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Fishing in the lagoon of North Efate, Vanuatu. Image: ©David Welch

What's happening with Pacific tuna harvest strategies?

Finlay Scott, Robert Scott and Nan Yao

Members of the Western and Central Pacific Fisheries Commission (WCPFC) agreed to the development and implementation of harvest strategies for skipjack, South Pacific albacore, yellowfin and bigeye tunas in 2014 (see Yao et al. 2021 for a brief overview). A harvest strategy is a set of pre-agreed on management actions for a fishery, and are designed to achieve agreed on management objectives such as stock sustainability and economic benefits. The pre-agreed actions to be taken are dependent on the status of the stock and are defined through a management procedure. The harvest strategy approach is widely recognised as a best practice in fisheries management and should increase the speed, transparency and robustness of decision-making.

At its heart, the harvest strategy approach is a stakeholder-driven process in which members identify their collective goals and objectives for the fishery, and select the preferred management procedure to achieve them.

Here we briefly summarise the recent and upcoming developments of the WCPFC tuna harvest strategies.

2023 was a busy year with several key outcomes that had been scheduled under the harvest strategy workplan. A notable achievement was the implementation of the skipjack management procedure, which had been formally adopted by the WCPFC in 2022 (Pilling G. et al. 2023; WCPFC 2022). The output from the management procedure was used to set skipjack fishing levels, including for purse-seine and pole-and-line fisheries, until the end of 2026 through the "tropical tuna measure' (WCPFC Conservation and Management Measure 2023-01; WCPFC 2023).

Another important achievement was the agreement of an interim target reference point for South Pacific albacore (WCPFC 2023). The target reference point is a key component of a harvest strategy and, in the case of albacore, has been the subject of considerable debate in recent years.

Looking ahead, the main focus for 2024 is to continue developing the harvest strategy for South Pacific albacore (SPA). Under the current WCPFC workplan the management procedure is scheduled for adoption at the end of the year.

To support meeting this ambitious target, the SPC harvest strategy team will be busy with the technical work: running simulations and communicating results. Along the way, WCPFC members and stakeholders will provide feedback and steer the process. Opportunities to do this

Future film stars Giulia Anderson and Hettie Sem preparing for their role in the latest harvest strategy training film. Image: Finlay Scott ©SPC

include, but are not limited to, meetings of the WCPFC SPA Intersessional Working Group, WCPFC Scientific Committee in August, and the second Science-Management Dialogue (SMD02) scheduled for September.

As well as conducting the technical work, the SPC harvest strategy team will continue their capacity building and stakeholder engagement work, including national harvest strategy and regional workshops (see Manrique and Yao 2024 for an overview of recent capacity building activities).

Finally, the training films prepared by SPC are now available as a YouTube playlist[1], including the recent film on management procedures, featuring Marino Wichman and Raijeli Natadra, and a magic wand. The latest film on performance indicators is close to completion and will be available soon.

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References

Manrique L. and Yao N. 2024. Capacity building on harvest strategies: Progress and areas of improvement. SPC Fisheries Newsletter 172:12–15. https://purl.org/spc/digilib/doc/4zxkm

Pilling G., Scott R. and Scott F. 2023. Adopting a WCPO skipjack tuna harvest strategy: A big step forward at the 19th Western and Central Pacific Fisheries Commission meeting. SPC Fisheries Newsletter 169:5–6. https://purl.org/spc/digilib/doc/vcbzn

Yao N., Scott R., Scott F. and Hamer P. 2021. Harvest strategies – the future of tuna fisheries management in the western and central Pacific. SPC Fisheries Newsletter 165:7–9. https://purl.org/spc/digilib/doc/zkgdb

WCPFC (Western and Central Pacific Fisheries Commission). 2022. Nineteenth Regular Session of the Commission – Summary Report. Da Nang, Vietnam. https://meetings.wcpfc.int/file/12419/download

WCPFC (Western and Central Pacific Fisheries Commission). 2023. Twentieth Regular Session of the Commission – Summary Report. Rarotonga, Cook Islands. https://meetings.wcpfc.int/file/14767/download

[1] See the "Developing Harvest Strategies for Pacific Tuna Fisheries" playlist on YouTube: https://youtube.com/playlist?list=PLCq-WnF3HdrjCtkevYvru-OeiMOxD4oZn&si=NvZV9CU5yIpaEKsA

The first Micronesia regional coastal fisheries project funded by the Kiwa Initiative embarked on its journey!

Angelica Salele[1] and Ludovic Branlant[2]

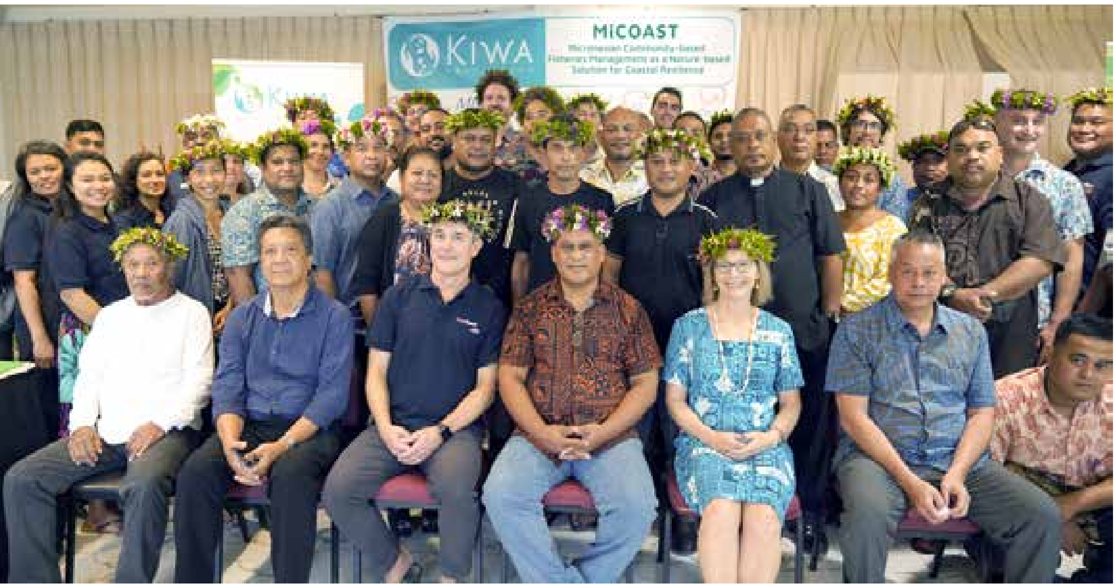
In a collaborative effort to enhance coastal fisheries faced with a changing climate, a group of local and national organisations in Micronesia participated in an inception workshop marking an important milestone of the Kiwa Initiative's Regional MiCOAST Project.

The kick-off workshop, held from 22 to 26 January 2024 in Pohnpei, Federated States of Micronesia, and co-hosted by the Conservation Society of Pohnpei and OneReef Worldwide Stewardship, provided a platform for meaningful discussions, collaboration, and knowledge-sharing among MiCOAST project stakeholders. Established regional organisations and agencies joined this activity, including the Marshall Islands Conservation Society, Kosrae Conservation and Safety Organization, Rare, cChange, the Nauru Fisheries and Marine Resources Authority, the Pacific Community (SPC), and other FSM national, state and local government and traditional representations.

The Kiwa MiCOAST project (short for "Micronesian Community-based Fisheries Management as a Nature-Based Solution for Coastal Resilience") is a three-year initiative that aims at advancing community-based fisheries management and nature-based solutions across a large portion of the Micronesia region, spanning the Marshall Islands, Nauru, Kosrae, Pohnpei, Yap and Palau. The project applies the concept of "nature-based solutions" – an approach of working with nature in applying climate adaptation solutions. This initiative aims to enhance collaboration among local fishers, communities and stakeholders, thereby improving the sustainability of coastal fisheries management in the region. The project will contribute to achieving the targets of regional and global commitments such as the Micronesia Challenge 2030 and the United Nations Sustainable Development Goals.

The Kiwa Initiative, managed by the French Development Agency, builds both local and national capacities, promotes approaches that are sensitive to social vulnerability and gender inequality, and fosters dialogue among donors, regional organisations and countries and territories to improve official development assistance coordination.

The event was graced by the Honorable Stevenson A. Joseph, Governor of Pohnpei, and Her Excellency Jo Cowley, Ambassador of Australia to FSM, along with traditional leaders and other natural resource government and community representatives from around Pohnpei. Their comments and contribution to the workshop underscore the importance of such collaborative efforts and the significance of involving coastal communities in achieving sustainable coastal fisheries management in Micronesia. It is anticipated that local inception meetings to introduce the MiCOAST project will be organised in other represented jurisdictions within the first quarter of 2024.



Successful kick-off meeting of the Kiwa MiCOAST project in Pohnpei, FSM. Image: ©Sachi Jones Singeo, Kiwa Initiative

Name and title of first row of participants (left to right): Yuber Soram (Lepen Madau en Metipw village chief), Hubert Yamada (Director of Pohnpei State Department of Resources and Development), Christopher LaFranchi (CEO of OneReef Worldwide Stewardship), T.H. Stevenson A. Joseph (Governor of Pohnpei State), H.E. Jo Cowley (Ambassador of Australia to the FSM); William Kostka (SPC Micronesia Regional Director) and McShane Chipen (Natural Resources Coordinator of Madolenihmw Municipal Government, Pohnpei).

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It's a great opportunity for us to learn with our regional partners and our neighbouring countries within the subregion of Micronesia, and we are very honored to be part of the MiCOAST project, so we can contribute towards better coastal fisheries management and improve what we are doing in FSM. Eugene Joseph, Conservation Society of Pohnpei Director, FSM

As a technical partner of the project, I believe this initiative has the potential to empower community networks in advocating for recognition from their government regarding their efforts in accessing and managing resources. This could ultimately enhance and legitimise their capacity to operate effectively. Watisoni Lalavanua, Community-Based Fisheries Adviser, SPC Noumea, New Caledonia

MiCOAST is a really important project in terms of providing resources and solutions for the future, and also being able to transfer much of our traditional knowledge and practices to younger generations. A lot of the project's activities are meant to support not only economic livelihoods, but also to ensure that we have food security for our communities. Madelsar Ngiraingas, OneReef Micronesia, Director of Operations, Palau

The MiCOAST project aims to enable a regional collective of organisations with the ambition to implement and scale community-based fisheries management approaches, while recognising national contexts and frameworks, by working with nature for the benefit of the Micronesian communities. Martin Romain, Kiwa MiCOAST Regional Project Manager

Key initiatives of the MiCOAST project across Micronesia

- **In the Federated States of Micronesia:**
  - **Pohnpei State** — *whole-of-island*, the Conservation Society of Pohnpei (CSP) will collaborate with communities and municipalities to bolster the monitoring and regulation of marine protected areas, mitigating impacts from land-based activities like *sakau* plantations and piggeries.
  - **Kosrae State** — *whole-of-island,* the Kosrae Conservation and Safety Organization (KCSO) aims to expand marine resource monitoring programmes and expand rabbit fish aquaculture to enhance livelihoods and food security.
  - **Yap State** — the communities of Okaw and Kaday supported by OneReef Micronesia will work with local entities and partners to extend fisheries management practices throughout the Weloy municipality.

Visit the Kiwa MiCOAST Project website
www.bit.ly/Kiwa-MiCOAST

- **In the Republic of Palau** — Hatohobei State, Sonsorol State, Ngarchelong and Kayangel states, and Koror State, OneReef Micronesia will partner with communities to develop or enhance local fisheries management plans and to strengthen compliance and enforcement efforts, along with fostering intercommunity exchanges and learning.
- In the Republic of the Marshall Islands — Mili Atoll, Maloelap Atoll, Ujae Atoll, Lae Atoll, the Marshall Islands Conservation Society will support local resource committees to implement and enhance their resource management plan and promote additional nature-based solutions such as clam farming and virgin coconut oil production.
- In Nauru — *whole-of-island,* the Nauru Fisheries and Marine Resources Authority (NFMRA) is set to launch a widespread campaign to apply community-based fisheries management at an island-wide level and to support clam and coral restocking initiatives.

The Kiwa MiCOAST project, as a partnership of national and regional organisations, will advocate for beneficial policy reforms, disseminate knowledge, replicate successful models, and foster partnerships between communities to amplify the impact of CBFM/NbS approaches.

About the Kiwa Initiative

The Kiwa Initiative — Nature-based Solutions (NbS) for Climate Resilience — aims to build the resilience of Pacific Island ecosystems, communities and economies to climate change through NbS by protecting, sustainably managing and restoring biodiversity. It is based on simplified access to funding for climate change adaptation and biodiversity conservation actions for local and national governments, civil society and regional organisations in Pacific Island states and territories. The initiative is funded by the European Union, French Development Agency, Global Affairs Canada, Australia's Department of Foreign Affairs and Trade, and New Zealand's Ministry of Foreign Affairs and Trade. It has established partnerships with the Pacific Community, the Secretariat of the Pacific Regional Environment Programme, and the Oceania Regional Office of the International Union for Conservation of Nature. For more information: www.kiwainitiative.org.

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Digital Earth Pacific – Approaches to monitoring fishery ecosystems

Nicholas Metherall,[1,2,3] Joeli Bili,[4] Milika Sobey,[4] Shyam Lodhia,[4] Vanessa Dirking,[4] Raphael Linzatti,[4] Jesse Anderson[5] and Sachindra Singh[3]

Introduction

Mangrove and seagrass habitats provide a range of ecosystem services for fisheries as nursery sites that support spawning and recruitment (Unsworth et al. 2014; Nagelkerken et al. 2008). The breakdown of litter from both mangroves and seagrass beds supports microbial and planktonic food webs (Peduzzi and Herndl 1991), and these symbiotic relationships further support fisheries (Legendre and Rassoulzadegan 1995). However, many of these ecosystems face threats from environmental and climate-driven stressors as well as natural disasters (e.g. local processes on land, including sediment mobilisation and transport, resulting in downstream sediment burial of these fisheries). Global ocean processes, including thermal inertia and ocean acidification, are a further looming threat. These hazards present challenges for both future biodiversity and sustainable biomass yields of fisheries. Despite these ongoing challenges, there are limitations to the availability of verified data for monitoring mangrove forests, seagrass meadows and the impacts threats have on these ecosystems. Government authorities, environmental regulators and conservation agencies are constrained in their ability to systematically measure the extent of these ecosystems over time.

Digital Earth Pacific: A public technology infrastructure

Earth observation – using satellite imagery datasets – has emerged as an approach to support environmental monitoring across vast ecosystems, including those that support fisheries. Digital Earth Pacific (DEP)[6] is a public technology infrastructure that has been built by the Pacific Community (SPC) in collaboration with its Pacific Island country and territory (PICT) members. The initiative supports these countries to access the cloud computer infrastructure of DEP, including levels of computer processing, access to satellite imagery databases and memory storage that, in the absence of DEP, would not be possible in the Pacific Islands region. To ensure that this technological capacity is made more accessible to PICTs, DEP has been made as an open-access infrastructure that PICTs can use at no cost. This allows PICT member countries to save significant costs on accessing satellite data. To date, DEP has accessed 450,000 NASA Landsat and 300,000 European Space Agency Sentinel-2 satellite images. DEP has processed over 500 terabytes of data. If a country attempted to replicate this process, it would cost tens of millions in United States dollars (USD)

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[6] Digital Earth Pacific: https://www.spc.int/DigitalEarthPacific

Mangroves in Nakelo District, Tailevu Province, Fiji. Image: ©GIZ Pacific to build the infrastructure, and a further USD 300,000 annually to operate. Through cloud computing, DEP can deliver this infrastructure at USD 30,000 per year; equivalent to a 1000% cost saving.

How earth observations can be used to support monitoring and decision-makers

Analysis of the large datasets accessed through DEP can produce a range of different data products. Evidence leads to insights, and these insights support policy-makers and land and ocean planners to make decisions. For example, as part of its coastline change data product, DEP has already mapped 22 years of seashore change along the 34,000 km of coastline within the Pacific Islands region. Similarly, the Water Observations from Space product has provided insights into surface water dynamics over the past 11 years. These decision-ready DEP products can help bridge the science–policy gap to support policy-makers.

MACBLUE supports DEP product for mangrove and seagrass extents

The Management and Conservation of Blue Carbon Ecosystems (MACBLUE) project is coordinated by the German Agency for International Cooperation (GIZ), in collaboration with the Secretariat of the Pacific Regional Environment Programme and SPC. MACBLUE seeks to support Fiji, Papua New Guinea, Solomon Islands and Vanuatu in mapping and monitoring seagrass and mangrove ecosystems. Mapping and remote sensing is a crucial part of blue carbon stock assessments, as the MACBLUE project intends to follow the Intergovernmental Panel on Climate Change guidelines (IPCC 2003). The mapped mangrove and seagrass habitats, in conjunction with verified ground truthing data, can be used to accurately quantify the carbon stocks within these ecosystems. The value of stored carbon, and the ecosystem services they provide, can be used as a basis for creating or improving policies to protect and conserve these ecosystems.

Through this MACBLUE project, participants from each of the participating countries will support in the co-design, data collection, calibration and validation of the DEP products, which will aim to map the extent of mangrove and seagrass ecosystems. Currently, DEP has generated datasets for the past seven years of mangrove forests throughout all PICTs. The next stages will include the further assessment, re-calibration and validation of these data products. Seagrass meadows will be a longer-term product, given the additional complexities associated with these commonly submerged intertidal ecosystems.

Local Papua New Guinea government representatives provide input into calibration and validation of Digital Earth Pacific mangrove and seagrass products. Image: ©GIZ Pacific

Localising earth observation: A case study from Papua New Guinea

The process of assessment, re-calibration and validation of mangrove and seagrass earth observation products has already begun in Papua New Guinea (PNG). This process has been initiated through the co-design of workshops facilitated by PNG's Climate Change and Development Authority, GIZ and SPC. The workshop also involved collaboration with the Conservation and Environment Protection Authority, the PNG Forestry Authority, the National Fisheries Authority, and the University of Papua New Guinea. Through the workshop, participants provided input into areas of potential underestimation and overestimation of the extent of mangrove and seagrass areas based on existing earth observation products. Insights from this process were then incorporated into the design process for calibrating and validating the extent of DEP mangrove and seagrass areas.

Digital Earth Pacific's methods for determining the extent of mangrove areas

The main methods used were based on peer-reviewed remote sensing studies, including those of Veldarrama-Landeros et al. (2018) and Tran et al. (2022). Both studies used spectral indices, including the normalised difference vegetation index-based classification approach. These kinds of approaches have been used for similar products such as Digital Earth Africa and Digital Earth Australia. The workflow includes the following seven steps:

1. Collation of datasets and images, including the Global Mangrove Watch (GMW) dataset, is generated as a baseline mask layer.

2. Sentinel 2 satellite imagery data is downloaded for all areas within the GMW baseline mask.

3. Sentinel 2 datasets, including many sentinel images across a single year, are pre-processed. These images are compressed into a median composite for each year.

4. The model is calibrated using spectral band values, including the normalised difference vegetation index (NDVI) and/or field data points. This is used to determine the extent of different vegetation types.

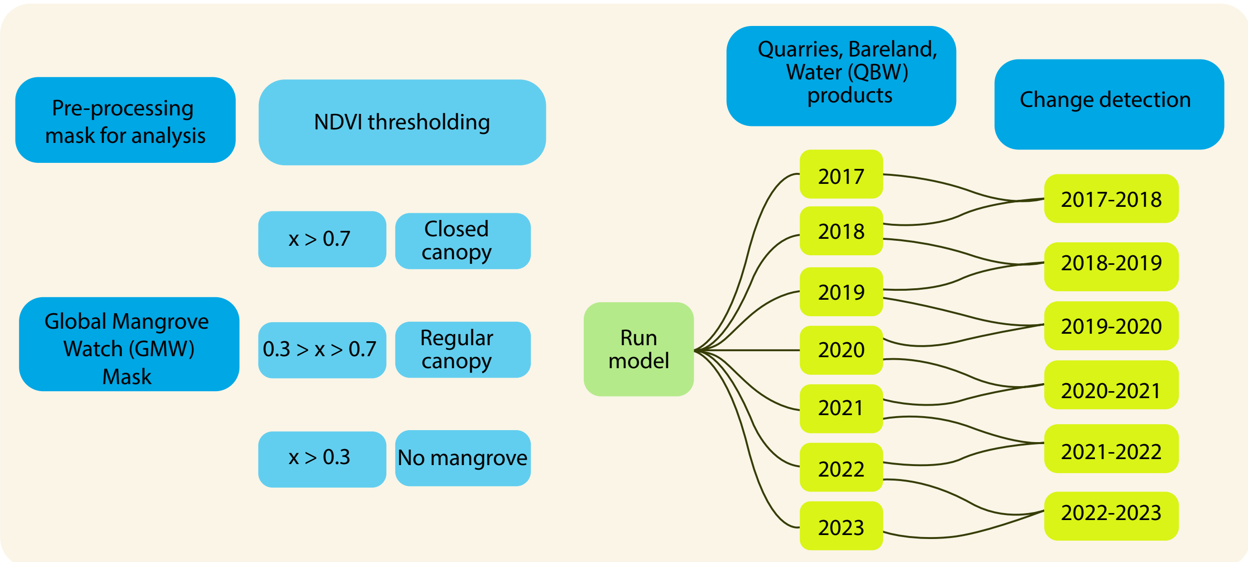
5. The model is used to classify or predict the extent of different vegetation types.

6. NDVI threshold values are applied to distinguish different categories of mangrove canopy density, including regular (lower density) canopy and closed (higher density) canopy cover.

7. Data may be validated by local partners and further field data collection.

8. With these inputs, the model may be re-trained and calibrated as part of a cyclical process to continuously improve model outputs.

9. Once there is a satisfactory output this output can be scaled across a wider region using (DEP) cloud computer capacity.



High-level overview of methods used in generating the extent of mangrove areas from earth observation datasets.

According to DEP's technical product development team, there are several challenges in revising the methods used by global models to build mangrove extent maps for the Pacific region. These challenges include issues with cloud cover obscuring the view of satellite sensors, particularly during rainy seasons.

The next stages of incorporating further input from local countries into the DEP mangroves product will enable DEP to improve the GMW dataset. The next stages of development will make progress towards a first seagrass extent product and an enhanced mangroves product. Both DEP products will apply machine learning techniques and country-collated data points for capturing more refined extent and density. Incorporating these local inputs and localised data for validation and calibration enables DEP to provide a more accurate representation of the extent of mangrove areas at the local scale. To learn more, you can explore examples of these earth observations datasets and products at www.digitalearthpacific.org

References

IPCC (Intergovernmental Panel on Climate Change). 2003. Chapter 2 – Basis for Consistent Representation of Land Areas. In: IPCC Good practice Guidelines for Land Cover and Land Use Change and Forestry (LULUCF). Penman J., Gytarsky M., Hiraishi T. et al. (eds). Geneva, Swizerland: Intergovernmental Panel on Climate Change.

Legendre L. and Rassoulzadegan F. 1995. Plankton and nutrient dynamics in marine waters. Ophelia 41(1):153–172. https://www.tandfonline.com/doi/abs/10.1080/00785236.1995.10422042

Nagelkerken I., Blaber S.J.M., Bouillon S., Green P., Haywood M., Kirton L.G., Meynecke J.-O., Pawlik J., Penrose H.M., Sasekumar A. and Somerfield P.J. 2008. The habitat function of mangroves for terrestrial and marine fauna: A review. Mangrove Ecology – Applications in Forestry and Coastal Zone Management 89(2):155–185. https://doi.org/10.1016/j.aquabot.2007.12.007

Peduzzi P. and Herndl G.J. 1991. Decomposition and significance of seagrass leaf litter (Cymodocea nodosa) for the microbial food web in coastal waters (Gulf of Trieste, northern Adriatic Sea). Marine Ecology Progress Series 71(2):163–174. https://www.int-res.com/articles/meps/71/m071p163.pdf

Tran T.V., Reef R. and Zhu X. 2022. A review of spectral indices for mangrove remote sensing. Remote Sensing 14(19):4868. https://www.mdpi.com/2072-4292/14/19/4868

Unsworth R.K.F., Hinder S.L., Bodger O.G. and Cullen-Unsworth L.C. 2014. Food supply depends on seagrass meadows in the coral triangle. Environmental Research Letters 9: 094005. https://iopscience.iop.org/article/10.1088/1748-9326/9/9/094005

Valderrama-Landeros L., Flores-de-Santiago F., Kovacs J.M. and Flores-Verdugo F. 2018. An assessment of commonly employed satellite-based remote sensors for mapping mangrove species in Mexico using an NDVI-based classification scheme. Environmental monitoring and assessment 190:1–13. https://link.springer.com/article/10.1007/s10661-017-6399-z/

Digital Earth Pacific maps showing the extent of mangrove areas in Malakula, Vanuatu and Santa Isabel in Solomon Islands.

Seagrass – More than just carbon sinks

Falma Aiviji,[1] Henry Kaniki,[2] Joeli Bili,[3] Mazzella Maniwavie[4] and Shalini Singh[5]*

Abstract

Seagrasses are marine flowering plants that form meadows along the coastlines of every continent except Antarctica, and inhabit mostly sandy and muddy substrates. Globally, it is estimated that 7% of seagrass meadows decline annually. Scientists attribute this to poor water quality caused by pollutants, especially nutrients and sediments. Seagrasses are important nursery grounds for a rich diversity of marine species such as certain finfish, shellfish, sea cucumbers, penaeid prawns, dugongs and sea turtles. Covering a mere 0.1% of the ocean surface, seagrasses provide more than 24 ecosystem services that benefit humans. Seagrasses are often considered to be the "lungs of the ocean" due to their capacity to trap carbon, thus making them one of the Earth's greatest carbon sinks. Research has shown that 10 seagrass species are at an elevated risk of extinction (14% of all seagrass species), with 3 species qualifying as endangered. On 23 May 2022, the United Nations General Assembly adopted a resolution to commemorate 1 March annually as World Seagrass Day. The conservation and management of seagrass ecosystems is paramount, demonstrating the critical role of seagrass meadows in achieving 16 of the 17 Sustainable Development Goals. This paper examines an open dialogue with representatives from Pacific Island countries on best practices, lessons learned, and developing joint strategies on seagrass conservation and management.

Background

Seagrasses are believed to be the third most valuable ecosystem in the world, preceded only by wetlands and estuaries (McKenzie 2008). Additionally, seagrass meadows contribute to vital ecological functions in the marine environment, many of which provide up to 24 different ecosystem services for humans, including coastal protection, nursery habitats, and sediment accretion and stabilisation (Nordlund et al 2017; Singh et al. 2022). They also provide important fishing grounds for local communities for sustenance and income. Around the Pacific, seagrass meadows are critical habitats for marine species such as dugongs and sea turtles. Notably, these coastal ecosystems are often interconnected by means of migrating animals, nutrient fluxes and organic carbon. They are also effective in purging pathogens that threaten humans and coral reefs.

Globally, there are 72 known seagrass species, which occupy less than 0.2% of the ocean floor. The highest biodiversity is found in the Indo-Pacific region (Waycott et al. 2009).

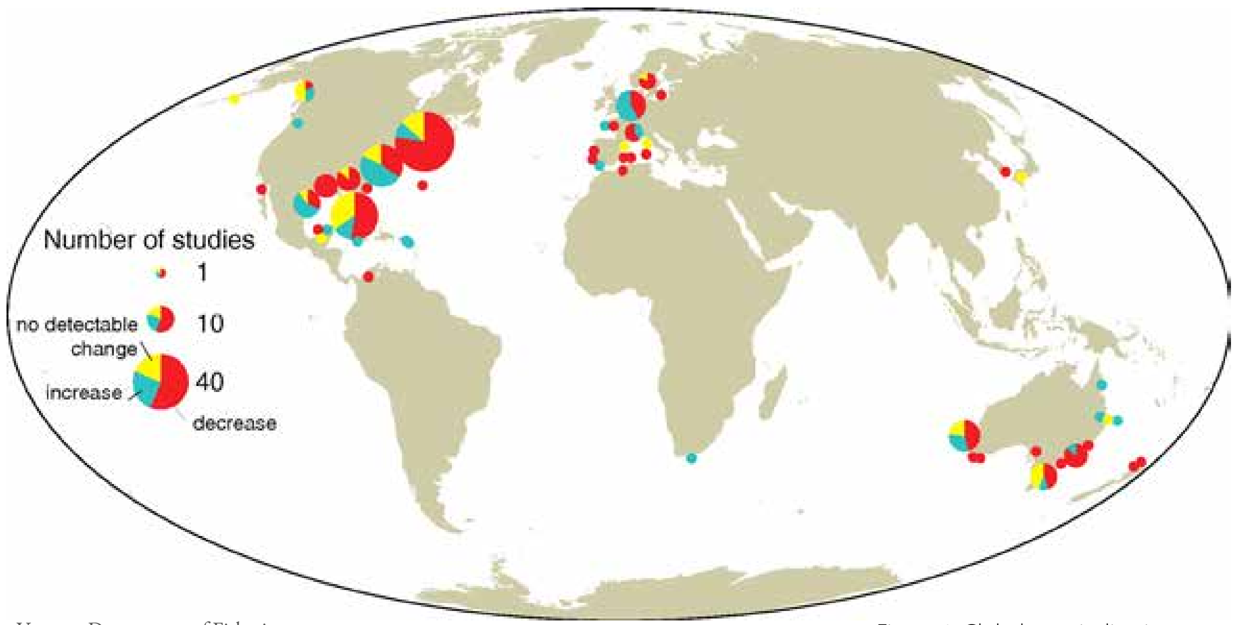


Figure 1. Global map indicating changes in seagrass areas plotted by coastlines. Source: Waycott et al. 2009

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The distribution of seagrasses around the world, as shown in Figure 1, indicates areas where seagrass ecosystems are declining (shown in red) due to human activities and areas where seagrasses are increasing (indicated in green). While global data have shown that there are no changes in some areas, this does not translate to seagrass meadows showing no actual change; instead, this may be due to limited seagrass research. Because most of the available data are from developed countries, which have a larger variety of seagrass species, these data could not be used for a comparative analysis in the Pacific Islands region. This is because differences in species composition and environmental conditions play a key role in estimating carbon stocks, which are valuable data for the conservation and monitoring of seagrass ecosystems. Seagrass meadows consist of different species that vary in size, form, growth and turnover rates. As a result, carbon sequestration in seagrass meadows vary in different regions and within meadow landscapes themselves. Recognition of seagrass species and seagrass meadow carbon data cannot rely on a "universal approach" based on carbon storage data from developed countries where they have been estimated from a greater variety of seagrass species (Singh et al. 2022). Hence, current regional and global estimates of carbon stocks and accumulation rates are based on limited datasets. Pacific Island countries need more studies and research on seagrass to further assess variability in carbon accumulation in seagrasses and sediments. By localising carbon estimates, it is possible to map the carbon accumulation in various seagrass species and the type of sediments they grow in coastal areas of the Pacific Islands region. Such carbon estimates will be useful for planners and policy-makers in blue carbon management plans.

Seagrass as a potential carbon storage

Seagrass is one of the largest coastal carbon sinks on the planet (Duarte et al. 2013). An important part of the oceanic carbon sink is that it can capture and store up to 55% of atmospheric carbon known as "blue carbon" (Singh 2019). This carbon is reserved and stored in the form of sediments in mangroves, salt marshes and seagrass meadows. Thus, seagrass meadows play a key role in global carbon cycling and are responsible for storing up to 10–18% of the total ocean carbon mass each year. Singh et al. 2022). Research has also established that seagrass carbon storage rates are up to 35 times greater than that of tropical rainforests (Fourqurean et al. 2012; Singh et al. 2022). Blue carbon in coastal systems is more efficient than green carbon on land due to slower decomposition and greater storage in sediments. Carbon storage in seagrass ecosystems is divided into three carbon pools: 1) upper seagrass biomass, including

Figure 2. One of the seagrass species found in Fiji (*Halodule uninervis*). Image: ©GIZ Pacific

sheaths, leaf blades and attached epiphytic biota; 2) lower seagrass biomass, including rhizomes and seagrass roots; and 3) sediments, originating both inside the ecosystem (autochthonous) and outside the ecosystem (allochthonous) (Fourqurean et al. 2014). The carbon content at the bottom of the substrate is higher than at the upper biomass because carbon accumulates in the sediment. The complex and dense root system of seagrass meadows results in trapped carbon in the sediments, and continues to increase as the seagrass beds expand. Therefore, lower seagrass biomass is up to 90% of the total plant biomass which, if left undisturbed, can be stored in seagrass ecosystems for a very long time (millennia) (Howard et al. 2014).

The role of seagrass in climate change mitigation

Seagrass habitats also increase coastal protection by trapping and stabilising sediments and dissipating wave energy, thereby allowing suspended material to settle on the bottom and increase water clarity. They are also considered to be "ecosystem engineers", playing key roles in ecosystem organisation. Seagrasses provide conditions and resources essential for species to complete their life cycles, and help to maintain niche diversity by supporting complex habitat structures on which thousands of other species depend. Seagrasses are nutrient sinks, buffering or filtering excess chemicals, and act as nutrient pumps by releasing important compounds into nutrient-poor regions. This service is estimated to be worth over USD 29,000 (equal to FJD 65,000) per hectare per year (Singh 2019). Additionally, seagrasses could potentially have wastewater treatment properties. They may be able to remove various disease pathogens from seawater, such as Enterococcus, which affects humans, fishes and invertebrates, and reduces coral reef diseases by 50% in relative abundance of bacteria (Lamb et al. 2017).

Figure 3. Picture of degraded (left) and non-degraded or healthy (right) seagrass meadows in Suva, Fiji. Image: ©Shalini Singh

Conservation efforts around the Pacific

Scientists have found 16 varieties of seagrass in the Pacific, with one subspecies found only in Fiji, Tonga and Samoa. A recent study from selected coastal Fijian sites have acknowledged and confirmed that seagrass habitats in these areas can be carbon sinks. The soil carbon contents ranged from 0.50% to 0.95%, which is lower than the reported

Figure 4. Fiji National University's Dr Shalini Singh during a seagrass restoration demonstration with volunteers of the World Wide Fund for Nature (WWF) Pacific. Image: ©GIZ Pacific

global average of 2.0% (Singh et al. 2022). This study, which used the Intergovernmental Panel on Climate Change (IPCC) methods, investigated the carbon storage potential of small seagrass plants in Fijian coastal communities. The study confirmed that more carbon is stored in seagrass meadows than adjacent unvegetated areas, and carbon contents depend on seagrass species, geomorphic context and local environment influences. Carbon storage in plants and seagrasses help combat the increase in atmospheric carbon. Therefore, it is critical to preserve and sustain seagrass areas.

In Solomon Islands, dugongs and seagrass meadows are closely linked to customs through myths such as that of Lau Lagoon on the north coast of Malaita Island (Worldfish 2018), and many people in Lau Lagoon will not hunt or eat dugongs. The lagoon harbours the largest seagrass meadow in Solomon Islands. In the past, conservation efforts have been coordinated by the Wildlife Conservation Society, WorldFish, WWF and The Nature Conservancy (TNC). TNC for instance is currently including nesting beaches for endangered hawksbill turtles and a focus on nature-based solutions.

Papua New Guinea has the highest number of seagrass species in the Pacific, yet these species remain underestimated and threatened. Work on the conservation of seagrass ecosystems and protection have been largely done by the Locally Managed Marine Area Network in partnership with local tribes. Due to a lack of monitoring and limited survey data, local threats are not fully understood. While the recently passed Protected Areas Policy[6] allows for seagrass protection, it does not include seagrass species. Currently, TNC in collaboration with the PNG Climate Development Authority is working on developing a Blue Carbon Ecosystems Policy Framework to provide a structure and policy pathway for its blue carbon ecosystems. PNG is also home to tidal marshes, which makes it unique to other Pacific Island countries.

The Vanuatu Fisheries Department (VFD) and the Pacific Community (SPC) have developed a monitoring system that has been adopted from Seagrass Watch. To date, 13 species of seagrasses have been confirmed in Vanuatu's waters, with one likely error as it is not supported by an herbarium specimen (McKenzie and Yoshida 2017). Marine protected areas, locally known as *tabu erias*, are set up by traditional landowners in coastal communities that cover the reef, seagrass meadows and mangrove ecosystems as part of the larger Community-Based Fisheries Management Program that VFD implements. Through adaptive management, VFD collaborates with local communities to conduct various habitat and resource monitoring surveys (creel and underwater), presenting the results back to communities to drive management changes. Non-governmental organisations (NGOs), such as the Vanuatu Environmental Science Society, also contribute to the monitoring of seagrass areas in prominent communities around Vanuatu.

Threats and challenges

There are various threats to seagrass ecosystems, including climate change, coastal development, sedimentation (land-use changes), storm surges, pollution, tropical cyclones and overfishing. These are further exacerbated by a lack of regulations to monitor seagrass ecosystems. Furthermore, Pacific communities' lack of awareness and recognition of seagrass ecosystems often hinders conservation efforts, even though most coastal communities rely on its marine resources.

Research gaps exist on seagrass ecosystems' adaptive capacity to climate change, including ocean acidification and investigation of overpredation, which calls for long-term monitoring and data collection. Monitoring should include assessing seagrass distribution and health over time. The potential for blue carbon markets is still unknown. Therefore, knowledge gaps need to be addressed by further research to assess variability in carbon accumulation in seagrasses and sediments around the Pacific for site-specific data.

[6] https://www.spc.int/CoastalFisheries/Legislation/legaltext/7258f9ff-28c2-4920-9787-5f7e5f078532

Figure 5. Participants at the MACBLUE project inception workshop in Honiara during a mapping exercise on the extent of seagrass and mangrove areas in Solomon Islands. Image: ©GIZ Pacific

Figure 6. Participants of the World Seagrass Day hybrid *talanoa* session held on 1 March 2024 at the SPC Lotus Building in Suva.
Image: ©GIZ Pacific

Opportunities

More research and outreach awareness are needed for the promotion and recognition of seagrass ecosystems in the Pacific. It is important, however, that this awareness provides linkages between seagrass ecosystems and with other marine life and ecosystems. For instance, the link between seagrass as a source of food for dugongs and sea turtles. Additionally, it can be incorporated into other ecological conservation awareness and community-based fisheries management initiatives that already exist within government, academia and NGOs. The importance of NGOs such as the Locally Managed Marine Area Network, and local communities in protecting and managing marine ecosystems through engagement and community involvement is crucial. Emphasis should be placed on hands-on learning for citizen science initiatives.

To create a better understanding of the loss and general state of seagrass ecosystems in the Pacific Islands,[7] MACBLUE is currently mapping the extent of seagrass ecosystems in Fiji, PNG, Solomon Islands and Vanuatu. This will help better understand drivers of degradation and identify the most important threats. The project will additionally test appropriate management strategies. The resulting data will allow inventories of associated natural capital and will support government partners in their efforts to strategically develop and implement conservation, management and rehabilitation efforts.

This initiative, as well as many others by civil society, governments, and academia, should finally help keep seagrass meadows in the public mind and effectively contribute to their conservation. Only then, can we maintain these unsung heroes of ocean life so that they can continue to contribute to our well-being.

Conclusions

The Pacific Islands region has been identified as having limited information on carbon storage in tropical seagrass species and meadows. The available literature on seagrasses in the Pacific is very limited and for a lot of the available data, ground-truthing is needed. Where possible, more research is needed to drive actions to lobby for a specific or standalone seagrass policy.

A healthy seagrass meadow supports fisheries that in turn support people and income-generating activities; therefore, more attention is needed in seagrass conservation and management. While there is slow shift towards a greater recognition of seagrass ecosystems in the Pacific, this is mostly done as part of community-based fisheries management in collaboration with conservation NGOs. Due to their importance in climate change mitigation, biodiversity conservation, and the local economy, it is vital that we protect this ecosystem together using a coordinated and unified approach.

Acknowledgements and disclaimer

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The views expressed in this article are the authors' and do not necessarily reflect the view of their organisations.

[7] See the MACBLUE project webpage: www.macblue-pacific.info

References

Duarte C.M., Losada I.J., Hendriks I.E., Mazarrasa I. and Marbà N. 2013. The role of coastal plant communities for climate change mitigation and adaptation. Nature Climate Change 3: 961–968. DOI: 10.1038/NCLIMATE1970

Fourqurean J.W., Duarte C.M., Kennedy H., Marba N., Holmer M., Mateo M.A., Apostolaki E., Kendrick G.A., Jensen D.K., McGlathery K.J. and Serrano O. 2012. Seagrass ecosystems as a globally significant carbon stock. Nature Geoscience 5(7):505–509. https://www.nature.com/articles/ngeo1477

Fourqurean J.W., Johnson B., Kauffmann J.B. and Kennedy H. 2014. Conceptualizing the Project and Developing a Field Measurement Plan. p. 25–38. In: Howard J., Hoyt S., Isensee K., Pidgeon E. and Telszewski M. (eds). Coastal Blue Carbon: Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows. Arlington, Virginia: Conservation International, Intergovernmental Oceanographic Commission of UNESCO, International Union for Conservation of Nature. https://seagrass.fiu.edu/resources/publications/Reprints/Fourqurean%20et%20al%20conceptualizing%20project%20Blue%20Carbon%20Methods%202014.pdf

Howard J., Hoyt S., Isensee K., Pidgeon E. and Telszewski M. (eds). 2014. Coastal Blue Carbon: Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows. Gland, Switzerland: International Union for Conservation of Nature. https://unesdoc.unesco.org/ark:/48223/pf0000372868

Lamb J.B., Van de water J.A.J.M., David G.B., Altier C., Hein M.X., Fiorenza E.A., Abu N., Jompa J. and Harvell C.D. 2017. Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. Science 355(6326):731–733. https://www.jstor.org/stable/24918406

McKenzie L.J. 2008. Seagrass Educators Handbook. Clifton Beach, Australia: Seagrass-Watch. https://www.seagrasswatch.org/wp-content/uploads/Citizenscience/education/pdf/Seagrass_Educators_Handbook.pdf

McKenzie L.J and Yoshida R.L. 2017. Proceedings of a workshop for monitoring and mapping seagrass habitat, 7–9 August 2017, Port Vila, Vanuatu. Seagrass-Watch. 44 p

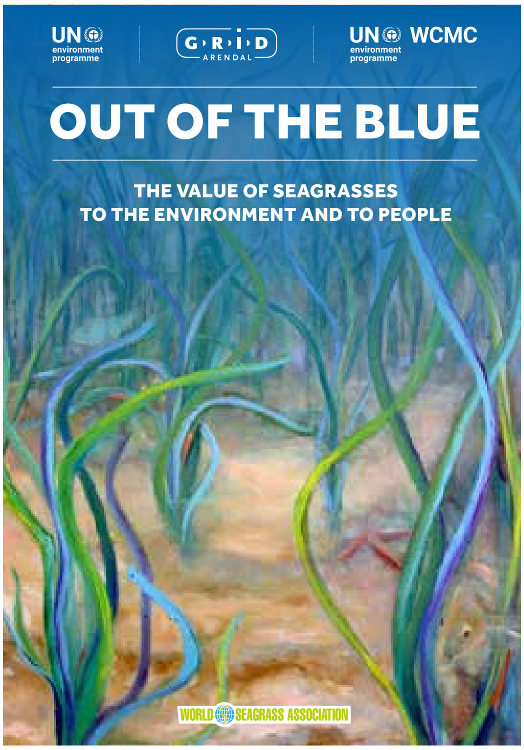
Nordlund L.M., Koch E.W., Barbier E.B. and Creed J.C. 2017. Seagrass ecosystem services and their variability across genera and geographical regions. PLoS One 12(1);1–23. https://doi.org/10.1371/journal.pone.0169942

Singh S. 2019. Importance of seagrasses: A review for Fiji Islands. International Journal of Conservation Science 10(3):587–602. https://ijcs.ro/public/IJCS-19-54_Singh.pdf

Singh S., Lal M., Southgate P.C., Wairiu M. and Singh W. 2022. Blue carbon storage in Fijian seagrass meadows: First insights into carbon, nitrogen and phosphorus content from a tropical southwest Pacific Island. Marine Pollution Bulletin. 176:113432. https://doi.org/10.1016/j.marpolbul.2022.113432

Waycott M., Duarte C.M., Carruthers T.J.B., Orth.R.J., Dennison.W.C., Olyarnik S., Calladine A., Fourqurean J.W., Heck K.L., Hughes A.R., Kendrick G.A., Kenworthy W.J., Short F.T. and Williams S.L. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. Proceedings of the National Academy of Sciences of the United States of America 106(30):12377–12381. https://doi.org/10.1073/pnas.0905620106

WorldFish. 2018. Conservation strategy for dugongs and seagrass habitats in Solomon Islands. Penang, Malaysia: WorldFish. https://digitalarchive.worldfishcenter.org/bitstream/handle/20.500.12348/1987/2018-22.pdf?sequence=1&isAllowed=y



The 2020 UN report on the value of seagrasses: Out of the Blue. https://www.unep.org/resources/report/out-blue-value-seagrasses-environment-and-people

Conservation International launches Phase 2 of jurisdictional initiatives for Pacific tuna in Fiji, New Caledonia and Samoa

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Introduction

Jurisdictional initiatives (JIs) – also referred as jurisdictional approaches (JA) – are place-based approaches in commodity-producing geographical areas (Kittinger et al. 2021). In 2021, Conservation International (CI), with support from the Walmart Foundation, launched place-based JIs in Fiji and New Caledonia to drive holistic improvements within each country's albacore tuna fisheries. By aligning incentives among key stakeholders – including producers, government, civil societies, and private sector entities – jurisdictional initiatives utilise policy and market-based approaches to support environmental, social and economic improvements at scale.

Jurisdictional initiatives are gaining momentum within the sustainable seafood movement as an effective model to bring these elements together, focusing efforts at scale to ensure sustainability and secure long-term benefits for stakeholders. This approach moves beyond fragmented environmental and human/labour rights projects, instead focusing efforts on place-based investments that ensure a continued supply of seafood products, while contributing to national and global conservation goals that address biodiversity loss, climate change impacts and social responsibility.

Driving alignment around management practices, buyer-sourcing commitments (e.g. some of the large market retailers are moving towards the standard policy of sourcing from geographies that have a 100% monitored fishery either through human observers or electronic monitoring systems), and supply chain accountability are integral to the success of this work. Strong sustainability policies and standards must be adopted by management authorities, which in-turn need to be supported by aligned voluntary commitments and sourcing policies of seafood suppliers and buyers. Transparency and accountability systems to ensure compliance must also be implemented.

By simultaneously focusing on stakeholder engagement, government policies and market incentives, and at the proper geographic scale, JIs have the capacity to unlock holistic change and ensure both the longevity and resilience of ecologically and economically important species such as albacore tuna.

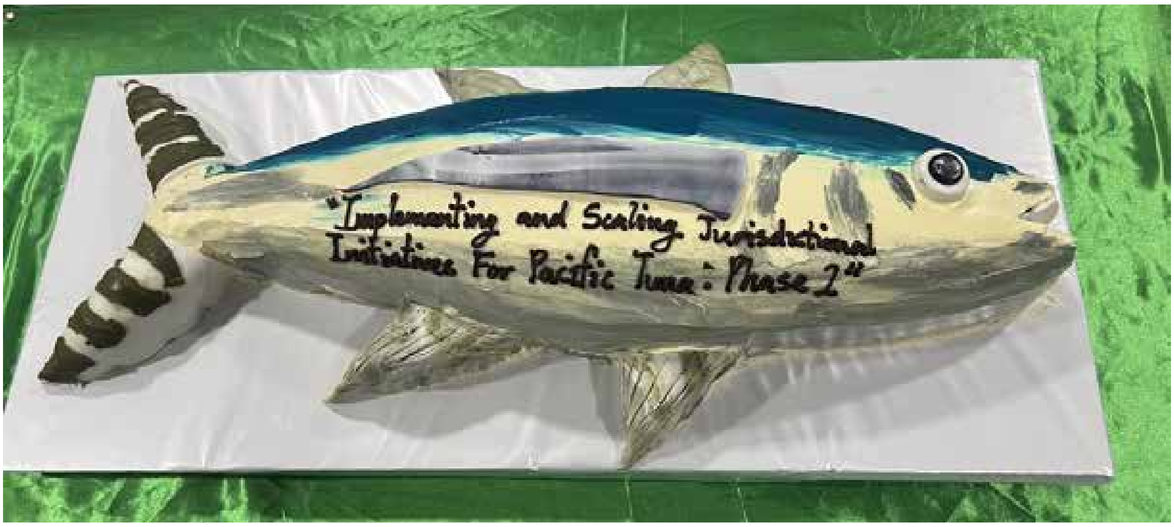

Figure 1. The cake that was made in the shape of a tuna to celebrate the commitment of the three countries to this jurisdictional initiative. Image: ©Conservation International

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Figure 2. Phase 2 launch participants from Fiji, New Caledonia, Samoa and Conservation International's global team.
Image: ©Conservation International

Project objectives

In 2022, after two years of collaborative efforts, CI signed five-year memoranda of understanding with the fishing industries in Fiji and New Caledonia that focused on strengthening the performance of domestic longline tuna fisheries. This partnership was further strengthened in Fiji through a three-year partnership statement with the Fijian government.

The next phase of CI's work will focus on the following.

Implementing co-designed improvements in Fiji and New Caledonia

In Fiji, this will include addressing fishing mortality of protected species; illegal, unreported and unregulated (IUU) fishing; decent work at sea; and a lack of transparency or electronic monitoring within the fleet. As part of this work, we aim to ensure that fishers, the private sector partners, government, and local civil society have improved awareness of legal and ethical human rights obligations and the ability for rights holders to organise, know and claim their rights. In New Caledonia, we will work closely with the government to support the establishment and implementation of new marine protected areas. CI also plans to conduct an assessment to determine whether New Caledonian fishing methods are compatible with new International Union for Conservation of Nature categories for marine protected areas. We also plan to work with private sector partners to address specific improvements regarding human and labour rights.

Expanding place-based tuna initiatives to Samoa

Building on our collaborative work in Fiji and New Caledonia, CI is expanding our jurisdictional work to Samoa. Project implementers will focus on building relationships and working with local stakeholders and government entities to map regulatory deficiencies and supply chain risks that may be perpetuating environmental and human rights abuses within Samoa's waters.

Scaling to the subregional albacore production geography

Noting the highly migratory nature of albacore tuna across the South Pacific, sustainable management is required at a scale that matches the wide distribution of tuna to ensure their longevity, environmental sustainability, and commercial viability. While tangible progress can be achieved at the country level, those efforts must be expanded regionally. To support this, CI is engaging in regional forums and supporting regional partnerships that can help drive collective action.

Regional- and global-scale tuna engagements

Driving alignment and collective action around a set of priority tuna issues and approaches requires working beyond the South Pacific albacore production area. For instance, climate change will have profound consequences for the regional and global management of tuna fisheries. This will require ongoing engagement with regional and global forums such as the Western and Central Pacific Fisheries Commission, the InterAmerican Tropical Tuna Commission, the Pacific Tuna Forum, and the NGO Tuna Forum to enhance cooperation and collaboration frameworks.

Phase 2 Launch meeting

Conservation International launched the second phase of its place-based work in a four-day workshop held in Suva, Fiji from 25 to 28 March 2024. Dr Sivendra Michael, Fiji's Permanent Secretary of Environment and Climate Change, opened the workshop. The first day focused on a learning exchange with regional partners and national stakeholders – Council of Regional Organisations in the Pacific agencies, the Pacific Community, Australian National Centre for Ocean Resources and Security, the Fiji Fishing Industry Association, government agencies from Fiji (Ministry of Fisheries and Forests and Ministry of Employment, Productivity, and Industrial Relations), and training institutes such as the Pacific Centre for Maritime Studies, formerly known as the Fiji Maritime Academy.

The rest of the workshop was centered on developing a programmatic approach and project deliverables for the next 18 months. Discussion topics included:

- a Pacific fisheries strategy for coastal and offshore fisheries;
- a knowledge and learning exchange between CI staff in Fiji, New Caledonia and Samoa;
- the challenges and opportunities that exist at the nexus of marine conservation and fisheries management; and
- enhancing collaboration and innovation in the subregional management of South Pacific albacore tuna.

Our hope is that the establishment of multiple, national-level, albacore-focused JIs within the South Pacific, alongside regional and global-scale engagements within the wider sustainable tuna community, can act as a catalyst to drive long-term, positive change within South Pacific albacore fisheries and the communities that deeply depend upon them.

Figure 3. Project teams from Fiji, New Caledonia, Samoa and Conservation International's global team. Image: Conservation International

Expected outcomes

The expected outcomes of this project are discussed below.

Implementation of co-designed albacore tuna initiatives in Fiji and New Caledonia

Fiji

In Fiji, new tuna fishery improvement areas are identified through the MSC Standard 3.0 assessment[7] and Social Responsibility Assessment Tool.[8] Government and private-sector partners engage in addressing specific tuna fishery improvements, including fishing mortality of protected species, IUU fishing, decent work conditions at sea, and lack of transparency within the fleet. Fishers, private-sector partners, government and local civil society have improved awareness of the legal and ethical human rights obligations and the ability to organise, know and claim rights. New investment opportunities and potential sourcing arrangements to improve the economic performance of Fiji's domestic tuna fisheries have been identified.

New Caledonia

The government supports the establishment and implementation of new Marine Protected Areas (MPAs). Assessments are completed and socialised to determine whether new highly protected MPAs have a significant impact on domestic fisheries and whether New Caledonian fishing methods are compatible with new IUCN categories IV (habitat/species management area) and VI (protected area with sustainable use of natural resources). Government and private-sector partners engage in addressing specific tuna fishery improvements identified through the social responsibility assessment and the Kanak vision of the ocean and its protection.

Expanding tuna initiatives to one new Pacific Island country

Key enabling conditions and relationships required to build a JA in one new Pacific Island country are identified in alignment with the credible JI guidance documents. Regulatory deficiencies and supply chain risks that may be perpetuating environmental and human rights abuses within an exclusive economic zone are mapped, including opportunities, entry points and policy levers (domestic, private sector) to address institutional and data gaps and multi-lateral partnerships. Immediate impact of these activities will be measured through the number and level of government and supply chain partners meaningfully engaged in scoping: 1) the institutional and regulatory frameworks enabling environmental and social issues; 2) the existing mechanisms that will support or impede collaboration to address them; and 3) data deficiencies or gaps.

Scaling to the subregional albacore production geography

National-scale interventions applicable to the ecological distribution of South Pacific albacore tuna populations are co-identified and supported by the South Pacific Group (SPG), Pacific Island Forum Fisheries Agency, Pacific Community, and International Labour Organization, among other stakeholders associated with the South Pacific albacore region.

Regional and global-scale tuna engagement

The latest climate science is leveraged by national governments and members of the Western and Central Pacific Fisheries Commission (WCPFC) to implement effective climate adaptive policies. Immediate impact of these activities will be measured through the number of regional workshops to incorporate climate-resilience models into tuna management. WCPFC members have increased awareness of their legal and ethical duty to protect human rights through the binding Conservation and Management Measure (CMM) on crew labour standards and its close association with IUU fishing countermeasures under a changing climate. Immediate impact of these activities will be measured through the inclusion of a roundtable at the WCPFC annual meetings on the CMM on crew labour standards.

Acknowledgment

Conservation International acknowledges the Walmart Foundation for funding the second phase of our place-based, jurisdictional work in Fiji, New Caledonia and Samoa.

Reference

Kittinger J., Bernard M., Finkbeiner E., Murphy E., Obregon P., Klinger D., Schoon M., Dooley K. and Gerber L. 2021. Applying a jurisdictional approach to support sustainable seafood. Conservation Science and Practice. https://doi.org/10.1111/csp2.386

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[1] The MSC Fisheries Standard version 3 | Marine Stewardship Council
[2] https://riseseafood.org/topics/the-social-responsibility-assessment-tool/

Overcoming legal barriers: Advancing community-based fisheries management in Kiribati

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Introduction

In Kiribati, the official endorsement of community-based fisheries management (CBFM) plans has faced significant challenges during the programme's inception in 2014. At that time, pilot communities were actively developing plans, yet the absence of specific legal provisions supporting the adoption of CBFM plans posed a major obstacle. Kiribati's Fisheries Act 2010 primarily focused on offshore fisheries, neglecting coastal fisheries management, thereby complicating the conservation and management of coastal marine resources.

In response to this regulatory gap, efforts began in 2015 to develop targeted coastal fisheries regulations 2019[1] that were aimed at the conservation and management of coastal marine resources. This collaborative endeavour, spanning four years, was facilitated by legal advisors from the Pacific Community (SPC), the Attorney General's office, and the University of Wollongong in Australia. Finally endorsed in late 2019 and operationalised in 2020, the Coastal Fisheries Regulations not only established fisheries management rules but also laid out specific requirements for legalising CBFM plans, marking a significant milestone in the journey towards sustainable fisheries management in Kiribati.

The task of legalising a CBFM plan commenced in early 2020, with extensive assistance from SPC's legal advisors. Given the groundbreaking nature of this work, efforts were focused on one community to undergo the legalisation process. Nanikaai Village emerged as the chosen community due to its geographical proximity to national agencies (i.e. Island Council office, Attorney General's office, and Coastal Fisheries Division), which would facilitate efficient communication with Nanikaai community members.

Journey towards official endorsement

Nanikaai Village is within the Teinainano (South Tarawa) Urban Council, and, is the smallest recognised ward in the area. Despite its size, Nanikaai has been actively engaged in environmental conservation efforts, particularly through initiatives such as beach clean-ups. The village's successful implementation of various projects, ranging from health to gardening, has raised attention from multiple ministries, making it a focal point in the urban area.

The initial engagement with Nanikaai in the CBFM programme occurred in 2019 through a collaborative health project on ensuring food security with assistance from the CBFM programme. Through this engagement, Nanikaai managed to draft its community fisheries management plan. Subsequently, the Kiribati Ministry of Fisheries further reinforced Nanikaai's engagement in CBFM efforts. Through the assistance of the CBFM project, Nanikaai Village was able to develop a draft management plan, which was later consolidated into a final plan by late 2019.

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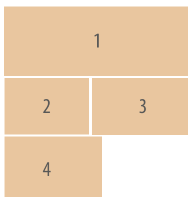
3 Fisheries (Conservation and Management of Coastal Marine Resources) Regulations 2019; https://purl.org/spc/fame/cfp/legaltext/cepsi

Nanikaai community gets ready to celebrate. Image: © Kiribati MFMRD



1 - Nanikaai Village members and stakeholders celebrate the endorsement of their CBFM plan. Image: © Kiribati MFMRD

2 - Diplomatic corps representatives take part in the training activities. Image: ©Kiribati MFMRD

3 - Raising awareness among youth through a drama competition. Image: © Kiribati MFMRD

4 - Official signing ceremony of Nanikaai community-based fisheries management plan. Image: © Kiribati MFMRD

The long-term vision of Nanikaai's CBFM plan states: "Nanikaai will lead the way in overcoming the effects of declining marine resources, ecosystem habitat degradation, and ocean acidification". Management measures in Nanikaai's CBFM plan include:

- a prohibition on the use of destructive fishing gear and methods;
- reinforcement of nationally established government rules;
- specific village size limits;
- mangrove and seagrass planting and protection areas; and
- and the establishment of a marine protected area (MPA) that is primarily aimed at the protection of the strawberry conch (*Conomurex luhuanus*; te nouo) and ark shells (*Anadara* spp; te bun).

With the enactment of the Coastal Fisheries Regulations 2019, the process of legalising the Nanikaai's CBFM plan commenced in 2020. This marked the first instance of a CBFM plan to undergo legalisation, presenting unique challenges that were made easier through the assistance of SPC's legal advisors, the University of Wollongong, and an I-Kiribati legal advisor working at SPC during that time who, through her understanding of the local context, enabled particular concerns and challenges specific to Kiribati to be addressed appropriately throughout the process.

In early 2021, MFMRD started demarcating Nanikaai's MPA with visible marker buoys, despite the endorsement of the CBFM plan still pending. These markers served not only to raise public awareness but also to solidify the boundaries of Nanikaai's marine area for better visibility.

As stated, the primary objective of the MPA is to conserve and replenish the stock of ark shells and strawberry conch. Although fishing within the MPA is restricted under Nanikaai's CBFM plan, entry for recreation and research purposes is permitted upon obtaining an approved permit from the community, and adherence to the code of conduct outlined in the endorsed management plan.

Impacts of the MPA

Since the demarcation of the MPA, there has been a noticeable decline in fishing activity within its boundaries, thanks to greater awareness. One year on, Nanikaai residents and those from neighbouring areas on South Tarawa and Betio are increasingly mindful of the MPA boundary. Consequently, significant positive changes were observed in the abundance of strawberry conch and ark shells.

Community feedback and socialeconomic surveys conducted in Nanikaai supported these observations, highlighting the increase in these species. Testimonies from community members, including those from the Disability Center (Te Toa Matoa) in Nanikaai, emphasised the profound impact of the MPA. People with disabilities expressed both their surprise and satisfaction with the reduced effort in catching strawberry conch, a remarkable shift from previous years.

A statement by Mr Tabaia, a representative from Te Toa Matoa, acknowledged the strong positive effect of CBFM: "It is surprising that even a person with impaired vision can gather a lot of strawberry conchs and fill up a small cracker bucket. It is unbelievable." Such testimonials serve as strong evidence of the extensive benefits that CBFM can generate, inspiring neighbouring communities to support Nanikaai and embark on their own fisheries management initiatives.

Billboard to raise awareness about Nanikaai community-based fisheries management measures. Image: © Kiribati MFMRD

Milestone for the CBFM project

On 31 January 2024, Nanikaai's village members celebrated a significant milestone as the Minister of Fisheries legally endorsed the community's CBFM plan. This achievement, after a decade of dedicated CBFM implementation efforts, stands as a testament to the commitment and perseverance of the community and the CBFM project. Nanikaai's success sets a precedent for other CBFM communities awaiting endorsement, creating momentum and recognition for their contributions to coastal marine resource management. The endorsement shines a new light on communities, especially Nanikaai knowing that their efforts have not gone unnoticed. With a legalised CBFM plan, Nanikaai is now empowered to enforce its fisheries management rules through its own governance structure and community-based compliance rules, but can further be supported by the Ministry of Fisheries to prosecute cases if necessary. Shifting towards decentralised fisheries management is more efficient and effective, and empowers communities to lead the way to sustainable coastal fisheries.

To mark this important milestone, the Ministry of Fisheries, in close collaboration with Nanikaai Village, worked with key stakeholders including the Teinainano Urban Council (Island Council of South Tarawa), line ministries (Environment and Conservation Division of the Ministry of Environment; Tourism Authority of Kiribati), and the private sector. Considering the need for wide awareness, the launching of Nanikaai's CBFM plan was held over three days, culminating with the signing ceremony. The major highlight of this event was the official signing ceremony of the Nanikaai management plan, which was witnessed by the Vice President of Kiribati and representatives of the diplomatic corps. The Nanikaai management plan was signed by the Minister of Fisheries (HM Ribanataake Awira), Mayor of Teinainano Urban Council (Baraniko Baaro) and Nanikaai Village chairman (Timeon Matatia).

In his speech, the Minister of Fisheries proudly acknowledged the extensive efforts that have gone into developing and legalising the plan, tracing its origins back to the inception of the CBFM programme in Kiribati in 2014. The recognition of communities' initiatives in fisheries management provides a reassuring pathway toward sustainable coastal fisheries, upon which the I-Kiribati people heavily depend.

Awareness raising and training

Prior to the official signing ceremony, two extra days were dedicated to awareness raising and training workshops. Social media influencers were engaged to produce a brief play showcasing Nanikaai's management plan. The performance brought significant public attention, with over 30,000 viewers. Social media proved to be a powerful and effective method of communication, dominating social media platforms, and providing the public with valuable insights into the importance of Nanikaai's initiatives. Other initiatives included games targeting children, a drama competition, and a beauty contest to better engage the people of Nanikaai.

Training workshops were also provided to complement Nanikaai's efforts on sustainable coastal fisheries management at the community level. The Ministry of Fisheries provided training on the maintenance of outboard motors, seaweed farming, and released sea cucumber hatchlings into the demarcated MPA. Tourism Authority Kiribati provided training sessions on tourism business fundamentals, developing eco-tourism packages, and handicraft-making using repurposed plastics and seashells; all activities that would contribute to generating additional revenue for Nanikaai's community. The Environment and Conservation Division provided trainings to support Nanikaai manage waste.

Nanikaai community members were extremely happy and proud of the event and of the endorsement of their community efforts through the signing of their CBFM plan. As Nanikaai ventures onto a new path, the Ministry of Fisheries, along with key stakeholders, has ambitious plans to empower community members with the necessary capacity and knowledge, including training on community enforcement. This will enable Nanikaai community members to effectively implement their CBFM plan into the future.

Acknowledgements

We would like to thank members of Nanikaai's community, members of the Friends in Nanikaai Community Executive Committee, Teinainano Urban Council, Ministry of Fisheries and Marine Resources Development, Ministry of Environment, Lands and Agriculture Development, and Tourism Authority Kiribati. We would like to acknowledge financial support from the Australian government under ACIAR project FIS-2020-172 to the CBFM project and financial support from Tobwan Waara – New Zealand Ministry of Foreign Affairs and Trade.


Women in Tabonibara engaging in agricultural initiatives to boost the village's nutrition security. ©Tarateiti Uriam, CBFM team in Kiribati

A community approach to reducing costs linked to nutritious diets in Kiribati

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Introduction

Food security in Kiribati has always been fraught with unique challenges. With a land area of just 811 km^2 that is unevenly distributed across 33 low-lying coral islands, Kiribati's land area is limited and predominantly composed of alkaline coral soil. This, coupled with factors such as tidal surges, climate change-induced sea level rise, and prolonged droughts, restricts traditional food production on the islands (SPC 2022). As a result, the diet in Kiribati heavily relies on marine foods and imported items such as rice, sugar, wheat flour, and canned meats. Despite over 70% of the diet consisting of locally produced fish and fish products, the country's heavy dependence on imported foods with low nutritional value poses significant challenges to achieving food security and health (Troubat and Sharp 2021).

The Australian-funded Community Based Fisheries Management (CBFM) project, introduced in Kiribati in 2014, aims to enhance food security through coastal fisheries management (Latu-Sanft 2021). The project has achieved success in implementing fisheries management plans in 27 communities in Kiribati (Govan and Lalavanua 2022). However, its narrow focus on marine resources has constrained its efforts to explore broader food production activities that could enhance community access to nutritious foods. Nevertheless, CBFM programmes have undergone a transformation in one of its communities, Tabonibara Village, to address the requirement for an enhanced nutritional diet.

Tabonibara Village is on North Tarawa, and grapples with food security issues due to its significant reliance on less nutritious imported foods, which has a substantial impact on community health (Delisle et al. 2016; Uriam et al. 2022). Recognising these challenges, Tabonibara villagers have expanded their CBFM efforts to include agricultural food production and marketing strategies, spearheaded by a women-led institution and supported by the entire village (Nikiari et al. 2021; Uriam et al. 2022). This study aims to assess how data-driven research, using tools such as the Cost

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of the Diet analysis[5], can support Tabonibara's mission towards healthier living. The research questions guiding this study include:

- What are the locally available foods that are inexpensive sources of essential macro- and micronutrients that can provide support to the nutritional wellbeing of the Tabonibara community?
- What is the minimum cost of nutritionally adequate and culturally acceptable diets for a typical household in Tabonibara village?
- How can the cost of diet analysis help in promoting better food and nutrition security outcomes in Tabonibara and the rest of Kiribati?

Methodology

Cost of the Diet methodology and software

This study utilised the Cost of the Diet (CotD) methodology, an innovative approach developed by Save the Children as a programme design and advocacy tool to inform discussions on food, dietary diversity, nutrition and livelihoods. The CotD method employs a software that estimates the financial resources needed by an average family to obtain the minimal required quantities of calories, protein, fat and micronutrients recommended by the World Health Organization and the Food and Agriculture Organization of the United Nations. By utilising linear programming, the CotD software selects a combination of locally available foods that fulfil the macro- and micronutrient requirements of individuals at the lowest possible cost. This enables users to assess the affordability of the diet by comparing its cost along with non-food expenditure with income. The software also allows users to create models to predict the potential impact of various food security interventions, such as feeding programmes, on the affordability of a nutritious diet (Deptford et al. 2017; Haque and Rana 2019).

While the CotD methodology and software offer significant utility, it is crucial to recognise the limitation inherent in the analytical process and the resultant outcomes provided by the software. These limitations include:

- The software's projected diet represents the theoretical minimum-cost diet tailored exclusively to the specified family size and composition.
- Since individual micronutrient requirements are unknowable, the software sets the recommended nutrient intake (RNI) at 2 standard deviations above the mean to mitigate deficiency risks. Consequently, if the foods selected by the software fully meet the family's RNIs, it could result in nutrient intake surpassing the needs of 97% of individuals.
- While the software can pinpoint a diet meeting recommended macro- and micronutrient levels using a relatively small selection of foods, it operates under the assumption that this diet would be consumed daily by family members at every meal, which may not be practical.
- The software overlooks several nutrient requirements, such as vitamin D, iodine, essential amino acids, and essential fatty acids. Vitamin D is not factored in as it can be synthesised in skin exposed to UV light, while iodine's absence is due to variations in soil affecting its presence in food. Furthermore, essential amino acids and fatty acids data are often missing from food tables.

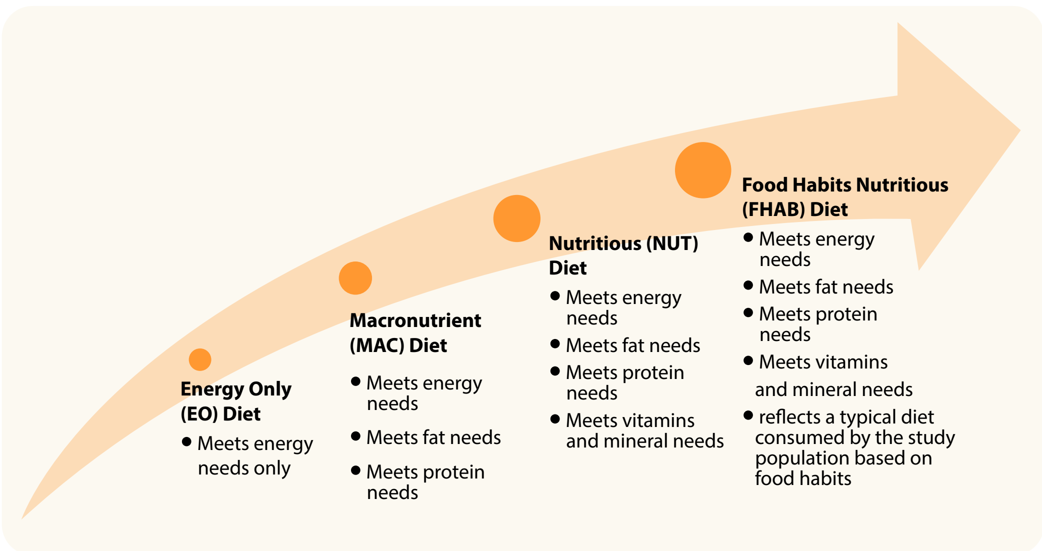


Figure 1: Summary and definitions of diets analysed by the Cost of the Diet software.

- In interpreting CotD results, it is essential to consider intra-household food distribution, as the software calculates food quantities for the entire family based on aggregate RNIs, while food distribution within households often reflects individual nutrient needs.
- The method does not accommodate additional nutritional requirements for illness or recovery due to insufficient data.
- Lastly, it is important to understand that the CotD software is not intended for diet planning or for analysing the nutrient composition of specific foods.

Identification of local foods, their nutritional information, and average household income in Tabonibara

The study utilises national data for household income because local data for Tabonibara is unavailable. According to the latest Kiribati Household Income and Expenditure Survey (HIES) report, the average annual income for rural households in Kiribati is AUD 10,907, while the median lowest household income is estimated at AUD 8736. The report also indicates that the average annual non-food expenditure is around AUD 5227.

Local foods are classified based on the *Food Consumption in Kiribati* report, which incorporates data from various sources such as the 2019 Kiribati HIES, the Global Individual Food Consumption data tool, and the Pacific food guideline (KNSO and SPC 2021). Additional local foods, including those commonly consumed in Tabonibara, were included based on information from primary sources such as the CBFM team and Tabonibara villagers.

Nutritional information for most food crops were added from data factsheets titled "Tackling NCDs from the ground up: Nutritious leafy vegetables to improve nutrition security on Pacific atolls (Kiribati and Tuvalu)" (Lyons 2018). Nutritional information for all other selected foods were sourced from the Pacific Islands Food Composition Tables[6] and the in-build food nutrition database of the CotD software that were compiled from sources that include the World Food Dietary Assessment System published by FAO[7]and the United States Department of Agriculture[8] (Haque and Rana 2019).

Data collection and modelling

The data collection process targeted food preparers who are mainly women. Data collection comprised a multifaceted approach, including 32 household interviews, 7 market surveys, and 2 focused group discussions (FGDs). Household interviews were meticulously distributed across three distinct sectors of Tabonibara Village. Market surveys encompassed various market types, including fish distributors, local stores, and agricultural producers. Survey forms were developed by the CotD software. Equipment used was recommended by the CotD methodology.

FGDs were useful in uncovering food consumption insights and healthy diet promotion efforts. They were conducted throughout the research to enhance an understanding of the survey results and assist in developing supportive models for the overall study.

Table 1: Themes and topics explored during focus group discussions (FGD).

Themes	Explored topics
Community policy on improving community nutrition	Examining community strategies that are implemented to enhance community nutrition.
Food consumption patterns	Top 10 most consumed foods in the village. Are they locally produced or imported and what are their consumption constraints? How do FGD participants perceive the stability, reduction, or increase in consumption of these foods over the last 10 years and reasons behind it? -Special occasion foods, food supplements, and taboo foods.
Household income and expenses, and cash crops	Approximate household income in Tabonibara. Lists of cash crops and their significance to the village's livelihood.
Consumption constraint review	Review of household food consumption constraints from the previous trip's results. Examination of constraints associated with the most consumed foods. Comparison of food consumption constraints from the FGD session.
Scenario overview	Review of the list of food crops recommended by the CotD software. Discussion of scenario development to support Tabonibara initiatives.

[6] https://pacificdata.org/data/dataset/food-nutrients-df-food-nutrients
[7] https://www.fao.org/infoods/infoods/tables-and-databases/en/
[8] https://fdc.nal.usda.gov/

A family model used in this study was devised through FGDs to reflect typical household demographics in Tabonibara. This model encompasses a family of five: a father, a pregnant mother on her second trimester, a five-month-old baby, and two children from the age group 6–19 years.

Results

Cost of the Diet analysis Part 1: Hypothetical Baseline diet Cost

Table 2 illustrates the assessed affordability of each diet recommended by the CotD software, derived from the baseline cost of each diet as suggested by the software. Calculations were conducted for two types of households: those with median-low annual incomes of AUD 8736, and average annual income of AUD 10,907. The annual non-food expenditure cost for both household types are set at AUD 5227.

As presented in Table 3, the affordability gap for the baseline food habits nutritious diet (FHAB)[9] diet ranges from AUD 4482.76 to AUD 6653.76. Table 3 also indicates that households with a median low annual income cannot afford a nutritious diet. However, a household with an average annual income can only afford a nutritious diet if they do not consider their food habits.

Scenario development to improve food security in Tabonibara

Part of this study, which focuses on supporting Tabonibara agricultural initiatives, developed an initial scenario that incorporates food crops, which was agreed on through FGDs. Table 3 outlines a "What if" model for an agricultural scenario wherein crops are chosen for their adaptability, cost-effectiveness, nutritional value, practicality, and high likelihood of successful cultivation.

Moreover, it is crucial to recognise the fisheries potential in Tabonibara as it is a coastal community where fish can be readily accessed through fishing. Considering the community's circumstances, this study also integrates a fishery scenario "What if" question, to try to understand the potential of fisheries in lowering the cost of a nutritious diet in Tabonibara.

Table 2: Affordability estimates for baseline cost of a nutritious food-habits nutritious diet (FHAB) only diet for a family of five.

	Household with an average annual income of AUD 10,907	Household with a median low annual income of AUD 8736
Energy only diet	3372.71	1201.71
Macronutrient diet	3219.01	1048.01
Nutritious diet	882.17	**-1288.83**
Baseline FHAB diet	**-4482.76**	**-6653.76**

Table 3: Scenario conditioning

Scenario	Food groups	Type of food	"What if" scenario	Food Habit Diet Constraints – CotD adjustments
Agriculture scenario Developed through support from FGDs	Vegetable and vegetable products, fruits and fruit products	Amaranth, stem, raw/cooked (*te mota*), bele (*nambere*), spinach cooked and raw, cooked pumpkin, cooked pumpkin leaf, boiled sweet potato, cooked sweet potato leaf, cooked Chinese cabbage pe tsai, raw Chinese cabbage pak choi, tomato	**What if people in Tabonibara access these foods through home gardening initiatives?**	The hypothetical consumption frequency of these specified foods for this scenario were adjusted from a minimum of one day to a maximum of three times daily.
Fisheries scenario Developed regarding fisheries potential in lowering nutritious diet cost.	Fish, seafood, amphibians, and invertebrates	Reef fish cooked and raw, octopus cooked, dried salted fish, snapper	**What if Tabonibara villagers do not eat imported fish products but consume fish that is freshly harvested/fished from the lagoon?**	The hypothetical consumption frequency of these specified foods in this scenario were changed to vary from at least once a day to a maximum of two times a day. Consumption of imported fish items, such canned fish, is eliminated in this scenario.
Agriculture and fisheries scenario	Foods are combined from the agriculture scenario and fisheries scenario		**Combined "What if" scenario**	CotD consumption constraint adjustments combined from both the agriculture and fishery scenarios.

[9] The Baseline FHAB diet reflects the financial status in achieving a healthy diet in Tabonibara, based on the village's food consumption patterns as of August 2023. https://fdc.nal.usda.gov/

Fried fish with rice and the smaller leaves of a Noni tree, known locally as 'taberan te non'. Image: ©Tarateiti Uriam, CBFM team in Kiribati

Cost of the diet analysis Part 2: Integrating the scenarios with the baseline FHAB diet data

Figure 2 demonstrates the potential reduction in food expenses in Tabonibara when the scenarios are incorporated into the baseline FHAB data. It is evident that the agriculture scenario and the combined fisheries and agriculture scenarios exhibit the most significant impact, reducing the cost of a nutritious FHAB diet by 68% and 86%, respectively.

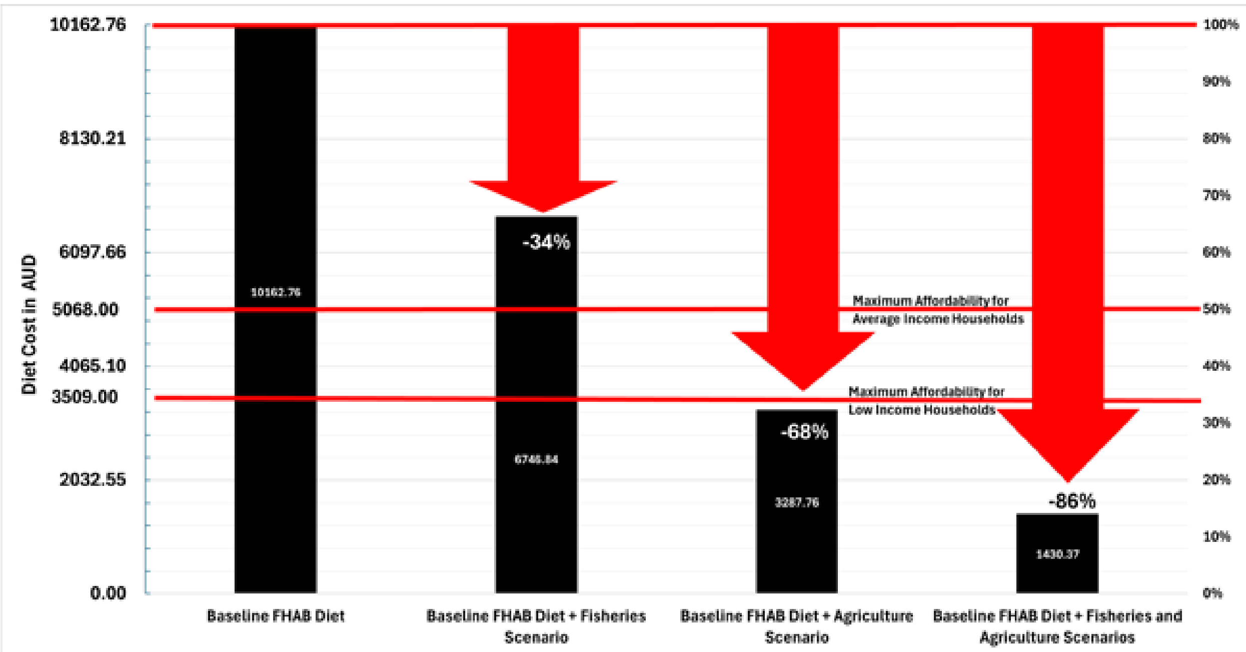
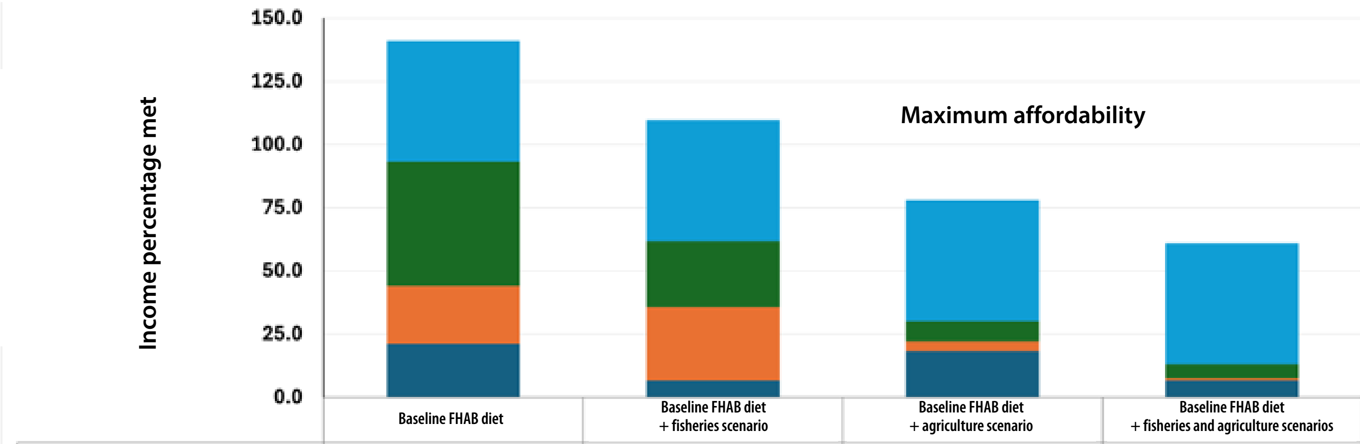
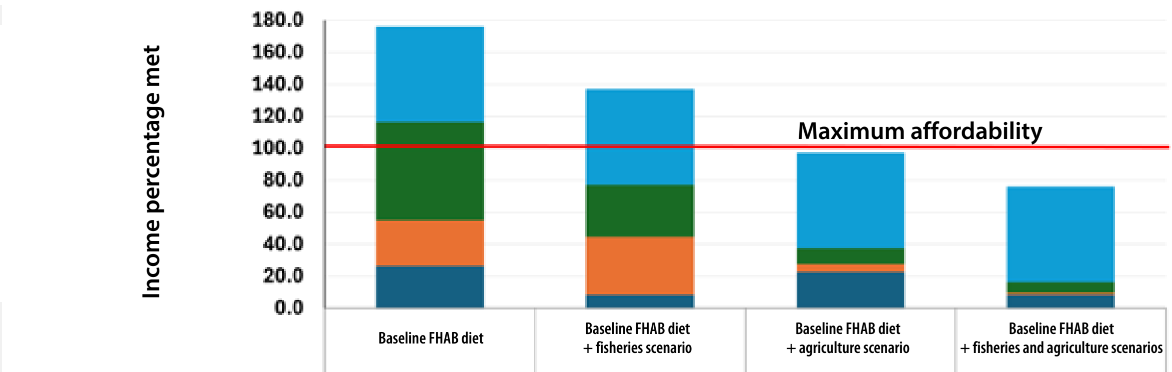


Figure 2. The potential effects of the scenarios on the baseline annual cost a nutritious FHAB diet.



	Baseline FHAB diet	Baseline FHAB diet + fisheries scenario	Baseline FHAB diet + agriculture scenario	Baseline FHAB diet + fisheries and agriculture scenarios
% non food expenditure (NFE)	47.9	47.9	47.9	47.9
% extra cost of food habits nutritious diet	49.2	26.0	7.9	5.5
% extra cost of nutritious diet	22.8	29.1	3.9	0.9
% income of energy only diet	21.2	6.7	18.3	6.7

Figure 3. Affordability comparison between the baseline FHAB diet and the three scenarios for households with an average annual income of AUD 10,907.



	Baseline FHAB diet	Baseline FHAB diet + fisheries scenario	Baseline FHAB diet + agriculture scenario	Baseline FHAB diet + fisheries and agriculture scenarios
% non food expenditure (NFE)	59.8	59.8	59.8	59.8
% extra cost of food habits nutritious diet	61.4	32.5	9.9	6.9
% extra cost of nutritious diet	28.5	36.3	4.9	1.1
% income of energy only diet	26.4	8.4	22.8	8.4

Figure 4. Affordability comparison between the baseline FHAB diet and the three scenarios for households with a median low annual income of AUD 8736.income of AUD 10,907.

Table 4: Scenario excess and shortfalls: The potential effects of each scenario on the affordability of FHAB diets.

<table>
<tr><th rowspan="2">FHAB diet and scenario models</th><th colspan="2">Excess or shortfall compared for each FHAB affordability for the two household incomes that are used in this study for a family of five (AUD)</th></tr>
<tr><th>Household with average annual income of AUD 10,907</th><th>Household with median low annual income of AUD 8736</th></tr>
<tr><td>Baseline FHAB diet + fisheries scenario</td><td>-1066.84</td><td>-3237.84</td></tr>
<tr><td>Baseline FHAB diet + agriculture scenario</td><td colspan="2">2392.24
221.24</td></tr>
<tr><td>Baseline FHAB diet + fisheries and agriculture scenarios</td><td>4249.63</td><td>2078.63</td></tr>
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The analysis reveals that the agricultural scenario and the combined fisheries and agriculture scenarios can bridge the affordability gap for households with both an average and median low annual income. The hypothetical income excess for both scenario ranges from AUD 221 for a household with a median low annual income, to AUD 4249 for a household with an average annual income.

However, the fisheries scenario alone cannot bridge this and falls short in meeting the affordability requirements of recommended diets for both average and low annual income households with the affordability gap ranging from AUD 1066 to AUD 3237. Yet, as depicted in Figures 3 and 4, the hypothetical affordability cost associated with the fisheries scenario could potentially cover the combined cost of CotD recommended diets that include energy only diets, nutritious only diets, and food-habit nutritious diets. Nonetheless, when factoring in non-food expenditures, the overall cost to maintain a healthy diet for both average and low-income households, will surpass the limits of both household's annual income.

Figure 5 below compares the hypothetical weekly cost of the baseline FHAB diet with the three developed scenarios. It indicates that upon integrating the scenarios into the baseline FHAB data, certain food groups such as "fish, seafoods, amphibians and invertebrates", "vegetable and vegetable products", "milk and milk products", "fruits and fruits products", and "eggs and egg products" hypothetically either have their cost reduced, or they incur no cost at all, either because they are considered as free foods or are no longer recommended by the CotD software as they do not form an important part of the village food habit diet.

Food groups that were no longer recommended after integrating the scenarios into the baseline FHAB data include "milk and milk products", and "eggs and egg products". The only food groups recommended as free foods after integration are "fish, seafoods, amphibians and invertebrates", "vegetable and vegetable products", and "fruits and fruits products".

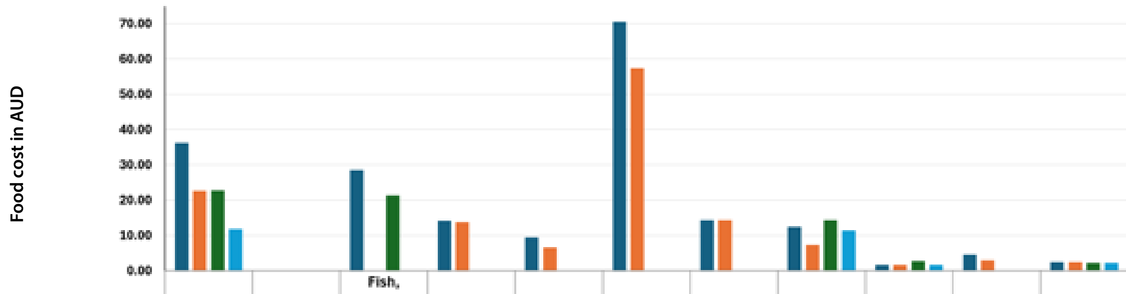
Foods that continue to incur weekly costs after each scenario's integration into the baseline FHAB data are primarily imported foods that form an important part of the village's food consumption habits. These include foods falling under the food groups "grains and grain-based products", "beverages", "sugars and confectionary", and "oils and fat". The prices of foods within these groups cannot be adjusted since they are imported unless they are provided as free items or further subsidised by the government.

Limitations in using the fisheries scenario

A limitation in using fisheries as a scenario in this assessment is the lack of nutritional information for many marine species commonly consumed in Tabonibara. A good example is that this study relies on generalised nutritional information for reef fishes, without specific categorisation by species. This absence of specific data makes it challenging to accurately determine the precise nutrient composition of marine foods for use in the analysis. Consequently, it impedes a comprehensive understanding of the potential nutritional benefits offered by marine resources that are commonly consumed in Tabonibara, including various reef fish species, marine plants, invertebrates, and seaweeds such as seagrape (*kureeben taari*), sea noodles (*te iaia*), peanut butter worm (*te ibo*), and strawberry conch (*te nouo*), and their role in promoting a balanced diet in Tabonibara.

Scenario recommendation and extra expenditures

The combined scenario (baseline FHAB diet and fisheries and agriculture scenarios) is possibly the most effective approach for the Tabonibara community to achieve an affordable FHAB diet. Moreover, it is arguable that this scenario demonstrates how broadening recommendations (such as incorporating additional locally available nutritious no-cost foods in Tabonibara) could decrease the cost of a nutritious FHAB diet in the village.



	Grains and grain-based products	Roots and tubers	Fish, seafood, amphibians and invertebrates	Eggs and egg products	Milk and milk products	Vegetables and vegetable products	Fruit and fruit products	Oils and fats	Sugars and confectionary	Herbs, spices and condiments	Beverages
Baseline FHAB diet	$36.25	$-	$28.59	$14.25	$9.48	$70.60	$14.43	$12.47	$1.73	$4.65	$2.46
Baseline FHAB diet + fisheries scenario	$22.66	$-	$-	$13.79	$6.60	$57.43	$14.43	$7.34	$1.73	$2.96	$2.46
Baseline FHAB diet + agriculture scenario	$22.76	$-	$21.42	$-	$-	$-	$-	$14.45	$2.75	$0.07	$2.28
Baseline FHAB diet + fisheries and agriculture scenarios	$11.86	$-	$-	$-	$-	$-	$-	$11.49	$1.73	$0.07	$2.28

Figure 5. Weekly food cost (AUD) comparison between the baseline FHAB diet and the three scenarios.

Women in Tabonibara developing their food security plans to support their village's CBFM goals. Image: ©Tarateiti Uriam, CBFM team in Kiribati

However, it is crucial to emphasise that the initiatives endorsed within this study do not involve distributing free food; instead, it focuses on enhancing Tabonibara's household food production initiatives, which may require household investments or expenditures. For example, due to Tabonibara's location on a coral island with predominantly alkaline soil, limited fresh water, and frequent droughts, Tabonibara households would incur extra expenses for environmental rehabilitation to support the growth for food crops such as cabbage and tomatoes. Such costs could include soil fertilisation and the provision of supplementary fresh water.

Similarly, in the fisheries scenario, fishermen would need to invest in fishing gear to access fish, which also adds to financial considerations. While both agriculture and fisheries scenarios may involve setup costs, the agriculture scenario may require higher and continuous investments due to the need for soil rehabilitation and ongoing maintenance compared to fishing gear for the fisheries scenario, which could be one-time investments.

Conclusion

The CotD analysis has established a benchmark for Tabonibara's initiatives on improving the community's livelihoods components to make sure that household income is sufficient to ensure an improved nutritional status. However, it should be noted that the CotD analysis is purposely designed to examine pre-existing affordability gaps, and not the effects of intervention.

This study identified marine foods alongside vegetable food crops as major food sources that could provide Tabonibara villagers access to a free and nutritious FHAB diet. Even though the agriculture scenario developed through FGDs can bridge the affordability gab for Tabonibara to access a cheap and nutritious FHAB diet, combining it with the fisheries scenario could further reduce costs for access to nutritious FHAB diets by 86%.

This study concludes that the annual cost of AUD 1430 for a family of five is possibly the most adequately and culturally appropriate diet cost for a typical Tabonibara household to afford a nutritious FHAB diet. Integrating the fisheries scenario with the agriculture scenario in Tabonibara is culturally appropriate, considering Tabonibara is a coastal community, and fisheries play a crucial role in the traditional lifestyles of the villagers. The integration not only ensures the suggested scenarios are affordable and nutritionally adequate, but also promotes their cultural significance in addressing the community's dietary requirements.

Given the significant opportunity presented by the fisheries scenario to help Tabonibara achieve their goal of free access to an affordable and nutritious diet, this study strongly recommends further research on the nutrient content of marine species that are not only available in Tabonibara, but throughout Kiribati. Enhancing our understanding of the nutritional value of marine species, which play a crucial role in the diets of Tabonibara (and all of Kiribati), could offer valuable insights into how fisheries can contribute to achieving nutritious diets in Kiribati communities in a cost-effective manner.

Finally, this study acknowledges the valuable support provided by CBFM for community food security. It suggests that CBFM should consistently prioritise both nutrition and ensuring affordable access to free foods as key aspects of its objectives to effectively address food security goals. Therefore, CBFM activities should promote sustainable fishing practices while also exploring other potential initiatives to improve community access to nutritious diets. Hence, it is strongly suggested that similar studies be undertaken in other CBFM communities to explore strategies that could alleviate affordability gaps and enhance CBFM community access to nutritious diets.

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References

Delisle A., Namakin B., Uriam T., Campbell B. and Hanich Q. 2016. Participatory diagnosis of coastal fisheries for North Tarawa and Butaritari island communities in the Republic of Kiribati. Program Report: 2016-24. Penang, Malaysia: WorldFish. https://hdl.handle.net/20.500.12348/448

Deptford A., Allieri T., Childs R., Damu C., Ferguson E., Hilton J., Parham P., Perry A., Rees A., Seddon J. and Hall A. 2017. Cost of the Diet: A method and software to calculate the lowest cost of meeting recommended intakes of energy and nutrients from local foods. BMC Nutrition 3(1). https://doi.org/10.1186/s40795-017-0136-4

Govan H. and Lalavanua W. 2022. Status of community-based fisheries management in Pacific Islands countries and territories: survey report. Noumea, New Caledonia: Pacific Community. 70 p. https://purl.org/spc/digilib/doc/ocw6w

Haque M.R. and Rana M. 2019. A Cost of the Diet Analysis in Sylhet and Moulvibazar District of North-East Bangladesh. London, England: Save the Children: Studies, Reviews and Research.

Latu-Sanft J. 2021. Case study: Community-based fisheries management in Kiribati (on-going). London, England: London, England: The Commonwealth. https://thecommonwealth.org/case-study/case-study-community-based-fisheries-management-kiribati-going

Lyons G. 2018. Tackling NCDs from the ground up: Fact Sheet #1. Nutritious leafy vegetables to improve nutrition security on Pacific atolls. Noumea, New Caledonia: Pacific Community. https://doi.org/doi:10.13140/RG.2.2.30021.29928

KNSO (Kiribati National Statistics Office) and SPC (Pacific Community). 2021. Kiribati 2019–2020 Household Income and Expenditure Survey Report. Noumea, New Caledonia: Pacific Community. http://purl.org/spc/digilib/doc/kjrto

Nikiari B., Uriam T., James L., Karekenatu I., Delisle A. and Li O. 2021. Women of

Tabonibara lead fisheries management into the future. Women in Fisheries Information Bulletin 34:28–31. https://purl.org/spc/digilib/doc/dzzu8

SPC (Pacific Community). 2022. Kiribati Census Atlas. Noumea, New Caledonia: Pacific Community (SPC). https://nso.gov.ki/wp-admin/admin-ajax.php?juwpfisadmin=false&action=wpfd&task=file.download&wpfd_category_id=117&wpfd_file_id=2022&token=&preview=1

Troubat N. and Sharp M. 2021. Food consumption in Kiribati: Based on analysis of the 2019/20 household income and expenditure survey. Tarawa, Kiribati: Food and Agriculture Organization of the United Nations, and the Pacific Community. https://doi.org/10.4060/cb6579en

Uriam T., Vanguna T., Ebanrerei E., Tonganibeiaand T. and Karekennatu I. 2022. Tabonibara women's continued journey into fisheries management. Women in Fisheries Information Bulletin 37:28–31. https://purl.org/spc/digilib/doc/gz99g

Monitoring community fisheries: Exploring utility of automated monitoring to support adaptive management

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Introduction

Community-based fisheries management (CBFM) in the Pacific has been widely accepted as being critical to meeting the food security and livelihood needs for island populations (Govan and Lalavanua 2023). The need for such tools is evident, in part, by dedicated efforts and initiatives over the last decade to develop fit-for-purpose policy, strengthen capacity for local management, reinforce (and/or expand) support networks, and integrate appropriate science (Forum Fisheries Agency 2015; Pacific Community 2015, 2021).

National programmes of various forms have been established across the region to support people living in coastal communities to manage their own immediate marine resources, often through community managed areas. Common to all these programmes is the critical role of monitoring, as a key source of information for local management, and an early warning of change (Shedrawi et al. in review). While conventional tools for fisheries monitoring are typically designed to produce maximum sustainable yield or stock assessment-type metrics, such tools have proven unsuitable in the context of the highly diverse and dynamic fishing practices encountered in community fisheries (Andrew et al. 2020). In our view, monitoring should primarily serve local forms of management, sometimes codified in community management plans. Design of data collection strategies, and associated data applications should, therefore, be usable by local communities as they take management action that ensures benefits continue meeting their needs over the long term. The magnitude and diversity of this challenge is such that there is no single solution. With current advancements and increased accessibility in artificial intelligence (AI) technology progressing alongside a better understanding of the needs for community-based fisheries management (CBFM) in the Pacific, it is useful to explore how automated forms of CBFM monitoring could potentially help support the long-standing ambition of feeding timely relevant information into local management. In presenting experiences here, we do so with the acknowledgement that resourcing and technical support remain a challenge at scale.

This contribution is made up of four parts, with this introductory article setting the scene and background to the subsequent articles. The articles by Sami and Sokach, and by Nikiari et al. summarise experiences in designing and implementing monitoring in Vanuatu and Kiribati, respectively. They contextualise their experiences in relation to the broader national programmes for CBFM in their countries. The final article by Aisea et al. presents early experiences as part of a PhD research project (led by Latu Aisea) that critically examines the evolution and functioning of the special management areas (SMA) Programme in Tonga. As part of his research project, CBFM monitoring will be applied across three communities, thereby offering insight for national SMA coordinators. The four articles collectively outline how the methods emerged, from design to implementation, and with that present lessons that may usefully integrate into a broader regional discussion on the challenges to monitoring CBFM.

Integrating automation into CBFM monitoring

The initiatives and instruments presented in this set of papers are novel for CBFM monitoring. The applications developed marry in-country capacity and state-of-the-art AI computing technology. This integration streamlines data collection with rapid subsequent processing and analysis, and timely feedback of findings into management. Two fundamental pieces of work were integrated to enable this advance. First, previous CBFM monitoring paper-based tools, which set out some key principles for CBFM monitoring, were used as a foundation for next steps (for more details see Andrew et al. 2020). This includes, in the most pragmatic sense, the use of photo mats to capture fish catches, thereby minimising time and effort burdens on participating fishers. Second, it builds on the parallel development of the broader *Ikasavea* platform, an AI-enabled, regionally implemented coastal fisheries monitoring system developed by the Pacific Community (SPC) with its partners (for more details see Shedrawi et al. 2023; Shedrawi et al. in review). What has resulted is a community monitoring module (hereafter referred to as the "community module") within the *Ikasavea* platform. Below we briefly outline the specifics of the community module, and with that contextualise it within *Ikasavea*.

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In basic terms, *Ikasavea*, through its mobile application on tablets, forms a portal between the field and advanced data computing systems hosted and managed at SPC, in Noumea, New Caledonia. The application houses several monitoring modules that allow tailored data collection methods to feed data into, and outputs from, the same computing system. Current modules on *Ikasavea* support include, for example, monitoring at fish markets, from central landing sites, and from coastal communities. Data are collected by taking photos of fish and running surveys to capture additional data associated with the fishing event or market stall, depending on what module is being used. All data are saved on tablets to be uploaded to the central server when connection to the internet is established. Once uploaded, survey data are saved in a database and images are entered into a series of automated processing and analysis steps broadly summarised as follows:

- First, raw images are made ready for the AI system to extract information. This involves calibration of the image (e.g. straightening image perspective), fixing the colour spectrum, isolating particular fish specimens, and adjusting orientation of the specimen for length measurements.
- Second, the species is identified whereby computer vision models are used to suggest likely species options (and confidence estimates). During learning phases of the system this stage requires human validation to either confirm the suggested species name, or correct it.
- Third, using species information and length measurements, a weight estimate is produced based on standard known length-weight ratios by species. All these data are used as a basis for running queries and generating tailored data reports as needed.

The above sequence of steps is largely the same for data coming in from all modules. However, the way data are collected, and information afterwards applied, is module-specific. In that, the community module has a specific guiding methodology, as outlined in a three-part manual. The articles from Vanuatu and Kiribati outline in more detail how this has practically been implemented. Broadly speaking, monitoring takes place once or twice a year over intensive two-week periods, simultaneously in select communities that each have a CBFM plan. Enumerators are selected and trained before data collection (enumerator teams typically include fisheries staff and community members). On return, data are uploaded for processing and data validation. The system provides national data coordinators with automated reports from the data, by community and aggregated at a national level. These reports are then used to close the loop and produce material for information feedback to those communities as part of CBFM awareness and planning meetings. These sometimes involve the data coordinator and other times simply by the CBFM committee themselves.

Considerations for "going AI"

The application of computer vision and machine learning technology is radically altering the broader field of fisheries monitoring (Ditria et al. 2022), and so too how data informs management. In comparing manual, paper-based monitoring and the automated AI-driven monitoring, time taken for data turnaround during the first round of implementation in 2023 (i.e. from data collection to reporting) was estimated to be 12 times faster, with data returned to communities within weeks rather than months. The first round of implementation of the automated monitoring method involved validation of 11,456 fish. The system's digital structure allows for tailored analysis for application at various governance levels, from single communities to aggregated data at national, and even regional level. The use of imagery as the raw data, moreover, means retrospective analyses can conceivably be run at any point, something of value into the future as technology advances and/or historical baselines are needed.

The rate of development of AI technology integration in fisheries is rapid. Throughout the region there are examples of AI-driven monitoring systems being trialled and tested. What makes the *Ikasavea* platform distinct is how its design, evolution and development has been embedded within national monitoring programmes. The testing and refining of all stages of development was carried out through fisheries officers from across the region, monitoring at market sites, landing sites and in communities. What is emerging is a system designed by and for Pacific national monitoring needs, where all data remain in ownership of member countries and shared to accelerate learning, under SPC's Pacific data agreement.

With specific reference to the community module, CBFM teams from national fisheries agencies in Kiribati and Vanuatu spearheaded the development and current application, underscoring the Pacifica identity and ownership of *Ikasavea*. Overall, it is another example of emerging technical expertise and science capacity in the region, further supporting arguments for directing investments towards the growing number of Pacifica researchers and practitioners. In noting this, significant challenges remain in considering practically how such technology can be made part of ongoing national programmes. Resourcing, sustainable financing and technical support will remain a challenge given the contemporary pressures that communities and their supporting national agencies face. Experiences presented here reflect work undertaken in communities within specific timeframes (rounds) and across a small subset of communities based on criteria by country that ensures meaningful representation. These are measures taken because of limited resources. With that, we invite discussion on what part this technology can play next to other monitoring activities in national programmes to not only effectively inform CBFM locally, but also coastal fisheries management at large.

Acknowledgements

We first and foremost acknowledge the invaluable contributions from participating communities, fishers, staff from national agencies, and partners in the region. This work is not possible without the time, resources and efforts by all. We thank, in particular, MFMRD staff in Kiribati and VFD staff in Vanuatu for their role in supporting the module's development, and MoF in Tonga for supporting Latu Aisea's research. Eleanor McNeill assisted in developing graphics for the Vanuatu and Kiribati articles. Development of the community monitoring module is supported by the Australian government through ACIAR project FIS-2020-172. The broader development of *Ikasavea* draws from SPC-FAME core funding support by the Australian Department of Foreign Affairs and Trade, and the New Zealand Foreign Affairs and Trade Aid Programme, and through the European Union and the Government of Sweden under the Pacific-European Union Marine Partnership programme.

An insight into innovative CBFM monitoring in Vanuatu

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Fitting monitoring into Vanuatu's national CBFM programme

In Vanuatu, there are two principal policies directing the management of coastal fisheries towards achieving the target of sustainably supporting the health and well-being of all ni-Vanuatu: the *Vanuatu National Fisheries Sector Policy 2016–2031* and the *Vanuatu National Roadmap for Coastal Fisheries – 2019 to 2030.* The implementation of these is under the responsibility of the Vanuatu Fisheries Department (VFD). These documents clearly identify the need for enhanced information and communications to strengthen consistent and reliable coastal fisheries' data collection that better supports communities, and with that, understand the status of resources.

Various initiatives in community-based monitoring have been implemented in Vanuatu over the last decades (e.g. see Dumas et al. 2009; Johnson et al. 2020; Sami et al. 2020). VFD's implementation of paper-based CBFM monitoring between 2019 and 2021 stands as the lead example. Following this, VFD sought to integrate its CBFM monitoring tools such as TAILS++ and solar-powered freezer monitoring. Reflections by data enumerators during these early CBFM monitoring phases, indicated interest to transition from paper to a digital format, primarily to reduce workload and error during data collection. Given the simultaneous advancements in AI monitoring systems at a regional level (automating the identification of species and providing cloud-based platforms for data management), the transition to a new generation of CBFM monitoring was supported by VFD in 2022 (in 2021 early field testing of *Ikasavea* was undertaken in Peskarus [Malampa Province] and Mangaliliu [Shefa Province]). Three main reasons drove this decision to: 1) enhance fishers' participation in an adaptive management process for coastal fisheries resources; 2) minimise the burden on measuring the effectiveness of CBFM; and 3) contribute meaningfully to the VFD Data Division.

Vanuatu Fisheries Department enumerator during a practical training in Takara (Shefa Province), using the Ikasavea application to collect community-based fisheries management monitoring data from a fisher (2023). Image: ©VFD

In addition to this transition, VFD proposed further adjustments to the implementation strategy. Emphasis by the Government of Vanuatu to operationalise the decentralisation policy saw VFD prioritising the alignment of its existing networks so as to achieve fair distribution throughout the six provinces. To meet this goal, CBFM monitoring's reach was adjusted to include one community site per province, using community representatives within VFD's networks for data collection (i.e. TAILS+ monitoring officers and Authorised Officers). VFD supported the transition by co-financing and co-implementing the first round of the new generation of automated CBFM monitoring, and providing access to fisheries observers for data collection. Efforts have been made to also ensure that data are utilised in management. As an example, in December 2023, VFD's CBFM unit conducted a "data translation workshop" with community representatives and provincial fisheries officers. Its focus was to help practitioners identify patterns and trends and to translate these into meaningful implementation actions.

Collaborative design

In early 2022, CBFM officers from VFD and Kiribati's Ministry of Fisheries and Marine Resources Development (MFMRD), through the ongoing collaboration with UOW and SPC-FAME, assisted in integrating aspects of the manual CBFM monitoring questionnaires and photo mat method into the *Ikasavea* application. A workshop was held in Noumea, bringing together expertise under these partnerships, to develop a first iteration of the community monitoring module. Following this, the module went through several refinements as the fish species identification system and fish measurements software were trialled, questionnaires tested, and final design of the photo mat to be used for data collection was complete. In early 2023, the community module was field tested in both countries with final feedback sent to SPC-FAME, which further informed the three-part accompanying manual.[1] The manual functions to support implementation as well guide training sessions. The implementation of the first round of data collection occurred in the second half of 2023.

The module consists of two questionnaire forms:

i. A catch survey, which captures catch data for single trips by each fisher surveyed during a data collection round, and which is linked to photos taken of fish caught during that fishing trip; and

ii. A context survey, which captures broader perceptions (e.g. on management, state of the environment) and fishing behaviour data from each fisher that participates in the catch monitoring survey during a round.

While the former is carried out each time a fisher returns home from a fishing trip, the latter is carried out just once per fisher per round. Data from both surveys are important in providing insight not only to what was caught during the round, but also how that fits into the context of local fishing habits, changes and management actions.

Implementing a first round

In August 2023, VFD's CBFM unit and Research Division organised a three-day training on the use of *Ikasavea*. Workshop participants included eight community representatives (including Tails++ monitors and Authorised Officers) and 12 VFD observers, totalling 20 enumerators. The training covered two coastal fisheries monitoring modules on *Ikasavea* – the community module and the landing survey module. The training included a field visit to a nearby community to put into practice how to collect the data with fishers (photo 1 and 2). Enumerators were deployed immediately afterward to the community sites for two weeks (enumerator teams per community were made up of a community member and a VFD observer). David Abel, VFD Observer and Enumerator at Peskarus, noted:

> *I was allocated to do data collections at Peskarus, a site with a huge amount of fishing activity on a daily basis. Using the digitised form has massively improved the data collection process and also enhanced fishers' satisfaction*.

Vanuatu Fisheries Department enumerator using the community module on Ikasavea to take a photo of the catch laid on the fish mat catch in Vanuatu (2023). Image: ©VFD

Table 1 shows the six sites where the community module was conducted. In addition to the six sites, there was an additional seventh site during the same round (Malokilikili island, Sanma Province), where the Research Division led monitoring efforts using the landing survey module. Of the six community sites surveyed, Loh (Torba) was still developing a CBFM plan, and its tabu area was managed by the chiefs and community without formal collaboration with VFD. Since the training undertaken with the CBFM Unit and Research Division, they are now working alongside VFD to develop their CBFM plan, and are seeking to finalise it before the end of 2024.

Round 1 commenced with a community awareness meeting, led by the enumerator team. These meetings informed fishers and the general community of the upcoming monitoring activities. With conclusion of the data collection round, each enumerator team debriefed with the CBFM data coordinator back at VFD headquarters. During these debriefs data were checked before uploading through the web interface. Once the fish identification was verified, a report was fed back to the community. The same cycle repeats for each round of data collection, with the exception that training in repeated rounds will involve a shorter one-day refresher and that awareness meetings in communities involve a specific focus on reflecting on previous data results and any actions taken towards that.

[1] You can access the community survey manuals here: https://www.spc.int/CoastalFisheries/FieldSurveys/PtwSurvey

Table 1. Community fisheries monitoring was conducted in the six sites, noting number of participating fishers.

#	Province	Site	Lead (CBFM unit / Research unit)	# Fishers
1	Torba	Loh	CBFM unit	16
2	Sanma	Port Olry	CBFM unit	17
3	Penema	Noane	CBFM unit / Research unit	31
4	Malampa	Peskarus	CBFM unit / Research unit	34
5	Shefa	Takara	CBFM unit	36
6	Tafea	Kwamera	CBFM unit	13

Preliminary results

While all six surveyed sites indicated that fishers mostly targeted reef habitats to catch reef fish and invertebrates, the results in Figure 1 show considerable diversity in fishing practices. Gear use can be highly community-specific, with Kwamera still practising traditional fishing methods that use bamboo rods and bow and arrow; something rarely done in the other communities. Naone (Penama Province) offered a distinctly different context with the fishing ground, including the river mouth and areas farther upstream where freshwater prawns are commonly caught. Freshwater prawns are highly valued and tend to be targeted more often during the rainy season, which coincided with the first round. This change in target species likely affected the total weight of finfish recorded, which was low, despite fishing effort being high.

Results in Figure 2 shows a series of perception and knowledge-based variables of fishers in surveyed communities, including knowledge of the status of tabu areas (i.e. open or closed), average time it takes to reach fishing sites, extent of fishers' knowledge on current fishing rules, perceptions on compliance, and any concerns regarding the resource. With the exception of Peskarus (Malampa Province) and Port Olry (Sanma Province), where some people reported that the tabu area was opened during the monitoring period, all fishers in all sites noted closed tabu areas. The average time taken to reach the main fishing grounds reflect levels of accessibility to fishing grounds, where market-driven fishing in Peskarus (Malampa) reported boats and canoes taking more time to reach the fishing sites than the more subsistence-oriented fishing in Kwamera, where the majority of fishing sites are within walking distance. Takara (Shefa

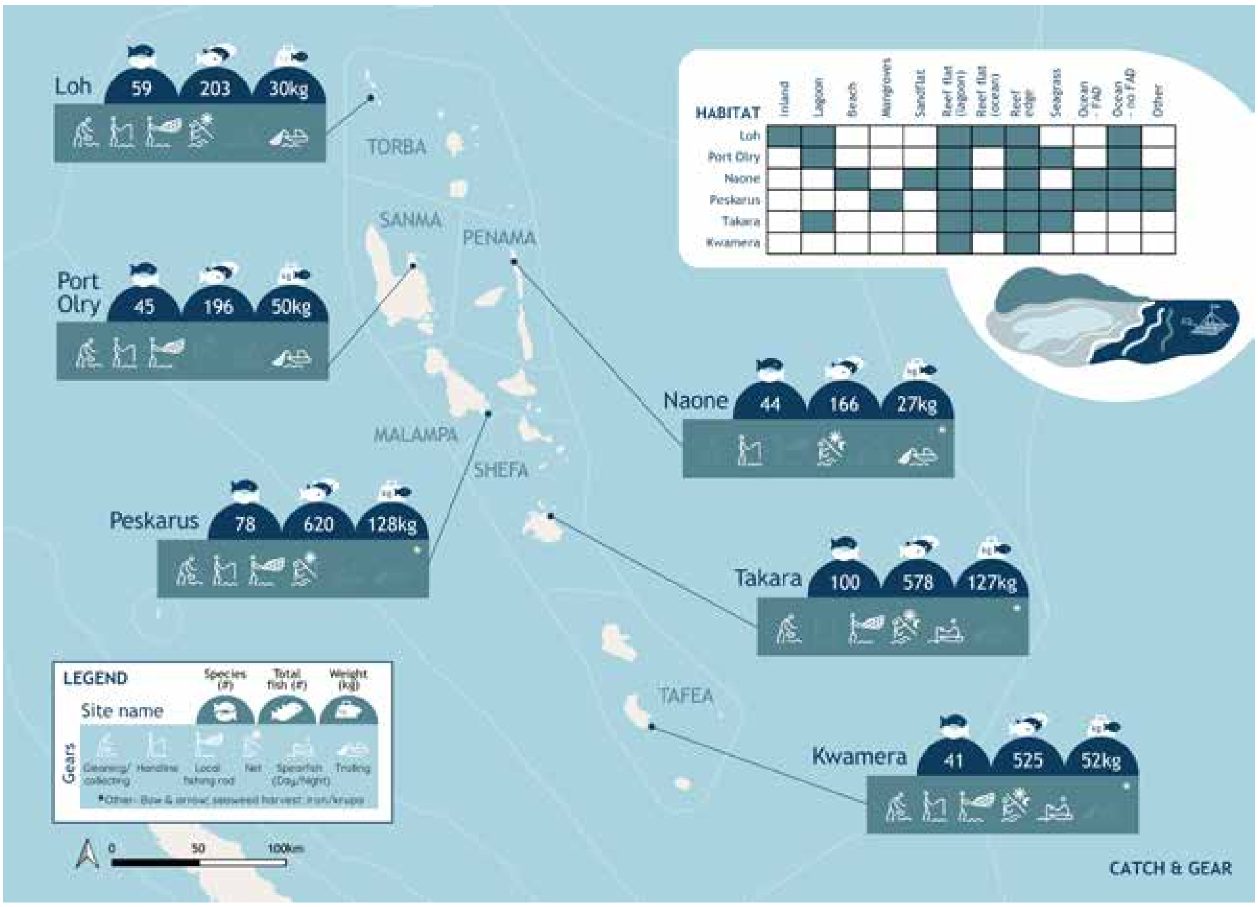

Figure 1. Catch monitoring findings for the six survey sites completed in August 2023 in Vanuatu.

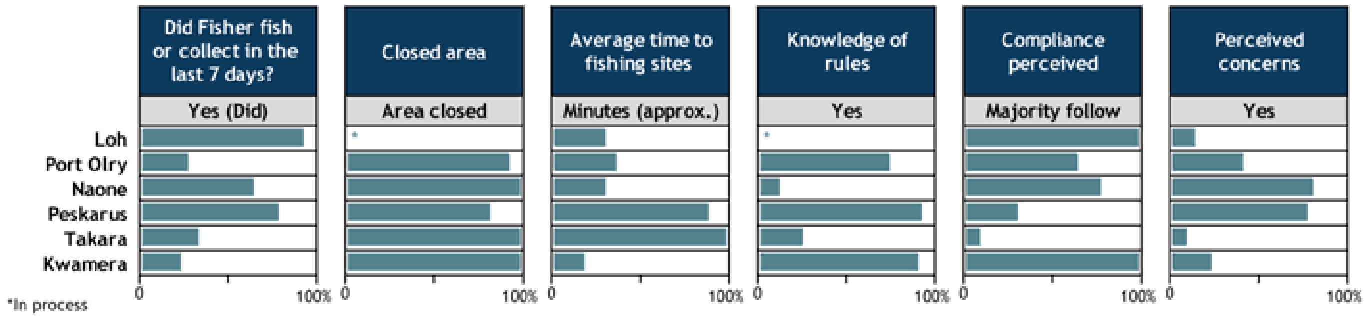

Figure 2. Findings from the context survey (qualitative section) with individual fishers at the six community sites in August 2023, reflecting on key perception- and knowledge-based variables for community-based fisheries management. The grey cells above the charts indicate the fisher responses being measured, for which bars below are displaying results.

Province) indicated poor levels of knowledge on rules, suggesting more awareness may be needed, possibly through the tabu area committee. It is worth noting the reasons why people appeared as concerned in Peskarus and Naone. Results showed that in Naone, concerns are mainly linked with the use of a local poison during fishing activities and substantial pollution. On the other hand, in Peskarus these concerns appeared more related to a lack of fish outside of tabu areas and the community's growing population, culminating in low compliance with rules.

Signs of informing active management

Community CBFM plans are subject to periodic reviews. These are moments when community leaders and/or community committees can use data from CBFM monitoring to make informed adjustments to their plans. The qualitative data in particular may help in assessing compliance of local fishing regulations. Kwamera (Tafea Province) is a good example of this; the community was in the process of reviewing its CBFM plan during the first round, with the final consultations and local endorsement of the revised CBFM plan expected in late April 2024. The community report indicated large quantities of small reef fish caught, many of which were herbivores. The species caught most often also contributed the most weight to finfish catches in Kwamera – the Little Spinefoot (*Siganus spinus*). A total of 190 Little Spinefoot were recorded, with a total weight of 17.6 kg, and an average length of 16.5 cm. While size at first sexual maturity is unknown for the Little Spinefoot, these figures suggest that there may be a need to monitor this species more closely, and to understand its ecology and role on the reef. The report also highlighted key information from qualitative data. Results reflected good knowledge of recent collectively developed local rules resulting from local meetings led by the chair of the tabu area. A ban on night diving and use of small-sized hooks were, for example, well known and more effectively monitored. These have become included in the revised CBFM plan.

In Takara (Shefa Province), leaders were particularly interested in data on invertebrate harvests since youths and women were anecdotally noted to have started collecting and gleaning more. As a result of the increasing number of people gleaning and collecting invertebrates, VFD received a request to report on species of invertebrates (e.g. numbers and weight of catch, participation) as part of the community information feedback. It is worth noting that the compliance level in Takara was perceived as low (i.e. 16%, see Fig. 2). Some noted that this is likely related to the passing of the late Chief Robbie earlier in 2023. Chief Robbie was a respected leader in the community and an authorised officer in Takara. He was heavily involved with fisheries activities and contributed to ensuring that high levels of compliance were met.

While data collected from *Ikasavea's* community module primarily supports communities to manage their resources, the potential for wider applications of data is well appreciated. Application of *Ikasavea* in Vanuatu is at a relatively early stage (i.e. community and landing site modules), but VFD continues to commit resources and staff to support development and implementation efforts. In subscribing to the platform (i.e. integrating *Ikasavea* functioning within VFD systems and training of staff in its use), application of other *Ikasavea* modules is likely to help address some of VFD's enduring challenges, including monitoring fish trade, FAD fishing, and/or specific economically important fisheries (e.g. deep bottom snapper, and diamond back squid). VFD's Research Division notes the value of the photo mat collection method, as it allows for bulk data collection in a short period of time, proving to be an effective way to gather data quickly with little burden to the fisher. Furthermore, data are contributing to VFD's species-specific fish stock assessments, involving the analysis of spawning potential ratios and other metrics of health status (i.e. building national baselines for certain coastal resources). VFD is also interested in monitoring significant fishing events (e.g. associated with church fundraising, tabu area openings, or custom practices), for which *Ikasavea* can be a useful application.

Experiences in digital CBFM monitoring in Kiribati

Beia Nikiari, Tooreka Teemari, Karibanang Tamuera, Manibua Rota and Tarateiti Uriam Timiti

Ministry of Fisheries and Marine Resources Development, Kiribati

People in Kiribati rely heavily on coastal fisheries resources for food security, livelihoods and rural economic development. Sustainable management of these resources is essential to ensure their long-term viability. Monitoring plays a crucial role in guiding management decisions in communities where CBFM is established. Under the Coastal Fisheries Division, a CBFM monitoring programme initially commenced in 2019, under a first generation of monitoring that involved five communities. In 2022, the programme initiated a transition to its second generation, with a shift in its approach that substituted paper-based surveys with digital monitoring. With that, it expanded to service eight communities. This article provides an overview of digital catch monitoring efforts in Kiribati, highlighting key initiatives, challenges and future directions.

The collection of substantial data during the first generation of CBFM monitoring between 2019 and 2021 represented a significant milestone in supporting community management plans. Providing feedback that gave insights into each community's fishery resources allowed community leaders to make better decisions regarding fishing practices and implement necessary management measures. The data also played a crucial role for MRFMD, contributing to national research reports, for example, on the status of bonefish (*Albula* spp.) in Nonouti island and informing policy decisions. Having established the value of community-level catch monitoring, the next step was to make gathering that data more efficient, and monitoring functionality attune to management needs (i.e. quicker data turnaround). Hence a co-design and trialling process started of a digital mode of catch monitoring, developed under the existing set of partnerships between MFMRD, VFD, University of Wollongong (Australia) and SPC-FAME, which resulted in the community monitoring module on *Ikasavea*.

Implementing a first round of digital monitoring

The initial stage involved training sessions for both data collectors and trainers. The training sessions were conducted separately, with data collectors concentrating on gathering and uploading fishing data. Data trainers on the other hand needed expertise on both data collection techniques and how to instruct data collectors to conduct the CBFM

Kiribati Ministry of Fisheries and Marine Resources Development staff participating in training of the community module in 2023. Image: ©Kiribati MFMRD

Women participating in community-based fisheries management monitoring in Kiribati in 2023. Image: ©Kiribati MFMRD

monitoring surveys in the field. The training was guided by the co-developed community module manuals. The training also aimed to expand the programme's reach, enabling other units within MFMRD to assist and ultimately undertake monitoring activities. The training encompassed sharing details about CBFM monitoring, the objectives behind it, and efficient methods for conducting the surveys using *Ikavasea* and its community module. Trainees were taught how to conduct awareness meetings, use the two survey forms (catch and context survey) to interview fishers, capture high-quality photos of the catch, and securely backup and upload their data to the web interface.

CFD officers served as data collectors, a decision made during an evaluation meeting with senior staff where results from the 2019–2021 monitoring programme were reviewed. The principal fisheries officer and senior officers expressed support of the CBFM monitoring programme, noting how it was generating useful data for the CFD's research activities, and encouraged the participation of officers in the programme. The introduction of digital CBFM monitoring garnered further interest among staff and practitioners, prompting further expression of interest to join the programme. Fisheries officers sought hands-on experience in community-level data collections, while others were eager to compare its methodology and data with other similar surveys.

Eight community sites were selected for implementation; Bikaati (Butaritari Island), Tekuanga (Marakei Island), Nuotaea (Abaiang), Buariki (North Tarawa Island), Nabeina (North Tarawa Island), Bubutei (Maiana Island), Tebwanga Maiaki (Abemama Island), and Kabuna (Tabiteuea Island). These communities have management plans, actively engage within CFD's national CBFM programme, and are strategically located across the Gilbert Island groups (encompassing northern, central and southern region coverage). It is hoped that this spread of communities will more accurately and comprehensively help capture the kind the fishing activities in Kiribati's communities. During fieldwork, officers spend two weeks monitoring all fishing activity in a community, conducting interviews with fishers spanning various demographics (i.e. men, women and youth of different ages). Additional information, concerns, comments or unanswered requests are recorded either in the comment section of each question or in a fieldwork observation diary. These records facilitate subsequent follow-up with the relevant units, ultimately enabling comprehensive reporting back to the community.

Preliminary results

In total, 260 fishing context surveys and 523 catch surveys were completed during the two-week monitoring period. The data revealed that there was little in common between the communities in terms of the finfish they harvested. Not only did the total estimated weight of the catch vary between 766 kg (Bubutei) and 143 kg (Nuotaea), but the fisheries also differed in terms of diversity (99 species reported in Bubutei versus 44 species reported in Tebwanga Maiaki, see Table 1).

One common thread between several communities, however, was the importance of the silver biddy (*Gerres* spp.). Silver biddy was the most often caught fish in five out of the eight surveyed communities (Fig. 1).

In fact, cumulatively, the silver biddy was the most often caught finfish, and contributed the greatest amount of biomass to finfish catch (Fig. 2). This finding reflects the fact that silver biddy are considered a delicacy in Kiribati.

The popularity of the silver biddy is also connected to its widespread availability throughout lagoons, especially to fishers using gill nets. The data supports this, with lagoons being the most heavily fished habitat in Kiribati by a large margin, and nets the most often used equipment for men, and the second most favoured by women (Figs. 3 and 4).

Length data allows us to gauge whether interventions are required to ensure that community fisheries are sustainable. The average length of the 2905 silvery biddies recorded during the survey period was 15.17 cm (Fig. 2). This figure

Table 1. Biological summary of finfish caught across all eight communities during the two-week survey period.

	Communities							
	Buariki	Bikaati[1]	Bubutei	Kabuna	Nabeina	Nuotaea	Tebwanga Maiaki	Tekuanga
Total no. of fish species	68	**39**	99	48	60	50	44	58
Total no. of fish caught	996	**204**	3363	486	840	500	582	1651
Total estimated weight (kg) of fish caught	228	**116.1**	766.4	209.2	190.7	143	250.8	179.4
Total no. of fish caught by families	17	**14**	26	21	20	18	10	22

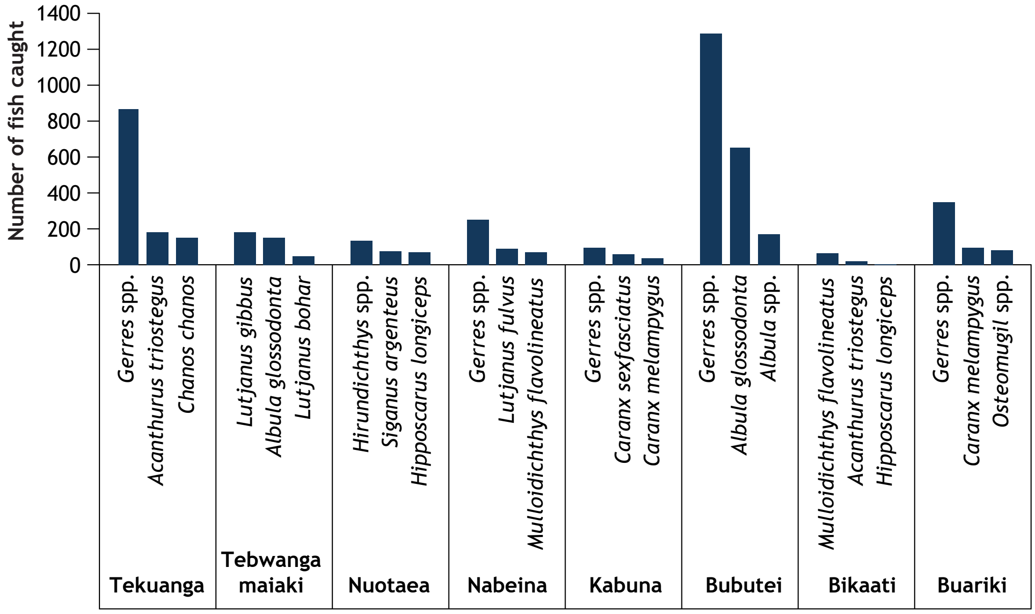

Figure 1. Top 3 most frequently caught species per community during the two-week survey period.

[1] Catch data presented here from Bikaati is incomplete as uploading to SPC servers was partially complete at the time of reporting.

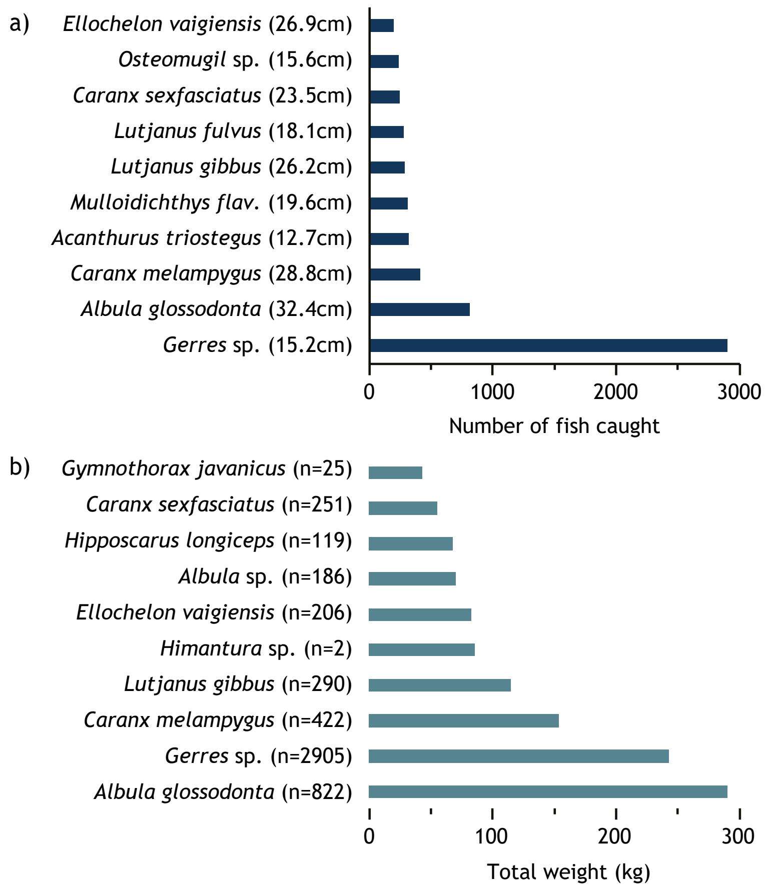

Figure 2. A comparison across all eight communities during the two-week survey period of: a) the most frequently caught finfish species (with average length in brackets) and b) those that contributed the most weight to the total catch (number of specimens in brackets).

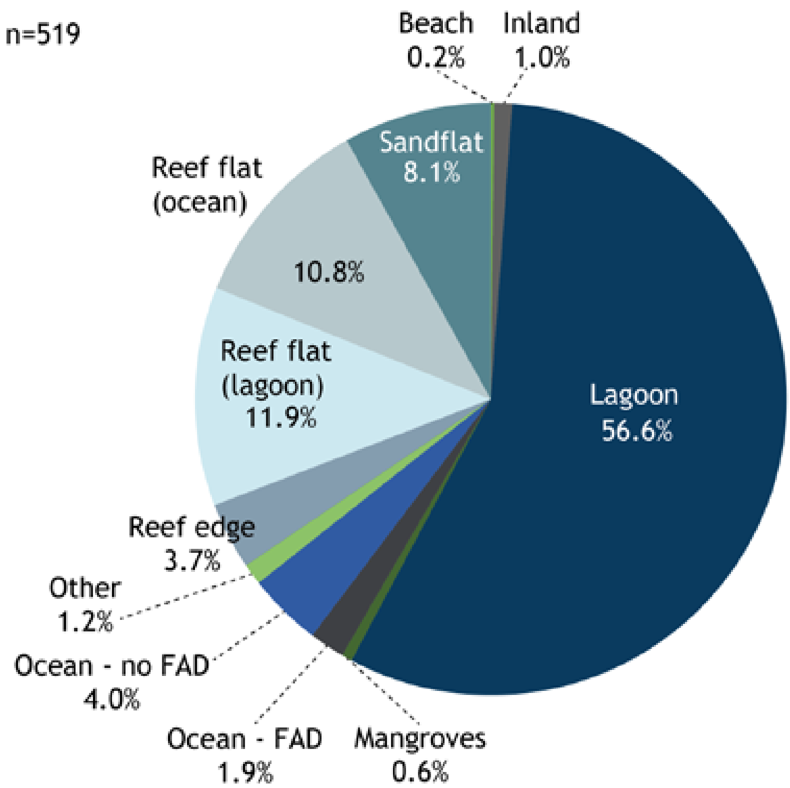

Figure 3. The relative percentage of fishing trips that fishers spent in each habitat from all eight communities reported during the two-week survey period.

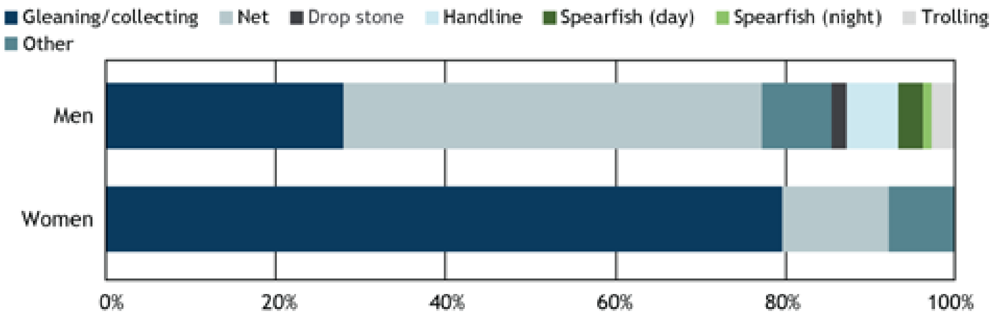

Figure 4. Gear and techniques reported by women and men from all eight communities during the two-week survey period. Note: The category "Other" includes multiple traditional techniques used to harvest specific invertebrates that have no equivalent English name.

aligns with the regulation stipulating a minimum size of 15 cm for silver biddy, which ensures those fish caught are sexually mature, and can spawn at least once before being harvested. This suggests that intervention is likely not required at this stage.

However, among the 323 convict surgeonfish (*Acanthurus triostegus)* harvested, 98% were not yet mature, averaging only 12.7 cm (Fig. 2). Since convict surgeonfish are herbivores that perform important ecological services in coral reef ecosystems, this poses a significant concern (Cvitanovic et al. 2007; Ogden and Lobel 1978). If populations of herbivores decrease, an overgrowth of algae could occur, disrupting the fish assemblages that depend on the reefs.

Feedback from community members flagged a few burgeoning issues. In Buariki, certain fishermen highlighted noticeable shifts in the sea, particularly regarding the quantity and size of fish they usually catch. These changes suggest a decline in marine resources within the lagoon. Fishers suspect that the adoption of destructive fishing techniques, such as the use of small mesh gill nets and overfishing practices, might be driving these declines. Temoone, a fisher from Buariki recounted:

> *In the past, when we went fishing at the lagoon, we would often observe abundant schools of fish, causing the water to ripple and making it easier to capture them. However, today, the situation is different as such sightings are increasingly rare.*

Community leaders have made a commitment to restore fish populations and have implemented regulations, including enforcing measures such as a ban on harvesting goatfish during spawning seasons.

While both women and men target invertebrates to a significant degree (Figs. 4 and 5), our data corroborates past studies showing that invertebrates are particularly important to women in rural I-Kiribati communities. They not only spend more time targeting invertebrates, but also usually have less access to other gear and fishing locations (Fig. 5) (Fröcklin et al. 2014; Grantham et al. 2020).

Translating monitoring findings to management action

The results and findings of CBFM monitoring are crucial for the implementation of community management plans. By leveraging these results, communities can make informed decisions and take proactive measures to manage their marine resources for the benefit of present and future generations.

Some of the actions communities can take by using CBFM monitoring results include:

- Setting catch limits: Establishing sustainable catch limits for various fish species, ensuring that harvesting remains within ecological limits.
- Monitoring compliance with seasonal closures: Catch photos can record fish being caught during seasonal closures that have been set in place during peak spawning periods.
- Designing marine protected areas (MPAs): Catch monitoring can inform the selection and design of MPAs, helping communities designate areas where fishing activities should be restricted or prohibited.

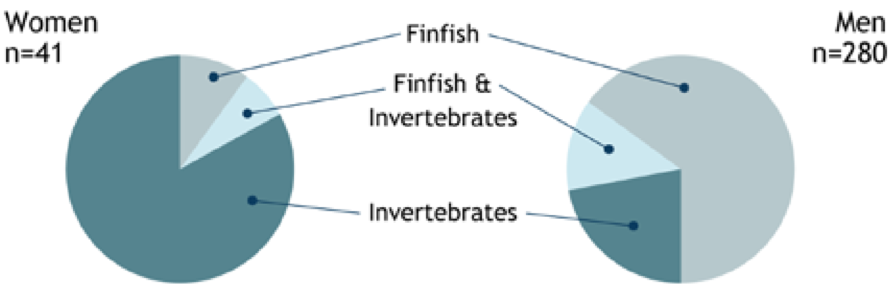

Figure 5. Relative proportions of women and men who reported their preferred fishing target to be "finfish only", "finfish and invertebrates", or "invertebrates only" from all fishers surveyed during the two-week period.

- Promoting selective fishing practices: Communities can use results to promote selective fishing practices that target specific species or size classes, reducing bycatch and minimising impacts on non-target species.
- Educating fishers: The data and findings can be used to educate fishers about the importance of sustainable fishing practices and the need to conserve marine resources for long-term benefits.
- Collaborating with stakeholders: Communities can share catch monitoring data with stakeholders, including government agencies, non-governmental organisations, and other communities, to collaboratively ensure coordinated management efforts.
- Monitoring and evaluation: Regular monitoring allows communities to track changes in fish populations over time and evaluate the effectiveness of their management measures, enabling adaptive management strategies as needed.

From CFD's standpoint, using the *Ikasavea* community module makes gathering fishing behaviour data in communities more efficient, and therefore, more sustainable.

> *It was much easier to move quickly from place to place when we do not need to carry paper survey forms, pens, clipboards, a gridded mat and a camera … we had a better chance to survey more fishers/collectors returning from multiple locations*. Toaiti Vanguna, CBFM officer

The centralisation of data storage, and the structure of the survey also reduces the chances of human error that often diminishes the quality of the data. Tokaimoa Tonganibeia, Fisheries Extension Officer based in North Tarawa, mentioned that he appreciated collecting data without needing to think about how to arrange his data, since the application did it for him: *The application put fisher information together including catch photos which avoid common error of data arrangement*.

While initial results are starting to see communities react, repeatability and the sustainability of this catch monitoring activity will be vital for long-term support of CBFM:

> *It will take time for people to get along with the activity, but in the end they realise it is another tool to help them in their fisheries management*. Nabuti Mwemwenkarawa (Chairman of Buariki)

CBFM monitoring will continue to be conducted in these communities for the next two years, offering support as communities oversee their marine resources. The communities need to be commended for actively contributing their fishing experiences and providing vital data that reflects the status of marine resources. Through learning from these experiences, community members will gain the knowledge and skills needed for making informed decisions and managing resources effectively, ensuring sustainability for both present and future generations.

What can research on CBFM monitoring mean for Tonga's Special Management Area programme

Latu Aisea,[1,2] Viliami Fatongiatau,[2] Poasi Ngaluafe[2] and Siola'a Malimali[3]

We present this work in honour of Poasi Ngaluafe, the late Deputy CEO and head of the Science Division at Ministry of Fisheries in Tonga, as an acknowledgment of his dedication and invaluable contributions to coastal fisheries in Tonga and the region. May his kind soul rest in peace.

Up until the turn of the century, coastal fisheries in Tonga were managed centrally by the government under its constitutional monarchy (Gillett et al. 1998; Petelo et al. 1995). The recognition and adoption of community-based approaches saw the establishment of the special management area (SMA) programme (Likiliki and Haraldsson 2006; Malimali 2013) to support coastal communities in managing fishing activities and promoting conservation of marine resources. The programme commenced with the amendment of the Fisheries Management Act (hereafter "the Act") on 22 October 2002 (Tonga's Fisheries Management Act 2002). The amendment sought to empower coastal communities and enable shared responsibility between communities and the government to improve the management of Tonga's coastal fisheries. In 2006, Tonga registered its first coastal community under the SMA programme, and since then an additional 64 have registered, spread across the three main island groups of Tongatapu, Ha'apai and Vava'u. The Ministry of Fisheries coordinates the national programme on behalf of the government, providing resources and community support channelled through its three main island-based offices in Nuku'alofa (Tongatapu), Pangai (Ha'apai) and Neiafu (Vava'u).

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The fundamental ideas behind the SMA programme are to: 1) strengthen communities' ownership rights over adjacent coastal zones and surrounding waters (Likiliki and Haraldsson 2006); 2) mitigate external drivers of exploitation and overfishing on coastal resources that typically persist under open access regimes (Gillett et al. 1998; Petelo et al. 1995); and 3) enable environmental and economic benefits for Tongans living in coastal communities (Gillett and FAO 2011). These principles are articulated in the SMA programme's key outcomes, which include:

- restricting unauthorised access of outside fishers and/or resource users into the SMA communities' fishing areas;
- for SMA communities, to effectively conserve marine resources and manage fishing activities responsibly; and
- support community well-being through economic growth, human development and employment opportunities (Bell et al. 1994).

Community-based monitoring in Tonga

As with analogous fisheries co-management initiatives throughout the region, one of the focal areas in the SMA programme is to ensure that communities are able to make informed management decisions. Monitoring activities are, therefore, a fundamental part of the programme design, in the same way that community management plans are (Taufa et al. 2018). Monitoring is primarily geared to feed information into management plan implementation, but is also critical to overall programme management and national tracking of coastal fisheries. Quarterly SMA meetings allow the SMA Coastal Community Management Committee(s) and communities to come together to report and share updates on management efforts. It also allows any challenges encountered by the communities while managing their SMA area to be addressed. These meetings serve as a platform for MoF to offer appropriate technical guidance and solutions to emerging issues, and to report on data from monitoring activities conducted by either the community or MoF, often at aggregated national or island level. The SMA programme applies a portfolio of monitoring tools, including periodic benthic monitoring, socioeconomic surveys, and community fish catch monitoring. While benthic monitoring and socioeconomic surveys are driven by MoF's science team, the community fish catch monitoring is community-led and depends on community submissions of manually completed paper data sheets, which are then entered into a database by fisheries officers.

By registering under the SMA programme, communities commit to monitoring catches in their SMA area through the community fish catch monitoring activity. This responsibility falls under the function of the SMA committees of each SMA community as part of their roles in managing their SMA areas. The community fish catch monitoring is a voluntary and participatory community-based monitoring activity that is ongoing throughout the year. It involves members of the SMA committee (CCMC) gathering information from community fishers' fishing activities. Training CCMC members in the collection of catch data is conducted by MoF staff as part of community capacity building

Presentation on community module during the community-based fisheries management monitoring training. Image: ©Latu Aisea

activities. The method involves the regular and standardised collection of information about fish catch (weight and average length), fishing effort (fishing gear, fishers, travel time and actual fishing time), and fishing grounds (location, habitat, depth).

Monitoring data are collected and submitted to MoF and entered to the database for analysis. It is presented to the MoF during the quarterly Data Working Group meetings of the Ministry and with CCMCs and SMA communities during the quarterly SMA meetings. The data can be used to assess whether there has been a positive or negative impact on the community fish catch and/or harvesting and effort levels, due to the establishment of the SMAs.

While challenges remain, the SMA programme has been successful in collecting long time series of catch data. Experiences of the programme's community-based monitoring thus far indicates that participation is highly variable, with only a select few communities consistently providing data. The reality of voluntary year-round community-based monitoring in Tonga reflects the magnitude of the challenge in gathering data from many remote communities. In addition to the physical barriers of distance and weak connectivity, is the fact that people lead busy lives. Monitoring is time consuming and laborious, so committing people or groups to voluntarily doing it is a tall order. The influx of seasonal work programmes furthermore sees many individuals in the community, including members of the CCMC, spending long periods of time abroad, often disrupting data collection efforts due to the travel of trained CCMC members.

Examining other approaches in community fisheries monitoring

Tonga has contributed to designing and testing new digital forms of monitoring, with the MoF science team playing an important role in testing and refining the technology in *Ikasavea*. Many thousands of images gathered since 2021 at markets and landing sites in Nuku'alofa have been fed into machine learning processes that have improved the functionality of *Ikasavea*. To date, MoF has focused primarily on applying the "landings" and "market" monitoring modules, where "single-fish-on-a-board" images have been used.

It is in this context that a broader PhD research project led by Latu Aisea offered an opportunity for new insights. Aisea's PhD research commenced in 2023 and looks to critically examine the evolution of community approaches under the SMA programme. As part of the research project, three SMA communities (Ovaka, Koloa and Makave) in Vava'u have agreed to participate in carrying out two rounds of data collection in 2024. Data collected will serve both local management under the guidance of SMA coordinators and contribute to the PhD research. Monitoring will use the *Ikasavea* infrastructure to collect, process and provide feedback data from catch images, something MoF science staff are already familiar with. As such, this offers a unique

Community enumerators taking photos of the catch as part of the community module's Catch Survey. Image: ©Latu Aisea opportunity for the SMA coordinating team to examine other methods and how they relate to the needs of the SMA programme.

In March 2024, Aisea commenced fieldwork, and as part of that, a training was organised involving 13 participants (6 women and 7 men) that included community enumerators, staff from the Vava'u Environmental Protection Agency (VEPA), a local NGO, SMA fisheries officers based in the northern Vava'u fisheries office, and senior staff from the MoF coastal fisheries science team. Led by a collaborative team made up of Aisea and data coordinators from the Vanuatu (A. Sami) and Kiribati (B. Nikiari) monitoring programmes, the training represented an intra-Pacific skills exchange. Utilising the three-part manual for the community module, participants were guided through three days of training that involved introduction to the theory and mechanics of the system, run-through of all the data collection tools, scenario testing, and finally, practical field testing. The training also covered a session on displaying images in the web interface and highlighted the features of how the AI calibrates those images. Community enumerators will engage in catch data collection within their respective communities throughout the research fieldwork, while other enumerator team members (from MoF and partners) rotate every two weeks across the three study communities.

Critical considerations for integration

Since the SMA's inception 18 years ago, the programme has expanded to include more than 50% of coastal communities in Tonga. MoF's interest to assess the effectiveness and outcomes of the SMA programme is timely, and one that complements emerging monitoring methodologies. The transition from paper-based to photo-based data collection has significantly improved the accuracy and efficacy of collected data in market and landings surveys, and allows for more streamlined data management.

In noting the above opportunity, there are important considerations to be worked out in realising targets and ambitions of the SMA programme. First and foremost, it is critical to consider if adequate resources and funding are available for implementation over the long term, particularly given the commitment that communities will be making. Any application of the community module nationally would have to consider carefully what the most cost-effective approach would be, given available resourcing. This requires determining whether data collection is driven by MoF staff or by community enumerator teams (or a combination), and whether community monitoring should be implemented across all SMA communities or in select communities in each island group. If the latter, then what kind of criteria would guide the selection to adequately represent the diverse community fishing contexts across the SMA programme? Whatever implementation strategy is used, it is imperative to understand how data from communities could contribute to estimating the coastal fisheries' contribution to Tonga's gross domestic product, a principal ambition of the SMA programme. Finally, some challenges remain regardless of the technical methods applied, such as issues of varying levels of commitment among SMA communities, and of sustaining consistent and reliable monitoring in the face of people spending long periods of time out of the community.

References

Andrew N., Campbell B., Delisle A., Li O., Neihapi P., Nikiari B., Sami A., Steenbergen D. and Uriam T. 2020. Developing participatory monitoring of community fisheries in Kiribati and Vanuatu. SPC Fisheries Newsletter 162:32–38. https://purl.org/spc/digilib/doc/a3ejz

Bell L.A.J., Fa'anunu U. and Koloa T. 1994. Fisheries Resources Profiles, Kingdom of Tonga.

Cvitanovic C., Fox R.J. and Bellwood D.R. 2007. Herbivory by fishes on the Great Barrier Reef: A review of knowledge and understanding (unpublished report to the Marine and Tropical Sciences Research Facility).

Ditria E.M., Buelow C.A., Gonzalez-Rivero M. and Connolly R.M. 2022. Artificial intelligence and automated monitoring for assisting conservation of marine ecosystems: A perspective [Review]. Frontiers in Marine Science 9. https://doi.org/10.3389/fmars.2022.918104

Dumas P., Jimenez H. and Leopold M. 2009. Training in community-based monitoring techniques in Emau Island, North Efate, Vanuatu. Noumea, New Caledonia: Coral Reef Initiatives for the Pacific Programme.

Forum Fisheries Agency and Pacific Community. 2015. Future of fisheries: A regional roadmap for sustainable Pacific fisheries [Leaflet]. Noumea, New Caledonia: Secretariat of the Pacific Community. 4 p. https://purl.org/spc/digilib/doc/xnc9f

Fröcklin S., de la Torre-Castro M., Håkansson E., Carlsson A., Magnusson M. and Jiddawi N.S. 2014. Towards improved management of tropical invertebrate fisheries: Including time series and gender. PLoS ONE 9(3):e91161. https://doi.org/10.1371/journal.pone.0091161

Gillett R., Cusack P., Pintz W., Preston G., Kuemlangan B., Lightfoot C., Walton H. and James D. 1998. Tonga Fisheries Sector Review, Volume I: Main Report of the Consultants.

Gillett R.D. and Food and Agriculture Organization of the United Nations. 2011. Fisheries of the Pacific Islands: regional and national information. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific Bangkok, Thailand. 279 p.

Govan H. and Lalavanua W. 2023. The "Pacific Way" of coastal fisheries management: Status and progress of community-based fisheries management. SPC Fisheries Newsletter 169:33–47. https://purl.org/spc/digilib/doc/svtsz

Government of Tonga. 2002. Fisheries Management Act.

Grantham R., Lau J., and Kleiber D. 2020. Gleaning: Beyond the subsistence narrative. Maritime Studies 19(4):509–524. https://doi.org/10.1007/s40152-020-00200-3

Johnson J.E., Hooper E. and Welch D.J. 2020. Community Marine Monitoring Toolkit: A tool developed in the Pacific to inform community-based marine resource management. Marine Pollution Bulletin 159:111498. https://doi.org/https://doi.org/10.1016/j.marpolbul.2020.111498

Likiliki P.M. and Haraldsson G. 2006. Fisheries co-management and the evolution towards community fisheries management in Tonga. Reykjavik Iceland: United Nations University.

Malimali S. 2013. Socioeconomic and ecological implications of special management areas (SMAs) regime in the Kingdom of Tonga. PhD Thesis, Bangor University, Wales.

Ogden J.C. and Lobel P.S. 1978. The role of herbivorous fishes and urchins in coral reef communities. Environmental Biology of Fishes 3(1):49–63. https://doi.org/10.1007/BF00006308

Pacific Community. 2015. A new song for coastal fisheries pathways to change: the Noumea strategy. Noumea, New Caledonia: Secretariat of the Pacific Community. 28 p. https://purl.org/spc/digilib/doc/b8hvs

Pacific Community. 2021. Pacific framework for action on scaling up community-based fisheries management: 2021–2025. Noumea, New Caledonia: Pacific Community. 22 p. https://purl.org/spc/digilib/doc/yr5yv

Petelo W.A., Matoto S. and Gillett R. 1995. The case for community-based management fisheries management in Tonga [BP 61]. Noumea, New Caledonia: South Pacific Commission. South Pacific Commission and Forum Fisheries Agency Workshop on the Management of South Pacific Inshore Fisheries, Noumea, New Caledonia. 6 p. https://purl.org/spc/digilib/doc/5axss

Sami A., Neihapi P., Koran D., Malverus V., Ephraim R., Sokach A., Joy L., Li O. and Steenbergen D. 2020. A novel participatory catch monitoring approach: The Vanuatu experience. SPC Fisheries Newsletter 16239–45. https://purl.org/spc/digilib/doc/uhijh

Shedrawi G., Magron F., Andrew N., Fepuleai F., Gislard S., Gilchrist H., Halford A., Jalam S., Li O., Steenbergen D., Tiitii S. and Vigga B. 2023. Boosting data collection in Pacific Island's coastal fisheries using artificial intelligence technologies. Information paper 13. Sixth SPC Regional Technical Meeting on Coastal Fisheries and Aquaculture, 13–17 November 2023, Noumea, New Caledonia. 4 p. https://purl.org/spc/digilib/doc/tznu5

Shedrawi G., Magron F., Vigga B., Bosserelle P., Gislard S., Halford A. R., Tiitii S., Fepuleai F., Molai C., Rota M., Jalam S., Fatongiatau V., Sami A., Nikiari B., Sokach A., Joy L., Li O., Steenbergen D. J. and Andrew N. L. (in review). Leveraging deep learning and computer vision technologies to enhance management of coastal fisheries in the Pacific region. Nature Scientific Reports.

Taufa S.V., Tupou M. and Malimali S. 2018. An analysis of property rights in the Special Management Area (SMA) in Tonga. Marine Policy 95:267–272. https://doi.org/https://doi.org/10.1016/j.marpol.2018.05.028

Coastal fisheries data collection in the Pacific Islands region, and the need for a fresh approach to management

David J. Welch[1]

Data-less and data-poor management are, under the circumstances, not just valid alternatives. They are an imperative. (Johannes 1998:145)

Background

In the Pacific Islands region, marine fish and invertebrates are critically important for food security and livelihoods, providing 50–90% of animal protein for Pacific Islanders (FAO 2015. Per capita marine resource consumption rates in the region significantly exceed the global average by as much as three to five times in some Pacific Islands countries and territories (PICTs) (FAO 2015). While the recent Benefish study[2] cannot identify an actual monetary value for the social, health and cultural values that coastal fisheries support, it does demonstrate that coastal fishing is a significant contributor to the GDP of PICTs (Gillett and Fong 2023). Despite this importance, and the recent development of notable regional, subregional and national policies for coastal fisheries management (e.g. SPC 2015; MSG 2015; Vanuatu Fisheries Department 2019), implementation has been hampered by resourcing not yet matching what is required (Gillett 2016). While there are examples of positive progress continuing to emerge in recent times, particularly in support of community-based fisheries management (CBFM) approaches, management of coastal fisheries in PICTs is considered to be lacking or largely ineffective (e.g. Gillett et al. 2014; Govan et al. 2013; CFWG 2019; Welch 2021). From the latest Benefish study, Gillett and Fong (2023:19) stated the following as one of only two key recommendations:

> *The remarkable drop of per capita production from coastal fisheries over the period 2007–2021 alone (a decrease of 14% over 21 years) should be a "wake-up call" for countries that do not focus much attention on effective coastal fisheries management. Because it is coastal fisheries that provide most of the fisheries-related employment and food in the region, implementing the difficult task of improving coastal fisheries management should be pursued with greater vigour.*

Current situation in the Pacific

In 2021, with support from the Subregional Office for the Pacific Islands of the Food and Agriculture Organization of the United Nations (FAO), C_2O Fisheries reviewed available literature, and conducted consultations with all 22 PICT national fisheries department staff and the Pacific Community (SPC), to identify and document:

- What coastal fish and invertebrate data collections and activities exist?
- How have these data have been used to assess stock status?
- Have the outcomes of stock assessments informed effective management action?

After reviewing more than 100 historical Pacific coastal fisheries reports and data collections, it was found that even basic reliable data was generally absent, and data collected lacked replicability in time and space. Also, data collection activities were infrequent, often *ad hoc* and limited in scope, and most were associated with short-term external projects. In addition, data were rarely linked explicitly to assessment outcomes; the reliability of collected data was questionable; and, critically, strategic approaches to data collection were limited (Welch 2021). Further, there was limited use of data collections to assess the status of specific targeted species, due partly to the nature of the available data, but also an apparent lack of knowledge and/or technical capacity in data-limited stock assessment methods. Where assessments were available, the vast majority used only simple methods. While the use of simple stock assessment methods is completely valid, these assessments were reliant on external expertise, and explicit links to management responses were rare. It is, therefore, not surprising that the management of coastal marine resources in the Pacific Islands region is regarded as limited and that available data suggests that in many localities, a high proportion of marine resources are considered fully exploited or overfished (Gillett and Fong 2023).

The underlying challenges that have impeded effective coastal fisheries data collection and assessment for data-poor fisheries globally are well documented (see Johannes 1998; Orensanz et al. 2005; Pilling et al. 2008; Dowling et al. 2015a). Similar to these studies, the recent FAO data collection review and consultation with individuals from the majority of PICTs of Welch (2021) summarised the key challenges for the Pacific Islands region as:

- a lack of sustained and relevant funding;
- lack of personnel;

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[2] The Benefish study provides information on the benefits to Pacific Island countries and territories from the fisheries in the region: https://fame.spc.int/resources/documents/fisheries-economies-pacific-island-countries-and-territories

- limited relevant expertise;
- lack of equipment;
- large distances and remote areas to monitor; and
- technology and database issues, particularly the failure to leverage databases for quick access to information for management.

Compounding these challenges has been a long history of external projects and "experts" promoting and introducing Western approaches to "data-limited" monitoring and assessments that have all too often been disproportionately time-consuming, data-intensive and complex. Western practitioners regularly promote data-limited fisheries approaches that require the collection of many years of accurate catch and/or effort data. While perhaps well intended, the tendency is that such approaches do not benefit Pacific communities in the long term.

One of the key issues with past efforts by external projects and experts has been the failure to acknowledge the local socioeconomic, cultural and governance context (e.g. Cinner and McClanahan 2006; Barclay and Kinch 2013). Often, these challenges are accompanied by other factors, including: a lack of political will, ineffective policies, poor governance and low motivation among key staff (e.g. CFWG 2019). Collectively, these factors result in the lack of a strategic and achievable approach to coastal fisheries management for the entire region. Therefore, there is a need to rethink approaches for nationally led data collection, assessment and management of coastal fisheries historically used in the Pacific Islands region.

A fresh approach for the Pacific

The key overarching recommendation from Welch (2021) was for the development and adoption of an appropriate management framework designed to the "normal operating conditions" of the region, and that if implemented appropriately, has the potential to transform Pacific coastal fisheries management, thereby securing future food security and livelihoods for the people of the Pacific Islands. This recommendation was endorsed by an FAO-led roundtable meeting of several Pacific coastal fishery experts and scientists held in August 2021 (Welch and Halford, unpublished report). This recommendation also aligns with multiple regional papers, reports and policies, including the findings of Gillett and Fong (2023). Furthermore, the application of the framework proposed has the potential to significantly help meet the recommendation in the Benefish4 Report.

What is a management framework?

There are three main components to a fisheries management framework, all of which are linked to each other, and well-managed and sustainable fisheries apply these components (Sloan et al. 2013; Cochrane and Garcia 2009). These three components are:

1) data collection; 2) stock assessment; and 3) management actions (Fig. 1) (Dowling et al. 2015b).

The key to successful implementation of such a framework is recognising that each component has a clear purpose. That is, fisheries data are collected for the purpose of under-

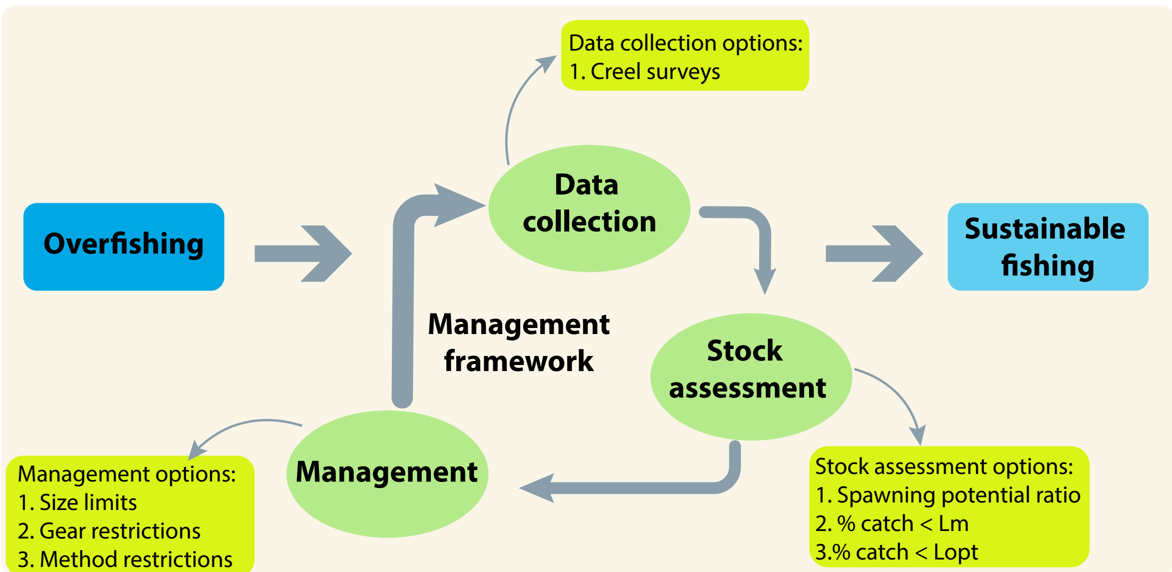

Figure 1. Conceptual diagram illustrating the three components of a management framework and their linkages: 1) data collection, 2) stock assessment, and 3) management actions. Examples of some options are given for each of these three elements. The key to a successful Pacific management framework would be to include options appropriate to the local context (e.g. capacity to conduct creel surveys given spatial extent of fishing, time and staff; and the technical capacity of staff to conduct different assessment types. Adapted from Dowling et al. (2015b).

standing how fishing is impacting the health of fish stocks. Generally, this is achieved using stock assessments, and the data collected must be commensurate with the intended assessment methods. The purpose of understanding the health of fish stocks, or their status, is to inform whether management intervention is required. It is also important to recognise that a management framework is a continuous cycle to ensure that existing management actions are effective and to identify emerging threats to stock health. Therefore, the application of a management framework as part of a national fisheries agency's routine (e.g. annual) is also an important aspect of success.

A management framework needs to match the local context

Because of the routine nature of a successful management framework, the scope of each component – and the approaches adopted – must align with the capabilities and capacity of the implementing entity. In many parts of the world, management frameworks are implemented although they are unable to be applied sustainably due to a reliance on data- and resource-heavy monitoring and assessment methods. A key concept to a successful Pacific fisheries management system is "less is more" (see Johannes 1998). Successfully adopting a regional management framework in the Pacific Islands region means developing each of the components to match the overall capacity characteristics for the entire region. This in turn means that a regional framework should incorporate the full range of characteristics of all PICTs (e.g. development status, fishery types, governance structures). Doing so ensures that the regional framework becomes a common and relevant template for all PICT to individually develop their local management system.

For example, creel and market surveys have been increasingly used by PICTs in recent years because they are recognised as being relatively cost-effective and able to collect large amounts of simple, but useful, fisheries data (e.g. species and size) (Kaly et al. 2016). Furthermore, some PICTs have begun to assess stock status using methods such as the length based-spawning potential ratio (LB-SPR) and the percentage of the catch that is below their size at maturity (Froese 2004; Hordyk et al. 2015; Prince et al. 2019). Such methods are often overlooked as they are considered too simple to reliably base management decisions on, when in fact, such methods are highly informative where data and information that informs management are limited. The uptake of the LB-SPR method is largely due to the recent development of resources and tools that have greatly assisted PICTs in using this method (see https://biospherics.com.au/barefoot-ecologists-toolbox/).

Developing a Pacific management framework

For the Pacific Islands region, there are many benefits of adopting a common, overarching regional framework. While there are obvious differences in coastal fisheries settings among PICTs, there exists many common characteristics and challenges that a regional framework can accommodate. Developed appropriately, a regional framework would provide an appropriate system for an individual PICT to independently adapt and develop their own national management system; one that is customised so that implementation requirements are well within local capabilities and local coastal fisheries management does not rely on external interventions or support (Fig. 2). For example, while the regional framework can provide data collection, and stock assessment and management options that may be suited to any PICT, a local national-level management framework should choose and only include options that are deemed appropriate to the local capacity to implement routinely (Fig. 2).

Furthermore, the framework would provide the flexibility for a PICT to modify its management system through time to include increasing or decreasing complexity in data types,

Local ni-Vanuatu fishing in the lagoon of North Efate, Vanuatu. Image: ©David Welch

monitoring methods and assessment approaches as, and if, capacity changes. Effectively, a regional management framework would provide all PICTs with a choice of options for data collection and stock assessment methods that match the data required and technical capacity available, and then to inform relevant management choices (Fig. 2). Furthermore, a common approach enables PICTs to share experiences readily through existing forums and processes hosted by SPC, non-governmental organisations and FAO.

The application of such a framework has the potential to vastly improve the management of coastal marine resources in the Pacific Islands region, if it is locally driven. However, for a regional framework to be successful in supporting local action, regional and local political will continues to be needed. Political will needs to be sufficient to counter the risk of commercial incentives over-riding the mechanisms of good management (e.g. Govan 2023). Successful implementation of any management framework will be dependent on genuine "buy-in" at all management levels and is possibly the single biggest challenge to be overcome. Therefore, consideration of meaningful strategies for achieving a collective higher sense of purpose at all levels of government will be key.

While the development and initial implementation of this regional framework approach would likely require external donor funding, longer-term and sustainable adoption should be possible under existing PICT national fisheries agencies budgets; and, if successful, may even reduce costs in the longer term. The Pacific region has a history of external aid for development projects, often aimed at addressing conservation and sustainability issues. In the past, the typical project cycle has meant that funding and effort has progressed to the stage of data collection and storage, but rarely to the point that the data are incorporated in an iterative and routine system of management. This is too often a consequence of ill-conceived projects that do not focus on local capacity development or sustainable outcomes from the outset. Ideally regional project donors would be more accountable to outcomes that genuinely match local priority needs (e.g. Enrici et al. 2023). Despite this, with local political will and a fully adopted regional or national coastal fisheries management system, relevant donor-funded activities can more readily be leveraged to provide meaningful and sustainable benefits.

For the development of a coastal fisheries management framework that is appropriate to the Pacific Islands regional context, there are several key elements that would need to be considered and incorporated into the process.

1 Consultation and ownership

The development of a regional framework must have significant involvement and leadership from PICTs, with local recognition and genuine "buy-in" to the system at all levels. While expert guidance and facilitation may be necessary and desirable during initial development and start-up, meaningful involvement of national fisheries agencies and other appropriate government agencies is needed to ensure the outcomes are locally appropriate. Ultimately, there should also be support by all relevant local research institutions, non-governmental organisations and civil society organisations.

2 Regional and cultural diversity

While a single regional framework could provide a consistent overarching framework across the Pacific Islands region, acknowledging diversity amongst PICTs is necessary to ensure the overall scope and framework specificity is appropriate to the local context. For example, the range in local capacity, artisanal and commercial fisheries, and current management and governance systems in place also need to be considered in a regional framework. This will ensure that available choices for each PICT are appropriate to the local context when developing its own management framework.

3 Informing regional policy

The development and implementation of a successful regional framework can help to meet many of the objectives of the relevant regional and national policies (e.g. the Noumea Strategy). Explicit and clear linkages of the regional frame-

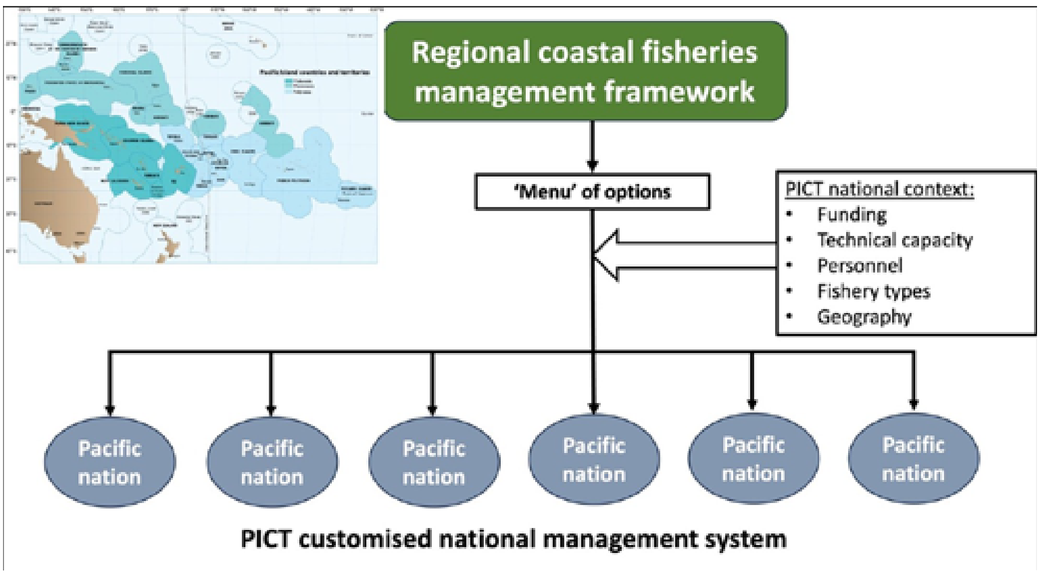

Figure 2. Conceptual diagram illustrating the process for each Pacific Island country or territory in developing its own coastal fisheries management framework to suit the local context and guided by the regional management framework.

work to these policies will be key for obtaining the necessary regional and individual PICT support.

4 Integrating CBFM

While the development of a regional framework is inherently a top-down management approach (i.e. implemented through government or other entities), in the Pacific Islands regional context, it is essential that any regional framework accommodates and integrates locally relevant CBFM approaches and activities (e.g. through co-management). In this regard, the management framework proposed here aligns with and provides the means for an overarching national system to support the *Pacific Framework for Action on Scaling up Community-based Fisheries Management: 2021–2025* (Pacific Community 2021). The Framework for Action provides implementation guidance that has significantly enhanced the implementation and "scaling up" of CBFM in the Pacific region in recent years (Govan and Lalavanua 2022; see https://cbfm.spc.int). Therefore, the management approach outlined here provides the appropriate national level support and guidance, and system template, for governance of coastal fisheries in the region while also providing an overarching national framework for successful strategies such as the Framework for Action.

5 Pilot phase and scaling up

Several PICTs have acknowledged the need for a strategic national framework to guide management of coastal fisheries in their PICT. Development and testing of a regional framework will need to occur with the involvement of several PICTs willing to act in a pilot phase. Successful practical application would provide the motivation and means for developing the full regional management framework package, thereby facilitating scaling up across the Pacific Islands region.

6 Integrating current resources

Several resources, tools and systems exist that are currently developed or under development and are relevant to a regional framework, and exploring and integrating these resources where possible is important. An obvious example is SPC's range of data management services that includes advanced tools that support data collection, data quality, data curation and analysis (e.g. the Ikasavea data tool; see https://fame.spc.int/resources/tools/ikasavea). Development of a regional and national management framework should carefully review and incorporate applicable tools and resources where they support successful implementation. For example, incorporating the Ikasavea data tool and associated resources could support data collection guidance, sharing and storage, creating efficiencies that enables resources to be directed to other components of the management system, such as capacity building in assessments.

What it would mean for the Pacific

The need to ensure food security and sustained livelihoods for Pacific Islanders into the future underpins much of the current efforts for sustainable fisheries management, both nationally and regionally. This is a key overarching goal for the Pacific Islands region. While the continued support and partnership with regional agencies such as SPC is important, a history of predominantly site-based and short-lived projects across the region have done little to provide an overarching and consistent approach that is effective in meeting regional goals. The successful development and implementation of a regional framework approach as outlined here, has the potential to be transformational in meeting these goals.

With sufficient and genuine desire at the national level to achieve food security and livelihood goals for coastal fisheries, the benefits and outcomes for PICTs could include:

- A clear but simple and strategic approach to focus PICT national efforts to achieve sustainable coastal fisheries goals, by formalising linkages between data collections and management outcomes.
- An achievable system customised to national policy and adapted to more effectively utilise and maximise local capacity.
- A management system that facilitates local (national) ownership and sustainable implementation.

Typical reef fish selection (caught by local commercial fishers) at the Suva fish market. Image: ©David Welch

- Guidance and a clearly defined purpose for national fisheries agencies staff in their roles.
- A system of fisheries management that provides greater ownership and empowerment for Pacific Islanders.
- A system of management that can more strategically direct recurrent national budgets.
- Providing an overarching national framework that puts into context all activities associated with the management of coastal fisheries, such as implementation of CBFM through the Framework for Action.
- Providing significant leverage and purpose for national fisheries agencies to align external actors and donor funded projects to invest in meaningful and positive outcomes that better align with local needs.
- Providing a common platform for inter-regional knowledge sharing and learning, across all aspects of the management system.
- Improved and regionally consistent linkages with regional agency support mechanisms, such as the SPC Ikasavea tool and resources.
- Apply relevant currently available technology, tools and resources that can be easily integrated, with potential for increased efficiencies as more tools and systems are developed. This will need to include easily accessible data products available for CBFM, through to national and regional actors and the use of artificial intelligence to improve data collections by supporting species identifications and measurements as the technology improves.
- Significantly improve the capacity for PICTs to readily meet international targets and indicators for key Sustainable Development Goals, specifically SDG2, SDG13 and SDG14, and for improved capacity to report on Indicator SDG14.4.1.

While the presentation of the above regional framework for the Pacific was well received at the 6th SPC Regional Technical Meeting on Coastal Fisheries and Aquaculture held last year at SPC in Noumea, this approach will only progress through further discussions among PICTs, and endorsement, if agreed to, be tabled at higher political forums such as the Fisheries Ministers Meeting. Calls for affirmative action on Pacific coastal fisheries such as the one in this article have become increasingly common in different forms. It is hoped that this article maintains the momentum and represents a "conversation starter" for a meaningful solution and ultimately helps to facilitate significant improvements in coastal fisheries management for the Pacific Islands region.

For further information or a copy of the full Pacific data mapping report, contact: d.welch@c2o.net.au

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References

Barclay K. and Kinch J. 2013. The importance of locally specific contexts in engaging with capitalism: Coastal fisheries in Papua New Guinea and the Solomon Islands. In: McCormack F. and Barclay K. (eds). Engaging with capitalism: Cases from Oceania. Research in Economic Anthropology 33:107–138.

CFWG (Coastal Fisheries Working Group). 2019. A call to leaders – Most urgent actions required for sustaining or increasing the contribution of coastal fisheries to our communities. Noumea, New Caledonia: Coastal Fisheries Working Group. 4 p. https://purl.org/spc/digilib/doc/t6zjq

Cinner J.E. and McClanahan T.R. 2006. Socioeconomic factors that lead to overfishing in small-scale coral reef fisheries of Papua New Guinea. Environmental Conservation 33 (1): 73–80. doi:10.1017/S0376892906002748.

Cochrane K.L. and Garcia S.M. (eds). 2009. A fishery manager's guidebook. The Food and Agriculture Organisation of the United Nations and Blackwell Publishing.

Dowling N.A., Dichmont C., Haddon M., D. Smith D., Smith T. and Sainsbury K. 2015a. Empirical harvest strategies for data-poor fisheries. A review of the literature. Fisheries Research 171:141–153. http://dx.doi.org/10.1016/j.fishres.2014.11.005

Dowling N.A., Dichmont C.M., Haddon M., Smith D.C., Smith A.D.M. and Sainsbury K. 2015b. Guidelines for developing formal harvest strategies for data-poor species and fisheries. Fisheries Research 171:130–140. https://doi.org/10.1016/j.fishres.2014.09.013

Enrici A., Gruby R.L., Betsill M.M., Le Cornu E., Blackwatters J.E., Basurto X., Govan H., Holm T., Jupiter S.D. and Mangubhai S. 2023. Who's setting the agenda? Philanthropic donor influence in marine conservation. Ecology and Society 28(3):2. https://doi.org/10.5751/ES-14091-280302

FAO (Food and Agriculture Organization of the United Nations). 2015. The State of World Fisheries and Aquaculture 2014. Rome, Italy: Food and Agriculture Organization.

Froese R. 2004. Keep it simple: Three indicators to deal with overfishing. Fish and Fisheries, 2004 (5): 86-91. https://doi.org/10.1111/j.1467-2979.2004.00144.x

Gillett R.D. 2016. Fisheries in the economies of Pacific Island countries and territories. Noumea, New Caledonia: Pacific Community. 684 p. https://purl.org/spc/digilib/doc/pvyuo

Gillett R., Lewis A. and Cartwright I. 2014. Coastal fisheries in Fiji: Resources, issues and enhancing the role of the fisheries department. A review supported by the David and Lucille Packard Foundation. Suva, Fiji.

Gillett R. and Fong M. 2023. Fisheries in the economies of Pacific Island countries and territories (Benefish Study 4). Noumea, New Caledonia: Pacific Community. 704 p. https://purl.org/spc/digilib/doc/ppizh

Govan H. 2023. Corruption below water: Improving governance through corruption prevention in the fisheries sector of the Pacific Island Countries. Technical report prepared by the United Nations Pacific Regional Anti-Corruption (UN-PRAC) Project, a joint initiative by the United Nations Office on Drugs and Crime (UNODC) and United Nations Development Programme (UNDP), supported by the New Zealand Aid Programme. 17 p.

Govan H., Kinch J. and Brjosniovschi A. 2013. Strategic review of inshore fisheries policies and strategies in Melanesia: Fiji, New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu. (Part II: Country reports). SPC report to the Melanesian Spearhead Group. 65 p. https://purl.org/spc/digilib/doc/m4sa2

Govan H. and Lalavanua W. 2022. Status of community-based fisheries management in Pacific Island countries and territories: Survey report. Noumea, New Caledonia: Pacific Community. 70 p. https://purl.org/spc/digilib/doc/H_uNgzxUo7kB36r

Hordyk A., Ono K., Valencia S., Loneragan N. and Prince J. 2015. A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor Fisheries. ICES Journal of Marine Science 72(1):217–231. doi:10.1093/icesjms/fsu004

Johannes R.E. 1998. The case for data-less marine resource management: Examples from tropical nearshore finfisheries. TREE 13(6):243–246.

Kaly U., Preston G., Yeeting B., Bertram I. and Moore B. 2016. Creel and market surveys: A manual for Pacific Island fisheries officers. Noumea, New Caledonia: Pacific Community. 136 p. https://purl.org/spc/digilib/doc/izw66

Melanesian Spearhead Group Secretariat. 2015. Melanesian Spearhead Group roadmap for inshore fisheries management and sustainable development. Melanesian Spearhead Group Secretariat and Secretariat of the Pacific Community (SPC), Port Vila, Vanuatu. 12 p. https://purl.org/spc/digilib/doc/mgtfs

Orensanz J.M., Parma A.M., Jerez G., Barahona N., Montecinos M. and Elias I. 2005. What are the key elements for the sustainability of "S-Fisheries"? Insights from South America. Bulletin of Marine Science 76(2):527–556.

Pacific Community. 2021. Pacific framework for action on scaling up community-based fisheries management: 2021-2025. Noumea, New Caledonia: Pacific Community. 22 p. https://purl.org/spc/digilib/doc/yr5yv

Pilling G., Apostolaki P., Failler P., Floros C., Large P.A., Morales-Nin B., Reglero P., Stergiou K.I. and Tsikliras A. 2008. Assessment and management of data-poor fisheries. p. 280–305. In: Payne A., Cotter J. and Potter T. (eds). 2008. Advances in fisheries science: 50 years on from Beverton and Holt. Oxford, England: Blackwell Publishing.

Prince J.D., Lalavanua W., Tamanitoakula J., Loganimoce E., Vodivodi T., Marama K., Waqainabete P., Jeremiah F., Nalasi D., Tamata L., Naleba M., Naisilisili W., Kaloudrau U., Lagi L., Logatabua K., Dautei R., Tikaram R. and Mangubhai S. 2019. Spawning potential surveys reveal an urgent need for effective management. Fisheries Newsletter 158:28–36. https://purl.org/spc/digilib/doc/y6mf4

Sloan S.R., Smith A.D.M., Gardner C., Crosthwaite K., Triantafillos L., Jeffries B. and Kimber N. 2013. National guidelines to develop fishery harvest strategies. FRDC Report – Project 2010/061. Adelaide, South Australia: Primary Industries and Regions.

SPC. 2015. A new song for coastal fisheries pathways to change: The Noumea strategy. Noumea, New Caledonia: Secretariat of the Pacific Community. 28 p. https://purl.org/spc/digilib/doc/b8hvs

Vanuatu Fisheries Department. 2019. Vanuatu National Roadmap for Coastal Fisheries: 2019–2030. Noumea, New Caledonia: Pacific Community. 24 p. https://purl.org/spc/digilib/doc/bhawm

Welch D.J. 2021. Mapping data collection strategies of Pacific Island countries and territories. Final report to Food and Agriculture Organization of the United Nations (FAO) through their Subregional office for the Pacific Islands. C2O Fisheries, Cairns, Australia. 88 p.

Welch D.J. and Halford A. (unpublished report) Pacific SDG14.4.1 expert roundtable discussion. Joint FAO and SPC expert virtual meeting, 19 August 2021. 21 p.

Diffusion of small-scale tilapia aquaculture development in Solomon Islands through the expression of interest analysis, 2005–2022

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Abstract

The Solomon Islands' Ministry of Fisheries and Marine Resources has supported the development and growth of small-scale tilapia aquaculture over the past decade. Given the potential for aquaculture to enhance food security and generate income, the Solomon Islands government has prioritised this sector. The goal is to address the negative impacts of climate change and unsustainable development caused by increasing population. Despite challenges in the suitability of the Mozambique tilapia strain for aquaculture in Solomon Islands, the industry has thrived through public–private partnerships, benefiting communities across various provinces. To sustain this growth, the government needs to expedite the importation of more suitable tilapia strains, establish robust governance frameworks, and allocate resources for the sector's sustainable development.

Introduction

Small-scale aquaculture (SSA) is well-established in Asia and Africa, supported by robust research and development efforts (Naylor et al. 2021). In 2021, SSA yielded an average revenue of USD 265 billion, with a significant 95% originating from developing countries, including small island developing states (SIDS) (FAO 2023a). The Food and Agriculture Organization of the United Nations defines SSA as aquaculture activities with limited production inputs, outputs, and minimal technological and capital investments (FAO 2023a). This definition aligns with SSA's prevalence in rural communities, where it serves as a vital means of livelihood, contributing to food security, income stability, and local development (Harohau et al. 2020; Naylor et al. 2021). In addition, small-scale seaweed farming aids climate mitigation by acting as a carbon dioxide sink, biofuel producer, soil enhancer, and wave-breaker, reducing fossil fuel reliance and ocean acidification. (Duarte et al. 2017).

Figure 1. *Oreochromis mossambicus* a non-native freshwater species currently farmed in the Solomon Islands (MFMR). Image: ©Billy Meu

Climate change impacts have a mixed effect on Pacific Island countries' fisheries and aquaculture. It is widely acknowledged that SIDS communities are confronted with a growing threat caused by climate change impacts, including rising sea levels, erosion, flooding, droughts, temperature shifts, altered rainfall patterns and increasing frequency of El Niño-Southern Oscillation events (Connell 2018). These climate-induced changes have significantly affected food security in the Pacific and are of utmost concern. According to the International Panel on Climate Change Assessment Report (IPCC 2023), Heck et al. (2023) confidently state that human-induced climate change has negative effects on fisheries and aquaculture productivity in SIDS. In addition, the vulnerability of Pacific communities has been influenced by complex interactions between climate and non-climatic factors (McCubbin et al. 2015). These challenges are exacerbated by pressure on aquatic ecosystems due to increasing human populations, pollution, overfishing and unsustainable development activities (Mcleod et al. 2019). The depletion of these resources has led to food insecurity, resulting in malnutrition, health problems, and poverty, especially among vulnerable groups in rural areas (Bell et al. 2009; Harohau et al. 2020; Dey et al. 2016). Fish serves as a critical source of protein and a major component of livelihoods in coastal communities (Blythe et al. 2017; Dey et al. 2016). Thus, the Solomon Islands government is exploring small-scale tilapia (SST) and seaweed aquaculture as an alternative livelihood activity to supplement wild captured fisheries because of pressing food insecurity and malnutrition issues.

The Mozambique tilapia of the *Oreochromis* genus was introduced to Solomon Islands in the 1960s and gradually became accepted as a source of fish protein (Nandlal and Pickering 2004). People have been fishing and farming tilapia in natural and aquaculture systems over the last 70 years, and gradually, it has become a part of their diet. Although tilapia was initially introduced as a biological agent to control mosquito populations, over time, it became an alternative fish protein source alongside other native fishes in freshwater and marine ecosystems.

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Subsequently, in 2008, the tilapia aquaculture sector emerged following consultations to develop a comprehensive national plan for freshwater inland aquaculture. After this deliberative process, MFMR requested support from the Pacific Community (SPC) and WorldFish, highlighting the potential of tilapia as a promising commercial commodity (MFMR 2018). SPC and WorldFish assisted MFMR by assessing the viability of tilapia and milkfish farming in Solomon Islands. This assessment report emphasised the importance of land-based aquaculture, with tilapia being a more viable commodity than milkfish. Thus, to improve the contributions of tilapia aquaculture to community livelihoods, food security and income, a better strain of tilapia or other endemic species should be introduced in the country (Cleasby et al. 2014; Harohau et al. 2020; Blythe et al. 2017). Studies have shown that Mozambique tilapia was not suitable for intensive aquaculture because of its sluggish growth, rapid reproduction (early sexual maturation), and limited genetic diversity resulting from extensive inbreeding (Pickering 2009; Lloyd 2011; MFMR 2018).

To enhance this sector, the Solomon Islands National Aquaculture Development Strategy (SINADS 2009–2014), subsequently revised as the Solomon Islands National Aquaculture Management and Development Plan 2018–2023, charts a course toward a sustainable tilapia aquaculture industry. This entails the commendable aim of importing an improved tilapia strain specifically for aquaculture in the Solomon Islands. However, there exists a knowledge gap on the current dissemination and inclusion of SST as a livelihood activity that could effectively complement coastal fisheries.

Objectives

The overall goal is to assess how SST development was diffused in Solomon Islands from 2005 to 2022 using available SST production data in the country. Thus, the three specific objectives are articulated.

1. Contextualise the historical development of the tilapia sector in Solomon Islands for the period 2005 to 2022.
2. Discuss the expressions of interest trends of tilapia aquaculture farmers in Solomon Islands from 2005 to 2022.
3. Outline the various interventions undertaken by the national government and non-government organisations to support the development of tilapia aquaculture in Solomon Islands.

Methodology

Study sites

Solomon Islands is an archipelago consisting of 1000 islands in the South Pacific, only about 350 of which are inhabited. The total land area is approximately 28,900 km^2, and the country has a 1,589,477 km^2 exclusive economic zone (FAO 2016). With a population of about 720,956 people in 2019 and an annual growth rate of 2.6% from 2009 to 2019, the nation faces climate challenges from climate change and rising sea levels. Mean daily temperatures range between 24°C and 32°C and annual rainfall ranges from

[2] https://statistics.gov.sb/

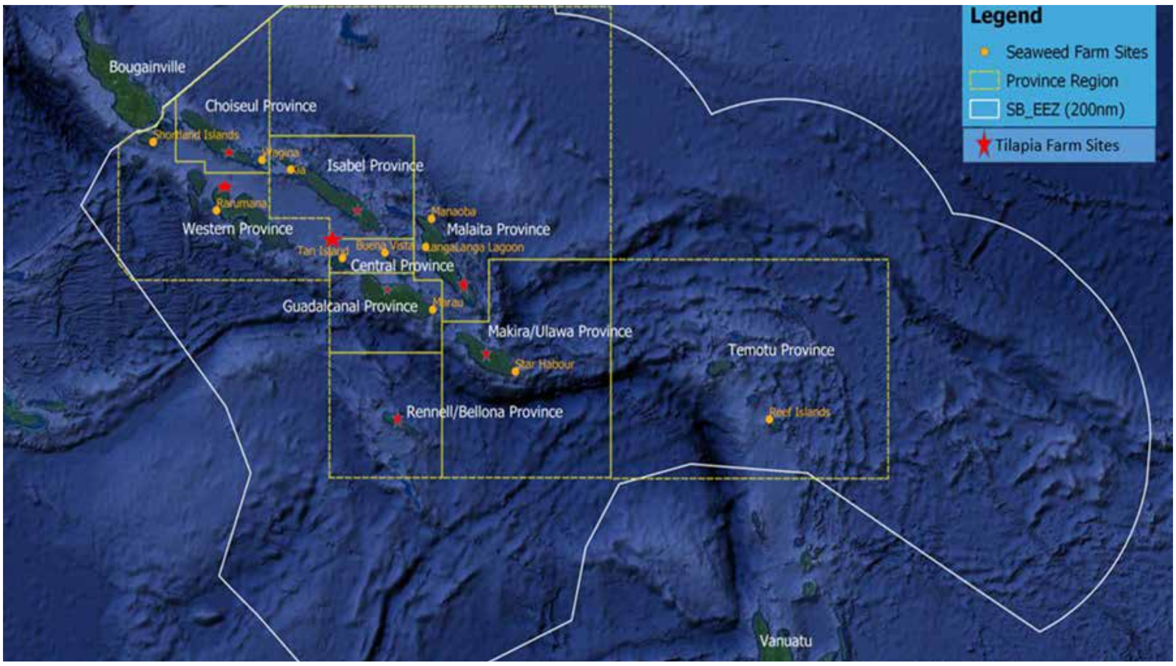


Figure 2. Tilapia and seaweed aquaculture sites in Solomon Islands. Image: ©Sebastian Misiga

3000 mm to 6000 mm. Primary livelihoods in rural areas include agriculture, fishing and forestry, while the economy relies on imports, foreign aid, and exports such timber, fish, agricultural products and gold according to the Solomon Islands National Statistic Office Census report in 2019.[2]

The study was conducted in provinces where small-scale tilapia aquaculture is practised, including Choiseul, Western, Isabel, Malaita, Guadalcanal, Makira, Renbel and Temotu (Fig. 2).

Data sources and collection

Primary datasets for tilapia were retrieved and requested from MFMR management in Honiara, Solomon Islands. Data included tilapia expressions of interest (EOIs) received from individuals, families and institutions from 2008 to 2022. The desktop review was conducted on unpublished reports, including the MFMR's SST database as well as published articles and reports. The authors also shared their individual experiences over the last 10 years in areas such as farming community profiles, community vulnerability, and the developmental history of tilapia in Solomon Islands. SPC's library[3] and the University of the South Pacific's online databases were also consulted.

The following questions were asked during the data collection process outlined above:

1. What is the historical development of SST aquaculture at production sites within Solomon Islands?
2. What are the trends of farmer interests recorded or received by MFMR from individuals, families, communities and institutions over the study period?
3. What interventions have been made in the tilapia sector to date in Solomon Islands?

Data analysis

To determine the historical EOI trends for the tilapia data, time-series methods were employed, spanning the period 2008 to 2022, using basic descriptive statistics. Temporally, the EOI count was plotted against years, while spatially, the EOI count was mapped against province. Additional information about tilapia case studies pertinent to income, food security, policy and development history was cited from past reports and articles retrieved from online databases.

Results and discussion

History of aquaculture development in Solomon Islands

Aquaculture was first introduced in Solomon Islands in the 1960s with pearl oyster *(Pinctada margaritifera and P. maxima)* farming on Wagina Island. However, this initial venture faced economic challenges and was abandoned in the 1970s. During this period, there was a lack of proper governance for fisheries and aquaculture development, as the national fisheries department had not been established (Pickering 2009; FAO 2023b).

In the early 1980s, aquaculture activities re-emerged, with a *Macrobrachium rosenberggi* (prawn) farm established in northwest Guadalcanal in 1983 (Fig. 3). The project was launched by the South Pacific Aquaculture Ltd, which imported post-larvae from Tahiti. In 1986, production amounted to 439 kg of *Macrobrachium*, utilising locally made feed pellets. Most of this harvest was sold to local restaurants and supermarkets at approximately SBD 10 per kg. Production in 1987 was reported to range from over a few hundred kilograms (MFMR 2001). This success led to the initiation of a shrimp farm by a Chinese entrepreneur in west Guadalcanal, and by 1998, around 37,000 kg of prawns were exported from the Solomon Islands (FAO 2023b).

In 1984, the International Centre for Living Aquatic Resource Management (ICLARM) established its Coastal Aquaculture Centre at Aruligo in northwest Guadalcanal. By 1988, the first seaweed grow-out trial occurred in Vona Vona Lagoon, Western Province. Unfortunately, these activities were disrupted by ethnic unrest in 1999 (FAO 2023b).

The period from 2000 to 2010 was marked by reconstruction and recovery, with the resurgence of seaweed aquaculture funded by the European Union. Within this period, the aquaculture department under the MFMR was established and tilapia and seaweed were identified as priority species commodities for aquaculture (Fig. 3). Subsequently, in 2009, a national aquaculture development plan (2009–2014) was formulated to guide aquaculture development in the country (MFMR 2019; FAO 2023b).

Since 2010, there has been a growth in aquaculture research and development, enhanced by a national development plan (2009–2014) that prioritises tilapia and seaweed development. For instance, under the national aquaculture development plan, tilapia was a high-priority species for aquaculture, which led to the development of the first national tilapia action plan that prioritised importing a strain more suitable to Solomon Islands, and approval from the Cabinet in 2017. Since then, preparation work encompassing infrastructure development, building technical capacity, and policy development has been started. Besides these commodities, MFMR has been conducting sea cucumber research since 2010, supported by the Japan's Overseas Fishery Cooperation Foundation and implemented in pilot sites in Marau, Guadalcanal, and Buena Vista, Central Islands.

The aquaculture industry in Solomon Islands encounters various obstacles that hinder its growth. Challenges

[3] https://www.spc.int/DigitalLibrary/FAME/Search

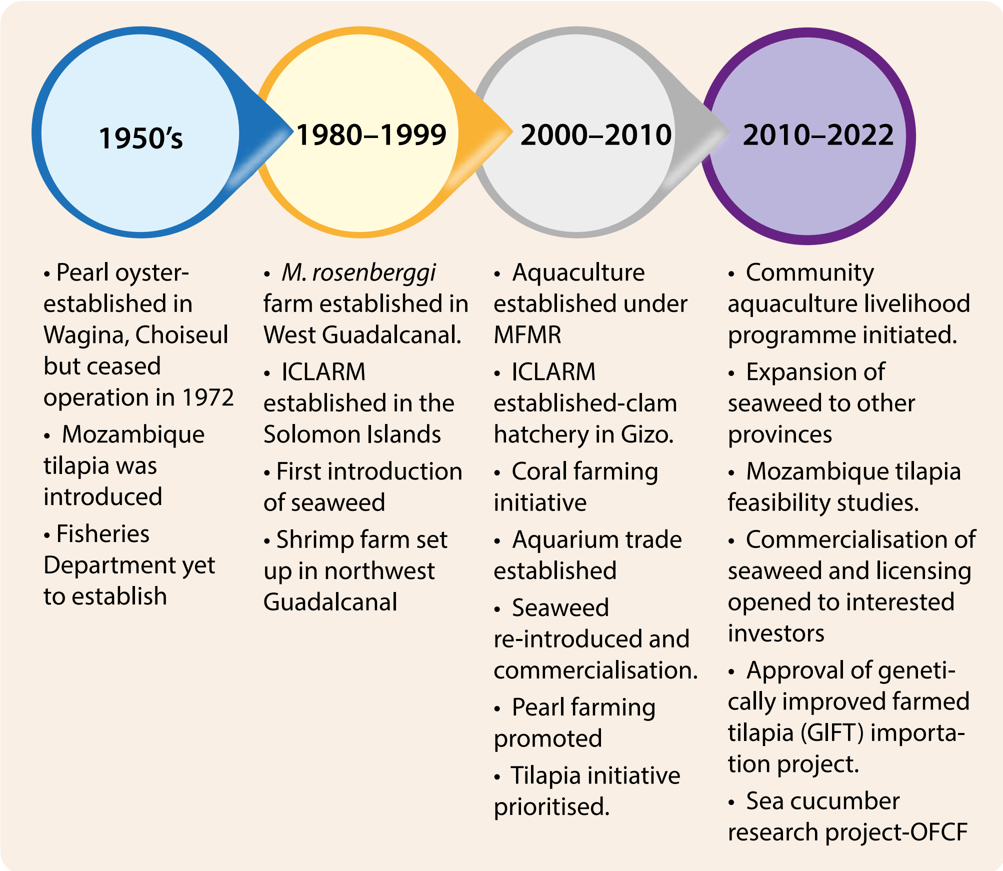
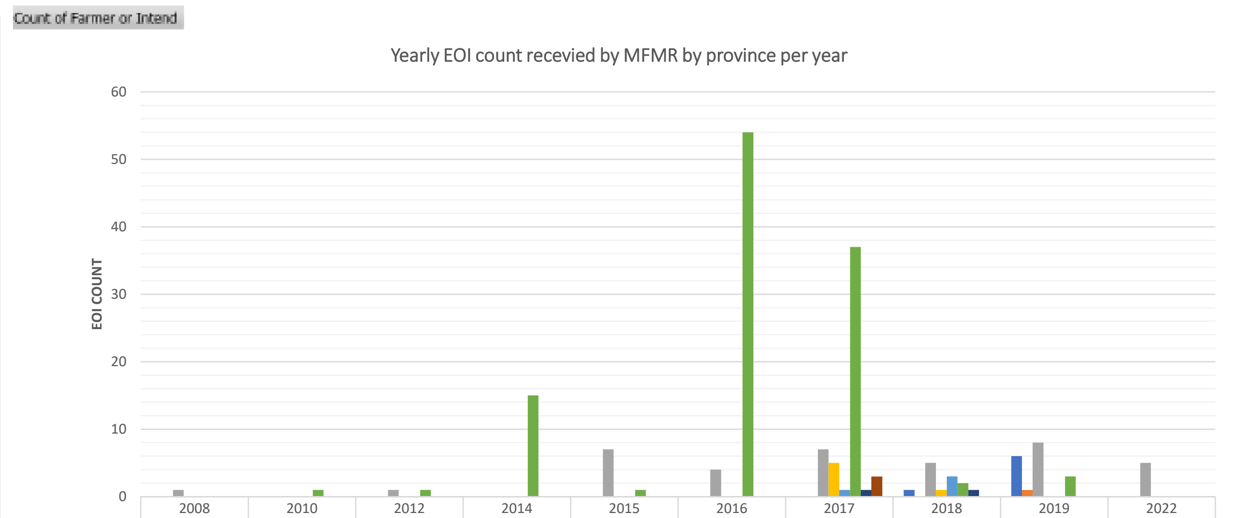


Figure 3. History of aquaculture in Solomon Islands, 1960–2022.



	2008	2010	2012	2014	2015	2016	2017	2018	2019	2022
Central								1	6	
Choiseul									1	
Guadalcanal	1		1		7	4	7	5	8	5
Isabel							5	1		
Makira Ulawa							1	3		
Malaita		1	1	15	1	54	37	2	3	
Renbel							1	1		
Western							3			

When started?

Figure 4. Expressions of interest in tilapia farming by province per year in Solomon Islands, 2008–2022.

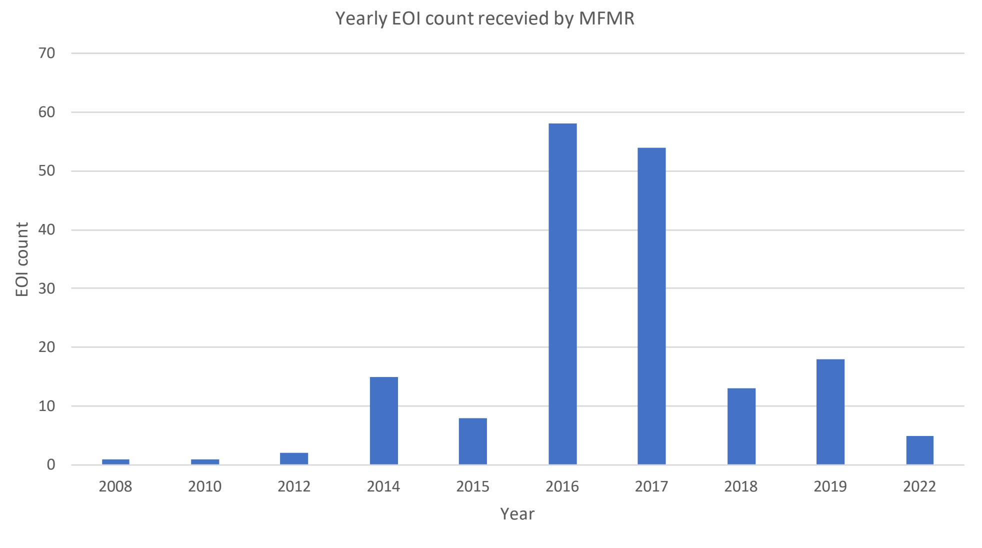


Figure 5. Annual expressions of interest received over the study period 2008–2022.

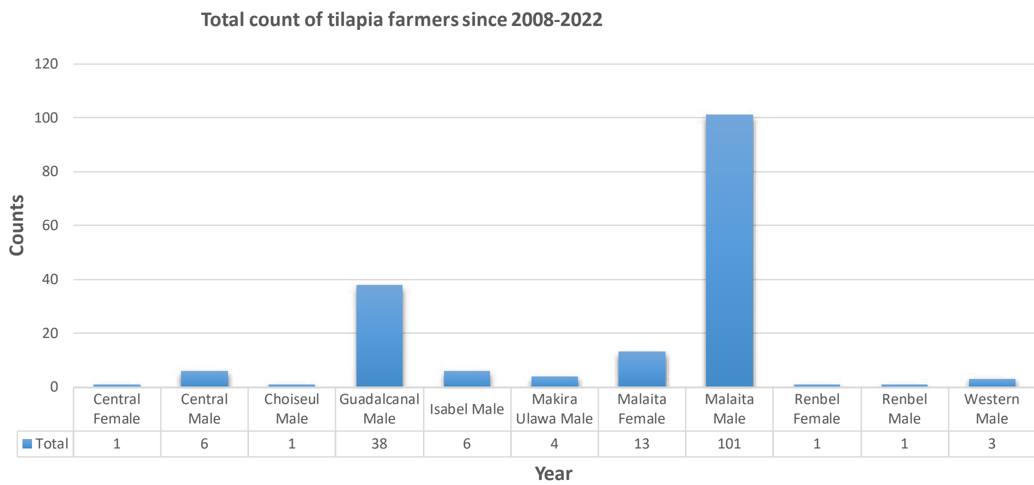


Figure 6. Gender composition of tilapia farmers in Solomon Islands over the period 2008–2022.

Tilapia pond in Aruligo, Guadalcanal Province. Image: ©Billy Meu

Table 1. Summary of case studies of tilapia farming in Malaita and Guadalcanal provinces, Solomon Islands.

Topic	Summary	References
Limits of tilapia aquaculture for rural livelihoods in Solomon Islands Study site: Malaita Province Date: 2017/2018	• 50% confirmed the contribution of tilapia farming to livelihood assets (human well-being, increased income, food security, sustainable use of natural resources, reduced vulnerability) and social assets. • Mozambique tilapia's contribution is insignificant to enhancing food security and income generation for rural farmers. • Import a better strain of tilapia (GIFT). • Household fish consumption level, 0.014 kg to 0.210 kg fish consumption per household per week. • Weekly income ranging from SBD 325.56 to SBD 8925.19 (0.002% to 0.5% of total income per week)	(Harohau et al. 2020).
Income and food security	***Farmer Story 1*** • Tilapia farmer with hatchery work experience with WorldFish Center. • Breed tilapia and sell fingerlings at SBD 0.50/fingerling. • Mature tilapia sold at SBD 10/fisher (> 100 grams) to Asia, with an estimated SBD 4000 per year in 2021.	(Maxwell H., pers. comm., 3 March 2023)
	Farmer Story 2 • Production for family consumption and sales. • Annual revenue ranging from SBD 600 to SBD 1000. • Ecotourism entry fees from individuals and families (fees at SBD 2/head to SBD10/family).	(Meu 2023) (Dola R., pers. comm., 21 October 2021)

such as the country's remote location makes it difficult to transport goods and to access markets. Land and sea tenure issues add complexity, requiring careful negotiation of ownership rights. A crucial limitation is the lack of hatcheries, which affects the production and supply of seed, essential for industry expansion. Unfortunately, there is a shortage of skilled technical staff and limited expertise in aquaculture, highlighting the need for investment in education and training. Government incentives to attract private investment are lacking, alongside high credit risks and irregular shipping services. Political instability further undermines the private sector's confidence, thereby affecting long-term planning and investment. Addressing these challenges requires coordinated efforts, including policy reforms, infrastructure development, and capacity-building initiatives, to unlock the full potential of aquaculture in Solomon Islands (MFMR 2018).

It is, therefore, vital to understand that the private sector took a leading role in establishing the Solomon Islands' aquaculture industry in the early 1950s and later the national government. It denotes that private entrepreneurs played a crucial role in supporting the government to attain sustainability of the sector.

EOIs for tilapia farming in Solomon Islands

Since 2008, MFMR has received 175 EIOs from eight provinces in the country. The EOIs received came in through application letters addressed to the Permanent Secretary of MFMR.

As shown in Figure 4, Malaita has shown the greatest interest in tilapia farming, followed by Guadalcanal with little interest recorded for other provinces. The recording of EOI data at the MFMR office began in 2008 and was primarily through written requests that were recorded in the tilapia inventory database.

Notably, from 2008 to 2012, the number of EOIs received was small compared to 2014–2018, reflecting levels of awareness campaigns conducted by WorldFish and MFMR (MFMR 2018). The decline of EOIs after 2018, as shown in Figure 5, is attributed to MFMR's redirection policy towards infrastructure development and staff capacity building to prepare for the importation of genetically improved farmed tilapia (GIFT) and the COVID-19 global pandemic. It is vital to note that there are a huge number of households that continue to engage in tilapia farming but are not captured in the MFMR dataset. This is due to a lack of a centralised database for aquaculture production at MFMR.

The levels of interest in tilapia farming varied across different provinces in the Solomon Islands, with Guadalcanal and Malaita standing out with significantly higher numbers of EOIs. This difference can be attributed to several factors. First, MFMR's policy has focused on tilapia development in these two provinces, leading to greater awareness and support for the sector over the years. Notably, both Guadalcanal and Malaita have many inland communities, which are often distant from urban centres where fish markets are located (Cleasby et al. 2014; Blythe et al. 2017). As a result, the cost and logistical challenges of accessing fish from coastal areas make tilapia farming a more attractive option for ensuring food security in these regions. There is also a cultural preference for freshwater fish among inland communities in these provinces (Cleasby et al. 2014). Conversely, other provinces such as Choiseul, Isabel and Makira have recorded fewer EOIs, largely because of limited awareness and outreach efforts, as well as geographical distance limiting access to information and resources. Closing the gap in awareness, and providing support for

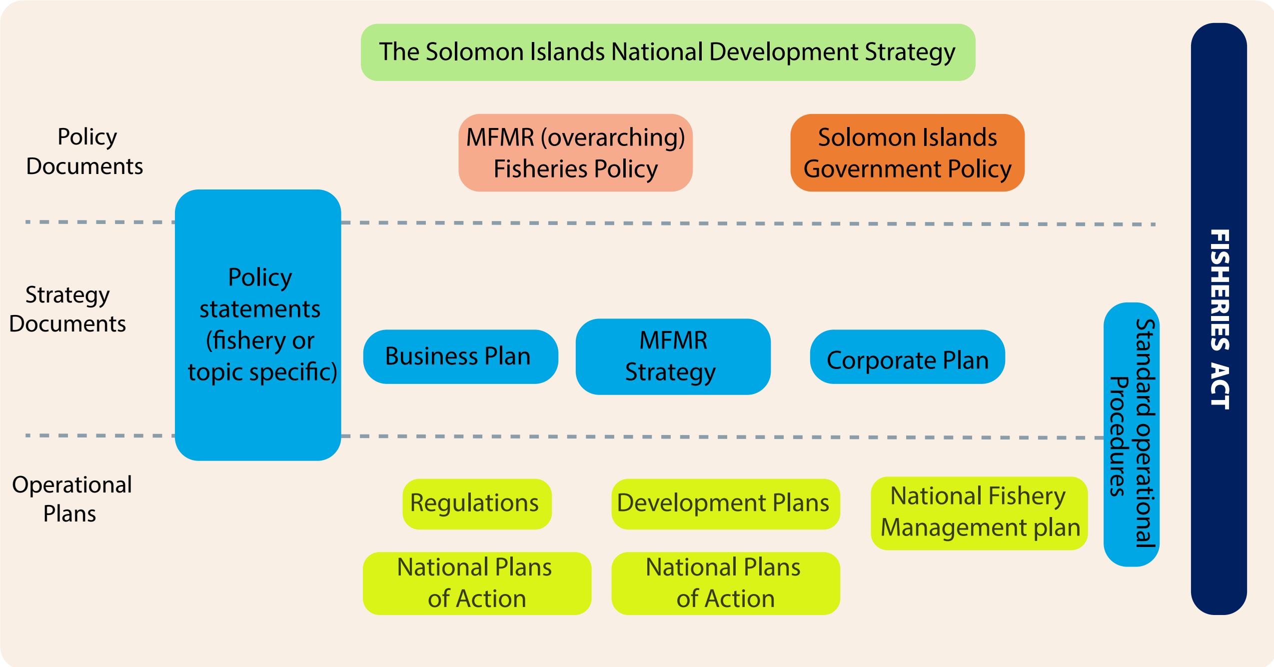


Figure 7. The Solomon Islands' fisheries policy and legislative framework. Source: MFMR 2019

tilapia farming in these regions, could help to promote greater inclusivity and sustainability in the sector across Solomon Islands.

Moreover, tilapia farming is also a male-dominated activity, as depicted in Figure 6. In Malaita Province, although a patrilineal society, the highest number of female farmers is recorded compared to other provinces. As the sector grows, women's involvement is anticipated to increase, as seen in other farming regions such as Asia. The majority of women who are currently participating in tilapia farming are single mothers who got involved purposely to provide for their families the associated SST benefits mentioned in Table 1.

A brief overview of tilapia aquaculture case studies

Several studies have been conducted on the feasibility of tilapia aquaculture in Malaita and Guadalcanal Province since 2008. Since 2008, the culturing of *Oreochromis mossambicus* has continued until this day. It is evident that several tilapia farmers began by learning from other farmers, a concept described as the diffusion of innovation, which was well articulated in a study conducted in Malaita in 2015 (Blythe et al. 2017). With their basic knowledge and technology, new farmers usually start their small backyard fishponds before seeking help from MFMR. In other communities, lead farmers took the initiative to help new households build their fish ponds (Harohau et al. 2020). MFMR has been training lead farmers under its community livelihood programme since 2010.

Students harvesting tilapia in a concrete pond at the Afutara Rural Training Centre, Malaita Province. Image: ©Billy Meu

Some of the benefits and impacts of SST aquaculture shared by lead farmers are summarised in Table 1.

Complimentary to Table 1, Cleasby et al. (2014) found that tilapia farming is becoming popular among men, women and children in farming communities in Malaita Province. The survey's findings alluded to the fact that 92% of participants were eager to acquire more knowledge about tilapia farming.

Expanding on these findings, research by Harohau et al. (2020) demonstrated that approximately 53% of farmers were satisfied with the contributions of tilapia farming to their human and social assets. It also indicated that 28% of farmers acknowledged the positive impact on their physical assets, while 13% expressed satisfaction regarding the financial assets generated by tilapia farming. These are the facets that motivated many tilapia farmers in Guadalcanal and Malaita (see Figs. 4 and 6). However, the current tilapia aquaculture system has limited contributions to food security and income because of the low productivity of the Mozambique tilapia farmed in the country (Cleasby et al. 2014).

Another project implemented by MFMR and partners from 2017 to 2020, engaged 26 farmers and three vocational schools in Malaita Province to grow larger tilapia. This resulted in an increased number of EOIs recorded as depicted in Figure 5. The project outcomes included 71% of participants who farmed tilapia for their consumption, predominantly among inland farmers, while approximately 43% of farmers sold their fish to support household financial needs. The project has supported 35 new tilapia farms over the past three years (Meu 2023).

In summary, the recent increase in EOI submissions received at MFMR is because of several positive drivers. First, information about the government's intention to import GIFT has been promoted through an awareness programme hosted by MFMR. The influx of project support from the government and development partners has also motivated prospective tilapia farmers. As depicted in Figures 4 and 5, this surge in EOI submissions has not only been observed in Malaita and Guadalcanal but also on other islands. Thus, these findings illustrated the positive drivers of SST farming on rural community livelihoods, encompassing social, economic and food security benefits.

Government and private sector interventions

The tilapia industry in Solomon Islands owes its existence to a synergy of government and private sector efforts since its establishment in 2001 (see Fig. 3). The national government, through MFMR, is responsible for creating and implementing relevant legislation and policy frameworks to nurture aquaculture and fisheries development (Fig. 7). The Fisheries Act (2015) is the national law that governs all fisheries and aquaculture operations in Solomon Islands. MFMR has since developed its national overarching fisheries policy, which served as the foundation for the current national aquaculture development plan, which governs the operations of the tilapia sector to meet the government's policy objectives. All development partner support have been governed by the legislative framework outlined below.

Drawing on the policy map, MFMR has collaborated with development partners and communities to develop aquaculture in the country. Donor partners have supported tilapia and seaweed farming, providing farming materials, technical support, and funding grants. For example, the European Union's funding in 2001 procured valuable assets such as boats, farming materials and training programmes for various communities in high-production areas.

In 2008, with support from SPC and WorldFish, a national aquaculture development plan was developed and later a tilapia action plan with support through the ACIAR Project (FIS/2009/061) targeting aquaculture and food security in Solomon Islands. This paved the way towards the commencement of *O. mossambicus* research and a grow-out pilot programme in 2009. Under this programme, MFMR, with support from its development partners (WorldFish and SPC), provided technical and material support to rural farmers based on EOIs. In 2011, an import risk assessment was developed, and Cabinet approval to import GIFT tilapia for SSA in Solomon Islands was granted to MFMR in 2017. Subsequently, since 2018, MFMR has been supported by the New Zealand government to develop a national hatchery and quarantine facility to supply quality tilapia fingerlings to farmers.

Besides tilapia, private entrepreneurs buy and export dried seaweed products to overseas markets and established buying agents in seaweed-producing communities. They offer loans to farmers for materials, which are repaid from sales of their dried seaweed. Some buyers also provide essential resources, such as boats and outboard motors, to support farming activities, especially at farming sites like Wagina. (S. Diake, pers. comm., 16 October 2023).

In contrast, SST production is predominantly for local consumption, and surpluses are sold fresh or processed (Harohau et al. 2020). Several farmers began farming with minimal knowledge and technologies before seeking support from MFMR. This trend has been observed in Guadalcanal, Malaita and other provinces where tilapia farming is practised. Thus, SST development resilience and sustainability require ongoing government commitments compounded by community engagements and private sector investments in the country.

Conclusion and recommendations

Small-scale aquaculture in Solomon Islands, initiated in the 1960s by the private sector, has proven beneficial with more than 50% positive feedback, particularly from rural communities according to research studies. These benefits include human well-being, increased income, food security, sustainable natural resources utilisation and reduced vulnerability.. Since 2008, the collaborative efforts of MFMR and its partners have resulted in the diffusion of SST to other provinces besides Malaita and Guadalcanal. The diffusion of SST techniques and technology in rural communities was done through word of mouth and the look-and-learn method. Moreover, SST is a male-dominated sector supported by women who also play crucial roles in SST aquaculture, including daily farm management, financial aspects, and overall aquaculture development. The potential for SST to complement coastal fisheries in terms of income and affordable fish protein is insignificant with *Oreochromis mossambicus*. Despite the unpopularity of the Mozambique tilapia,, the number of EOIs received by MFMR continued to increase over the study period. From

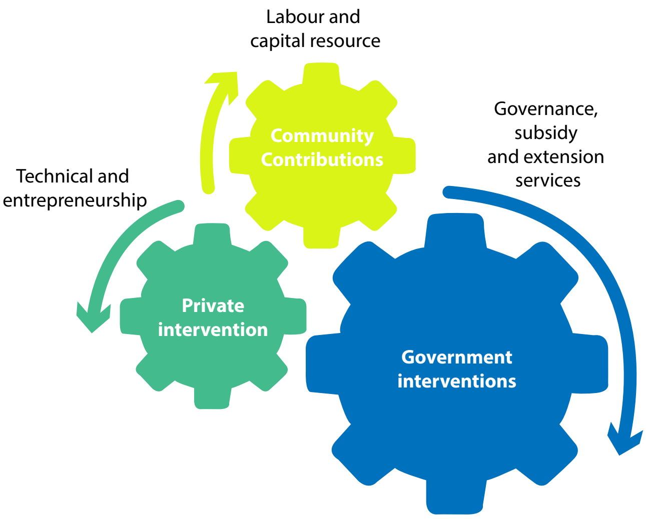


Figure 8. Diagram overview of key stakeholders' interventions to SSA in Solomon Islands.

a policy perspective, the need to strengthen the legislative frameworks governing SSA development in Solomon Islands remains a high priority.

Therefore, the following recommendations are proposed:

- MFMR must work collaboratively with partners to fast-track the importation of GIFT, and consider prioritising research on domesticating endemic freshwater species for aquaculture.
- Strengthen the data collection mechanism for SST in preparation for GIFT roll-out.
- The government should establish farmer extension services in rural farming communities.
- Develop policies embracing the promotion of local consumption and trade of tilapia across all provinces.
- The government should subsidise outreach activities to promote the grow-out and hatchery of Nile tilapia as part of its effort to establish the sector across all provinces.
- The government and private sector must collaborate on the establishment of working agreements in areas encompassing policies, technical support, materials, and economic trade initiatives.

Therefore, the Solomon Islands government will continue to ensure the sustainable development of small-scale aquaculture in the country in the present and future to meet the food security and income needs of its people.

Acknowledgement

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References

Bell J. D., Kronen M., Vunisea A., Nash W. J., Keeble G., Demmke A., Pontifex S. and Andréfouët S. 2009. Planning the use of fish for food security in the Pacific. Marine Policy 33(1):64–76. https://doi.org/https://doi.org/10.1016/j.marpol.2008.04.002

Blythe J., Sulu R., Harohau D., Weeks R., Schwarz A.-M., Mills D. and Phillips M. 2017. Social dynamics shaping the diffusion of sustainable Aquaculture innovations in the Solomon Islands. Sustainability 9. https://doi.org/10.3390/su9010126

Cleasby N., Schwarz A.-M., Phillips M., Paul C., Pant J., Oeta J., Pickering T., Meloty A., Laumani M. and Kori M. 2014. The socio-economic context for improving food security through land-based aquaculture in the Solomon Islands: A peri-urban case study. Marine Policy 45:89–97. https://doi.org/10.1016/j.marpol.2013.11.015

Connell J. 2018. Impacts of climate change on settlements and infrastructure relevant to the Pacific Islands. Pacific Marine Climate Change Report Card: Science Review 2018:159–176.

Dey M.M., Gosh K., Valmonte-Santos R., Rosegrant M.W. and Chen O.L. 2016. The economic impact of climate change and climate change adaptation strategies for the fisheries sector in the Solomon Islands: Implication for food security. Marine Policy 67:171–178. https://doi.org/10.1016/j.marpol.2016.01.004

Duarte C.M., Wu J., Xiao X., Bruhn A. and Krause-Jenson D. 2017. Can seaweed farming play a role in climate change mitigation and adaptation? Frontiers in Marine Science 4. https://doi.org/10.3389/FMARS.2017.00100

FAO (Food and Agriculture Organization of the United Nations). 2023a. International year of artisanal fisheries and aquaculture 2022 – Final report. Rome, Italy: FAO. https://doi.org/10.4060/cc5034en

FAO. 2023b. Solomon Islands. Fisheries and Aquaculture Division [online]. Updated 2005-10-24 [Cited 15 October 2023]. https://www.fao.org/fishery/en/countrysector/sb/en

FAO. 2016. AQUASTAT Country Profile – Solomon Islands. Rome, Italy:

Harohau D., Blythe J., Sheaves M. and Diedrich A. 2020. Limits of tilapia aquaculture for rural livelihoods in the Solomon Islands. Sustainability 12(11):4592.

Heck N., Beck M.W., Reguero B., Pfliegner K., Ricker M. and Prütz R. 2023. Global climate change risk to fisheries – A multi-risk assessment. Marine Policy 148:105404. https://doi.org/https://doi.org/10.1016/j.marpol.2022.105404

IPCC (Intergovernmental Panel on Climate Change). 2023. Climate change 2023: Synthesis report. A Report of the Intergovernmental Panel on Climate Change. Geneva, Switzerland: IPCC.

Lloyd L. 2011. Risk assessment for the importation of genetically improved farmed tilapia (GIFT), Oreochromis niloticus, to the Solomon Islands for aquaculture. Honiara, Solomon Islands: Ministry of Fisheries and Marine Resources.

McCubbin S., Smit B. and Pearce T. 2015. Where does climate fit? Vulnerability to climate change in the context of multiple stressors in Funafuti, Tuvalu. Global Environmental Change 30:43–55. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2014.10.007

Mcleod E., Bruton-Adams M., Förster J., Franco C., Gaines G., Gorong B., James R., Posing-Kulwaum G., Tara M. and Terk E. 2019. Lessons from the Pacific Islands – Adapting to climate change by supporting social and ecological resilience [Perspective]. Frontiers in Marine Science 6. https://doi.org/10.3389/fmars.2019.00289.

Meu B. 2023. A snapshot of a partnership to drive tilapia farming in Malaita Province, Solomon Islands. SPC Traditional Marine Resource Management and Knowledge Information Bulletin 41:20–27. https://fame.spc.int/node/1315

MFMR (Ministry of Fisheries and Marine Resources). 2018. Solomon Islands National Aquaculture Management and Development Plan 2018–2023. Honiara, Solomon Islands. https://www.fisheries.gov.sb/#

MFMR (Ministry of Fisheries and Marine Resources). 2019. Solomon Islands National Fisheries Policy 2019–2029: A policy for the conservation, management, development, and sustainable use of the fisheries and aquatic resources of the Solomon Islands. Honiara, Solomon Islands. https://www.fisheries.gov.sb/mfmr-docs/mfmr-national-fisheries-policy-2019.pdf

Nandlal S. and Pickering T. 2004. Tilapia fish farming in Pacific Island countries. Volume 1. Tilapia hatchery operation. Noumea, New Caledonia: Secretariat of the Pacific Community. https://purl.org/spc/digilib/doc/n8ao2

National Aquaculture sector overview. National aquaculture sector overview – Solomon Islands. National Aquaculture Sector Overview Fact Sheets. In: FAO Fisheries and Aquaculture Division [online]. Updated 2005-10-24. [Cited 17 October 2023].

Naylor R.L., Hardy R.W., Buschmann A.H., Bush S.R., Cao L., Klinger D.H., Little D.C., Lubchenco J., Shumway S.E. and Troell M. 2021. A 20-year retrospective review of global aquaculture. Nature 591(7851):551–563. https://doi.org/10.1038/s41586-021-03308-6

Pickering T. 2009. Tilapia fish farming in the Pacific – a responsible way forward. SPC Fisheries Newsletter 130:24–26. https://purl.org/spc/digilib/doc/ j956a

Tilapia farm in the Malaita highlands. Image: ©Billy Meu

Tunas show us that we need to do more to reduce mercury pollution

Anaïs Médieu,[1] Anne Lorrain,[2] David Point[3] and Valérie Allain[4]*

Our study shows that since 1971, mercury concentrations in tunas have been stable worldwide, suggesting that massive reductions in mercury emissions are needed to meet human health objectives.

Whether it is sold as sushi, or comes in steak or filet form, or in a tin, tuna is one of the most widely eaten marine fish in the world (FAO 2022). Yet, it is known to contain methylmercury, the most toxic chemical form of mercury. Mercury poisoning can cause neurodevelopmental disorders in foetuses during pregnancy and in children, and cardiovascular risks in adults (Axelrad et al. 2007; Genchi et al. 2017). Environmental policy under the United Nations Minamata Convention[5] aims to protect human health by reducing mercury emissions from human (anthropogenic) activities. While such policy has led to an overall reduction in anthropogenic mercury emissions into the atmosphere, little is known about their impact on methylmercury levels in the oceans and in marine fish. This paper provides the longest time series of tuna mercury concentrations ever compiled at a global scale, and shows that these concentrations have remained stable since 1971, except in the northwest Pacific, where they increased significantly in the late 1990s. (Médieu et al. 2024). The stability is thought to be linked to The stability is thought to be linked to "ocean inertia", reflecting the accumulation of mercury released several decades (or even centuries) ago, which continues to flow into the oceanic waters that tuna live in..

This study is part of the French National Research Agency's MERTOX project,[6] and follows on from two previous studies on the Pacific, which revealed steep mercury gradients in tunas between regions, induced mainly by natural marine biogeochemical processes and differences in tuna feeding depths (Houssard et al. 2019; Lorrain et al. 2019; Médieu et al. 2022a, 2022b)yet crucial in the context of anthropogenic mercury (Hg. In this fresh cross-disciplinary study – led by the French Institute of Research for Development with the help of the Pacific Community and multiple partners, and assisted by access to several sample banks[7] – we have compiled nearly 3000 mercury concentrations measured in three tuna species in the Pacific, Indian and Atlantic oceans from 1971 to 2022 (Fig. 1). This study focuses on three tropical tuna species, yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*) and skipjack tuna (*Katsuwonus pelamis*), the most commonly eaten fish species worldwide (FAO 2022).

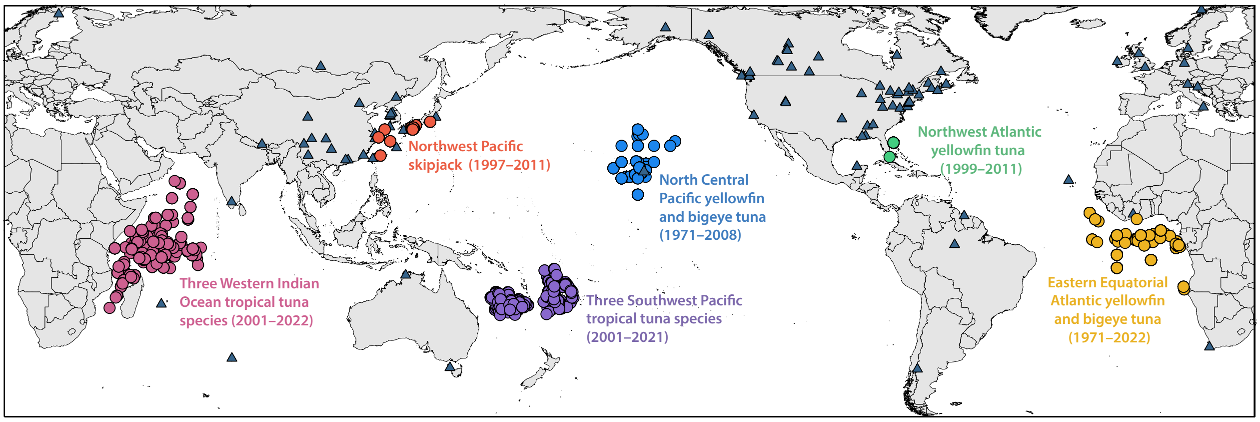

Figure 1. Spatial distribution of tropical tunas considered for mercury (coloured circles) and atmospheric mercury level observation sites (blue triangles).

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7 Pacific Marine Specimen Bank managed by SPC, Tokyo University Environmental Specimen Bank, Japan, and personal sample collections by Nathalie Bodin (Sustainable Ocean Seychelles, Seychelles), Douglas H. Adams (Fish and Wildlife Research Institute, USA), Frédéric Ménard (IRD, France), C. Anela Choy (Scripps Institute of Oceanography, USA), Paco Bustamante (La Rochelle University, France) and Bridget E. Ferriss (National Oceanic and Atmospheric Administration, USA).
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Using tunas to study the impact of emission reduction policies on methylmercury levels in the oceans

After five centuries, anthropogenic mercury emissions have significantly altered the natural mercury biogeochemical cycle (Fig. 2), and increased atmospheric mercury concentrations by 450% (Outridge et al. 2018). Europe and North America were, for a long time, the main mercury emitters (mainly associated with coal burning, and gold and silver mining), before considerably reducing their emissions in the 1970s. Conversely, emissions from Asia rose sharply from the 1980s onwards, linked to coal-fired electricity generation. In the ocean, anthropogenic emissions are thought to have tripled the total amount of mercury (inorganic mercury + methylmercury) (Lamborg et al. 2014), yet the impact on methylmercury concentrations in water and marine organisms remains undocumented. While mercury concentrations in the atmosphere are monitored extensively worldwide (Fig. 1), there is no temporal monitoring of methylmercury concentrations in the oceans, as the cumbersome logistics involved in collecting seawater samples using oceanographic vessels and the high cost of laboratory analysis have made for limited multi-year data acquisition in contrasting oceanic regions.

Tropical tunas are useful marine species for monitoring methylmercury levels in the oceans. From a health point of view, they are the three most heavily fished (mainly in the Pacific Ocean) and consumed tuna species and a major source of animal protein globally (ISSF 2021). From a biological and environmental point of view, the three species stand out by their different feeding depths: skipjack and yellowfin tunas generally swim within the upper 100 m of the water column, while bigeye tuna dive daily to depths of over 500 m to feed. By choosing to work with these three species, we posited that they would reflect changes in methylmercury concentrations at different depths in the water column. All three species have been studied under various research programmes for many years now and are used in regional sample banks based on work by onboard fisheries, which has enabled us to build up tuna mercury-content time series in six contrasting regions of the global ocean (Fig. 2).

Concentrations stable from 1971 to 2022, except in the northwestern Pacific

As mercury bioaccumulates naturally over the lifetime of an organism (e.g. older, larger fish have higher mercury concentrations), we first standardised mercury concentrations to a given size: 100 cm for yellowfin and bigeye tunas, and 70 cm for skipjack tuna. These are the average sizes for each species. Mercury concentrations in tunas are highly variable, but remained stable overall from 1971 to 2022, except for values in the northwestern Pacific, off the coast of Asia (Fig. 3). In this area, mercury concentrations in skipjack increased significantly in the late 1990s, probably as a result of the massive increase in anthropogenic emissions associated with the heavy use of fossil fuels for power generation in Asia (Médieu et al. 2022a, 2022b).

Stability due to ocean inertia and stored historically emitted mercury

Other than in the northwestern Pacific, the stability of mercury concentrations in tunas contrasts with a global decline in atmospheric mercury levels beginning in the 1970s. We assume that this stability in tunas is due to subsurface

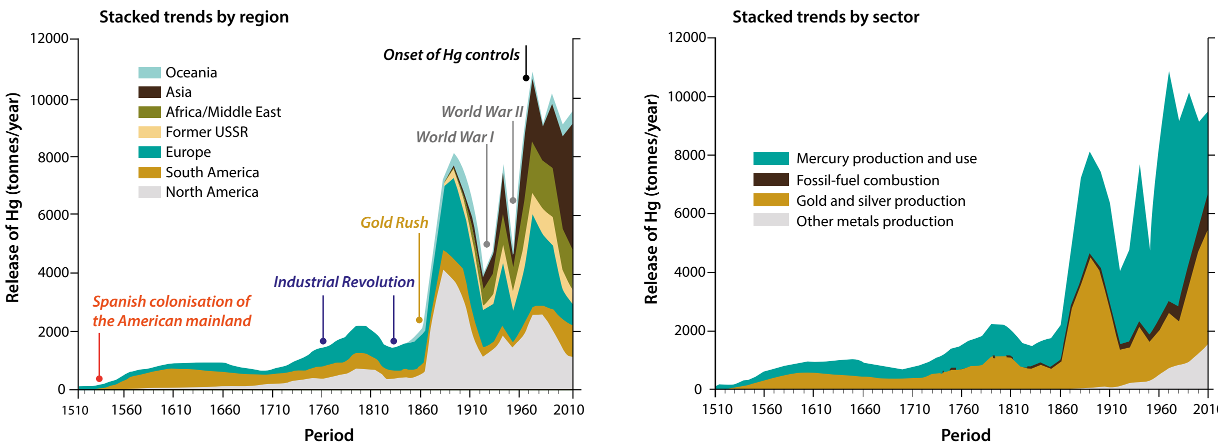


Figure 2. Temporal anthropogenic mercury release profiles from 1510 to 2010 by world region (left) and by emission source (right), adapted from Streets et al. (2019). The "mercury production and use" category includes mercury production in various industrial processes, such as cement-making, chlorine and caustic soda manufacturing, or waste processing.

(between 50 m and 1500 m) and deep (below 1500 m) ocean inertia, which carries mercury into surface waters (i.e. the uppermost 50 m of the water column). Mercury that was emitted several decades ago continues to circulate between the different parts of the biosphere (atmosphere, vegetation, surface ocean and deep ocean), but at varying speeds. While surface waters rapidly equilibrate with the atmosphere, deeper oceanic waters have a longer residence time, so the mercury that accumulated there takes longer to be redistributed to shallower waters where tuna live and feed. In those waters, the mercury could have been emitted years or even decades earlier, and not yet reflect the effects of the reduction in mercury emissions into the air.

In order to better understand how emission reductions impact mercury concentrations in the different ocean layers, we used a mercury circulation model featuring three emission reduction scenarios based on varying degrees of stringency (Fig. 4). Such modelling illustrated that even if mercury emissions into the atmosphere were drastically reduced (the most restrictive scenario; see the blue curve in Fig. 4A), it would take almost 10 years to detect a fall in mercury levels in surface waters, and approximately 25 years to detect them in subsurface waters; therefore, at least as long to see a decline in tuna (blue curves in Figures 4B and 4C). If as much mercury continues to be emitted as it is today (least restrictive scenario; see red curves), the model does not predict any decrease in the various ocean layers between now and 2100.

What are the implications for understanding the mercury cycle and the Minamata Convention?

Under the Minamata Convention, which came into force in 2017, large-scale biomonitoring studies of mercury are required to assess the effectiveness of emission reduction measures. Here, we show for the first time that mercury concentrations in tunas have remained broadly unchanged since 1971 and do not reflect declining emissions and atmospheric concentrations. Our results show that emission reductions are likely to take several years, or even decades, before they are reflected by falling levels in the oceans and marine fish. We predict that the greater the reductions in emissions, the sooner we can expect to see a decline in mercury concentrations in tunas. Far from suggesting that the Minamata Convention is ineffective, our study highlights the need to continue the global effort to reduce mercury emissions more energetically, and calls for continuous, long-term global monitoring of mercury levels in marine life.

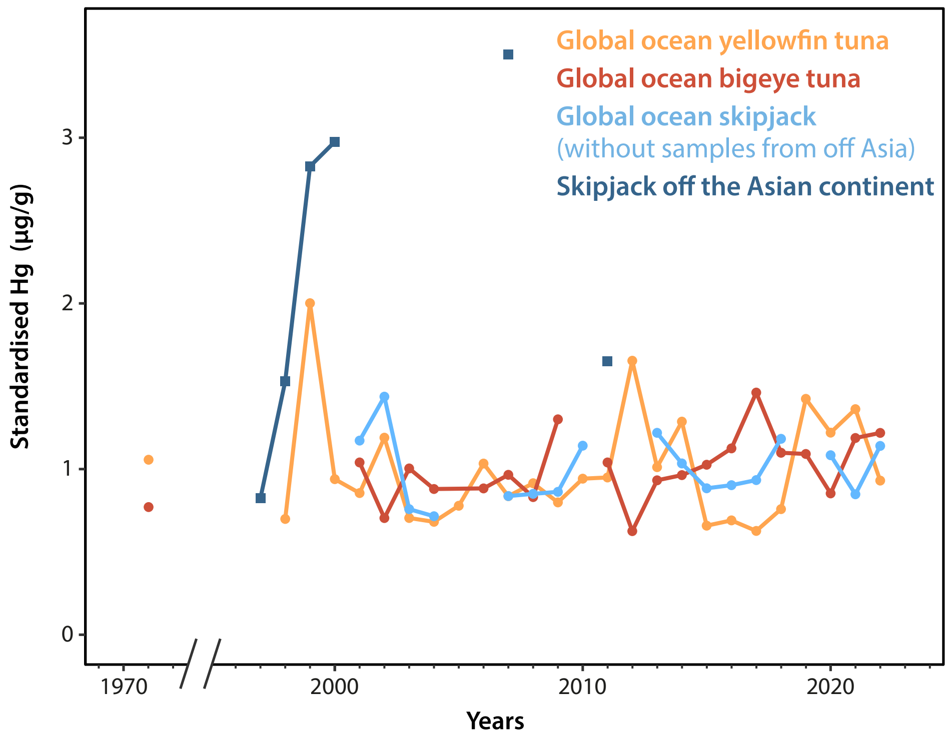
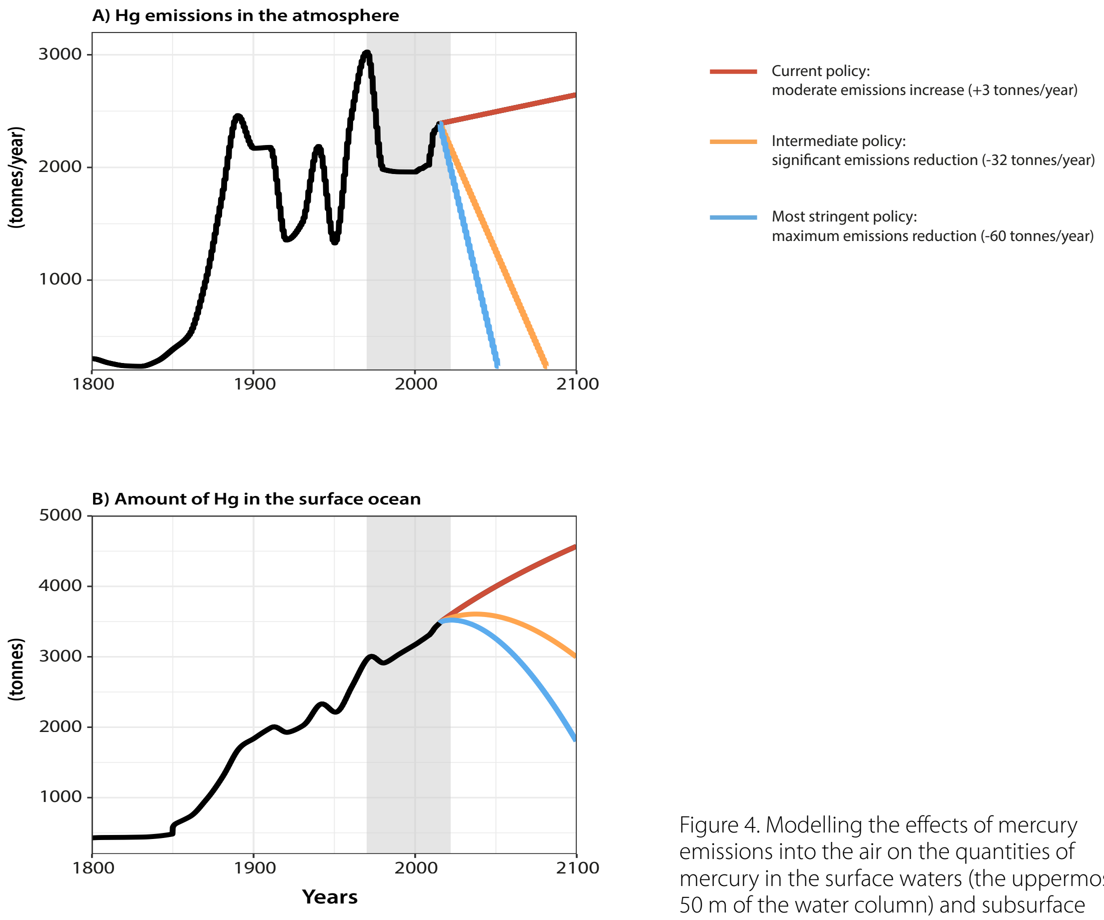


Figure 3. Temporal variability of mercury concentrations in tropical tuna: yellowfin tuna (orange), bigeye tuna (red) and skipjack (blue). Colored circles represent average annual concentrations measured in the global ocean, except in the northwestern Pacific off of Asia. In that area, average annual concentrations are represented by dark blue squares. Only data close in time are joined by a line.



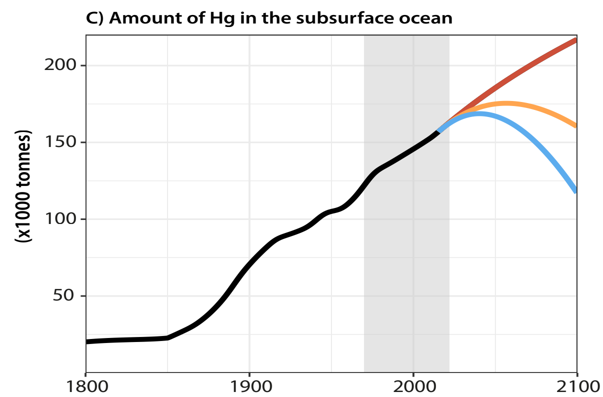


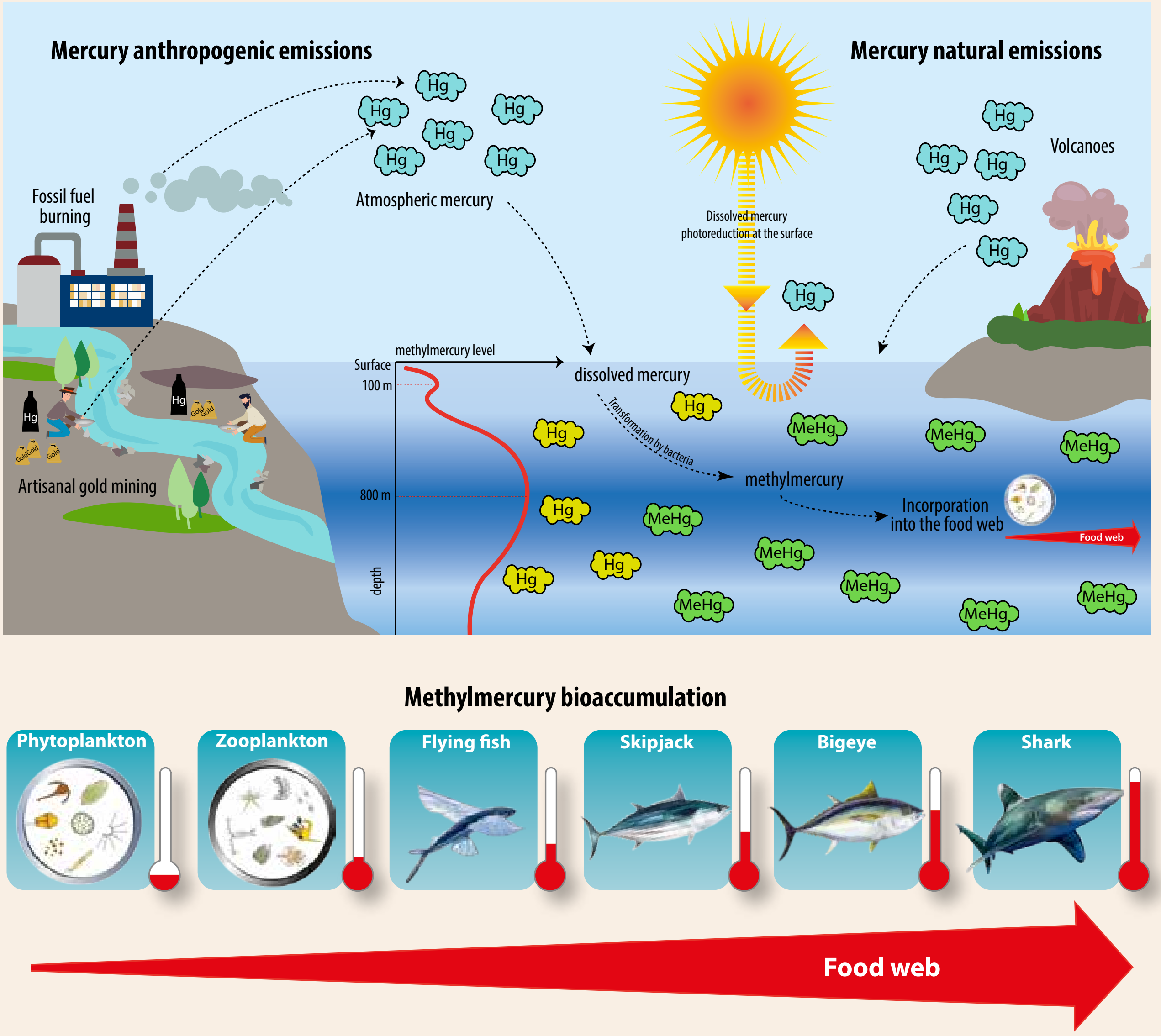
Figure 4. Modelling the effects of mercury emissions into the air on the quantities of mercury in the surface waters (the uppermost 50 m of the water column) and subsurface waters (from 50 to 1500 m) of the global ocean, based on a mercury circulation model developed by Amos et al. (2013). Three variously restrictive emission reduction scenarios were considered as adapted from Angot et al. (2018) transports and deposits globally, and bioaccumulates to toxic levels in food webs. It is addressed under the global 2017 Minamata Convention, for which periodic effectiveness evaluation is required. Previous analyses have estimated the impact of different regulatory strategies for future mercury deposition. However, analyses using atmospheric models traditionally hold legacy emissions (recycling of previously deposited Hg. Grey bands represent the years for which we have compiled tuna mercury data (i.e. 1971–2022).

Such monitoring of tropical tunas has been carried out since 2001 in the western Pacific, which enables many tuna samples to be collected yearly by onboard fisheries observers, and laboratory-tested for mercury.

As well as documenting the impact of emission reductions on mercury concentrations in tunas, these time series could help to better anticipate the impact of climate change on the formation of methylmercury in the ocean, and its bioavailability at the base of marine food webs (inset 1). It is generally accepted that inorganic mercury is converted into methylmercury (methylation) in less oxygenated areas of the ocean (between 400 m and 800 m below the surface). Because climate change may alter ocean circulation and productivity and extend oxygen-minimum zones, it may also profoundly alter the mercury cycle and affect the impact of emission reductions on methylmercury concentrations in marine food webs.

Inset 1. (Methyl)mercury cycle in the oceans

Mercury is emitted into the atmosphere in a gaseous form by natural sources (e.g. volcanic eruption) but mainly by human activities (anthropogenic emissions), such as coal combustion or gold mining (Fig. A). This inorganic mercury is deposited in the oceans, where it is partly transformed into methylmercury, a neurotoxin. This accumulates naturally in the tissues of organisms over their lifetimes (bioaccumulation) and up through food webs (biomagnification). This is why marine predators, such as tunas, have high methylmercury concentrations, methylmercury being the predominant form (91%) of total mercury in tunas. Humans are then exposed to methylmercury by eating marine fish.



Where does methylmercury (MeHg) in the oceans come from? Source: Lorrain et al. 2019; illustration by Constance Odiardo, SPC

References

Amos H.M., Jacob D.J., Streets D.G. and Sunderland E.M. 2013. Legacy impacts of all-time anthropogenic emissions on the global mercury cycle. Global Biogeochemical Cycles 27:410–421. https://doi.org/10.1002/gbc.20040

Angot H., Hoffman N., Giang A., Thackray C.P., Hendricks A.N., Urban N.R., Selin N.E. 2018. Global and local Impacts of delayed mercury mitigation efforts. Environmental Science and Technology 52:12968–12977. https://doi.org/10.1021/acs.est.8b04542

Axelrad D.A., Bellinger D.C., Ryan L.M. and Woodruff T.J. 2007. Dose–response relationship of prenatal mercury exposure and IQ: An integrative analysis of epidemiologic data. Environmental Health Perspectives 115:609–615. https://doi.org/10.1289/ehp.9303

FAO (Food and Agriculture Organization of the United Nations). 2022. The State of World Fisheries and Aquaculture 2022. Rome, Italy: FAO. https://doi.org/10.4060/cc0461en

Genchi G., Sinicropi M., Carocci A., Lauria G. and Catalano A. 2017. Mercury Exposure and heart diseases. International Journal of Environmental Research and Public Health 14:74. https://doi.org/10.3390/ijerph14010074

Houssard P., Point D., Tremblay-Boyer L., Allain V., Pethybridge H., Masbou J., Ferriss B.E., Baya P.A., Lagane C., Menkes C.E., Letourneur Y. and Lorrain A. 2019. A model of mercury distribution in tuna from the western and central Pacific Ocean: Influence of physiology, ecology and environmental factors. Environmental Science and Technology 53:1422–1431. https://doi.org/10.1021/acs.est.8b06058

ISSF (International Seafood Sustainability Foundation. 2021. Status of the world fisheries for tuna: March 2021 (ISSF Technical Report 2021-10). Washington, D.C.: International Seafood Sustainability Foundation.

Lamborg C.H., Hammerschmidt C.R., Bowman K.L., Swarr G.J., Munson K.M., Ohnemus D.C., Lam P.J., Heimbürger L.-E., Rijkenberg M.J.A. and Saito M.A. 2014. A global ocean inventory of anthropogenic mercury based on water column measurements. Nature 512: 65–68. https://doi.org/10.1038/nature13563

Lorrain A., Point D. and Allain V. 2019. Size, species, capture location: What makes tuna get high on mercury? SPC Fisheries Newsletter 158:37–41. https://purl.org/spc/digilib/doc/okbus

Médieu A., Point D., Allain V. and Lorrain A. 2022. Tuna help to map mercury pollution in the ocean. SPC Fisheries Newsletter 166:50–55. https://purl.org/spc/digilib/doc/cvpdm

Médieu A., Point D., Itai T., Angot H., Buchanan P.J., Allain V., Fuller L., Griffiths S., Gillikin D.P., Sonke J.E., Heimbürger-Boavida L.-E., Desgranges M.-M., Menkes C.E., Madigan D.J., Brosset P., Gauthier O., Tagliabue A., Bopp L., Verheyden A. and Lorrain A. 2022. Evidence that Pacific tuna mercury levels are driven by marine methylmercury production and anthropogenic inputs. PNAS 119:8. https://doi.org/10.1073/pnas.2113032119

Médieu A., Point D., Sonke J.E., Angot H., Allain V., Bodin N., Adams D.H., Bignert A., Streets D.G., Buchanan P.B., Heimbürger-Boavida L.-E., Pethybridge H., Gillikin D.P., Ménard F., Choy C.A., Itai, T., Bustamante, P., Dhurmeea, Z., Ferriss, B.E., Bourlès, B., Habasque, J., Verheyden A., Munaron J.-M., Laffont L., Gauthier O. and Lorrain A. 2024. Stable tuna mercury concentrations since 1971 illustrate marine inertia and the need for strong emission reductions under the Minamata Convention. Environmental Science and Technology Lett. 11: 250–258. https://doi.org/10.1021/acs.estlett.3c00949

Outridge P.M., Mason R.P., Wang F., Guerrero S. and Heimbürger-Boavida L.E. 2018. Updated Global and oceanic mercury budgets for the United Nations Global Mercury Assessment 2018. Environmental Science and Technology 52:11466–11477. https://doi.org/10.1021/acs.est.8b01246

Streets D.G., Horowitz H.M., Lu Z., Levin L., Thackray C.P. and Sunderland E.M. 2019. Five hundred years of anthropogenic mercury: Spatial and temporal release profiles. Environmental Research Letters 14:084004. https://doi.org/10.1088/1748-9326/ab281f

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