 30 knots (with gusts up to 40 knots) for the first four days. The pass through Wallis Lagoon to the open sea is very narrow, and so the harbour pilot decided that it was prudent to wait until sea conditions were calmer. In fact, an oil tanker had to wait outside the pass for several days before it could enter the lagoon to deliver its cargo. The tanker's crew later told us that they had had to contend with a three- to four-meter swell.

After spending three days at the Mata'Utu wharf, with cross winds and a swell that drove our research vessel against the wharf, the captain decided to leave the wharf and instead shelter in the lee of a small island in the lagoon. We spent two more days here before the wind dropped enough to allow us to go out the pass. Those two days were used to set up the expedition's equipment, in particular the new acoustic devices that included a surface sonar. When we were finally able to leave the lagoon, we tried to reach the sampling points that had been chosen. Unfortunately, with average winds of 25 knots and a strong swell, we were forced to return to the leeward side of Wallis and Futuna islands to find calmer waters. The final sampling effort ended up being much smaller than initially planned, with only four stations sampled offshore and six stations sampled (i.e. about half of the stations initially planned) on the leeward side of the Wallis and Futuna islands very close to shore.

New instruments deployed

This expedition provided an opportunity to deploy two new acoustic instruments: a wideband autonomous echo sounder and a surface echo sounder. During our mission we used several echo sounders designed to assess zooplankton and micronekton abundance and describe their horizontal and vertical spatial distributions. The RV *Alis* was equipped with a SIMRAD EK60 single-beam echo sounder (located under the hull) with four frequencies (38, 70, 120 and 200 kHz), which receives the echoes of organisms located at depths of 10–120 m for the 200 kHz transducer, up to 200 m for the 120 kHz transducer, 450 m for the 70 kHz transducer, and 800 m for the 38 kHz transducer. Because the signals returning from great depths are less accurate than those from organisms closer to the vessel, below a depth of 450 m we only received signals on a single frequency. In order to transform these acoustic signals into information that could be used to identify organism groups (e.g. gelatinous organisms, fish), the acoustic signals from at least two different frequencies were needed and three frequencies gave the best results.

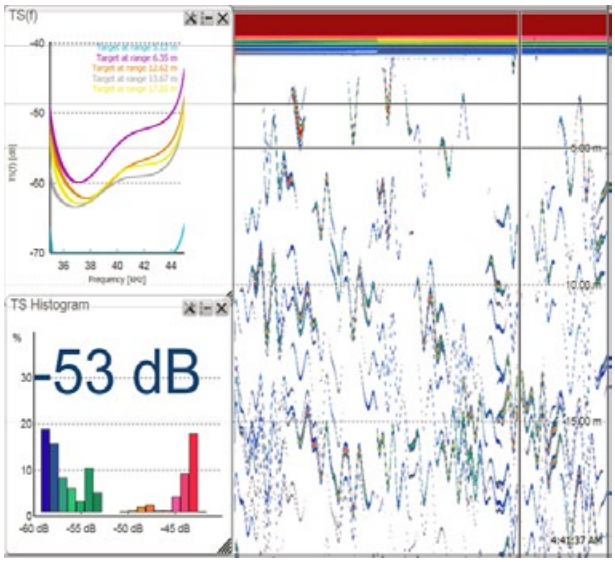

Figure 2. Wide-band echo sounder's 38 kHz echogram, showing, on the right, individual targets (individual curves) at a depth of 500–520m. Analysis of the frequency responses of each target should make it possible to categorise them as fish or crustacean for example and compare the results with the contents of related trawl hauls.

The first instrument tested was the Simrad Wideband Autonomous Transceiver (WBAT), an echo sounder with two frequencies (38 kHz and 120 kHz). This autonomous device can be sent down to great depths, and during our mission it was sent down to a depth of 500 m. When placed down into a micronekton layer, the sounder is very close to the organisms– as opposed to when using the hull sounder – and it becomes possible to observe and count individual signals. In addition, we gained access to the acoustic signal of each target on the two frequencies, something that would have been impossible to do with only the hull echo sounder. We were able to place the WBAT in the water five times in micronekton layers that we had previously sampled with the trawl. Several months will be needed to analyse these promising data.

The team also wanted to test a surface echo sounder in order to observe organisms in the first 10 m below the surface. We are particularly interested in this layer of water, which is not observed by the hull sounder because many pelagic predators feed directly under the surface such as mahi mahi, certain seabirds and tunas. One of the goals was to capture the acoustic signal of flying fish, which spend most of their time in the surface layer. It is not easy to observe the first 10 m, so specific arrangements were made, including installing a removable pole on the side of the ship. A customised stand was built for the base of the surface sounder (single-beam SIMRAD EK60, 120 kHz) so it could be installed on the end of the pole (Fig. 3). We waited until the ship was anchored away from the bad weather to finalise the sounder's installation and carry out the first tests of this instrument. The sounder's beam was directed towards the surface and to the side of the boat to avoid the bubbles created by

Figure 3. A surface echo sounder is mounted on the side of the RV *Alis* to observe organisms in the first 10 meters below the surface. Images: Valérie Allain

turbulence as the boat moved forward. However, if the ship rolled too much or listed, the surface waves would also cause bubbles that would interfere with the signal, although computer processing can partially remove the signal interference. Unfortunately, with the poor weather conditions during the survey, the sea was too agitated and we were only able to lower the pole into the water twice. The two trials we were able to carry out, including one around a fish aggregation device, have little chance of being useful because there was considerable interference in the signal. However, the data will still be analysed so as to improve the system before using it again in the future.

Sharing our work with students

Another high point of this mission was the awareness work we did with junior secondary and high school students on Wallis and Futuna. With the help of the staff of the Fisheries and Marine Resources Department and the Wallis and Futuna French National Education Office and the principals and teachers of several schools, we were able to organise school visits.

We made a stopover on Futuna during the mission and the scientific team went to Sisia Junior Secondary School as the

Figure 4. Wallisian high school students visited RV *Alis* to meet the scientists and technicians and get explanations on the research done in the waters around their island. Image: Françoise Lacourt-Millet

ship was moored out to sea and not at the wharf so students could not come on board. For an hour and a half, we presented our work to a year-11 class using PowerPoint presentations, videos and micronekton specimens collected at the beginning of the survey at sea.

On the final day of the trip at the wharf on Wallis, we were able to host a visit of two high-school classes in their final year of scientific studies and one year-10 class. The visit was arranged in five rotating workshops that changed every 15 minutes, involving groups of five to six students. There was a workshop on physical instruments and phytoplankton on the aft deck, one on micronekton in the wet lab, one on acoustics in the science station, another on the pelagic ecosystem in the mess hall, and finally, one on the bridge where the first mate and the lieutenant explained how the ship operated.

The discussions with students were very fruitful and they were both enthusiastic and curious. Some may now even be thinking of becoming scientists or sailors. We also hoped that we showed the girls that scientific professions are open to them as well, especially as five of the six members of the scientific team were women.

Mixed scientific results but impressive human interactions

The weather had a major influence on this campaign and the strong winds and high swell did not allow us to do everything we had planned. The restricted work plan will clearly limit the scope of our results for Wallis and Futuna's EEZ. However, we were able to visit four seamounts, including Lala Rock close to Wallis, which we will be able to better describe with the data and samples collected. We will need several months to complete the lab work and to analyse all the data that were collected. Despite the mixed scientific outcome, we will keep excellent memories of this sea expedition due to the warm welcome we received in Wallis and Futuna from the staff of Environment Department and the Agriculture and Fisheries Department, whose assistance was invaluable. We were very honoured to have an audience with the King of Wallis and to meet with members of the Territorial Assembly, the representative of the prefect on Futuna, and the staff of several institutions. The students both on Futuna and on Wallis were very enthusiastic and we enjoyed our discussions with them. The media also helped spread our message. Finally, we particularly want to acknowledge the crew of RV *Alis,* who played a large part in maintaining a good atmosphere on board, despite problems with the weather, and who displayed a great deal of skill, flexibility and humour. This mission was full of rich wonderful encounters and we will be happy to return to present our results in Wallis and Futuna during the first half of 2019

Acknowledgements

This survey at sea was carried out as part of the BIOPELAGOS project funded by the European Union's BEST2.0 programme and implemented by SPC and IRD.

A logbook and a website to learn more about Wallalis and Biopelagos

Wallalis logbook:
http://oceanfish.spc.int/en/ofpsection/ema/biological-research/nectalis/487-wallalis-journal-a-logbook

BIOPELAGOS project website:
http://oceanfish.spc.int/en/ofpsection/ema/biopelagos

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Tagging sharks to determine post-release mortality – the Pacific Shark Tagging Project

A New Caledonian fisheries observer about to place a satellite tag on a shortfin mako shark. Image: Charles Cuewapuru

Sharks are often caught incidentally by vessels fishing for tuna. Because sharks are top predators of oceanic ecosystems, evaluating the status of their stocks is important in the management of tuna fisheries. The Western and Central Pacific Fisheries Commission (WCPFC) assesses the status of shark populations, but data limitations often hold the Commission back making firm conclusions. There is considerable uncertainty about the number of sharks killed through fishing activities and this uncertainty leads to a lack of clarity in defining and refining shark conservation and management. Mitigation measures have been tested but results vary, and there is little information on the effectiveness of some of these measures. To reduce some of these uncertainties, and to provide confirmation that the condition of a shark at release is a reliable predictor of future survival, a regional shark tagging programme has been designed and implemented in the Pacific Islands region to measure post-release mortality in sharks.

Since 2010, several shark conservation and mitigation measures for the longline fisheries have been adopted by WCPFC. To reduce the practice of de-finning sharks, fishers were first required to fully utilise any retained catches of sharks and to guarantee retention by the fishing vessel of all parts of the shark. Oceanic white tip and silky sharks fishers (in 2013 and 2014, respectively) were asked to release these species as soon as possible after the shark is brought alongside the vessel. The number of releases and status upon release was to be monitored by observers. In 2015, wire leaders and shark lines (branch lines running directly off the longline floats to catch sharks) were banned. It is more difficult for sharks to bite through wire leaders than monofilament leaders, and this generally results in higher shark catch rates.

There is little information on the effectiveness of no-retention measures, and the Areas Beyond National Jurisdiction (ABNJ, or Common Oceans) Tuna Project, funded by the Global Environment Facility, has identified that tagging studies designed to quantify the survival rate of discarded and or released sharks are required to provide critical new inputs for assessment and mitigation studies. In addition to implementing the ABNJ Tuna Project by the Food and Agriculture Organization of the United Nations, the WCPFC also received a grant from the European Union for post-mortality studies on sharks. In January 2017, the initial phase of the tagging project was to design the study and a workshop with global expects was organised in New Zealand to review best practices and to develop a survey methodology for estimating shark post-release mortality (PRM).[1] The New Zealand National Institute of Water and Atmospheric Research (NIWA) was subsequently contracted by WCPFC to coordinate PRM tagging studies across the region with input from the Pacific Community (SPC). The output of the workshop provided the basis for an experimental protocol, and NIWA's expertise in shark

[1] See: Anon. 2017. Report of the Expert Workshop on Shark Post-Release Mortality Tagging Studies. Review of best practice and survey design 24–27 January 2017, Wellington, New Zealand. WCPFC and SPC. 43 p.

Tag attached to the telescopic pole. Image: Caroline Sanchez, SPC

tagging allowed the development of a training module for fisheries observers and fishers.

NIWA senior technician, Warrick Lyon, alongside SPC senior technician, Caroline Sanchez, delivered shark tagging training workshops to New Zealand, Fiji, New Caledonia and Marshall Islands National Observer Programs and associated fishing industries. The course was developed to allow observers and fishing captains to gain an understanding of the project, and the type of information required of them, as well as to gain confidence in the use of the tagging equipment and data recording.

Shark taggers are equipped with a tagging case that includes several satellites tags, a telescopic tagging pole, data sheets, a protocol, and a GoPro camera to film the tagging action. Collaboration from the fishing industry is critical because the vessel needs to slow down while the crew brings a shark alongside the vessel. The tagger grabs the pre-equipped tagging pole, puts on and starts narrating the tag event as well as observations of the shark's condition before and after release. To tag a shark, the tagger leans over the gunwale of the fishing vessel, and using the telescopic pole while the shark is still in the water, tags the shark close to its dorsal fin. Before the release of the tag, the tagger needs to assess the size and life status of the shark. If the shark measures less than 90 cm and presents obvious signs of potential death after release, the shark is not tagged (and the tagger waits for another opportunity). The tags used in this study record the shark's depth, and water temperature and light intensity. After 60 days, the tag automatically detaches from the shark and pops up to the surface where it transmits its data via satellite. The data

Training in the Marshall Islands onboard a Taiwanese longliner belonging to the Luen Thai Fishing Venture, July 2018. Image: SPC

are then used to determine whether the shark is alive or dead (e.g. a live shark will move in the water column whereas a dead shark will sink to the seabed). As a precaution, after two days of no vertical movement, the tag will prematurely release itself. If the tag remains attached for the entire period, the shark has most likely survived the fishing capture-and-release process.

The practical training for the tagging was undertaken onboard local longline vessels alongside the wharf, and trainees had the opportunity to tag different training objects. A dead shark in Fiji, a costumed polyester fake-shark in New Caledonia, and a watermelon in the Marshall Islands. The watermelon was shown to be a realistic alternative to a real shark and is relatively easily procured around the Pacific!

The project targets two shark species: shortfin mako and silky sharks. Shortfin sharks are found in New Zealand, New Caledonia and Fiji, and silky sharks are found in Fiji and the Marshall Islands. At this stage of the project, 43 shortfin makos and 23 silky sharks have been tagged. The tagging experiment is ongoing and the target is 100 shortfin makos and 100 silky sharks. After the tagging is completed, a review will synthesise and interpret the PRM shark tagging results in conjunction with similar studies in different fisheries. The review will be undertaken in early 2019.

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How to tag a watermelon from a Taiwanese longliner. Training in the Marshall Islands with the Luen Thai Fishing Venture, July 2018.
Image: Caroline Sanchez, SPC

Training in how to net the naughty people involved in coastal fisheries

Monitoring, control and surveillance mission in Aitutaki Lagoon, Cook Islands. Image: Aymeric Desurmont, SPC

In August, the online component of the inaugural Cohort 1 course for a Certificate IV in Fisheries Enforcement and Compliance – Coastal Fisheries and Aquaculture – began. This recently developed course will be accredited by the University of the South Pacific (USP) in late 2018, and delivered through USP's Pacific Technical and Further Education (TAFE) Programme. Trainers and assessors from the Pacific Community (SPC) will be responsible for administering the course's competency assessments.

The course complements the Certificate IV in Fisheries Enforcement and Compliance conducted by USP[1] and targets fisheries monitoring, control and surveillance (MCS) officers and administrators who have already completed that course. The initial two cohorts of the course will be funded by the New Zealand Ministry of Foreign Affairs and Trade project 'Improving fisheries food security and sustainable livelihoods for Pacific Island communities'.

This initial cohort will be offered competency assessments – through time-bound, online components, and culminating in eight days of face-to-face training – during November 2018. The online component is being conducted via the USP MOODLE (Modular Object-Oriented Dynamic Learning Environment), and covers 18 units of learning, including tutorials, quizzes and assignments for knowledge-based components. The purpose of the face-to-face meetings in November is to determine the skills competence of students through practical assessments based on the units of learning. Students have three chances to demonstrate their knowledge and skills, with success in all performance criteria leading to certification.

Students will receive financial support to attend the face-to-face training and competency assessments at Pacific TAFE in Suva, Fiji. However, SPC will only sponsor students who have *fully completed all online components of all four courses* to attend the face-to-face competency assessments.

This training programme targets current coastal and aquaculture MCS officers who have demonstrated strong engagement in their work and successfully completed the Certificate IV in Fisheries Enforcement and Compliance as a pre-requisite. The objective of the Cohort 1 training is to deliver a course that provides the technical and practical skills and knowledge expected of competent MCS officers when dealing in coastal fisheries and aquaculture. The programme will cover three new courses focusing on coastal fisheries and aquaculture in addition to a Pacific Islands Forum Fisheries Agency course that was developed for Enforcement Processes.

During the online learning phase of this course, students will be encouraged to share ideas and experiences with each other in order to learn about coastal fisheries and aquaculture situations in other countries or in other regions of their own country. This peer networking will hopefully facilitate future ongoing information sharing and communication among students.

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[1] An old Pacific Islands Forum Fisheries Agency Foundation course that focused on offshore fisheries.

Institutional collaboration is key to regulating coastal fisheries in Kiribati

Kiribati made significant progress towards strengthening national coastal fisheries governance with the recent National Consultation Workshop on Kiribati Coastal Fisheries Regulations, organised under the Coastal Fisheries Governance Project funded by the New Zealand Government. The workshop was held in Tarawa on 8–9 May 2018, and was attended by approximately 30 representatives from Kiribati's Ministry of Fisheries and Marine Resources Development (MFMRD), Ministry of Internal Affairs (MIA), Ministry of Women, Youth and Social Affairs (MWYSA), Ministry of Environment, Lands and Agriculture Development (MELAD), the Office of the Attorney General (OAG), a local fishers' association, donor partners, and a team from the Pacific Community (SPC) and the Pathways Project. The workshop provided an important opportunity for key stakeholders to come together, share information and experiences, and explore opportunities for future cooperation.

Teue Baikarawa, Deputy Secretary of MFMRD, opened the meeting and declared the workshop a *key milestone* in working towards MFMRD's vision for sustainably managed coastal fisheries. She noted that coastal fisheries had been sustaining the livelihoods of the I-Kiribati people for generations, and acknowledged the great value of traditional marine ecological knowledge for resource management. The Deputy Secretary highlighted the role of population growth, difficulties in enforcement, the impact of climate change, and land-based marine pollution in the decline of coastal fisheries resources. She emphasised the need to prioritise effective coastal fisheries management and the value in bringing key stakeholders together to work towards a coherent and comprehensive approach.

From right to left: Taati Eria, MFMRD Senior Fisheries Officer, was the workshop master of ceremony, under the guidance of Ian Bertram, SPC Coastal Fisheries Science and Management Adviser, and Teue Baikarawa, MFMRD Deputy Secretary. Image: Ariella D'Andrea

Presentations by MFMRD and OAG set the scene by summarising current fisheries legislation for Kiribati and the content of the Draft Fisheries (Protection of Certain Marine Resources) Regulations. Other presentations followed, including ones by MELAD, which included aspects of the Environment Act relating to protected species and protected areas, as well as its experience with enforcement; MIA on the role of Island Councils and the process for making fisheries bylaws; and MWYSA on the potential for incorporated community organisations to be involved in community-based coastal fisheries management. Workshop attendees then engaged in lengthy and detailed discussions about the scope of potential coastal fisheries regulations and licensing, the level of government at which different issues were best addressed, technical aspects of coastal fisheries management, and the manner in which community-based efforts to manage local resources could best be supported in the regulations.

The workshop provided an invaluable opportunity for participants to broaden their understanding of the role and responsibilities of each of the government ministries, and to identify where these interests intersect and overlap in relation to coastal fisheries. Considerable progress was made in clarifying the required scope and content of the proposed coastal fisheries regulations, and the Coastal Fisheries Office of MFMRD will continue to work closely with OAG, with support from SPC and the Pathways Project, in finalising the draft. The workshop also provided the foundation for ongoing coordination and collaboration between MFMRD and key ministries to ensure continuing support in the management of Kiribati's coastal fisheries for the benefit of current and future generations. In October, SPC will host staff from MFMRD and OAG on a two-week attachment to work on the draft regulations.

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Rock oyster Australian tour

Oyster farming is one of the most ancient forms of aquaculture. Yet, despite recent technological advances, notably in genetics (triploidy and selective breeding), it remains relatively low-tech and low-cost. Oysters were first cultured some 2,000 years ago in China, and first efforts to farm oysters using spat collectors began in Japan in the 17th century and in France in the 19th century. Edible oysters have since become some of the most widespread and largest commodities produced, by volume, in marine farming the world over. The farming of edible oysters is, however, virtually absent from the Pacific Islands region, except for two farmers, Patrick Morlet in New Caledonia, and Kuva Vatunilagi from Mago Island, Fiji. Patrick and Kuva rely on wild spatfall for their farms, and while they are now using recent basket designs to grow their produce to market size, they still apply the age-long principles of wild spat collection and grow-out. What sets Patrick and Kuva apart from other oyster farmers is the species they grow: the black lip rock oyster (Saccrostrea echinata). This species is found throughout the western Pacific, and in Australia and Southeast Asia. Interest in black lip rock oyster (BLRO) farming has been growing in recent years, with projects taking place in Australia's Northern Territory (Tropical Rock Oyster Aboriginal Economic Development Program), Western Australia (Pilbara Rock Oyster Research and Development), and in New Caledonia and Fiji where the Pacific Community (SPC) collaborates with national development authorities.

In July this year, SPC's Aquaculture Section brought Patrick Morlet and Kuva Vatunilagi, along with Moape Yabakiva (Fiji Ministry of Fisheries) and Flavien Dekoninck (ADECAL, New Caledonia's development agency) to Australia to see the current state of rock oyster farming, and apply any relevant techniques and technologies to Pacific Island oyster farming. This study tour was funded by the Pacific Fund[1] and the New Zealand Aid Programme.

The tour started with a visit to the New South Wales Department of Primary Industry (NSW DPI) in Port Stephens where we were welcomed by Dr Wayne O'Connor and his team who showed us the hatchery facilities, farm operations in the bay, commercial nursery operations, and gave an overview of the oyster sector in NSW. The Sydney rock oyster (SRO) industry is unique to Australia and the current outlook is very positive, with new investments being made and the modernisation of the sector. This is due to the convergence of a number of factors: 1) continued farm-gate price increases resulting from a shortage of oysters supplied to the Australian market; 2) the modernisation of farming techniques with access to cheaper farm building and operation material and equipment; and 3) the availability of hatchery-bred, disease-resistant and faster growing and

Top quality! A black lip rock oyster (BLRO) produced by Bowen Fresh Oysters. Image: Michel Bermudes, SPC

[1] The Pacific Fund of the French Ministry of Foreign Affairs was created in 1985 to promote social, economic, scientific and cultural development and integration in the Pacific.

higher quality oysters. The SRO industry has, until recently, relied essentially on wild spatfall for sourcing juveniles to farm on wooden rack structures along the NSW coast. SRO production peaked in the 1970s when it was as big then as the whole of the Australian oyster industry is now, all species combined (i.e. SRO, Pacific oysters, native flat oysters). Port Stephens was the largest production area by volume (peak of 2,700 tonnes per annum) and supplied 200 million spat annually to farmers across the state. Production has subsequently declined gradually due to disease, the introduction of Pacific oysters, the degradation of water quality, and market competition from oysters grown in other Australian states. The key take-home message for Pacific Island farmers is that the process of farming oysters is flexible and can be moulded to the local context and the goal of the operations (i.e. small or large scale). In a country like Australia, where the oyster sector has changed and modernised significantly, oysters are being grown in a number of different ways – from very basic and traditional stick culture (collecting and growing wild oysters on sticks) to the modern approach of sourcing hatchery-bred, single seed spat grown in manufactured, off-the-shelf plastic baskets, with all possible combinations in between.

Nice spat! From left, Flavien Dekoninck, Patrick Morlet and Kuva Vatunilagi admire the quality of the selectively bred oysters produced by the team of the New South Wales Department of Primary Industries.
Image: Michel Bermudes, SPC

From a governance and sector regulation perspective, the Australian experience is also highly valuable to the Pacific Islands region, and the NSW Oyster Industry Sustainable Aquaculture Strategy[1] presented to our participants highlighted some important considerations for countries investing in the development of shellfish aquaculture, particularly in terms of biosecurity, water quality and food safety.

From Port Stephens, the group travelled to Bowen (Queensland) to meet with John Collison who, in 2014, founded Bowen Fresh Oysters and started farming BLRO with his son Nathan. Before moving to Queensland, John had farmed SRO on the Shoalhaven River for 30 years. Seeing what an experienced oyster farmer can do with a new species such as BLRO was an eye opener for all. John operates a 10-ha lease in Bowen where he is able to collect spat, which is on-grown in floating baskets. From having sold only 1,000 dozen oysters last year, John is seriously ramping up production with millions of spat collected this year. There are some challenges to farming BLRO, one being access to seed. While John has expanded his spat collection capacity, only about 20% of the oysters collected are BLRO, the rest being the milky oyster (*Saccrostrea cucullata*), a smaller and slower growing oyster that ends up being graded out[2] during the production cycle but requires considerable handling that is time consuming and costly. The milky oyster can be sold but is a smaller product than the BLRO and does not withstand the overcatch treatment process[3] used on BLRO. There is always a strong market demand in Australia for locally produced oysters, especially if you are the only producer. Being a unique product, different to other oysters produced in Australia, the market outlook is very positive, hence the steps taken by John to expand his farming operations. For Patrick and Kuva, it was a great experience for them to see the farm in full expansion as we helped John and his sons Nathan and Leon to retrieve spat collectors and deploy oyster baskets on the farm. It was inspiring to see the piles of oyster seed being stripped off collectors, and the quality of the finished product serving as testimony of the efforts and ingenuity being applied in the process. Our island farmers had plenty to contribute to the exchange with John being particularly interested in Kuva's technique for spat collection to obtain a higher percentage of BLRO. We discovered that despite working in contrasting environments, all three farmers found much common ground and were reassured that in the end, working in their own little patch of the Pacific, they are all heading toward very similar farming techniques. We hope that the knowledge they are so willing to share will now speed up their progression because shellfish farming, and oysters in particular, is one of the most sustainable ways of producing food and part of the answer to food security in the region. Oyster farming is a low-cost entry to aquaculture, requiring low initial capital investment and the option to use locally available material such as hardwood. There

[1] See https://www.dpi.nsw.gov.au/fishing/aquaculture/publications/oysters/industry-strategy

[2] Oysters are graded every few weeks or few months throughout the production cycle to keep the small and large oysters separated as bigger oysters tend to out compete smaller ones. Because milky oysters grow more slowly than BLROs, they are separated from BLROs by grading.

[3] The overcatch is all the sea creatures that attach to oysters during the farming process. It can be other shellfish, smaller oysters, sponges, etc. Oyster farmers need to minimise overcatch through farming techniques or treatments. Treatment may include leaving the oysters out of the water for 2–3 weeks; the overcatch dies, but the farmed oysters survive.

are relatively few inputs compared with other commodities (i.e. no need for feed and farmers can catch their own seed in suitable areas). Plastic mesh to make baskets is relatively cheap and durable. One of the key attributes of oysters is the level of resilience they provide, with farmers able to take their stock out of water at the approach of a cyclone. In this way, farmers can save their stock and generate critical cash flow immediately after the cyclone has past, hence they are able to recover faster from a natural disaster and supply seafood from coastal areas that are often severely impacted and impoverished.

From this tour of rock oyster farming in Australia, SPC's work to promote small-scale, entry-level marine aquaculture continues, with oyster farming trials to expand in Fiji by the end of 2018 and hatchery and spat collection trials to continue in New Caledonia for the next two years under funding from the New Zealand Aid Programme.

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Oyster baskets loaded with recently collected spat are deployed on the farm at Bowen Fresh Oysters.
Image: Michel Bermudes, SPC

Moape Yabakiva (Fiji Ministry of Fisheries) working with John Collison to retrieve spat collectors in Bowen, Queensland, Australia.
Image: Michel Bermudes, SPC

Increasing capacity of government and private sector shrimp hatchery technicians in Fiji

The Pacific Community (SPC) is conducting a series of training workshops under the Sustainable Pacific Aquaculture (PacAqua) project in order to build the capacity of shrimp hatchery technicians from Fiji's Ministry of Fisheries (MoF) and the Crab Company (Fiji) Ltd (CCF). The PacAqua project is funded by the New Zealand Ministry of Foreign Affairs and Trade. The main objective of workshops is to build the capacity of participants and improve the supply of shrimp post-larvae for farmers in Fiji.

From left to to right: Salote Dumukoro and Paulin Law, from the Crab Company (Fiji) Ltd, and Teari Kaure, from the Fiji Ministry of Fisheries, handling shrimp broodstock during the training. Image: Avinash Singh, SPC

Working together, CCF staff could have access to the latest hatchery techniques, while MoF could get a better understanding of industry requirements. At the opening of the workshop, Principal Fisheries Officer – Aquaculture, Shalendra Singh, stated that developing the budding shrimp farming sector is critical to addressing Fiji's high imports of shrimp for the hotel and tourism sector. There is a need for the government and the private sector to work together so the step taken by CCF towards developing and operating its own shrimp hatchery will go a long way towards achieving the full potential of the sector.

During the opening, Make Liebregts, Director of CCF, stated that the Fiji Government – through the Ministry of Fisheries – has provided a supporting environment for initiatives such as those of our company: 'Over the years, we have developed an excellent working relationship with the Ministry of Fisheries, and in particular the Aquaculture staff at the Galoa hatchery. The attendance of government staff at this workshop will help to boost this relationship further as there will continue to be a need to share experiences and, at times, resources, to overcome the many possible issues that may arise so often and unexpected here in Fiji.'

The first training was conducted from 5 to 13 July 2018 by Dr Daniel Gruenberg, an international shrimp expert from Thailand. An additional two training sessions will be conducted over the next few months. Teari Kaure, Fisheries Assistant, commented that, 'We have visited several hatcheries abroad but had not had the opportunity to learn step-by-step processes that are required to successfully produce shrimp. There are opportunities to explore that would assist us to reach our annual production targets, and assist farmers and expand the sector.'

Dr Gruenberg highlighted that when using the superior specific pathogen-free shrimp *Panaeus vannamei* gene pool, performance in ponds was significantly better than when using wild-captured shrimp breeders. This is a significant factor that determines whether the industry would be profitable and competitive on the global market.

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Building the business skills of a tilapia farm operation in Papua New Guinea

The Pacific Community (SPC) has conducted a training workshop to improve the business skills of staff from the ASK Sanctuary Tilapia Farm (ASTF) in Yonki, Papua New Guinea (PNG). The training was conducted by the Lae-based 'Mind Your Own Business' (MYOB) provider Business Information Management Limited (BIML). The training assisted ASTF staff to improve their understanding of the use of MYOB Accounting Software to manage the financial records of its farm operation. With improved financial practices, ASTF staff will be able to manage finances and generate reports that will assist them in making sound management decisions and becoming a more viable and sustainable business.

The General Manager of ASTF, Mr Yogomul, stated that, 'We are more confident now to work in MYOB to enter transactions, reconcile records, generate reports and carry out end-of-year roll over. Our capacity in MYOB has been enhanced and with more hands-on use of the system and in close dialogue with BIML as and when required. We will master the MYOB system to positively benefit our farm operation.'

In order to expand the region's aquaculture sector, fish farms need to be placed on a business-like footing. Targeting growth in technical components of fish husbandry is only half of the formula for success. Strengthening staff skills in management, planning, product marketing, accountancy, computer literacy and modelling, branding, and communication are some of the areas that fish farmers must aim for in order to be economically sustainable. SPC's Aquaculture Section aims at building capacity in aquaculture business-related skills, whereby managers and investors apply knowledge acquired to build confidence in their businesses. Good accounting practices can be utilised to demonstrate to lending institutions that a farm that maintains good records, makes sound business decisions, is a lower risk, and is worthy of consideration for loans or investment.

Using a local service provider such as BIML for the training is important because they have a better understanding of accounting and legislation within PNG. The training can be conducted in English and local dialects to improve understanding and uptake. In addition, access to follow-up support will ensure that participants receive assistance when they need it.

The training was conducted under the Sustainable Pacific Aquaculture project and funded by New the Zealand Ministry of Foreign Affairs and Trade. The training was conducted on 10 and 13 August 2018.

Marianne Neiworo (front left) of Business Information Management Limited trains Lencie and Guna Yogomul of ASK Sanctuary Tilapia Farm on the use of the Mind Your Own Business accounting software in Lae, Papua New Guinea.

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Alternative resources to supplement the Tongan deepwater snapper fishery

The pressure on reef and benthic fish stocks is a leading concern for many Pacific Islands fisheries managers. Benthic fish are high on Pacific Islanders' food fish preference list so they are a prime target of small-scale fishermen. Naturally, the closest fishing grounds are regularly fished to supply demand, but as fish stocks gradually reduced, the fishermen shifted to fishing grounds further away.

In Tonga, the lucrative overseas market for deepwater snappers (DWS) has enticed some fishermen to upgrade their boats to fish offshore slopes and seamounts. They fished the closest grounds first then gradually moved farther offshore when the catch effort increased and the fish stocks diminished in size and numbers.

To further compound the pressure on DWS stocks, entrepreneurs took advantage of low-interest soft loans to add more boats to the fishery. This led to even greater catch effort on a dissipating stock, which eventually led to the need to re-assess the fishery's sustainability.

With funding from the New Zealand Government, the Tonga Ministry of Fisheries collaborated with the National Institute of Water and Atmospheric Research (NIWA), the Pacific Community (SPC), and the National Fisheries Council (NFC) to implement a project to regulate the DWS catch rate, with the objective of rejuvenating the fishery to sustainable levels. The first positive step in this direction was the establishment of a total allowable catch (TAC) of 80 tonnes per annum, which was amicably agreed to by all parties.

The next goal was to look at reducing the cost of fishing operations by identifying local species that could be used as bait. This would reduce the amount of sardine bait ordered from overseas, hence reducing operational costs.

This outlook was broadened to also consider alternative fishing methods to target other species. With an alternative source of income, fishers would be able to reduce their fishing effort on DWS while still running profitable fishing operations. Several options were suggested, including targeting species such as diamondback squid (*Thysanoteuthis rhombas*), small pelagic fish (e.g. sardines, mackerels), mahi mahi (*Coryphaena hippurus*), or tuna using small-scale longlines. It was decided to first assess the presence of diamondback squid in Tongan waters and train fishers in catching them.

The first of many diamondback squid caught during the trials. From left to right: William Sokimi, Taani Fe'ao and Petui Mateaki.

Fishing for diamondback squid in Tonga

In light of these plans, diamondback squid fishing trials were conducted from 11 to 28 June 2018. The fishing gear and equipment required for the trials were ordered and shipped to Nuku'alofa well ahead of the proposed dates. The technique and gear used has already been described in another article published in this newsletter.[1]

Fishing rigs were constructed during the first week, with assistance from eight fishermen and two fisheries officers. Four of the fishermen were boat owners as well. Two fishing trips were conducted over the next two weeks with five fishing days achieved in total.

The diamondback squid ranges in size from 60 cm to 100 cm mantle length, and can weigh up to 30 kg although they average around 20 kg. It is found in tropical and subtropical waters.

The neon flying squid (*Ommastrephes bartramii*) is another squid species and is usually fished with the same gear. Its mantle

[1] See: http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/144/FishNews144_14_Sokimi.pdf

Table 1 Summary of fishing effort and squid catches.

		Day 1	Day 2	Day 3	Day 4	Day 5	Total
	Number of hooks	24	48	60	60	52	244
Diamond back squid	Number	5	5	2	4	5	21
(*Thysanoteuthis rhombas*)	Weight (kg)	85.5	90.8	25.3	83.0	81.0	375.6
Neon flying squid	Number	5	4	3	4	5	21
(*Ommastrephes bartamii*)	Weight (kg)	36.3	22.5	17.3	45.0	46.0	167.1
Combined catches	Number	10	9	5	8	10	42
	Weight (kg)	121.8	113.3	42.6	128.0	127.0	542.7
	Snagged tentacles*	15	8	18	13	9	63

* Number of lures that were retrieved with snagged tentacles. Fine adjustments to the fishing technique should help reduce these missed catches.

length ranges in size from 25 cm to 60 cm and can weigh between 5 kg and 13 kg. This squid is smaller than the diamondback but much larger than the common *Loligo* species seen at the surface.

Catch and fishing information

Table 1 summarises squid catches during the five days of fishing. Both species of squid were caught. A total of 61 lines (244 hooks) were set for an overall catch of 42 squid (542.7 kg).

Comments

Diamondback and neon flying squid have already been successfully caught in trials carried out in New Caledonia in August 2012[2], the Cook Islands in July 2013[3], Fiji in July 2014[4] and Tahiti in June 2015[5]. It is presumed that the diamondback squid can be found around most Pacific islands.

Little is known about the use of the diamondback squid as bait but, given that the diamondback squid has a good market value, it could be sold to supplement income. It is not a traditional Pacific Island fishery and most Tongan fishermen are oblivious to its existence; but, it is potentially an untapped resource that DWS fishermen could capitalise on.

The recommendation was to try marketing the product locally first while more data are collected on the fishery's potential. If everything progressed well, then other prospective options could be considered. It would be prudent to get more information on the resource through continued trials with a small number of boats. Because this resource is currently unexploited in Pacific Island countries and territories, not much is known of its resilience to fishing pressure and the level of fishing effort that would make the fishery sustainable. Reflection on the Okinawa diamondback squid fishery indicates that the resource can be fragile if not managed properly, but this can be said for all fisheries. The key point is to know more about the species and then harvest it at sustainable levels.

There is likely to be some potential on the local market, notably in hotels and restaurants. A diamondback squid recipe booklet was written by Mitsuhiro Ishida in 2011 and was published by the Dominica Fisheries Division in cooperation with the Japan International Cooperation Agency after trials were conducted there. This booklet has 53 recipes for diamondback squid dishes. It can be distributed together with sample pieces to the hotels and restaurants. A questionnaire could also be issued along with the sample piece in order to get feedback from the chefs on their customers' responses to the dishes.

The prospects of exporting to overseas markets should be left to local entrepreneurs to evaluate. The product fetches USD 10–15 per kg on overseas markets.

If the marketing trials are successful, then the catch method should be adapted for use on small vessels so that small-scale fishers can also benefit from this development. At this stage, it is recommended that limited licensing be issued to local fishing companies to test the grounds and to gradually fortify the development bases for a local industry, if there are prospects for one.

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[2] http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/138/FishNews138_02_Blanc.pdf
[3] http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/141/FishNews141_09_Sokimi.pdf
[4] http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/144/FishNews144_14_Sokimi.pdf
[5] http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/148/FishNews148_02_Sokimi.pdf

Evaluation of the Pacific Islander Junior Professionals Programme (2013–2018)

Andrea Restrepo[1], Connie Donato-Hunt[2] and Bruce Chapman[3]

From left to to right: Lucy Joy, from Vanuatu, Berry Muller, from Marshall Islands and Lui Bell, from Samoa, were among the participants to the SPC Pacific Islander Junior Professionals (PIJP) Programme. Image: Ariella D'Andrea

The Pacific Islander Junior Professional (PIJP) Programme, run by the Fisheries, Aquaculture and Marine Ecosystems (FAME) Division of the Pacific Community (SPC), offers 12-month positions within FAME, to nationals and residents of Pacific Island countries and territories (PICTs) who are currently employed in a fisheries-related role. The evaluation of the PIJP Programme, summarised here, aims at identifying its strengths, weaknesses and opportunities for further improvement.

The PIJP Programme began in 2013 and 14 participants (six women, eight men) have participated as of April 2018, when the programme was evaluated.

Qualitative interviews were conducted with eleven PIJP participants (six past and five current) and six SPC staff members. The Kirkpatrick model for evaluating training was applied for the analysis.[4] The model identifies four levels: overall reaction and/or experience (level 1); gaining new knowledge, skills or confidence (level 2); applying learning (level 3); and outcomes resulting from training (level 4).

Findings

Programme overview

To join the PIJP Programme, a candidate must provide a letter of support from his or her home agency, and the agency must agree to hold a position open for the PIJP's return. When selected, most PIJPs interviewed were employed with government agencies, one with a non-governmental organisation and one was unemployed.[5]

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[3] Consultant, Marine and Pacific Consultants
[4] Kirkpatrick Partners. 2018. 'The Kirkpatrick Model'. Available online at: https://www.kirkpatrickpartners.com/Our-Philosophy/The-Kirkpatrick-Model
[5] This was an exceptional case due to a lack of applicants for one PIJP position.

While specific objectives for the PIJP Programme are not consistently articulated, it seems evident from the review that the programme has a key objective of building capacity in the region, including personal and professional development for participants.

Over the years, the range of areas within FAME where PIJP roles are offered have expanded, from initially just being coastal fisheries science to now including oceanic fisheries and coastal fisheries management and policy.

Recruitment process and logistics

Selection process

The PIJPs interviewed considered the selection process to be 'competitive' and 'fair', although this is perhaps unsurprising given they were all successful candidates. There was a mixed response with regard to how supportive home agencies were for participants to take up a PIJP position. One past participant commented that their agency 'did not initially support a one-year posting... but when they saw the benefits [my] immediate boss encouraged it'. Their concern was 'the workload left behind'. Current PIJPs, however, appear to have been generally encouraged by their workplace. One commented that their government agency was immediately supportive, recognising the PIJP Programme as 'long-term training' that was supportive of their agency's employee development plan.

Arrival in Noumea and settling in

PIJPs appreciated and acknowledged SPC's efficient organisation of travel arrangements to Noumea, where they were met at the airport and transferred to their accommodation.

The lack of baggage allowance was noted as a challenge for both arrival and return. Concerns were expressed about the limited amount of personal baggage for a one-year posting when 'only allowed one extra suitcase' and the extra cost of bringing additional baggage.

PIJPs, especially those recruited earlier, also commented on difficulties in the first few days on arrival, including finding it hard to cope and dealing with homesickness:

> *It was quite daunting coming to a foreign land and knowing no one.*

> *At the beginning it was difficult... I don't speak French.*

While early PIJPs encountered some difficulties, it is notable that SPC responded to the most pressing issues through improving the 'arrival experience' and developing induction and buddy systems for new staff. For current PIJPs who arrived around the same period, the induction process went smoothly because they had a network of support. Despite coming from different backgrounds, they felt they were living comparable experiences.

All PIJPs interviewed considered the remuneration for the PIJP positions to be adequate, although some felt that not having the same access to benefits as other internationally recruited staff at SPC made some things more difficult and expensive, particularly for those with dependents (e.g. extra costs of bringing and providing for their family, hiring a caretaker for young children).

Participants' experiences (Kirkpatrick Level 1 – Reaction)

Development and implementation of a work plan

Most of the former PIJPs indicated that their work programme was either set mostly by SPC (rather than developed around the PIJP's specific learning interests), or was unclear for the first few weeks. In 2018, PIJP managers' approach in the development and implementation of PIJP work programmes seem to have moved towards a greater balance of what PIJPs wish to learn and what SPC needs. One described it as an 'organic and ongoing' process, with meetings being driven by PIJP needs. For another, there was a recurring meeting every two weeks with their supervisor, with plans and priorities continuously being adjusted. Participants who frequently met with their supervisors appreciated the effective guidance and feedback.

> *Feedback and follow-up is good to know if you're on the right path and to make sure you're learning.*

Current PIJPs also seem to have had a stronger diversity of tasks and topics included in their work plans than previous participants, although some participants still expressed a desire to have more balance and diversity in their work, with one identifying skills they wished to acquire including strategic planning and leadership.

Work place expectations and field work

Some PIJPs commented on the high expectations at SPC in relation to workload, including the need to multitask and prioritise.

Overall, PIJPs found the fieldwork both challenging (in terms of professional work and the logistics of travel) and rewarding. Some earlier PIJPs felt they had been 'thrown in the deep end' in relation to field missions without sufficient preparatory training:

> *[The role was] 'to assist' – but after working with SPC onsite I then went out by myself! But it was a good experience and challenge – I learned a lot.*

This sentiment, however, was not shared by current and later PIJPs. One later PIJP stated; 'I was mentored well on the first trip and the second. For the third trip I did it myself

– even the letter of agreement', this was about four to five months after starting the PIJP term'. This was described as a 'big change and learning process for me'. While earlier recruits noted experiencing some difficulties with 'lack of guidance and/or advice during initial weeks and months', this seems to also have improved over time.

Final output of the PIJP posting

PIJPs took considerable satisfaction from being able to author or co-author a written report of their work. For example:

> *For me to have my name on the report was a big achievement.*
>
> *I was able to produce all the technical manuals.*
>
> *By the end [I was] co-author on four country reports.*

Participants' learning (Kirkpatrick Level 2 – Learning)

PIJPs commented positively on their professional learning experience; 'I am grateful to have had the opportunity to learn coastal fisheries science and management at an expert and professional level'.

The opportunity to travel and work in other countries was a highlight for most:

> *I travelled to Pacific Island countries to see first hand coastal issues and learn how communities and local governance deal with them.*
>
> *The best aspect? Working with other Pacific Island countries – visit and work with people – see how others approach things; their challenges. Makes a big difference in understanding.*

Learning was also not always limited to the work programme; "[SPC] pushed me to other opportunities for learning ... not specific to the project". One SPC staff member also noted that the programme is not just about technical skills, but 'also working to build professionals'. They felt that aspects relating to professional behaviour, however, were not always clearly articulated.

Participants' use of new knowledge and skills (Kirkpatrick Level 3 – Behaviour)

Of the past PIJPs interviewed, all returned to their home organisation after their PIJP term (excluding the participant who was not employed). This was in line with the organisations' commitments to hold a position open for the returning PIJP, however, PIJPs did not always return to the same role.

Navneel Singh, from Fiji, doing undewater survey work. Image: Pauline Bosserelle, SPC

Several past participants spoke positively about their use of knowledge learned at SPC in their current roles:

> *My experience has been vital in leading and assisting in conducting trainings, collecting data, doing monitoring and evaluation of data collection.*
>
> *They really appreciated, acknowledged the skills brought back to the organisation.*

For one, implementing a national survey on returning home was the 'biggest accomplishment of SPC work .... I produced the report directly using what I learned at SPC – organisation, science'. For another, 'the benefits of working with SPC are huge but I found it somewhat difficult to find work... on my return'.

Programme outcomes (Kirkpatrick Level 4 - Results)

The most positive outcomes seemed to be an increased confidence in the PIJPs' ability to deliver technical work and to face the challenges presented by working in new environments. On the technical side, the authorship of documents while at SPC was cited by several as key outcomes for example:

> *Good to learn writing and publications – I am still publishing reports from this learning.*
>
> *Before I found it hard to write – after SPC I'm more confident; 'I'll write that Report'!*
>
> *I specially learned to be more confident at meetings. Before, I would ask someone to speak for me – now, I'll take the mic!*

With respect to the overall learning experience, one participant summed it up by saying, 'There are ups and downs, but, you learn things; next time it comes up you know how to deal with the situation.'

Aaranteiti Kiareti, from Kiribati, and Christoper Kalnasei Arthur, from Vanuatu, certainly knew how to make the most of their weekends in Noumea during their one-year participation to the PIJP programme. Images: Sioeli Tonga and Michel Blanc, SPC.

SPC staff noted that while PIJP involves some costs, is also directly benefits SPC through:

- making available an extra pair of skilled, capable hands;
- establishing or maintaining country connections; and
- facilitating the standardisation of approaches and methodologies across the region.

Opportunities for improvement

Programme design

1. Clarify the professional development context and objectives

The emphasis on an 'exciting professional development opportunity' in job advertisements led to certain expectations that PIJPs were coming to SPC in a *teaching/learning* environment; instead, they found a more 'learning by doing' environment. SPC needs to more clearly clarify the type of development programme for PIJPs to expect and ensure professional development is formalised in work plans.

2. Broaden the programme so that it is inclusive of mid-career professionals

The term 'junior' may imply that the programme only targets recent graduates or junior staff when, in fact, this does not represent the group selected for these positions. As such, it is recommended that 'junior' be removed from the position title and possibly changed to, for example, 'Pacific Islander Fisheries Professional'.

3. Continue to broaden the scope for PIJP placements in other areas within FAME

Areas suggested included fisheries economics and monitoring, evaluation and learning.

4. Set the same start date for all PIJPs or have multiple PIJPs at the same time

It was recommended that participants undertake the programme at around the same time so as to provide a network of mutual support. If this is not possible, SPC should consider ensuring multiple PIJPs are at FAME at any the same time.

Individual work plans and learning outcomes

5. Identify clear individual learning outcomes and objectives

The evaluation found that PIJPs' individual objectives, priorities and work plans were not always clear, although this has improved more recently. SPC supervisors should continue to support PIJPs to identify the skills and learning outcomes they would like to work towards during their time at SPC.

6. Develop holistic workplans

Upon arrival, PIJP participants and their supervisors should develop a work plan and prioritise objectives in line with the identified needs of the participant and their supervisor. In developing work plans, PIJPs and SPC staff have noted the importance of considering a holistic work plan that may include multiple technical areas as well as soft skills[6].

7. Identify learning opportunities at the start

Identify opportunities to fulfil participants' learning and training needs at the start when individual work plans are developed. For example, these could include learning events, training attachments with other agencies, or short courses. A certificate of completion and/or a reference outlining the PIJP's accomplishments at SPC may also be appreciated by PIJPs and a motivation for successful completion.

8. Improve ongoing mentoring and work plan adaptation

SPC should assign the responsibility of supervising PIJPs to staff who are available to provide mentoring and support. Supervising staff could also be further supported in their management of PIJPs, including involvement in the recruitment processes, input into the start date, and any support they may require in developing mentoring and leadership skills themselves. Regular meetings between PIJPs and their supervisor should also take place for feedback, follow-up and adjusting work plans and priorities accordingly.

Logistics for moving to Noumea

9. Formalise a checklist system for moving to Noumea

Arriving in a new country and learning a new language, laws and processes may cause PIJPs to feel lost. A checklist for participants to know what to do on arrival could be beneficial, including administrative procedures for visas, banks and mobile and Internet connectivity. Before sending PIJPs on duty travel it is also important to consider that visas take time and can be difficult or costly to obtain.

10 Compare benefits and/or allowances between PIJPs and other international staff

Factors such as moving costs (e.g. baggage, plane tickets), childcare, and supporting accompanying adults may restrict access for qualified applicants who encounter additional barriers to participation, such as primary carers of children. To ensure equitable opportunities among applicants, SPC should investigate the possibility of including some of these benefits within all PIJP positions.

PIJP alumni

11. Establish an ongoing PIJP network

PIJPs felt they shared a common experience and were positive about the idea of maintaining contact with each other and SPC staff. One suggested the establishment of an online group for PIJPs, noting there may be challenges to managing and maintaining ongoing engagement.

12. Utilise former PIJPs more in FAME's work

It was suggested that SPC could make use of past PIJPs who were trained for short-notice requests or for south-south exchanges.

13. Continued evaluation

FAME should continue to conduct evaluations for continuous improvement and potentially investigating other aspects of the programme such the term length, and including perspectives of fisheries agencies.

Conclusion

The evaluation highlights that the PIJP Programme has been broadly successful, providing a positive experience for PIJPs, building capacity and professional development, and contributing to SPC's work. Of the PIJPs that were interviewed, 10 out of 11 were positive about their experience and felt grateful for the opportunity.

Past participants spoke positively about applying knowledge learned at SPC in their current work. The most positive outcomes of the Programme seemed to be an increased confidence in the PIJPs' ability to deliver technical work and to face the challenges presented by working in new environments.

> *Understanding all this gives one a sense ... openness to respect and appreciate life in general.*

> *I want to thank SPC for helping me get outside the box. Whatever I will do back home, I will do it with what I learned here.*

Most of the early challenges in terms of support provided to PIJPs on arrival and work planning seem to have been addressed as the programme has developed. The current evaluation highlights additional opportunities to continue improving the programme and build on its impact and effectiveness.

[6] According to the Collins English Dictionary 'soft skills' are defined as 'desirable qualities for certain forms of employment that do not depend on acquired knowledge: they include common sense, the ability to deal with people, and a positive flexible attitude'.

Customised leadership and management training for Pacific fisheries

Over the next five years, 125 current and emerging leaders in the Pacific Island fisheries sector will be able to apply for and complete a uniquely tailored three-stage modular programme in leadership and management. Participants can expect this learning journey to take up to 18 months through face-to-face workshops, learning experiences, coaching and resources relevant and applicable to their daily work. Integral to the success of the Pacific Fisheries Leadership Project (PFLP) are the coaching sessions that link the modules on Leadership for Effectiveness; Leadership Experience; and Leadership for Change.

Image: Colette Wabnitz, SPC

Funded by the New Zealand Government and contributing to the goals of the Regional Roadmap for Sustainable Pacific Fisheries, PFLP is being implemented by a consortium led by the Pacific Community (SPC) along with the Pacific Islands Forum Fisheries Agency (FFA), University of Queensland (UQ), People Focus (NZ leadership development specialists), and the Centre for Adaptive Leadership (CLA).

Calls for applications for Cohort 1 have now closed and the selection panel is assessing the applicants based on a set of criteria that was circulated to members in June 2018. Successful candidates who have been supported by their national senior leadership team (e.g. fisheries director, permanent secretary, minister or senior foreign affairs official) will soon be notified of logistics to commence their first coaching session and online learning. The inaugural face-to-face workshop will be conducted in January 2019 in Nadi, Fiji.

'It is deeply inspiring to be part of such a terrific consortium delivering PFLP,' said Cameron Bowles, Team Leader for PFLP. Bowles said 'as well as SPC and FFA, the consortium brings different perspectives, skills and experience from the University of Queensland, People Focus (NZ) and CLA (Centre for Leadership and Adaptation)'.

Cameron further added that PFLP is committed to applying to itself the same principles it is advocating in exercising leadership – reflecting on practice, engaging others, adapting and taking calculated risks in order to continually improve its response and relevance to the contexts and needs of fisheries participants from across the Pacific.

PFLP aims to improve quality and diversity of leadership and management in priority sectorial areas with an increased cooperation between relevant participants and their institutions for the fisheries sector. As such, PFLP wants to attract not only the most relevant, but the most committed and interested participants possible, including those that directly impact national fisheries succession planning.

A key outcome of these annual cohorts is the ability to successfully gain credits in the award courses 'Inclusive Strategic Leadership' and 'People and Teams' through UQ's graduate certificate in Leadership. This programme is based on real world issues and experiences, and is adapted to the context and needs of participants. Students can then complete the other two courses for the UQ graduate certificate on their own or with an employer or other sponsorship. UQ is willing to deliver these two courses nationally or subregionally if teams of 10 or more learners are enrolled.

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Recruitment of freshwater eels as 'glass eels' in Fiji Islands – New research results about species composition and seasonality

Tim Pickering[1]

Freshwater eels of the family Anguillidae (tuna or duna in Polynesia and Fiji) are iconic species in the islands of the South Pacific, and are of high cultural importance and of potentially high value as fisheries or for capture-based aquaculture. They are also vulnerable to habitat degradation, human-made physical barriers or water pollution in rivers along the routes of their long migrations to open-ocean spawning locations, from which their offspring ultimately return to swim back up-river as 'glass eels'.

The South Pacific is the least-studied of the world's freshwater eel regions, and there are large knowledge gaps. Little is known about their breeding locations, migration patterns, levels of recruitment, growth rates, population abundance, and age at reproductive maturity – the very information needed for science-based methods to manage the conservation and utilisation of South Pacific freshwater eels. With increasing pressure for the supply of anguillid glass eels for the Southeast Asian aquaculture market, a more robust understanding of the strength of glass eel recruitment in the South Pacific is vital for conservation and management.

This makes especially welcome two recently published scientific papers stemming from the work of Dr Chinthaka Hewavitharane, a Fijian post-doctoral researcher who gained his PhD on eels at Kyushu University in Japan under the supervision of Professor Mochioka at the Department of Animal and Marine Bioresource Science.[2] To confirm which of the six species of anguillid eels present in the western South Pacific actually do recruit into Fiji Islands, and to better understand the inshore recruitment mechanisms of tropical eels, the collaborative research team comprising Dr Hewavitharane, Prof Mochioka, Dr Pickering (Pacific Community) and Prof Rico (University of the South Pacific) collected 1,368 glass eels from the mouth of a small river near Navua on Viti Levu during monthly sampling for a period of 14 months. The scientists confirmed using both morphological characters and DNA barcoding that, of the six possible western South Pacific species, only three species are making landfall at their site in Fiji: one short-finned eel (*Anguilla obscura*) and two long-finned eels (*A. marmorata* and *A. megastoma*).

Anguilla obscura was the most abundant species (comprising 55.0% of the glass eel catch), with peak recruitment periods from February to April. *Anguilla marmorata* was the second most abundant species (41.4%), with peak recruitment periods in April and September–October. *Anguilla megastoma* only comprised 3.9% of the glass eels collected, with peak recruitment periods in April and October.

Outside of the peak recruitment times, *Anguilla obscura* and *A. marmorata* could be caught in low numbers at almost any time of the year. In other words, there's a steady, low level of 'trickle' recruitment, in contrast to temperate latitude eels where recruitment is strongly seasonal in massed 'eel runs'. Even in Fiji there are strong recruitment events – the results

Dr Chinthaka Hewavitarane and Prof Mochioka (Kyushu University) conducting an electrofishing population study of juvenile eels in a Fijian river near Suva.
Image: Tim Pickering, SPC

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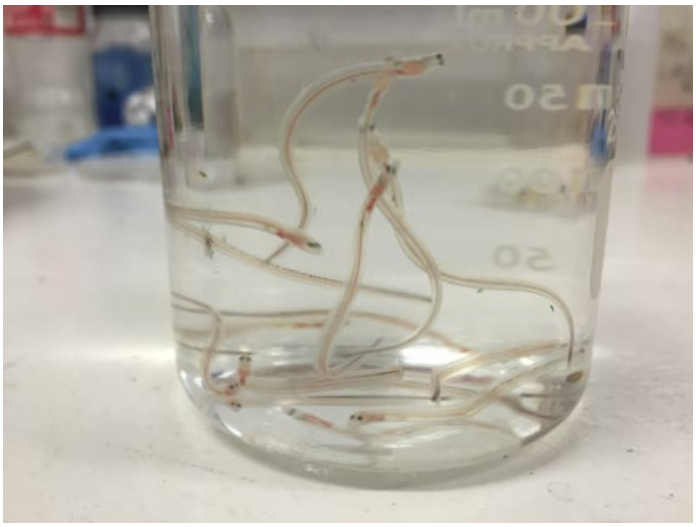
[2] See Hewavitharane et al. 2017 and 2018. These two new reports about glass eel recruitment are based on field work completed in Fiji during 2015 and 2016.

show that the best catches of glass eels occur during periods of heavy rain, from September to October and from February to April, commencing one hour after sunset on the day following a new moon.

Genetic techniques such as DNA bar-coding are powerful new tools for population studies of fish, especially early life history stages that have few morphological characters to reliably allow identification to species level. Even so, the capacity of national institutions in the South Pacific to utilise such high-tech tools is limited. It would be interesting and useful if reliable methods could be found to identify glass eels to species level using only observations of morphological characteristics made with the type of light microscope available in any high school. Hewavitharane (2017) demonstrated that the external morphological characteristics of anodorsal length ratios and the pigmentation patterns of the caudal fin and caudal peduncle are, together, sufficient to classify the three Fijian species of eels using morphological characteristics alone. This is a useful result that simplifies the research and monitoring techniques of anguillid glass eel recruitment for conservation, fisheries management or aquaculture purposes in the South Pacific.

Information on the recruitment of tropical eels in the South Pacific is still very rudimentary. The insights provided by Hewavitharane and colleagues (2017 and 2018) about key life history traits and ecology, such as seasonal patterns of recruitment, abundance and species composition of the glass eels arriving to inhabit freshwater bodies at this study site on Viti Levu, Fiji Islands, are important contributions toward the knowledge needed to design appropriate management and conservation programmes aimed at efficiently protecting or sustainably utilising these vulnerable fish species. Similar research is needed in other parts of Fiji, and in other island groups of the South Pacific.

Glass eel net deployed at the river mouth sampling site near Navua, Fiji Islands. Image: Tim Pickering, SPC



Glass eels captured in Fiji for identification and description as part of the eel recruitment research. Image: Tim Pickering, SPC

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Hewavitharane C.A., Pickering T.D., Ciro R. and Mochioka N. 2018. Species composition, abundance and seasonal recruitment patterns of freshwater eels (*Anguilla* spp.) to Viti Levu, Fiji Islands, in the western South Pacific. Marine and Freshwater Research. Available at https://doi.org/10.1071/MF1810

For more information

SPC recently published a Policy Brief about conservation and management of freshwater eels, available at: [http://purl.org/spc/digilib/doc/vroyz]

Two *SPC Fisheries Newsletter* articles relating to freshwater eel research in the region can be found at:

[http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/142/FishNews142_30_Pickering.pdf], and

[http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/150/FishNews150_11_Pickering.pdf]

The Pacific Fisheries Officer Training Course – Where to from here?

Alec Woods[1]

The Pacific Fisheries Officer Training Course hosted by Nelson Marlborough Institute of Technology, has, since 1979, trained over 360 junior fisheries staff from 21 countries throughout the Pacific Islands region. Funding for this training has now ceased and it is time for Pacific fisheries managers to turn their attention to the future for this type of training.

Outboard motor maintenance, 2014. From left to right: Teaiti Beetana (Kiribati), Malcolm Linawak (Vanuatu) and Joe Tiatia (Samoa). Image: Alec Woods

At the 2017 Heads of Fisheries meeting in Noumea, New Caledonia, Ben Ponia (Ministry of Marine Resources (MMR) Secretary, Cook Islands) posed the following question for delegates to consider: 'What is the future fisheries officer going to look like?' The point of this article is not to answer this question directly but rather to start some discussion on the topic and present some themes for consideration in an attempt to find an answer to Ben's question. In doing so, the article will look at how formal training for junior fisheries officers in the Pacific Islands region has evolved.

Regional training for fisheries extension officers began in 1979 with the creation of the Pacific Community (SPC)/ Nelson Polytechnic Pacific Fisheries Officer Training Course, or 'Nelson course'. It is now the longest-running training course in the region, and most managers regard it as a foundation programme for their fisheries officers. This course has run almost continuously since 1979 and over this time, 369 fisheries officers have attended the training.

From March 2013 to December 2017, the Nelson course was conducted under the Pacific Fisheries Training Programme, an NZD 7.4 million programme funded by New Zealand's Ministry of Foreign Affairs and Trade (MFAT) Aid Programme. The aim of this programme was to increase Pacific Islands' sustainable economic development through a greater contribution from the seafood sector. Over this time, more than 700 Pacific Island men and women received training in-country, regionally and in New Zealand.

For now, this training has finished. An end-of-programme evaluation was conducted in late 2017, covering the period March 2013 to December 2017. The reviewer's findings will be discussed later in this article. The full report can be

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Chartwork and navigation, 2013. From left to right: Scott Pelesala (Tuvalu), Aram Erietera (Kiribati) and Ioane Mamaia (Niue). Image: Alec Woods

STCW Firefighting course, 2013. From left to right: Sulia Peleni (Tokelau), Alice Mitchell (Cook Islands), Jobson Tabipala (Solomon Islands), Ioane Mamaia (Niue) and Bianca Bernicke (Nauru). Image: Alec Woods

found on the MFAT website[2] along with MFAT's response. Before responding to these findings it should be noted that MFAT has agreed to 'explore the option of a second phase of the activity'.[3]

When the programme was initially planned, the intention had been to provide junior fisheries officers with a multidisciplinary training programme that would give participants a grounding in a range of basic practical skills.

> *The course [was] designed for a fisheries extension officer working in an isolated situation with little technical or administrative support and needing the skills necessary to maintain and repair a variety of equipment, conduct or administer fishing operations and related activities and provide advice and technical assistance to village fishermen.*[4]

In the early stages of the programme, applicants' background reflected these criteria; later years have seen more diversification. Nowadays, it is not uncommon for intakes to be a mix of recent school leavers; women wanting to transition from a desk job to one involving field work and practical skills; principal fisheries officers and experienced extension staff wanting to refresh skills; and the odd private fisher looking for a career change. As the duties of many fisheries officers become more complex, the course syllabus has both reflected this and become a means of moving from one role to another. For some applicants, the training in Nelson has opened the door to a new career path, which could mean further training at a tertiary institution or an attachment to a regional agency such as SPC. Any discussion on the future of this course will need to consider the wider implications for future training.

The benefits of continuing to train applicants in New Zealand need careful consideration. New Zealand has a fisheries management regime that is both complex and comprehensive. While on the surface it might appear that there is little in common with the wider Pacific experience, closer examination shows that all fisheries in the Pacific seem to be facing similar challenges. The ever-present need for more data; the conflicting demands of shared fisheries; new monitoring, control and surveillance technologies; environmental changes; safety at sea; expanding tourism; and the changing geopolitical landscape are challenges faced by fisheries administrations everywhere. The fisheries officer of the future will still need some form of basic training but the transition to more specialised roles will require a clearer articulation of career paths and closer integration with a range of training providers than has happened in the past. Three case studies will show how the Nelson training has evolved in recent years.

The Nelson course was reviewed in 1984 and again in 2002. The recent evaluation of the Pacific Fisheries Training Programme did not get down to the level of syllabus content but such a reconsideration is well overdue and should be part of any review undertaken prior to the commencement of a Phase II of this activity. This should also include the linkage with the practical safety fishing and financial management course run by Vanuatu Maritime College (VMC).

In previous years, all those attending the training in Nelson went on to attend a practical fishing course in the region – first in selected countries, then in Noumea and, most recently, in Vanuatu. As the backgrounds of participants attending the Nelson course became more diverse, it was clear that not all of them would benefit from attending the practical fishing course and so a smaller number went on to VMC. Currently, the financial management course is taught

[2] https://www.mfat.govt.nz/assets/Aid-Prog-docs/Evaluations/2018/PFTP-Evaluation-report-final-Feb-2018.pdf
[3] https://www.mfat.govt.nz/assets/Aid-Prog-docs/Evaluations/2018/MR-4-Web-Pacific-Fisheries-eval-2018.pdf
[4] Questionnaire on Fisheries Training, Background paper 3, 16th Regional Technical Meeting on Fisheries, Noumea, 1984, p.1. http://www.spc.int/DigitalLibrary/Doc/FAME/Meetings/RTMF/16/BP3.pdf

Vessel safety, 2014. From left to right: Vea Kava (Tonga), Joe Tiatia (Samoa), Teaiti Beetana (Kiribati) and Malcolm Linawak (Vanuatu) with instructor Brian Fossett in background. Image: Alec Woods

both in Nelson (with a project management focus) and at VMC, where the emphasis is on the economics of a fishing operation. SCTW[5] Basic Safety is part of both courses. Not only is it a convenient 'bundle' of core skills, but it is an excellent team-building exercise and an opportunity to use the self-contained breathing apparatus skills that many already possess.

In 2004, Port Sampling and Observer Skills were introduced into the Nelson course. By 2011, the Regional Observer Programme had advanced to a point where this training was able to be supported in the region or as part of national programmes. Monitoring, control and surveillance (MCS) had by now become a function of most fisheries departments and this topic was introduced into the Nelson syllabus, albeit as a part of the wider compliance picture that included the role of the observer, linkages with the agencies of other countries, and coastal MCS activities. The intention was that this module would serve as an introduction to further MCS studies (Certificate IV) at the University of the South Pacific (USP).

Fisheries management has always presented a challenge in that each country presents its own unique blend of management priorities. With some of these in mind, the decision was taken to look at some themes common to all, study the New Zealand treatment and see if any lessons could be taken from this. Recent case studies have included charter fisheries, community-based fisheries management in Kaikoura, tourism and fisheries management and iconic species management with an emphasis on the importance of consultation. Many of these issues are present in Kaikoura, and the three-day field-trip based at Takahanga Marae has evolved over time to become a central feature of the course.

There has long been an expectation that training will contribute to a certified course, and discussion needs to happen as to why progress towards this end has been so slow. Short courses suit certain topics and timeframes. Distance learning via online platforms such as MOODLE[6] means that students no longer have to spend long periods of time away from home. Perhaps a start could be made by aligning the Nelson course with MS206 Marine Skills and Techniques course run by USP.

There is no doubt that the training landscape is short on oversight. The focus now needs to be on sustainability and whether New Zealand should continue to fund this training or whether Pacific nations should be prepared to shoulder some, if not all, of this responsibility themselves. Only once responsibilities have been defined and apportioned can work then begin on delivering the training needed to equip fisheries officers for the future.

[5] SCTW = Standards of Training, Certification and Watchkeeping for Seafarers

[6] MOODLE is a free and open-source learning management system. MOODLE (acronym for modular object-oriented dynamic learning environment) allows for extending and tailoring learning environments using community sourced plugins. Source: Wikipedia

Revitalising the fish warden system in Fiji: Outcomes of the Second Northern Division Fish Warden Forum

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The Second Northern Division Fish Warden Forum took place in Labasa, Fiji on 15 May 2018. The forum was co-hosted by Fiji's Ministry of Fisheries – Northern Division and the Wildlife Conservation Society. The forum was officially opened by Assistant Superintendent of Police, Beni Nasamu, Director of Crimes of the Fiji Police Force – Northern Division, and facilitated by Alivereti Tuinamata of Fiji's Ministry of Fisheries – Northern Division.

Background

The enforcement of inshore fisheries laws and regulations in Fiji is challenging, given the limited human and financial resources to support fisheries management and the size of Fiji's inshore waters. To address this issue, a provision was inserted into the Fisheries Act of 1959 stating, 'The Minister may appoint **honorary** fish wardens whose duties shall be the **prevention** and **detection** of offences under this Act and the **enforcement** of the provisions thereof'. On 11 November 1965, the power to appoint fish wardens was delegated to the Permanent Secretary for the Ministry of Fisheries (MoF).

Fish warden checking fishers' icebox. Image: Partners in Community Development Fiji (© PCDF)

Over the years there have been many recommendations to review and improve Fiji's fish warden system in order for the system to be more efficient and effective. It has been estimated that approximately 4,000 fish wardens were trained throughout Fiji in the last 20 years, at a cost of FJD 3,000–10,000 per training course (Gillett 2018). However, this figure is a rough estimate of trained fish wardens. Furthermore, it is further estimated that only 1–2 per cent of fish wardens had reported any illegal activity (Gillett 2018). In addition, the number of active and non-active fish wardens is unknown, and coordination with enforcement agencies has been challenging, leading to miscommunication and frustration on both sides. Given the important duties of the fish warden under the Act, a recent report by Gillett et al. (2017) recommended the formulation of a strategy to revitalise the fish warden system in Fiji in order to assist with compliance to fisheries laws and regulations, and prevent illegal fishing activities.

On 15 May 2018, MoF and the Wildlife Conservation Society (WCS) co-hosted the second Northern Division Fish Warden Forum in Labasa, with fish wardens and relevant stakeholders from Vanua Levu, to gather ideas and recommendations to help formulate a national fish warden strategy for Fiji. The fish warden strategy is considered an important tool in MoF's compliance delivery, and a key component of a national compliance strategy that is currently being developed by MoF's Inshore Fisheries Management Division. The forum was timely, as it provided a unique opportunity for MoF to consult with fish wardens and other stakeholders from the Northern Division to get their inputs into key aspects of fisheries compliance and enforcement.

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The main objectives of the 2018 Northern Division Fish Warden Forum were to: 1) present a review of the current fish warden system; 2) develop the criteria for the appointment of fish wardens in Fiji; and 3) review a draft fish warden manual and field guide.

The 2018 forum built on an earlier forum in 2015 that focused on improving fish wardens' knowledge of the Fisheries Act and Regulations, and introduced them to a Turtle Enforcement Toolkit developed by the Fiji Environmental Law Association (FELA). The 2018 forum was generously funded by the David and Lucile Packard Foundation.

Asaeli Drugu's experience as a Northern Fisheries Division fish warden for Nadi District in Bua Province

Mr Drugu recounted his experiences working as a fish warden in Bua Province. He was appointed as an honorary fish warden following a village meeting (bose vakoro). After completion of his first fish warden training, he was issued an identification card and he began carrying out his duties. According to Mr. Drugu, his role is to prevent breaches of the Fisheries Act (1942), detect any infringements, and enforce laws regarding fisheries and the marine environment. Mr Drugu has been serving as fish warden in his district for more than 10 years and he is also a committee member on the Bua Yaubula Management Support Team, a committee that looks after the sustainable management of natural resources in Bua Province.

Mr Drugu described some of the challenges he faced as a fish warden.

- He once caught a group of alleged poachers in the act of breaching fisheries laws for the fourth time. The third time Mr Drugu and some members from his community had taken the poachers ashore and confiscated their catch and gear. However, returning the fourth time, the poachers pointed a spear gun at him and verbally threatened him with harm.
- Sometimes a Fisheries Extension Officer (FEO) prefers to follow traditional ways of resolving a conflict rather than taking legal action. He gave an example where an FEO accompanied alleged offenders to the village where poaching occurred in order to seek traditional forgiveness of the poachers. Mr Drugu was unsure if the FEO had taken the correct course of action, and whether it was in the FEO's legal right to do so.
- There is an assumption by MoF and fish wardens that police are knowledgeable about fisheries legislation and well-versed in criminal law; however, this is not always the case and this knowledge varies among police staff.
- Fish wardens lack basic enforcement equipment to fulfill or aid the role of fish wardens such as torches, binoculars, uniforms, fuel and boats apart from identification cards issued to them by MoF.

Revitalising the fish warden system to improve service delivery by fish wardens

During the recent forum, fish wardens in the Northern Division reflected on their vast and diverse experiences, and provided suggestions on selecting and appointing fish wardens, and on the ideal structure and resources required to improve and support fish wardens in the field.

The three main recommendations made for the selection and appointment of fish wardens are discussed below:

- Fish wardens in the Northern Division suggested that the appointment of fish wardens should be through general consensus at the *bose vakoro* (village council). The selected candidates would then be presented to the *bose ni tikina* (district council) and the *bose ni yasana* (provincial council) for further screening and final endorsement. If selected, a warden would undergo extensive fish warden training to prepare him or her for the task.

- During the screening process due consideration should be given to candidates who are young (18–45 years), educated (i.e. able to read and understand the law), have a clear police record, have a boat master license or certificate, and have experience with small boat engine repair. It is important to note that the requirement for boat master qualification or engine repair experience may limit the selection of fish warden. For example, many women would not meet this requirement, thus limiting their chance to be fish wardens. Similarly, this requirement for seagoing knowledge and experience is based on limitations of the current legislation governing the fish warden system (the Fisheries Act 1942), where fish wardens are enforcement focused[5] and the powers of fish wardens to enforce fisheries rules are largely directed towards at-sea enforcement. Some broader consideration of the focus of the fish warden appointment, and the legislative powers available to fish wardens, may also assist in lessening the necessity for these requisite qualifications or experience across all appointed fish wardens.

- Although there was not 100 per cent consensus among participants, the majority believed that women should be encouraged to apply to be fish wardens given their role in coastal fisheries, and the fact that it is their constitutional right. To date, very few female fish wardens have been appointed from Vanua Levu. However, to play this role certain cultural norms and stereotypes about gender roles would need to be overcome, and more opportunity and support would be needed for interested and eventually appointed women.

[5] Section 3 of the Fisheries Act 1942 Cap 158 states that the Permanent Secretary 'may appoint honorary fish wardens whose duties shall be the prevention and detection of offences under this Act and the enforcement of the provisions thereof'.

Fish warden confiscating fishing gear from poachers. Image: Partners in Community Development Fiji (© PCDF)

During the forum, three priority needs were identified by fish wardens to enable them to carry out their duties:

- Improved understanding of the Fisheries Act and associated regulations and policies would make fish wardens more confident in their role. There is a need to develop educational materials or tools for fish wardens that summarise the relevant laws and policies in a way that is easy to understand and does not lead to misinterpretation. This is being partly addressed by FELA, which has been working with MoF to develop an enforcement manual.

- Fish wardens believe that the identification card issued to them following their training is not sufficient in terms of conducting their duties efficiently and effectively. A lack of basic field resources such as binoculars, formal uniforms, torches, fuel and boats limits their capacity to conduct effective compliance and enforcement work.

- Wardens believe they do not receive adequate compensation for the time they spend on their duties, and in recognition of the high risks that they may face during compliance and enforcement activities. Beyond financial payment, some suggested the need for some form of health or liability insurance to safeguard them against injury or loss of life. This is a challenging issue for MoF to address as it comes with some risk, as well as potential high financial costs to running the fish warden system. Thus far, much of the discussion on the role of fish wardens has centred around wardens playing a largely enforcement-focused role. However, the Fisheries Act of 1942 states that a fish warden's duties should include the prevention of offences, and prevention is broader than merely enforcing rules. Awareness and education are important tools to encourage compliance and prevent fisheries offences, and fish wardens can play a crucial role in encouraging voluntary compliance. The national fish warden strategy will need to address the role of fish wardens, and the minimum resources needed to implement such a strategy, in order for it to be effective.

Lastly, fish wardens were asked to consider and discuss what they felt would be an ideal structure for a national fish warden system in Fiji. Their recommendations would be taken into consideration as the MoF reviewed the current divisional-based system and worked towards an updated strategy over the next 12 months. There were six main suggestions from the fish wardens attending the forum:

- There is a need for clear lines of communication to be outlined and established between wardens and the Fiji Police Force and MoF, and these should be included in the national fish warden strategy. The communication strategy should clearly define roles and responsibilities, response time and actions, and modes of communication. This would improve the relationship between the wardens and enforcement agencies, and make their respective efforts more effective.

- The term of service for fish wardens should be clearly defined, with a review procedure built into the process, and a clear expiry date on their term of service included in the authorisation document. Although the exact term was not discussed at the forum, it is important to note that terms that are too short will result in high turnover and requirement for more frequent training, which would make the fish warden system ineffective and too expensive to be maintained by MoF.

- The formation and recognition of a district or provincial fish wardens' association came out strongly during the forum. Such an association would assist fish wardens with establishing a 'fish warden network' to better coordinate with each other and share information about poachers, especially repeat offenders. The association could also work with fishermens' associations to promote voluntary compliance with fisheries laws, regulations and policies in Fiji.

- Fish wardens suggested changes in the legislation to enable them to issue spot fines for fisheries offences. The legal and administrative implications of this would need to be further reviewed and discussed because the structures required to support spot fines could be extensive and alleged offenders must still be given the opportunity to dispute any spot fines should they deny liability.

- A licencing system and fees should be reviewed to cater for the payments[6] of fish wardens and to cover their operational costs (e.g. insurance, fuel cost, equipment, travel costs). MoF is currently undertaking a review of standardised access fees for traditional fishing grounds throughout Fiji; this may provide a potential financing option for consideration. Additionally, any discussions around the appropriateness, or level, of any resourcing and payments to fish wardens may be best undertaken when there is more clarity around the role that fish wardens play in Fiji fisheries compliance and enforcement. This is a key aspect that the fish warden strategy and broader compliance strategy are intended to deliver.

- Promotion of fish wardens' role and work through a range of media, including social media, to help build public understanding and support for the critical role wardens play in coastal fisheries in Fiji. Awareness about fish wardens is also needed at all levels of local governance and at key traditional meetings such as the *bose ni yasana* (provincial council), *bose ni tikina* (district council) and *bose vakoro* (village council). Publicising the apprehension and prosecution of poachers could help promote and acknowledge the vital role that fish wardens play in Fiji, and may go a long way towards getting long-term compliance.

Fish warden refusing to give his fish warden ID to poacher. Image: Partners in Community Development Fiji (© PCDF)

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[6] Recognising that the only current appointment allowed in the legislation is for 'honorary' fish wardens.

Small-scale tuna fishing at Kadavu Island, Fiji

Robert Gillett[1]

Introduction

In the past 50 years there have been many attempts to develop small-scale tuna fisheries in the Pacific Islands region. The main objective of that work has usually been to enable non-industrial fishers to take advantage of the relatively plentiful pelagic resources. Despite much development effort in most countries of the region, it is difficult to identify many success cases.

Kadavu Island, which is south of Viti Levu in Fiji, has been cited as a success story in small-scale tuna fishing development by several sources, including staff of the Pacific Community (SPC) and officials of Fiji's Ministry of Fisheries (MoF). To investigate the fishing situation at Kadavu, a short visit was made to the island in mid-August 2018. The trip was funded by an SPC/FAO (Food and Agriculture Organization) project on small-scale tuna fishery development.

Methodology

Prior to travel to Kadavu, senior officials of MoF in Suva were interviewed to obtain their views on Kadavu tuna fishing, the degree of success obtained, and reasons for that success. Hours of wide-ranging discussions were held with the very knowledgeable officer-in-charge of the Vunisea Fisheries Station (OIC/Vunisea). The chair of the Kadavu Fishermen's Association (KFA) was interviewed. During a meeting of KFA, several fishermen advanced their opinions of tuna fishing success and the role of KFA in that success. Information on general socioeconomic conditions on Kadavu was obtained from several knowledgeable individuals. Documentation on various aspects of fisheries development on Kadavu was made available by SPC and Fiji's MoF. This present report is, to some degree, oriented toward the situation in Vunisea and nearby areas due to the restrictions imposed by a short trip.

Information on Kadavu Island

Kadavu lies to the south of Viti Levu. The northeastern part of Kadavu (i.e. Dravuni) is about 38 nautical miles south-southeast from Suva, while the southwestern part of Kadavi (i.e. Cape Washington) is about 65 nautical miles south-southwest of Suva. The distance from Dravuni to Cape Washington is 42 nautical miles. From Dravuni, it is closer to Suva than to Cape Washington.

The road network on Kadavu is quite limited, and thus most intra-Kadavu travel is by boat, most of which are fibreglass skiffs powered by 40 horsepower outboard engines.

There are about 75 villages on Kadavu. Administratively, the island is part of Fiji's Eastern Division and is divided into nine districts. The most 'urban' area is Vunisea, which has a government station, an airstrip, a wharf, and some non-sealed roads. There is a shipping service several times per week from Vunisea to Suva, which also services the Kavala area towards the eastern side of Kadavu.

Kadavu is a mountainous island. Much of the land is too steep for farming, hence there is a considerable dependence on marine resources.

The Ministry of Fisheries on Kadavu

MoF has an office in Vunisea (with four staff) and an office in Kavala (with two staff). The Vunisea staff consists of an officer-in-charge, a conservation officer, a fisheries assistant, and a handyman. The OIC, Anare Turaga, has been based in Kavala for six years. It is also noteworthy that Fiji's Minister of Fisheries is from Kadavu.

MoF keeps a fibreglass skiff at Vunisea and at Kavala. Both are not currently operating as the outboards have been in Suva for repair for over a year. Fisheries officers are able to charter a fibreglass skiff from the Kadavu Fishermen's Association for FJD 20[1]/day plus fuel. MoF does not have a vehicle on Kadavu but the officers occasionally use the vehicles of other government departments.

MoF has an ice plant in Vunisea and one in Kavala, each of which has a daily capacity of 4 tonnes (t). Ice is sold to licenced fishers for FJD 0.13/kilogram (kg) and to everyone else for FJD 0.30/kg. The ice plants are maintained by Suva-based MoF technicians.

[1] Director of Gillett, Preston and Associates. Email: gillett@connect.com.fj

[2] FJD 1.00 = USD 0.47 (25/09/18)

Anare Turaga, Fisheries Officer-in-Charge at Vunisea on Kadavu. The Vunisea Fisheries Station sign is sideways because it was knocked down by Cyclone Keni in April 2017.
Image: Robert Gillett

Kadavu pelagic fishing situation

In April 2017, Kadavu was hit by Cyclone Keni, which wiped out the five fish aggregation devices (FADs) that were in position at the time. In May 2018, seven FADs were deployed, all of which were (and still are) located off the north coast of Kadavu (four FADs) and the west coast of Ono and Dravuni (three FADs). The FADs were deployed just outside the reef in relatively shallow water, from 95 to 190 metres in depth. The deployments were done from the vessel *Bai ni Takali*, formerly operated by MoF, with supervision by the ministry's FAD specialist, Sailosi Drili. Funding for the FADs came entirely from MoF's budget.

According to the OIC/Vunisea, about 75% of current pelagic fish catches come from the FADs. Of the people currently fishing around the FADs, most (perhaps two-thirds) were pelagic trolling before the FADs were deployed but some were divers that did not like the cold, wet and dark work conditions. This has important implications for the concept of using FADs to move fishing effort from inshore to offshore areas (i.e. only a portion of the current FAD effort is from inshore areas).

Most FAD fishing is by trolling but there is some vertical longlining and handlining. Because the FADs are in relatively shallow water, some handline fishing around the FADs at night for snappers and groupers is reported.

Certain areas of Kadavu produce much of the pelagic catch:

- Lomati: Five villages located just northeast of the western tip of Kadavu. This area has very little lagoon area as there is only a fringing reef. There is a significant heritage of pelagic fishing in this area.

- Galoa Island: Located inside the reef just southeast (windward) of Vunisea. Although the people on this island have access to a large lagoon area for fishing, there is very limited area for gardens, hence their increased dependence on the ocean for food.

The price of pre-mix outboard fuel is currently FJD 3.17/litre (L), while the price in Suva is FJD 2.45/L.

Results from the SPC 'Tails' fisheries data collection system indicates that in the sample locations across eight months spanning 2017 and 2018, 15% of fishing effort was by trolling and 26% of catches in Kadavu consisted of tuna. Because this data collection programme is one of the few sources of data on Kadavu fisheries, some additional attention is warranted (see box next page).

In the mid-2000s the SPC PROCFish programme conducted survey work in Fiji at Dromuna, Muaivuso, Mali and Lakeba. Estimations of per capita fish consumption at those locations were made, which averaged 83.5 kg of finfish and invertebrates across the four sites.[3] With a knowledge of Fiji, it could be stated that the consumption of fish at those sites is not remarkably different than in the villages on Kadavu. Applying the PROCFish level of consumption to the 10,000 people of Kadavu gives an annual consumption for the entire island for all types of fishing of 835 t. The Kadavu fish poster indicated that, at the sampled locations, about 6% of the catch is sold at urban markets (presumably Suva). This suggests that the total catch for Kadavu is about 888 t.

Post-harvest aspects of pelagic fishing off Kadavu

Some of the pelagic fish caught off Kadavu is consumed by family and friends of the pelagic fishers, some is sold in the village of the pelagic fishers, some is sold in Vunisea and Kavala, and some is sold in Suva. It is not possible to estimate the percentages of pelagic fish sold at the various locations, but the SPC 'Tails' fisheries statistical system indicates that for all fish (i.e. pelagic plus inshore), 10% is sold in communities, 28% is sold in provincial markets, and 6% is sold in urban markets.

KFA has an established price for tuna of FJD 7/kg. According to the OIC/Vunisea, in 2017 MoF sold 15 t of tuna for

FJD 7/kg. This is often in the form of 'sliced' tuna. MoF operates a slicing room with a slicing machine. According to MoF officials, slicing tuna enables individuals with small families to purchase part of a large tuna.

A Kadavu price for tuna of FJD 7/kg is remarkably high as the selling price for tuna in Suva (mainly longline bycatch) is often less than FJD 7/kg. In August 2018, Goldhold Seafood Ltd was selling sliced yellowfin in Suva for FJD 6.50/kg.

According to the OIC/Vunisea, there have been some attempts to market Kadavu fish (including pelagic fish) in Suva:

- In the past, Agro-Marketing purchased fish from Kadavu for sale in Suva, but fishers did not like the practice of being paid only in Suva and only after the fishing was sold to retail outlets.
- Premium Seafoods (also known as White Pearl) occasionally buys Kadavu fish for sale at their Walu Bay office.
- Some fishers take their fish to Suva on their own outboard-powered skiffs.
- The vessel *Bai ni Takali* has made some test purchases directly from fishers close to the fishing grounds for sale in Suva, but this vessel is no longer operated by MoF.

According to several fishers, the use of ice to keep pelagic catches fresh while at sea has increased since the SPC training. Fishers in the active tuna fishing area of Lomati take ice from the Vunisea ice plant, about 20 nautical miles away.

Indications of success in small-scale pelagic fishing off Kadavu

Senior MoF staff have indicated that small-scale tuna fishing development at Kadavu has been successful (A. Batibasaga and T. Toasi, Fiji MoF, pers. comm.). Similarly, SPC staff have also commented that small-scale tuna fishing is now thriving (M. Blanc, SPC, pers. comm.). These opinions are presumably based on the changes that these individuals have noticed over the years. At a KFA meeting, several fishers expressed satisfaction at the course of pelagic fisheries development and offered various reasons for the success.

Results of the SPC 'Tails' Fisheries Data Collection System on Kadavu

A prominent poster in the Vunisea Fisheries Office gives the Kadavu results of the SPC 'Tails' fisheries data collection system. The poster provides information on several aspects of fishing in Kadavu, including the number of fishing trips; percentages of the various types of effort (e.g. trolling, spearfishing); total catch; total cost of fuel, bait and ice; total weight and percentage of the important species groups; and percentage of the various channels of disposal. In short, the poster gives a lot of interesting, relevant and valuable information on the fisheries of Kadavu. The poster also contains a note that the results cover the period from 20 August 2017 to 30 April 2018 (i.e. about eight months).

In response to multiple questions during the present survey, the OIC/Vunisea provided some additional information on the 'Tails' system.[4] The raw data are obtained by nine collectors who are themselves fishers, six of whom are regularly active at collecting data. The collected data are focused primarily on the data collectors' villages (except in the case of Ono Island, which is covered by a collector from Kavala). The information obtained by the collectors presumably covers all catches from the sampled landing sites.

Some observations can be made:

- The nine sites sampled represent 12% of the 75 villages on Kadavu and associated islands.
- Each sampled site was selected by MoF and, according to the OIC, they probably do not represent a cross section of all villages on Kadavu, but rather villages that are especially active in fishing.
- The total catch estimation given in the Kadavu Tails poster is a sampling that requires a raising factor to determine total catch for all of Kadavu, although this raising factor is unclear. [5]

There is some quantitative evidence suggesting that tuna catches are proportionally much more important in Kadavu than in other parts of Fiji:

- A USP study in 2008 and 2009[6] of finfish fishing in 46 villages in 22 districts and 10 provinces in Fiji, and involving 2,802 fishing trips gives some indication of the relative importance of tuna in Fiji's coastal fisheries. It showed that, nationally, mackerels and tunas made up about 4.5% of the coastal catch.
- The results of the SPC 'Tails' fisheries statistical system on Kadavu for the period 20 August 2017 to 30 April 2018 (described above) indicate that 26% of the sampled catch was tuna. The high proportion of tuna in

[3] Friedman K., Kronen M., Vunisea A., Pinca S., Pakoa K., Magron F., Chapman L., Sauni S., Vigliola L., Tardy E. and Labrosse P. 2010. Fiji Islands country report: Profiles and results from survey work at Dromuna, Muaivuso, Mali and Lakeba (September to November 2002, April to June 2003, June and July 2007, and February 2009). Pacific Regional Oceanic and Coastal Fisheries Development Programme, Secretariat of the Pacific Community. Noumea, New Caledonia.

[4] Although this information may contain some inaccuracies, it is important to realise that it comes from somebody who is likely to be the most knowledgeable person about fisheries on Kadavu; therefore, other stakeholders reading the poster probably have much less understanding of the limitations of the information in the poster.

[5] The support for this data collection project from SPC will include this type of analysis once sufficient data have been collected.

the sampled catch appears even more remarkable considering that during some of the months covered by Tails, there were no FADs in position at Kadavu. Furthermore, some of the months covered by the Tails survey are low season months for surface tunas in Kadavu waters (August to November).

On reflection, in the present study it is difficult to separate two very different features: 1) the success of tuna fishery development in Kadavu, and 2) tuna fishing being historically important in Kadavu. On this matter, the study relies to some degree on the views of MoF staff and SPC, which suggest successful development.

Factors contributing to the success of pelagic fishing off Kadavu

In a short study of a few days it is not possible to determine with certainty why there is so much tuna fishing in Kadavu waters. What can be stated are possible and logical reasons for the development success and/or high production. This is based on stakeholder comments and on the observations and experience of the consultant carrying out the present study. In no particular order, some possible drivers of success in the Kadavu small-scale tuna fishery are:

- Favourable geography.
  The shape of Kadavu and its associated reefs is such that much of the surrounding sea is, to some degree, protected from the prevailing wind and swell. The underwater topography and long distances to other islands may be responsible for a naturally high abundance of surface tunas (i.e. good tuna fishing even without FADs).
- Fishing heritage.
  Many villages on Kadavu lack large areas of lagoon for inshore fishing. The hilly topography results in limited space for gardens for some villages. Both of these factors tend to encourage pelagic fishing. One stakeholder offered the opinion that many Kadavu fishers prefer pelagic fishing, which involves catching a few large fish rather than many less interesting small fish. There is also the fact that because Kadavu is a large island with a poorly developed road network, fast skiffs for intra-island transport are plentiful and available for offshore fishing.
- FADS.
  There is no doubt that FADs make tuna fishing more productive. According to the OIC/Vunisea, about 75% of current pelagic fish catches come from the FADs. It should be noted, however, that in recent periods without FADs the proportion of tuna in the entire Kadavu catch has been high.
- Development assistance.
  The fishers of Kadavu have enjoyed development assistance from Fiji's MoF and external agencies.
  - The efforts of the competent and experienced OIC/Vunisea are commendable.
  - According to the OIC/Vunisea, the installation of seven FADs in May 2018 was done entirely by MoF staff using funds from the ministry's budget.
  - All stakeholders interviewed expressed a high degree of satisfaction with the training received in recent years from SPC, especially in the areas of tuna fishing techniques, tuna quality, and boat operation. 'High quality gear' from SPC is also cited.
  - Other development assistance related to tuna fishery development has come from Japan (FADs in 2015 and 2016) and Korea (blast freezer).
- Tuna slicing.
  MoF operates a slicing room with a slicing machine at both Vunisea and Kavala. According to MoF officials, sliced tuna enables individuals with small families to purchase part of a large tuna, thereby increasing the demand for tuna. Currently, MoF does not charge for freezing or slicing fish.
- The Kadavu Fishermen's Association.
  According to KFA members, the association was able to set a price of FJD 7/kg for all fish sold by members. KFA is able to go straight to the Minister of Fisheries to discuss problems and request assistance, whereas individuals must make indirect circuitous approaches. KFA membership is more inclusive than other fisher associations in Fiji and, therefore, can speak with a louder voice to non-governmental organisations and the government.[7] About three-quarters of KFA members do at least some FAD fishing.
- The economy of Kadavu and kava.
  A striking feature of the sale of tuna on Kadavu is that prices are often higher than in Suva. According to several stakeholders this is because of the high income of many Kadavu farmers from a single crop: kava.[7] With Kadavu's large production of kava and the price of kava approaching FJD 120/kg, Kadavu farmers and their relatives can currently afford to pay very high prices for fish.

Some comment should be made about factors that do not appear to drive Kadavu tuna fishing. Adjacency to the large fish markets in Suva does not appear to be a factor, especially in periods of high fish prices on Kadavu. Exports to Suva entail transport costs from the fishers' base to Vunisea or Kavala, ship transport charges from there to Suva, and transport and/or retailing charges in Suva for a price that is currently less than on Kadavu. Although there have been

[6] IAS. 2009. A nation-wide survey of village-based fishing pressure in Fiji. In: Jenkins AP, Prasad SR, Bacchiochi J, Skelton P, Yakub N (eds). Proceedings of the Inaugural Fiji Islands Conservation Science Forum, Wetlands International-Oceania, Suva, Fiji.

[7] The chairman of KFA is likely to have been a champion for tuna fisheries development, but is much less active and vocal now, having suffered a stroke last year.

efforts in the past by MoF, the Japan International Cooperation Agency and others to export fish, prices in Suva would have to be significantly higher than on Kadavu for this to be worthwhile for the fishers. Some fishers take tuna to Suva in their own fishing boats, but this appears to be mostly opportunistic transportation of fish on trips made for other purposes (e.g. carrying passengers). The Kadavu price is such that some resorts on the island import fish from Suva.

There does not appear to be much subsidisation of the Kadavu tuna fisheries. According to MoF staff, significant direct subsidies are now limited to: 1) a scheme by the Commissioner's office in which most of the price of a boat and/or motor is funded by that office (this was limited to 15 units in 2017)[8]; 2) the handing out of some fishing gear in the annual Yaubula Festival; and 3) MoF does not charge for freezing or slicing fish.

Concluding remarks

Many factors may be contributing to the success of Kadavu's tuna fishery development. In this short study of a few days it was not possible to determine with certainty which factors are the crucial drivers of development. The current high price of fish is obviously important, but all of the factors mentioned above seem to be significant. It is likely that the combined impact of all cited factors results in the current favourable development conditions.

For future attempts at small-scale tuna fishery development in other places in Fiji and neighbouring countries, it may be useful to indicate which of the favourable conditions in Kadavu are readily transferable to other locations.

- The factors that could conceivably be transferable to other locations appear to be FADs, high quality development assistance (including competent and otivated national fisheries officers), tuna slicing, and a strong fishers association.
- The factors that are not readily transferable appear to be the favourable geography, tuna fishing heritage, and a very valuable cash crop.

In scrutinising the above list of transferable factors, several appear related. FADs are important but even more important for the long-term is an efficient nationally funded FAD programme. A fisheries association and associated fishery champions could push for both FADs and for a national FAD programme, and possibly even for high-performing fishery officers.

It should also be noted that many of the transferable favourable factors are within the control of the MoF's fisheries management and development efforts. Efforts to promote pelagic fishing in other parts of Fiji (and perhaps in other Pacific Island countries) should focus on promoting those. In the selection of sites for small-scale tuna fishery development efforts, consideration should be given to those locations where there are favourable geographic features and some tuna fishing heritage. Also to be considered is that past attempts by MoF (or by predecessor agencies or other government departments) to stimulate fisheries development by subsidising transport to markets have not be catalytic nor have they been sustained.

Nambukelevu Mountain at the west end of Kadavu. The Lomati area consists of five villages located on the north shore just below the mountain. This area has very little lagoon area as there is only a fringing reef. There is a significant heritage of pelagic fishing in this area. Image: Robert Gillett

[8] An SPC report states that 'Kava had been a cash crop in the 1930s, but its importance has significantly increased and it is now the paramount cash earner for Kadavu villagers. Kadavu is also a center for marijuana growing but the extent is unknown.' SPC. 2016. Initial diagnosis of the Kadavu Province, Fiji.

[9] A scheme similar to this used in the early 2000s by the then Fisheries Department, in which selected fishermen put up one third of the price of a motorised boat and the Fisheries Department would pay the remaining two thirds.

A new climate change vulnerability assessment for fisheries and aquaculture

Johann Bell[1,2] and Tarûb Bahri[3]

Abstract

The Food and Agriculture Organization of the United Nations (FAO) has released a new global assessment of the vulnerability of fisheries and aquaculture to climate change. This major report, published as FAO Fisheries and Aquaculture Technical Paper No. 627, explains the science behind the expected effects of climate change on marine and inland capture fisheries and aquaculture worldwide, and the implications for the millions of people who depend on the fisheries sector for their livelihoods and food security. The FAO Technical Paper also presents practical approaches to adaptation to assist fisheries and aquaculture operations at all scales to reduce the risks posed by climate change, and harness opportunities. The information is set in the context of poverty alleviation, and within existing policy commitments, such as United Nations Agenda 2030 and the Paris Climate Agreement. The advice in the FAO Technical Paper on adaptations is also firmly embedded in reality – it acknowledges the interactions within the sector, the relationships between fisheries and aquaculture and with other sectors, and the influence of other important drivers such as population growth and global demand for fish. In this article, we highlight the vulnerability assessments made for industrial tuna fisheries and small-scale coastal fisheries in the western and central Pacific Ocean, the relevance of this work to Pacific Island countries and territories, and to the 'Regional roadmap for sustainable Pacific fisheries' and the 'New song for coastal fisheries – pathways to change'. We also summarise the key messages from other chapters of the FAO Technical Paper relevant to the Pacific Islands region, including the chapters on freshwater fisheries and aquaculture.

Introduction

In July 2018, the Food and Agriculture Organization of the United Nations (FAO) published Fisheries and Aquaculture Technical Paper No. 627[4], entitled 'Impacts of climate change on fisheries and aquaculture: Synthesis of current knowledge, adaptation and mitigation options' (Barange et al. 2018). This important publication synthesises the latest knowledge on the impacts of climate change on the fisheries and aquaculture sector worldwide, highlights the vulnerability of the millions of poor people who depend on the sector for their livelihoods, and describes the adaptations needed at all scales to ensure that fisheries and aquaculture continue to make important contributions to poverty alleviation and food security.

The FAO Technical Paper will be particularly useful to fisheries managers and scientists in the Pacific Islands region because it updates the information in the book published by the Pacific Community (SPC) in 2011 on 'Vulnerability of tropical Pacific fisheries and aquaculture to climate change' (Bell et al. 2011), and in the FAO report on 'Priority adaptations to climate change for Pacific fisheries and aquaculture' (Johnson et al. 2013). Chapter 14 of the FAO Technical Paper (Bell et al. 2018a) summarises the latest information available on the impacts of climate change on marine fisheries in the western and central Pacific Ocean (WCPO), the vulnerability of these resources, and practical adaptations for economies and communities.

Chapter 14 is expected to be of special interest to fisheries agencies responsible for implementing the 'Regional roadmap for sustainable Pacific fisheries' (FFA and SPC 2015) and 'A new song for coastal fisheries – pathways to change' (SPC 2015). It identifies how climate change could disrupt these plans, and the adaptations needed to minimise the risks posed by climate change and maximise the opportunities.

The adaptations to climate change recommended for inland fisheries (Chapters 18, 19 and 26) and aquaculture (Chapters 20–22) in the FAO Technical Paper also have salient lessons for the management of freshwater fisheries and marine and freshwater aquaculture in the Pacific Islands region.

In Part 1 of this article, we summarise the main findings from Chapter 14 on the regional impacts of climate change

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[4] http://www.fao.org/3/I9705EN/i9705en.pdf

on marine fisheries in the WCPO. In Part 2, we draw on text from the 40-page summary of the FAO Technical Paper[5] (FAO 2018a) to outline several of the key messages for readers interested in the global perspective.

1 Climate change impacts, vulnerabilities and adaptations for WCPO marine fisheries

This latest assessment for the WCPO (Chapter 14) applies an end-to-end, climate-to-fish-to-fisheries approach to evaluate the vulnerability of the region's plans to secure and increase the socioeconomic benefits from marine fisheries for Pacific Island countries. After briefly describing the main marine fisheries of the region (Section 14.1.1), and the strategic plans and management arrangements for these fisheries (Section 14.1.2), the chapter summarises the observed and projected changes to the physical and chemical features of the WCPO, and how these changes are expected to alter fish habitats (Section 14.2).

The chapter then explains how the direct and indirect effects of continued carbon dioxide (CO_2) emissions are likely to affect the industrial tuna fisheries that underpin so many economies across the region, and the small-scale fisheries that provide coastal communities with food security and livelihoods. These analyses are based on global and regional modelling approaches incorporating the representative concentration pathways for greenhouse gas (GHG) emissions (see Part 2) used for the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), or emission scenarios from the IPCC Fourth Assessment Report (AR4).

Below, we use portions of text extracted from Chapter 14 to summarise the effects of climate change on the future production of the region's marine fisheries, the socioeconomic implications of climate-driven alterations in production, and the priority adaptations (readers interested in the full details and supporting references should read Sections 14.3 and 14.4 of the FAO Technical Paper). This information is presented firstly for industrial tuna fisheries (Section 14.3), and then for small-scale, coastal fisheries (Section 14.4).

1.1 Effects of climate change on industrial tuna fisheries

Observed and projected effects on distribution and abundance of tuna

The modelling of how tuna in the WCPO are likely to respond to long-term climate change (Fig. 1) indicates that there will be an eastward and poleward shift in tuna distribution, and reductions in total biomass, for both skipjack and yellowfin tuna under the RCP8.5 emissions scenario. These responses are driven mainly by changes in larval survival and spawning location. Decreases in the biomass of these two species will occur in most of the exclusive economic zones (EEZs) of Pacific Island countries west of 170°E, and will increase in EEZs east of 170°E. Projected percentage decreases by 2050 and 2100 relative to 2005 are particularly marked for Papua New Guinea (PNG), the Federated States of Micronesia, Nauru and Palau. However, for PNG, it is important to note that the modelling does not yet take account of possible beneficial effects of increased nutrients of terrestrial origin from higher rainfall. Substantial percentage increases in biomass relative to 2005 are projected for skipjack tuna in Vanuatu, New Caledonia, Pitcairn Islands and French Polynesia, and for yellowfin tuna in French Polynesia.

The projections for bigeye tuna and South Pacific albacore are somewhat different. For bigeye tuna, decreases in biomass are expected to occur in all EEZs (Fig. 1). For South Pacific albacore, the distributions of larvae and juveniles are expected to shift south towards the Tasman Sea after 2050. Densities of early life stages are projected to decrease in their core area (Coral Sea) by 2050, resulting in a stabilised adult biomass approximately 30 percent lower than in 2000. However, the north Tasman Sea could emerge as a new spawning ground after 2080 (Fig. 1), reversing the downward trend in abundance.

Implications for economic development

The redistribution of skipjack and yellowfin tuna is expected to result in lower catches across the prime fishing grounds by 2050, with knock-on effects on licence revenues. The plans to increase employment based on industrial fishing and processing in PNG and Solomon Islands could also be affected. This employment risk is tempered, however, by the fact that recent average tuna catches in the EEZs and archipelagic waters of PNG and Solomon Islands well exceed the capacity of existing and proposed fish-processing facilities. Nevertheless, changes in licensing conditions may be needed to ensure that more of the fish caught within the EEZs of these countries is delivered to national canneries (see below). Other possible negative impacts on economic development may occur from the eastward redistribution of bigeye tuna and the poleward movement of South Pacific albacore. In both cases, a greater proportion of longline fishing is eventually expected to occur outside the EEZs, reducing governments' revenue from licence fees. The projected eastward redistribution of skipjack and yellowfin tuna as a result of climate change could result in opportunities for Pacific Island countries and territories in the eastern WCPO (e.g. French Polynesia, and in the subtropical countries of Vanuatu and Fiji), to obtain increased economic benefits. However, although modelling indicates that the percentage increases in catch could be substantial in these EEZs, the scale of benefits is likely to be modest because present-day catches are low.

[5] http://www.fao.org/3/CA0356EN/ca0356en.pdf

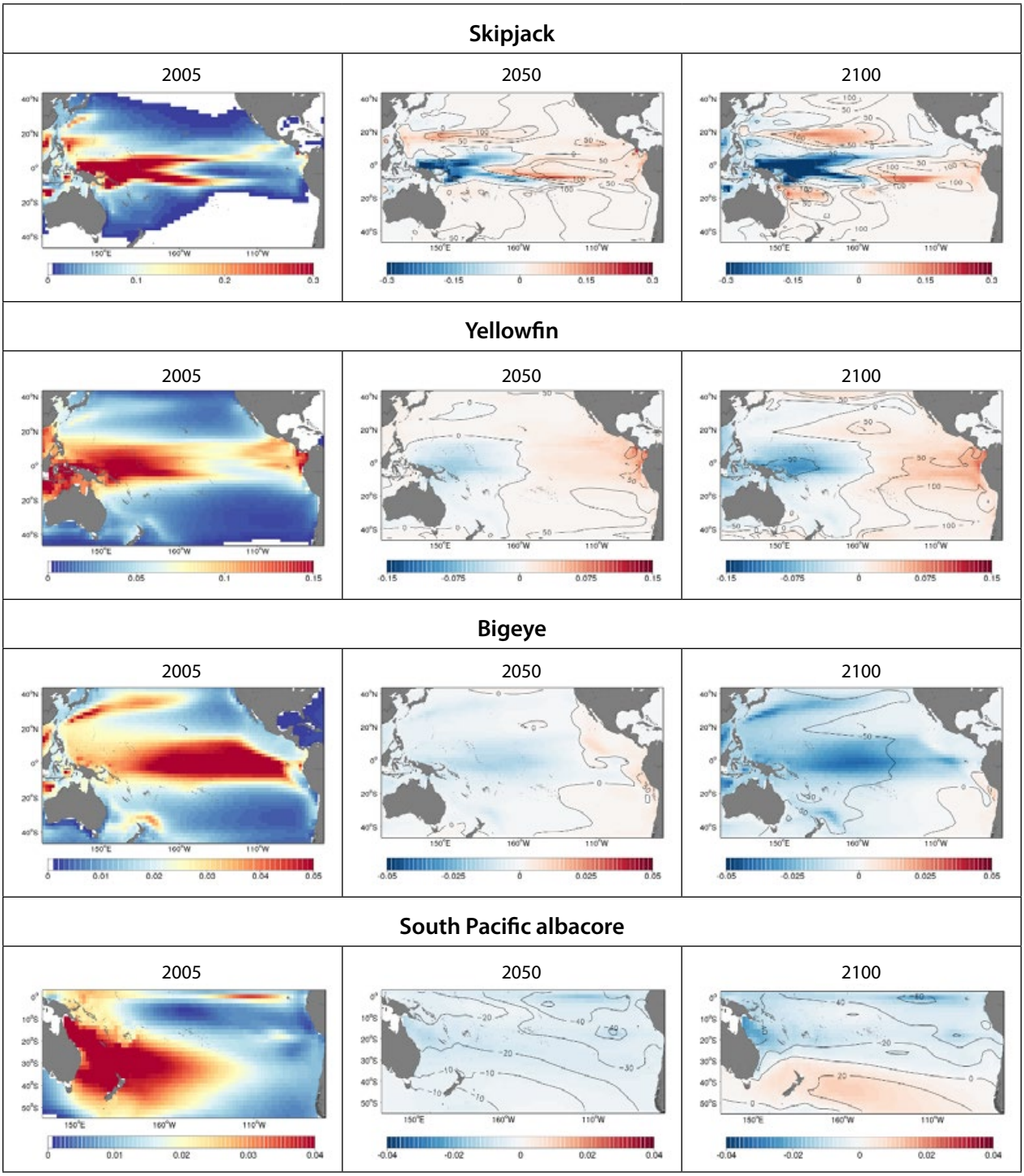


Figure 1. Average historical (2005) distributions of skipjack, yellowfin and bigeye tuna and South Pacific albacore (in tonnes per square kilometre) in the tropical Pacific Ocean, and projected changes in biomass of each species relative to 2005 under the RCP8.5 emission scenario for 2050 and 2100, simulated using SEAPODYM. Isopleths in the projections for 2050 and 2100 represent the relative percentage change in biomass caused by climate change. Source: based on modelling done for Chapter 14 of FAO Fisheries and Aquaculture Technical Paper 627 by Patrick Lehodey and Inna Senina.

Consequences for fisheries management

The modelling described above also indicates that an increase in fishing effort will exacerbate the overall decreases in the production of tuna species projected to occur as a result of climate change. To minimise the possible negative effects on tuna catches, fishing effort will need to be constrained and future harvest strategies adjusted to account for alterations in the distribution and abundance of tuna species. Other possible consequences include: 1) the need to transfer more management responsibility to the Western and Central Pacific Fisheries Commission (WCPFC) as a greater proportion of the catch is made in high seas areas; and 2) the eventual consideration of Pan-Pacific tuna management through a merger of WCPFC and the Inter-American Tropical Tuna Commission. The existing monitoring, control and surveillance of tuna catches by the Pacific Islands Forum Fisheries Agency (FFA), the Parties to the Nauru Agreement (PNA)[6] and WCPFC should help identify if and when such changes in management would be appropriate. Because eastward redistribution of tuna can be expected to increase the use of drifting fish aggregating devices (FADs) by purse-seine vessels, management will also need to ensure that the effects of FAD fishing on associated species (e.g. sharks) and juvenile bigeye tuna are mitigated effectively.

Vulnerability of tuna species, fisheries and economies

The four species of tropical tuna – albacore, bigeye, skipjack and yellowfin – are expected to have relatively low vulnerability to the projected physical and chemical changes to the WCPO, and to alterations in oceanic food webs, because they can move to areas with their preferred conditions. However, increased stratification of the water column due to increases in sea surface temperature (SST) could make the surface-dwelling skipjack and yellowfin tuna more vulnerable to capture. This assessment is based on higher catch rates for yellowfin tuna in the Western Pacific Warm Pool during El Niño events, when shoaling of the thermocline contracts the vertical habitat for this species. Increased vulnerability to capture by purse-seine fishing, and projected decreases in availability of these two species across much of the region, underscore the need for effective management. Small national economies with a high dependence on licence fees from purse-seine fleets (FFA 2016) are likely to be vulnerable to these changes by 2050. It is possible, however, that the plans to improve the value of tuna in the 'Regional roadmap for sustainable Pacific fisheries' could maintain existing levels of government revenue from licence fees even though catches decline. The economies of PNG and Solomon Islands are expected to have low vulnerability because tuna fishing and processing make relatively small contributions to the gross domestic product (GDP) of these relatively large economies.

Recommended adaptations

Priority adaptations to maintain the contributions of purse-seine fishing to economic development are based around continuing to: 1) maintain licence revenue and distribute it equitably among PNA members and other Pacific Island countries and territories; 2) deliver the tuna required by existing and proposed canneries in the region; and 3) finding ways to add more value to the abundant skipjack tuna. These adaptations are summarised in Table 1. Two of the key adaptations are already in place. The Vessel Day Scheme, operated by the PNA office, allows licence revenues to be shared among its member countries regardless of the prevailing El Niño Southern Oscillation (ENSO) phase, and adjusts the fishing days allocated to members as climate change alters the distribution of tuna. The Interim Economic Partnership Agreement with the European Union enables PNG to source tuna for national canneries from outside its EEZ, guaranteeing sufficient tuna for processing as the fish move eastward. If needed, other adaptations that would help maintain the supply of tuna for canneries include reducing access for distant-water fishing nations (DWFNs) to PNG's EEZ to provide more fish for national vessels, and requiring DWFNs operating within the EEZ to land fish at local canneries. Finding ways to add more value to skipjack tuna would allow countries to earn more from this resource in the short-term, and help offset the consequences of lower projected catches caused by climate change.

1.2 Effects of climate change on small-scale fisheries

Observed and projected effects on distribution and abundance of fish and invertebrates

Climate change and ocean acidification are projected to have a range of substantial direct and indirect effects on the distribution and abundance of demersal fish and invertebrates in the WCPO. The indirect effects will occur through changes to coastal fish habitats (Section 14.2.2). The main direct effects are summarised below.

Higher SST is expected to alter the metabolic rates, growth, reproduction and survival of demersal fish and invertebrates, resulting in changes in their abundance, size and distribution. Alterations to the strength of ocean currents are likely to affect the dispersal of larvae, thereby reducing recruitment success in some locations and improving success in others. Ocean acidification has been demonstrated to affect the behaviour, auditory responses and olfactory function of early life-history stages of demersal fish species. These changes are expected to alter the homing and settlement success of juveniles and their ability to detect and avoid predators, with implications for population replenishment.

[6] The Parties to the Nauru Agreement are Federated States of Micronesia, Kiribati, Palau, Papua New Guinea, Marshall Islands, Nauru, Solomon Islands and Tuvalu; more than 90% of the tuna caught from the waters of Pacific Island countries and territories comes from the EEZs of PNA members.

Table 1. Examples of priority adaptations and supporting policies to assist Pacific Island countries and territories reduce the threats posed by climate change to the contributions of industrial tuna fisheries to economic development, and capitalise on the opportunities. These measures are classified as 'win-win' (W-W) adaptations, which address other drivers of the sector in the short term and climate change in the long term, or 'lose-win' (L-W) adaptations, where benefits are exceeded by costs in the short term but accrue under longer-term climate change.

Adaptation options	Supporting policies
• Full implementation of the vessel day scheme (VDS) to control fishing effort by the Parties to the Nauru Agreement (W-W). • Diversify sources of fish for canneries and maintain trade preferences; for example, an Economic Partnership Agreement with the European Union (W-W). • Identify ways to add more value to skipjack tuna (W-W). • Continued conservation and management measures for all species of tuna to maintain stocks at healthy levels and make these valuable species more resilient to climate change (W-W). • Energy efficiency programmes to assist fleets to cope with oil price rises minimise CO_2 emissions, and reduce costs of fishing farther afield as tuna move east (W-W). • Environmentally-friendly fishing operations (W-W).	○ Strengthen national capacity to administer the VDS. ○ Adjust national tuna management plans and marketing strategies to provide flexible arrangements to buy and sell tuna. ○ Promote partnerships to process and market skipjack tuna in new ways. ○ Include addressing the implications of climate change in the management objectives of the WCPFC. ○ Apply national management measures to address climate change effects for subregional concentrations of tuna in archipelagic waters beyond WCPFC's mandate. ○ Require all industrial tuna vessels to provide operational-level catch and effort data to improve models for projecting redistribution of tuna stocks during climate change.

Source: Bell et al. 2018a.

Estimates of the combined direct and indirect effects of climate change and ocean acidification on the productivity of demersal fish in the region vary from decreases of up to 20% by 2050 and 20–50% by 2100 based on a high AR4 emissions scenario, to decreases exceeding 50% under RCP8.5 for AR5 by 2100 (Asch et al. 2018).

The projected changes to coastal fish habitats are also expected to alter the composition of catches. For example, herbivorous species are likely to be relatively more abundant as coral cover declines and macroalgae increase.

Productivity of invertebrates is projected to decrease by 5% by 2050, and by 10% by 2100 under a high AR4 emissions scenario. In particular, lower aragonite saturation levels are expected to reduce calcification rates for gastropod and bivalve molluscs and echinoderms, thereby reducing their quality and size and making them more vulnerable to predation.

The potential effects of climate change on coral reef fisheries are illustrated by the projections for coral trout (*Plectropomus* spp.), which are heavily fished in northeastern Australia and elsewhere in the WCPO. The combined effects of thermal stress on the physiology of these species and the degradation of reef habitat are expected to threaten the viability and sustainability of commercial fisheries by 2050 at low-latitude locations (even under RCP2.6). At subtropical latitudes, fisheries for coral trout are expected to become increasingly uneconomical towards 2100.

Implications for food security and livelihoods

The implications of climate change for the important role that fish plays in providing food security for Pacific Island people have to be placed in the context of the other factors affecting the availability of fish. In many Pacific Island countries and territories, population growth alone creates a large gap between recommended fish consumption (35 kg/person/year) and sustainable harvests from well-managed coastal fisheries.

Based on the total area of coastal fish habitats and the distance of these habitats from population centres, Pacific Island countries and territories fall into three groups with respect to their capacity to provide the fish needed for food security: 1) those with coastal fisheries expected to meet the increased demand for fish; 2) those with sufficient coastal habitat to produce the fish required, but where transportation of fish to urban centres will be difficult; and 3) those where the total area of coastal fish habitats will be unable to produce the fish required.

There are few implications of the projected decreases in coastal fish production arising from climate change for countries and territories in Groups 1 and 2. Possible exceptions are those outside the equatorial zone, where increases in ciguatera fish poisoning resulting from the degradation of coral reefs could result in localised shortfalls in fish supply. In such circumstances, communities will need to rely more heavily on catching tuna in nearshore waters.

For countries and territories in Group 3, the projected declines of up to 20% in coastal fisheries production by 2050 and up to 50% by 2100 are expected to increase the gap only marginally because the effects of human population growth on the availability of fish per capita are so profound (Table 2). The main implications centre on the need to provide better access to tuna to supply the fish required by growing populations, although developing fisheries for small pelagic fish and expanding pond aquaculture will also be important in some locations (see below). Maximising the number of livelihoods that can be sustained from coastal fisheries resources will involve progressively transferring some fishing effort from demersal fish to tuna and small pelagic fish species, and switching some of the remaining demersal fishing effort from resource 'losers' (e.g. coral-dependent fish species) to resource 'winners' (e.g. herbivorous fish species).

Consequences for fisheries management

The direct and indirect effects of climate change and ocean acidification are expected to increase uncertainty in the replenishment of coastal stocks. Increased uncertainty will require changes to the community-based ecosystem approach to fisheries management (CEAFM) and 'primary fisheries management' approaches (Section 14.1.2) used by Pacific Island countries and territories to keep coastal fisheries resources at sustainable levels. The reorientation of CEAFM that is needed to assist communities with adapting to climate change involves: 1) informing all stakeholders about the risks to fish habitats, stocks and catches, and facilitating their participation in decision-making; 2) supporting the transdisciplinary collaboration needed to monitor the wider fisheries system for climate impacts, and identify practical adaptations; and 3) providing the resources needed to implement climate-informed CEAFM.

The more conservative application of primary fisheries management that is needed to address the increased uncertainty is illustrated in Figure 2. Examples of the types of management changes likely to be needed include revised size limits to account for altered growth rates and maturity schedules, and ensuring that the herbivorous species likely to be favoured by climate change are not overfished. Healthy stocks of herbivores will be needed to ensure that macroalgae do not unduly inhibit the growth and survival of remaining corals.

Vulnerability of fish species, fisheries and communities

The small-scale fisheries underpinning food and livelihoods across the region have a moderate to high vulnerability to climate change because: 1) increases in SST will progressively drive many target species to higher latitudes; 2) degradation of coral reefs is expected to reduce the productivity of those fish species able to remain on reefs; and 3) the majority of the small-scale catch is derived from coral reefs.

In turn, many Pacific Island communities are highly vulnerable to decreases in productivity of demersal fish and invertebrates because they have few other sources of animal protein. A participatory approach is needed to raise awareness of the risks, and identify practical adaptations to provide nutritious food for growing human populations. The IPCC vulnerability framework and the Vulnerability Assessment and Local Early Action Planning Tool developed by the US Coral Triangle Initiative have been incorporated into such an approach for communities (Johnson et al. 2016). This approach will be strengthened by assisting communities with evaluating alternative sources of fish (e.g. through development of freshwater pond aquaculture and increasing access to tuna in nearshore waters).

Table 2. Projected gap between recommended fish consumption of 35 kg/person/year, and the estimated annual supply of fish per capita from coastal fisheries in 2050 and 2100 for selected Pacific Island countries due to the effects of population growth (P) and the combined effects of population growth and climate change (CC) under a high emissions scenario.

	Estimated sustainable catch (t)*	Population**		Total fish available per capita (kg)		Gap in fish needed per capita per year (kg)			
		2050	2100	2050	2100	2050		2100	
						P	CC	P	CC
Papua New Guinea	83,500	13,271,000	21,125,000	6	4	29	29	31	32
Samoa	6,100	210,000	240,000	29	25	6	11	10	16
Solomon Islands	27,600	1,181,000	1,969,000	23	14	12	15	21	24
Vanuatu	3,800	483,000	695,000	8	6	27	28	29	30

* Estimates assume sustainable median fisheries production of 3 t/km^2 of coral reef per year (but also include freshwater fisheries production for Papua New Guinea and Solomon Islands, and reef habitat to depth of 100 m for Samoa).
** Estimates provided by the Pacific Community's Statistics for Development Division.

Many Pacific Island communities are highly vulnerable to decreases in productivity of demersal fish and invertebrates because they have few other sources of animal protein. Going fishing, Kiribati, 2018. Image: Francisco Blaha, www.franciscoblaha.info

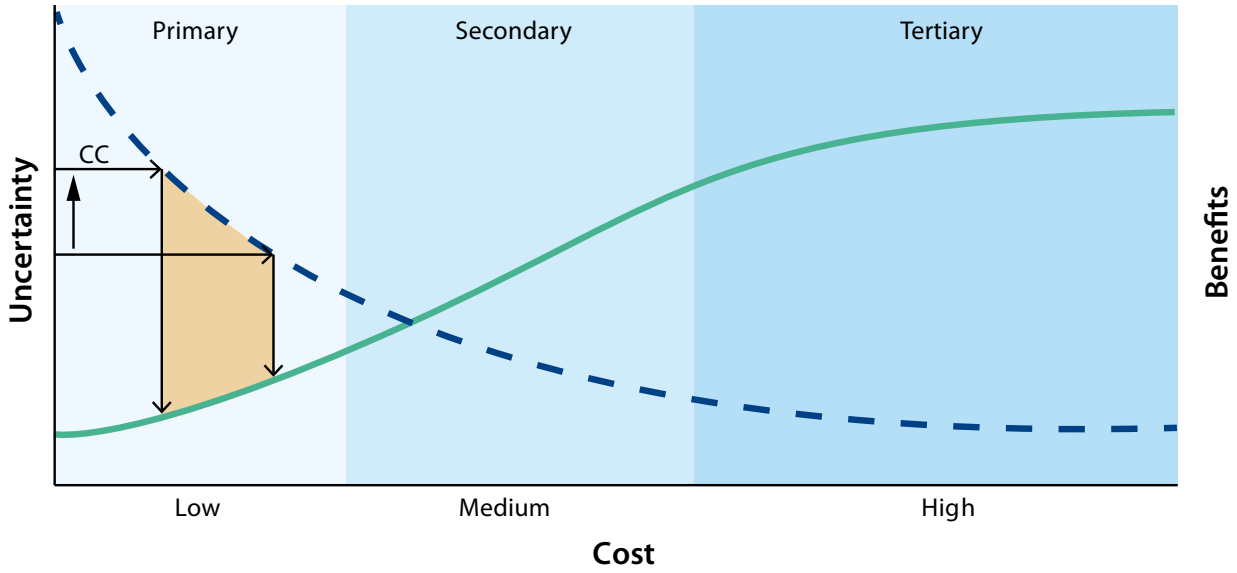


Figure 2. General relationship between potential benefits from fisheries for coastal demersal fish species and invertebrates (green line), and uncertainty in information for management (dashed line), as functions of costs, for primary, secondary and tertiary fisheries management; and the reduction in benefits under primary fisheries management as a result of the increased uncertainty caused by climate change (CC). Source: Bell et al. 2011; Cochrane et al. 2011.

Recommended adaptations

The priority adaptations to maintain the contribution of small-scale fisheries to food security and livelihoods of coastal communities involve finding ways to: 1) minimise the gap between sustainable harvests from coral reefs and other coastal fish habitats and the quantities of fish recommended for good nutrition of growing human populations; and 2) fill the gap (Table 3). Adaptations to minimise the gap centre on avoiding and reversing the degradation of coastal fish habitats and maintaining healthy stocks of demersal fish and invertebrates. Most of these adaptations are an integral part of coastal zone management and sustainable fisheries management (FAO 2003, 2015). Climate-informed, ecosystem-based approaches to fisheries management provide the most effective way forward. Adaptations to fill the gap will need to focus largely on making it easier for small-scale fishers to access the region's rich tuna resources, developing fisheries for small pelagic fish, expanding pond aquaculture, and improving supply chains to avoid waste.

Table 3. Examples of priority adaptations and supporting policies to assist Pacific Island countries and territories with reducing the threats posed by climate change to the contributions of small-scale fisheries to food security and livelihoods of coastal communities, and capitalise on opportunities. These measures are classified as 'win-win' (W-W) adaptations, which address other drivers of the sector in the short term and climate change in the long term, or 'lose-win' (L-W) adaptations, where benefits are exceeded by costs in the short term but accrue under longer-term climate change. Source: Bell et al. 2018 a, b.

Adaptation	Supporting policies
Adaptations to minimise the gap	
• Manage and restore vegetation in catchments (W-W)	○ Improve governance for sustainable use and protection of coastal fish habitats
• Avoid (and reverse) degradation of coastal fish habitats (W-W)	○ Strengthen fisheries legislation to apply community-based management, founded on an ecosystem approach and primary fisheries management
• Provide for landward migration of coastal fish habitats (L-W)	○ Enhance national regulation of small-scale, commercial fishing
• Reduce catches to help sustain production of coastal demersal fish and invertebrates (L-W)	○ Promote access to those groups of fish expected to increase in abundance
• Maximise the efficiency of spatial management (W-W)	○ Limit export of demersal fish
• Diversify catches of coastal demersal fish (L-W)	○ Develop ecotourism to relieve fishing pressure on demersal fish stocks
Adaptations to fill the gap	
• Transfer coastal fishing effort from demersal fish to tuna and other large pelagic fish in nearshore waters (W-W)	○ Include nearshore FADs as part of the national infrastructure for food security
• Expand fisheries for small pelagic species (W-W)*	○ Transfer some access rights and revenues from industrial tuna fisheries to small-scale fisheries
• Extend the storage time of nearshore pelagic fish catches (W-W)	○ Evaluate whether industrial fishing exclusion zones provide adequate access to tuna for small-scale fishers
• Increase access to small tuna and bycatch offloaded by industrial fleets during transshipping operations (W-W)	○ Apply targeted subsidy programs to support key adaptations
• Expand aquaculture of Nile tilapia and milkfish (W-W)	○ Limit tilapia farming to catchments with a shortage of fish and where tilapia are already established to reduce potential risks to biodiversity

* Small pelagic fish are expected to be favoured by climate change only where changes to currents and eddies deliver more nutrients to surface waters.

Source: Bell et al. 2018 a,b.

2 Key messages from FAO Fisheries and Aquaculture Technical Paper 627

Importance of fisheries and aquaculture

Excluding aquatic plants, total global production from fisheries and aquaculture peaked at 171 million tonnes in 2016, with 53% of this total coming from capture fisheries and 47% from aquaculture (FAO 2018b). Globally, the combined production from fisheries and aquaculture makes substantial contributions to the food security and livelihoods of millions of people. Average fish consumption worldwide is now >20 kg/person/year and an estimated 200 million people are employed directly and indirectly in the fisheries and aquaculture sector (FAO 2018b). Livelihoods sustained by fisheries and aquaculture activities are especially important to many poor communities in coastal, riverine, insular and inland regions.

Approach

The full Technical Paper uses an end-to-end approach to assess the vulnerability of marine and inland fisheries, and aquaculture to climate change. Information is presented on the projected changes in atmospheric climate, the ocean, ecosystems supporting fisheries and aquaculture, the direct and indirect effects of these changes on fisheries and aquaculture production systems, the implications for food security and livelihoods, and practical tools for effective adaptation.

Observed and predicted changes in air temperature

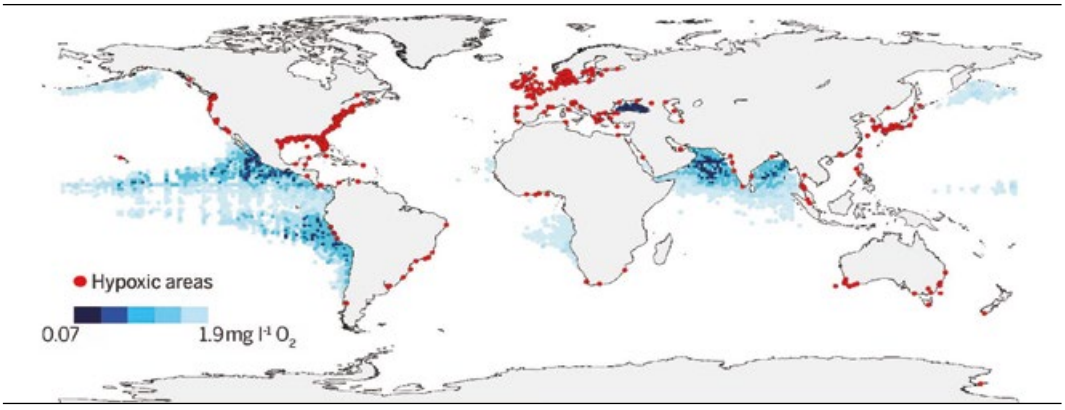
The Earth's average surface air temperature has increased by more than 0.8°C since the middle of the 19th century, and is now warming at a rate of more than 0.1°C every decade. Projected changes in surface air temperature by 2100 vary, depending on a number of social and economic assumptions (e.g. possible future trends in population size, economic activity, lifestyle, energy use, land use patterns, technology, climate policy). Several of the possible scenarios have been summarised into four representative concentration pathways (RCPs) for GHG emissions in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2014). These four RCPs are based on radiative forcings of +2.6, +4.5, +6.0 and +8.5 Watts/m^2. For all RCP scenarios, except RCP2.6, global average surface air temperature is likely to exceed 1.5°C by 2100 relative to the average for the 1850–1900 period, and by 2°C for RCP6.0 and RCP8.5.

Observed and predicted changes in rainfall

The warming of the climate has significant implications for the hydrological cycle. Observed changes in rainfall patterns since 1900 vary across regions. However, modelling indicates that rainfall is very likely to increase in high latitudes and near the equator, and decrease in the subtropics. The frequency and intensity of heavy rainfall events over land are also likely to increase in the near term, although this trend will not be apparent in all regions because of natural variability. For example, droughts are expected to be longer and more frequent in California, the Mediterranean basin, and in existing arid zones.

Observed and predicted impacts to the ocean

The surface waters of the world's oceans (0–700 m deep) have warmed by an average of 0.7°C per century since 1900. This has happened because the ocean absorbs heat from the atmosphere – more than 90% of the additional heat in the atmosphere generated between 1971 and 2010 has been taken up by the ocean. Nevertheless, ocean temperature trends vary among regions and have been most prominent in the Northern Hemisphere, especially the North Atlantic. Because the ocean absorbs >90% of atmospheric heat, SST increase is expected to approximate the projected increases in surface air temperatures described above. Increases in SST have knock-on effects on dissolved oxygen levels, which have decreased in surface waters due to ocean warming, resulting in an expansion of tropical 'oxygen minimum zones' in recent decades (Fig. 3).



Source: Breitburg et al., 2018

Figure 3. Coastal areas with oxygen deficiency (hypoxia – red dots) and ocean oxygen minimum zones at a depth of 300 m (blue shading). Source: Breitburg et al. 2018.

Increases in SST will strengthen the stratification of the water column, thus reducing the transfer of nutrient-rich waters to the photic zone to support the primary productivity at the base of the food web that underpins marine fisheries. There is also concern that climate change could disrupt the patterns of ocean circulation that redistribute heat and freshwater across the globe, thereby influencing local climates and the important areas of upwelling that drive the productivity of major fisheries. Any changes to the strength, timing and geographical variability of the eastern boundary upwelling systems in the Pacific and Atlantic oceans would have significant effects on some of the world's most productive fisheries.

Sea level is rising mainly due to ocean warming and the melting of land ice, and has risen globally by a mean of 0.19 m since 1900. The rate of sea-level rise varies across regions, however. For example, the rate in the western Pacific is three times the global average but the rate is null or negative in the eastern Pacific. Global average mean sea level is very likely to rise by 0.5 to 1.2 m under RCP8.5, 0.4–0.9 m under RCP4.5, and 0.3–0.8 m under RCP2.6.

Since the beginning of the industrial era, the pH of ocean surface water has decreased by an average of 0.1 due to the absorption of human-produced CO_2. This corresponds to a 26% increase in ocean acidification, causing a decrease in the saturated mineral forms of calcium carbonate ($CaCO_3$) in sea water needed by many marine species to build their shells (e.g. molluscs) and skeletons (e.g. corals). Since 1970, 30% of the additional CO_2 in the atmosphere has been absorbed by the ocean. Average global ocean pH is expected to decrease by 0.3–0.4 by 2100 under RCP8.5 (Fig. 4).

Climatic variability and climate change

Interactions between climatic variability (e.g. El Niño Southern Oscillation, ENSO), and climate change can be expected to occur. However, there is still debate about the extent to which ENSO is likely to be affected by climate change. ENSO is the interaction between the atmosphere and ocean in the tropical Pacific that results in three- to seven-year periodic oscillations between particularly warm and cold temperatures for surface waters of the equatorial Pacific, referred to as El Niño and La Niña events, respectively. The release of heat from the ocean to the atmosphere during El Niño events causes changes in global atmospheric circulation, cyclone and hurricane patterns, monsoons, and heating and rainfall trends linked to droughts and floods. ENSO has consequences for ecosystems and species that sustain fisheries, resulting in noticeable increases or decreases in marine fish catches in given areas and a greater frequency of harmful algal blooms (HABs). In many inland ecosystems, the droughts caused by El Niño can result in insufficient water for fisheries and aquaculture.

Climate change impacts on marine capture fisheries

The modelling done for the FAO Technical Paper (Chapter 4) indicates that the average total maximum catch potential in the world's EEZs is likely to decrease by approximately 3–5% by 2050 (relative to 2000) under RCP2.6, and by 7–12% under RCP8.5. The projected decrease does not change much by 2100 under RCP2.6 but is expected to increase 16–25% by 2100 under RCP8.5. However, these projections vary significantly across regions and the impacts are expected to be much greater for some parts of the world. In particular, the greatest decreases in catch potential are likely to occur in the EEZs of countries in the tropics (Fig. 5). In contrast, catch potential for the high-latitude regions is projected to increase, or to decrease less than in the tropics. These projections do not reflect potential changes that may result from current catch levels or the outcomes of fisheries management measures that could potentially be applied to reverse or counter these trends. Rather, they indicate changes in the capacity of the oceans to produce fish in the future compared to their current capacity.

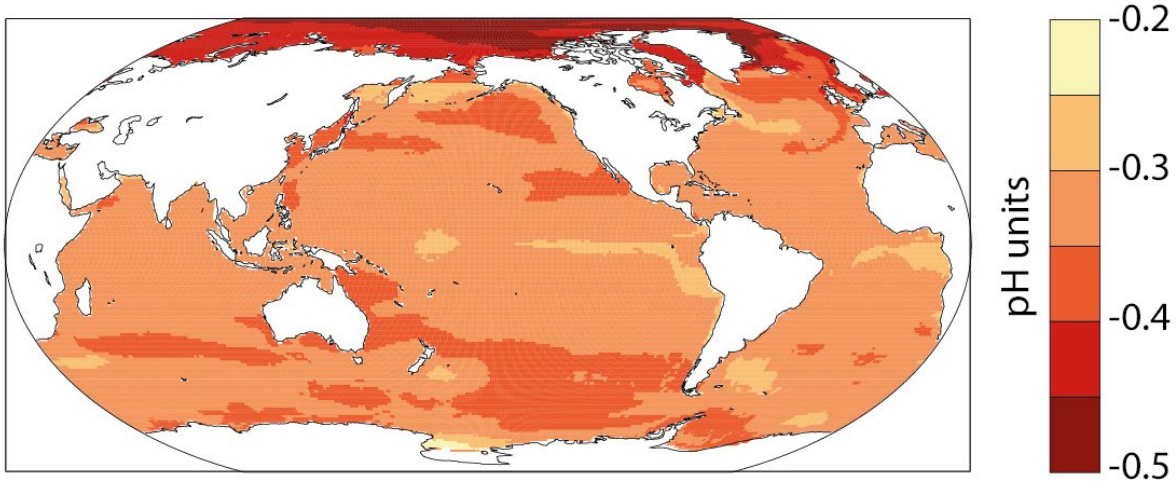


Figure 4. Projected decrease in surface pH from 1850 to 2100 resulting from expected changes in ocean acidification under RCP8.5. Source: Ciais et al. 2013.

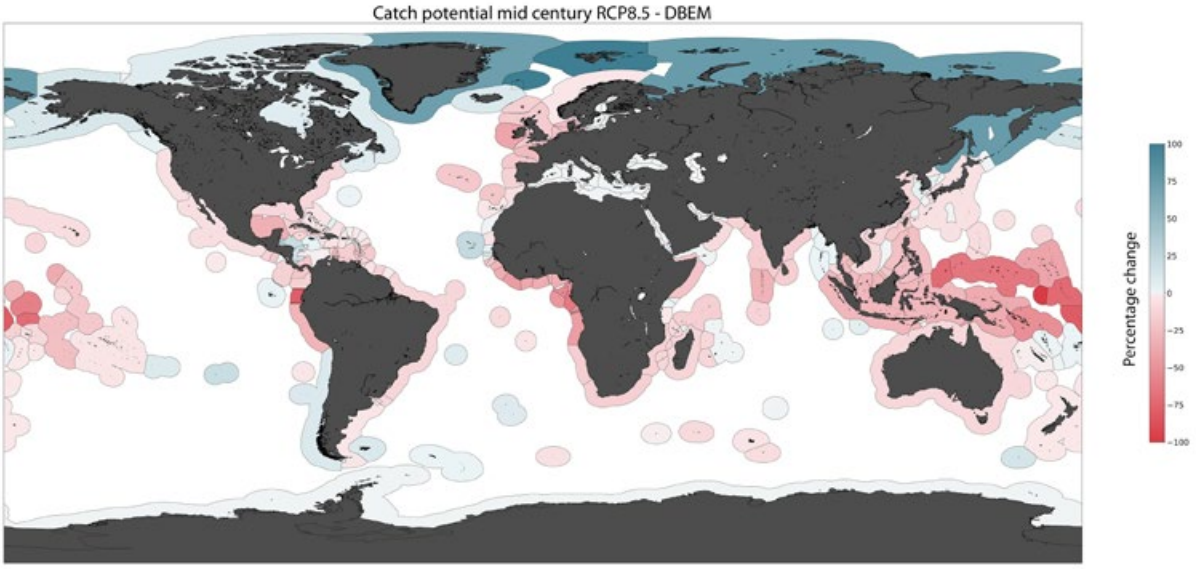


Figure 5. Projected changes in maximum catch potential (%) within national exclusive economic zones under RCP8.5 by 2050 (2046 to 2055), based on the Dynamic Bioclimate Envelope Model. Source: FAO 2018a.

The various case studies on the implications of climate change for marine capture fisheries from many regions of the world (Chapters 5–17) complement the model results. Collectively, they provide unequivocal evidence of the significant impacts that climate change has already had on marine fisheries and reflect the variability and patchiness of responses across the globe.

Climate change impacts on inland fisheries

Over 11 million tonnes of fish were caught by inland fisheries in 2015, equivalent to 12% of total production from all capture fisheries. Inland fisheries catches provide high-quality, affordable food and livelihoods for tens of millions of people, including some of the poorest and most vulnerable people in the world.

Predictions of the impacts of climate change on inland fisheries are difficult to make because they are often confounded with impacts from other sectors that compete with inland fisheries for the use of freshwater. The multiple and high demands for water are expected to increase with human population growth and development. Unless urgent remedial action is taken, the many other uses of freshwater will have serious negative impacts on inland fisheries and the benefits they provide. Unfortunately, in the competition for this scarce resource, the valuable contributions of inland fisheries are often unrecognised or under-valued.

Although there is high likelihood that changes in rainfall patterns and rising inland water temperatures, driven by the increases in surface air temperatures, will lead to alterations in the distribution and abundance of inland freshwater fisheries species, non-climate stressors are expected to be more serious threats to inland fisheries than climate stressors in the decades ahead.

Climate change impacts on aquaculture

Climate change can have direct and indirect, and short- and long-term, impacts on both freshwater and marine aquaculture. Examples of short-term impacts include loss of production and infrastructure arising from extreme events such as floods, and increased risk of diseases, parasites and HABs due to warmer temperatures. Climate-driven changes in surface air temperature, rainfall and SST, ocean acidification, incidence and extent of hypoxia, sea-level rise, availability of wild-caught 'seed' for grow-out, among others, will have long-term impacts on aquaculture at scales ranging from organisms to farming systems to regions. Although there are likely to be winners and losers at all scales, unfavourable changes are likely to outweigh favourable ones, particularly in developing countries.

Global vulnerability assessments carried out for marine, brackish and freshwater aquaculture provide detailed results by country and present a number of options for adaptation and building resilience, in line with the ecosystem approach to aquaculture. Ultimately, however, it is at the farm level where the greatest needs to reduce vulnerability can be expected to converge. Specific measures to reduce vulnerability at this scale include improvement of farm management and choice of farmed species, environmental monitoring and spatial planning that takes climate-related risks into account, and coordination of prevention and mitigation actions.

The projected reduction in renewable surface water and groundwater resources in most of the dry and subtropical regions is likely to lead to greater competition between aquaculture, agriculture and other sectors. Reducing the vulnerability of aquaculture to climate change will, therefore, require integration of these important activities into

holistic, multi-sectoral plans for watershed and coastal zone management.

Impacts of climate-driven extreme events and disasters

A warmer climate can be expected to change the frequency, intensity, timing, duration and location of extreme events such as cyclones. Accordingly, existing approaches to damage and loss assessment from climate-related disasters in fisheries and aquaculture need to be improved. There is an urgent need to invest in coherent and convergent disaster risk reduction and adaptation measures to anticipate and reduce the impacts of extreme events affecting fisheries and aquaculture. The sector needs to shift from reactive management after disasters have occurred to proactive risk reduction of climate risks and hazards.

Hazards in food safety and aquatic animal health

Climate change is affecting the growth rates of marine pathogenic bacteria, the incidence of parasites and food-borne viruses, and the dynamics of aquatic species as intermediate and definitive hosts for pathogens and parasites. Coping with these climate-driven risks to both the quality of food products and animal health will require greater attention to the monitoring of key environmental parameters and implementing effective early warning systems.

Collaboration among stakeholders, including those responsible for aquatic animal health, the marine environment and food safety and public health, will be essential. This also applies to best-practice biosecurity measures, such as improved spatial planning, border controls and emergency preparedness and risk communication. Aquaculture is particularly vulnerable to these hazards due to the need to rear animals in high density environments.

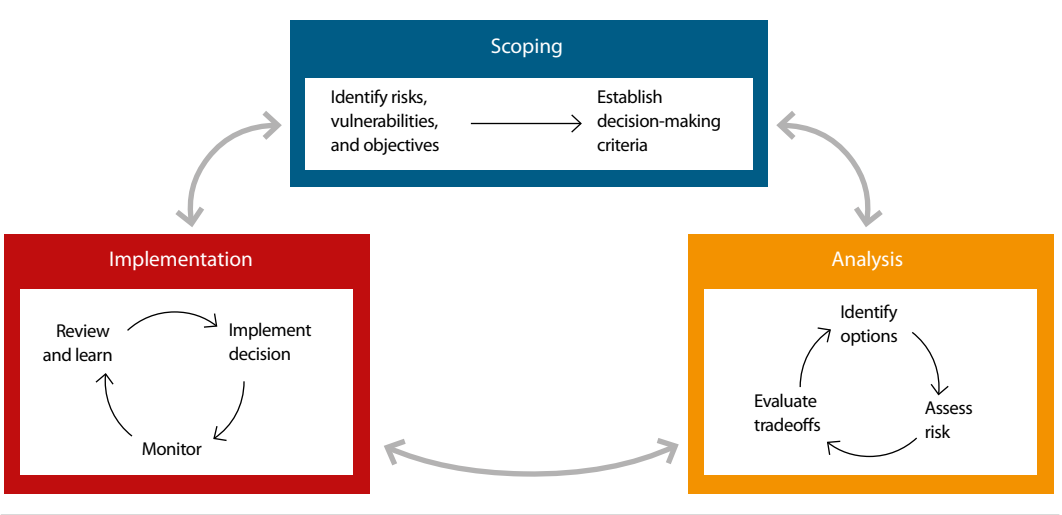
Adaptations for fisheries and aquaculture

A key feature of the FAO Technical Paper is the synthesis of methods and tools for climate change adaptation in fisheries and aquaculture (Chapter 25). This chapter provides a portfolio of recommended adaptation tools and approaches currently available for marine fisheries, inland fisheries and aquaculture. It also provides guidance for selecting, implementing and monitoring the effectiveness of adaptation actions, and limiting maladaptative practices. These adaptation tools fall into three categories, those for: 1) institutions, 2) food security and livelihoods, and 3) risk reduction and management for resilience. Adaptation should be implemented as an iterative process, equivalent in many respects to adaptive management in fisheries (Fig. 6). The vulnerability assessment of fisheries and aquaculture systems, the initial step in this iterative process, should start with determining clear objectives in consultation with key stakeholders. It should also be grounded in the best available science and traditional ecological knowledge.

To the greatest extent possible, the selected priority adaptations should address not only climate change but also other drivers affecting the sector (i.e. they should be 'no regret' or 'win-win' adaptations). Priority adaptations should also be planned and implemented with a sound understanding of the multi-faceted and interconnected complexity of fisheries and aquaculture activities, and the interactions between the sector and the wider natural and human environments. Failure to do this will increase the risks of inefficiency and maladaptation.

Climate change and poverty in fisheries and aquaculture

Many of the people who live in extreme poverty can be found in small-scale fishing and fish farming communities,



Source: Jones et al. 2014

Figure 6. An iterative risk management framework that incorporates system feedback. Source: FAO 2018a.

and are especially vulnerable to climate change because of both their geographic locations and their economic status. Eradicating poverty and ensuring food security is an essential part of increasing the resilience of these communities, as emphasised by the Paris Agreement, the United Nations Agenda 2030, and other international instruments. Tackling climate change through a poverty lens is a key strategy for moving people out of poverty, and for preventing others from becoming poor. Bringing people out of poverty is also essential for making communities more capable of dealing with the impacts of climate change. Achieving these important outcomes requires adaptation to climate change to be multidimensional and multi-sectoral. Poor people impacted by climate change should be provided with flexible practices and opportunities to diversify their livelihoods, allowing them to respond to the challenges of climate change. Active support for adaptation is required at local, national, regional levels of governance. A stronger emphasis should be placed on the contribution of fisheries and aquaculture to poverty reduction and food security in nationally determined contributions of developing countries.

Measures and tools to reduce energy use and emissions

The estimated global emission of CO_2 by all fishing vessels in 2012 was 172.3 megatonnes, which was about 0.5% of total global emissions that year. The aquaculture industry was estimated to have emitted 385 megatonnes of CO_2 in 2010. Overall, however, the energy used for protein production per unit mass of fish is comparable to chicken, but is much less than that from other land-based systems for producing animal dietary protein, such as those for pork and beef. Nevertheless, emission reductions of between 10% and 30% could be attained for marine capture fisheries through the use of more efficient engines and larger propellers on fishing vessels, improvements to vessel design, reducing the mean speed of vessels, and the use of fishing gear that requires less fuel. Opportunities to reduce GHG emissions in aquaculture include improved technologies to increase efficiency in the use of inputs, greater reliance on energy from renewable sources, improved feed conversion rates, and switching from feeds based on fish to feeds made from crop-based ingredients that have a lower carbon footprint. The integration of pond aquaculture with agriculture is also a potential option for reducing fuel consumption and emissions.

3 Concluding remarks

Despite the practicality of the adaptations for industrial tuna fisheries and small-scale fisheries described in Part 1, uncertainty and gaps in knowledge remain about how best to apply them. Staged actions are needed to: 1) identify the research to be done; 2) create effective research partnerships; 3) overcome constraints to sharing knowledge and uptake of technology; and 4) provide economies and communities with the resources needed for effective adaptation. Potential social barriers to the uptake of adaptations recommended for small-scale fisheries (e.g. cultural norms and gender issues that could limit broad-based community participation) also need to be addressed.

Pacific Island countries and territories already recognise the need to build capacity for an integrated approach to climate change adaptation (CCA) and disaster risk management (DRM) (Johnson et al. 2013). Combining DRM and CCA is particularly pertinent in the Pacific Islands region, where there is a large overlap between the most common natural disasters (cyclones) and the impacts of climate change on the fisheries sector. The recent 'Framework for resilient development in the Pacific: an integrated approach to address climate change and disaster risk management' provides strategic guidance for stakeholders about how to enhance resilience to climate change and natural disasters.

Ultimately, one of the most important ways for Pacific Island countries and territories to improve the enabling environment for maintaining the socioeconomic benefits of their marine fisheries will be to prepare, communicate and maintain their nationally determined contributions under the 2015 Paris Agreement to adapt to the impacts of climate change, and reduce national emissions.

The FAO Technical Paper described in Part 2 highlights the variability and complexity of the fisheries and aquaculture sector, and the interactions between the sector and the wider environment. It also shows that the impacts of climate change affect all aspects of the sector – from the underpinning resources through to human well-being – and that efforts to adapt to and mitigate the effects of climate change at all scales should be planned and implemented with full consideration of these complexities.

The onus is also on national and regional agencies to give particular attention to practical adaptations for the most vulnerable people. Otherwise, the vital contributions that fisheries and aquaculture can make to the Sustainable Development Goals related to poverty reduction and food security are likely to be compromised.

These various objectives will be advanced by including the fisheries and aquaculture sector in national climate change policies and instruments, such as the nationally determined contributions or national adaptation plans. Such initiatives should help build the resilience of the ecosystems supporting the sector, and the socioeconomic benefits they provide, and are particularly important for developing countries. Least developed countries and small island developing states can also take advantage of the assistance specifically available to them through climate finance schemes to implement priority adaptations for fisheries and aquaculture.

The entire international community should be encouraged to address the remaining gaps in knowledge about the direct and indirect effects of increased GHG emissions on

fisheries and aquaculture. Dismantling this uncertainty will inform progressive improvements to effective adaptation of the sector.

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