Fisheries Newsletter

175 | September–December 2024

ISSN: 0248-076X

SPC activities

Regional news

Feature articles

FAME
Fisheries, Aquaculture and Marine Ecosystems Division

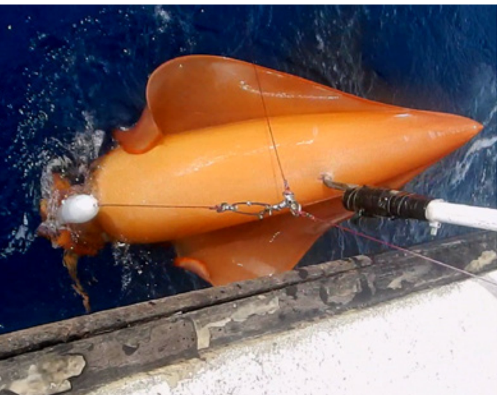
In this issue

SPC activities

News from in and around the region

Feature articles

page 3



page 29

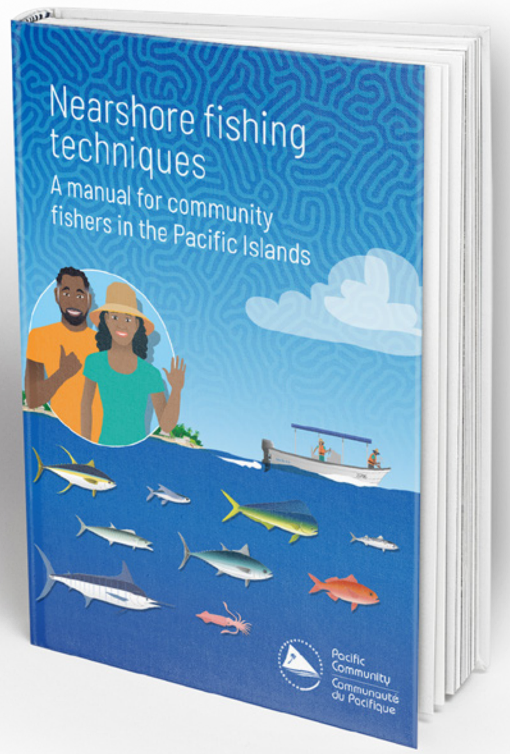
page 47

Reel it in: Night fishing made simple

The Pacific Community recently released the third season of Fish and Tips, a video training series on nearshore fishing techniques focused on more resilient pelagic species beyond the reef. This time, our fishing experts will take the audience into the dark yet rewarding world of night fishing.

Why nearshore fishing?

As Pacific Island communities grow, the strain on our reef fish has become impossible to ignore. Once abundant and easy to catch, these vital resources now face overfishing, thus urging us to seek solutions beyond the reef. Nearshore fishing offers hope by targeting resilient pelagic species such as tuna and mahi mahi that thrive in open waters. Techniques such as trolling, mid-water line fishing, and deep-water vertical longlining, especially with fish aggregating devices (FADs), help shift fishing pressure away from overexploited coastal habitats.

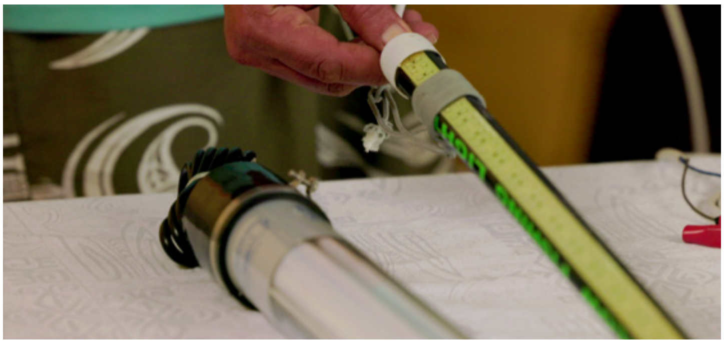


About *Fish and Tips*

Fish and Tips is a recent video series on nearshore fishing techniques produced by SPC. Based on a nearshore fishing manual[1] authored by SPC's expert fishers Ian Bertram, William Sokimi and Aymeric Desurmont, the series takes us on an inspiring journey, blending traditional wisdom with modern innovation to explore the rich potential of nearshore fishing. This toolkit provides Pacific Island fishing communities with accessible, hands-on learning resources. It takes fishers step-by-step through innovative


Uncle Ian and William gear up to take you on a nighttime fishing adventure.

[1] The manual: Nearshore fishing techniques – A manual for community fishers in the Pacific Islands. https://www.spc.int/digitallibrary/get/z3dwf



Underwater lights: These help to attract plankton and the rest of the food chain, including the pelagic fish you are targeting, including mackerel and yellowfin. Once the schools of fish have gathered, it's time to drop your gear and wait for the bite.

First, secure the light with a bit of rope to avoid putting too much pressure on its electric cable. Use a small weight to pull it under water but don't forget to waterproof it with silicone to avoid a short circuit.

Above-water lights: These are handy for watching your step on deck. But they also help when targeting certain species. Squids are attracted to light but are also shy. They often hunt in between light and shadow. By installing above-water lights, you create a shadowed space right under your boat! Quick tips: if you don't have access to a regular light on your island, you can always make your own with a bucket, and a light bulb socket. If you resort to this option, once again, do not forget to waterproof it with silicone.

How to set your lights: Setting a string of lights can require a certain dose of imagination, depending on the size and length of your boat. You can make a temporary set-up using your fishing rod holders and some rope or twine.

You can use alligator clips to connect your lights to your boat's 12-volt battery. But make sure to store it away from your fuel system as these clips can cause sparks.

Play it safe: Always keep a fire extinguisher nearby in case of any emergency.

That's it, you're now ready to go and learn everything about night fishing methods!

History and tradition of ika shibi fishing

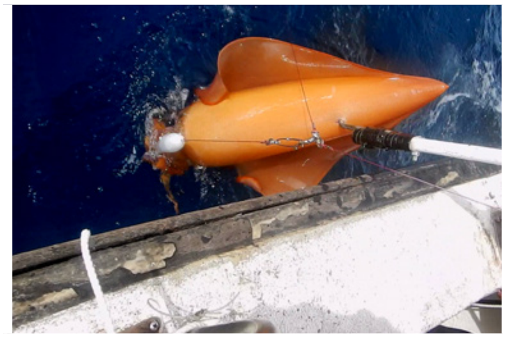
Embark with Kura and Ian to discover why and how our elders came up with this fishing technique. Ika shibi means "squid tuna". This technique came from Okinawan settlers in Hawaii in the 1900s. When fishing for squid, they kept being robbed of their catch by tuna. So, they decided to update their gear and actually target the available tuna instead.

Materials needed for baitfish jigging

If they can do it, you can do it! Learn how to use the resources available to you to improve your catch, using wasted plastic straws to make your jigs, and decide whether you prefer working your arms out with a spool, using your old fishing rod, or a brand new Sabiki rod.

Gear set-up for pencil squid jigging

New materials don't always mean new ways of preparation. Sit down with Ian and William to learn how to bring your pencil squid jigstogether without poking your finger with their barbed hooks. The more you set-up, the more you might catch!



How to use deep-water squid rigs

Setting your gear for deep-water squid fishing can take some time when you fish at over 500 m depth. Make the best of your time by drifting your line with simple floats and flags. As soon as one is out, you will be able to prepare another one and increase your chances of getting multiple squids in one trip. Don't forget to haul in quickly if you don't want to get caught by the "tax man" (sharks).

Top tips for flying fish scoop-netting

Make sure to stay until the end of each episode to hear Kura's top tips on each fishing method. They might not be in the books, but they will surely help you shift from being a skilled fisher to an expert fisher.

yet sustainable fishing methods, combining tradition with a touch of modern finesse. Beyond diversifying our catches and selling opportunities, these sustainable methods offer a chance to restore balance to our inshore ecosystems. There are now three seasons of this video series, covering various fishing strategies for fishing beyond the reef:

- **Trolling techniques** — with tips on efficient surface fishing and how to target species such as wahoo and mahi mahi.
- **Mid-water techniques** — describing methods such as drop stone fishing, *palu ahi* and jigging, with an emphasis on the potential of mid-water fishing and catches.
- **Night fishing techniques** — the newest addition: allows readers to dive into the art of fishing at night and catching baitfish such as mackerel scads, flying fish, squids and tuna.

Fish and Tips season 3: Night fishing essentials

After teaching the basics of trolling (season 1) and secrets of mid-water fishing (season 2), our fishing crew — Ian Bertram, William Sokimi and Kura Happ — will now guide our Pacific communities into the world of night fishing methods. When practised correctly, these techniques can yield larger and more varied catches. From deep-water squid fishing to flying fish scoop-netting, these new training videos highlight methods that fishers can use to boost their success after dark.

Because we'll be fishing in the dark, the first thing we need is light. Here's everything you might need before mastering these night fishing techniques:

Finally, don't forget to check out the *Fish and Tips* bonus episodes to make the best of your night-fishing experience:

- Everything you should know about fishing lights and how to set them on your boat.
- The benefits of a sea anchor and how to use it when you're fishing in depths over 300 m.
- How to set safely around FADs when you are outside the reef.

Aknowledgements

This toolkit was produced under the governance of the Pacific-European Union Marine Partnership programme, funded by the European Union and the Government of Sweden; the Sustainable Coastal Fisheries and Aquaculture for Pacific Livelihoods, Food and Economic Security, funded by the New Zealand Ministry of Foreign Affairs and Trade, with Australian Department of Foreign Affairs and Trade and the Pacific Coastal Fisheries Management and Compliance, funded by the United States Agency for International Development.

For more information:

William Sokimi - Nearshore Fisheries Development and Livelihoods Specialist, SPC
williams@spc.int

Ian Bertram - Senior Fisheries Adviser, SPC
ianb@spc.int

Hugo Nguyen - Information and Outreach Assistant, SPC
hugon@spc.int

Want to know more about these techniques yourself? Dive into the Fish and Tips *video series. Scan the QR code to unlock the secrets of Pacific master fishers*

A new culinary adventure in Samoan waters: Gearing up for diamondback squid fishing

William Sokimi

Are diamondback squid present in Samoan waters, and if so, how can they be fished? Team members of SPC's Nearshore Fisheries Development and Sustainable Livelihoods Unit recently visited Samoa to train fisheries officers there in small-scale fishing operations and safety at sea. This training demonstrated how to integrate fish aggregation device (FAD) trolling and midwater fishing methods with diamondback squid fishing, and how this can be linked to alia *fishers' operations.*

The Pacific Islands region has become more aware of the presence of diamondback squid following successful fishing trials in New Caledonia (2012), Cook Islands (2013), Fiji (2014), Tahiti (2015) and Nauru (2022).

Diamondback squid is said to be found throughout the year in tropical and subtropical regions, but a trial conducted off Wallis Island in November and December 2023 yielded no diamondback squid. There were no signs of squid interacting with the line despite having conducted more fishing trips here during trials than the other islands where trials took place, and with more variation in fishing areas. However, the seas were extremely rough at the time, so we are not sure if this influenced the results. We also attribute this to being an offseason period for the area, if we presume that there are peak seasons and possibly off-seasons for squid fishing. But, we need consistent and detailed catch records to confirm this.

Diamondback squid facts

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

Preferable fishing conditions include:

- sea temperature greater than 15°C;
- 2000-m contour or deeper, preferably over underwater canyons with deep seamounts up to 800 m or shallower;
- 500 m working depth (can be deeper or shallower depending on where the optimum sea temperature zone lies); and
- near where major plankton and phytoplankton movement exists, and areas off temperature breaks are also good fishing grounds.

The neon flying squid (*Ommastrephes bartramii*) is a secondary squid species that is often caught when fishing for diamondback squid. This squid is smaller than the diamondback squid but much larger than the common pencil squid species seen at the surface at night.

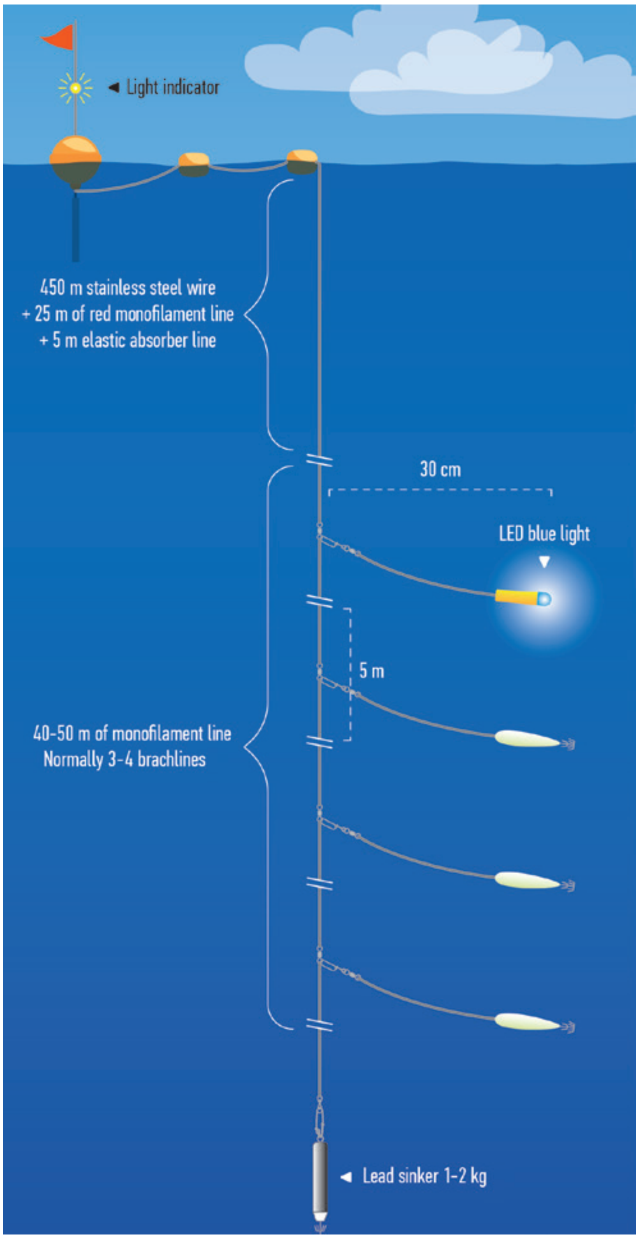


Figure 1. Fishing gear for diamondback squid fishing. Illustration: © SPC

The neon flying squid has a mantle length ranging from 25 cm to 60 cm and can weigh between 5 kg and 13 kg.

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

Fishing gear

The fishing gear used to catch diamondback squid is a vertical longline suspended in the water by a 1.2 kg sinker and four hooks at around 500 m depth. A blue light (some say green light is also effective) is attached at the top of the trunk line, above the hooks, to attract plankton and small fishes, which in turn attract squid.

Just before we left port, we were told that everyone was excited to know the outcome of our fishing trip. The media would be alerted if we caught any diamondback squid, and the Chief Executive Officer of the Ministry of Agriculture and Fisheries and high government officials would all be informed of the results. Everyone was wanting to eat the squid we hadn't caught yet, so this put pressure on us to catch something!

The fishing and FAD site survey activities were conducted off Apia (see Fig. 2). The first fishing trip was done directly 10.5 nautical miles northeast of Apia. The sea state was moderate (5 on the Beaufort scale, waves 2.5 m), with easterly winds gusting to 25 kt.

Our first challenge was that our fishing gear was brand new and still tainted with production chemicals. We washed and soaked the gear, and hoped that there might be some desperate squid that would be attracted to the lures anyway. But sadly no. We caught no squid and there were no signs of interaction with squid or other fish.

A tasty squid banquet at last

The following two days were happily more fruitful. On the second day, we fished 20 nautical miles southeast of Apia. The sea state was 5 (waves 2.2 m) with easterly winds gusting to more than 20 kt. We caught two diamondback squid: one weighing 15 kg and another 18 kg. Back at the fisheries base, we demonstrated how to gut and clean the squid.

On the third day, we fished 16 nautical miles northeast of Apia. The sea state was 4 (2 m waves), with northeasterly winds gusting 15–20 kt. This time we hauled in two diamondback squid, and each of them weighed the same as the ones on the previous day (15 kg and 18 kg). We also caught two neon flying squids, each weighing 9 kg.

There was a squid "cook up" competition once all the work was done to see who could cook the best diamondback squid dish. There were four teams comprising Fisheries Department staff. We can report, with great satisfaction, that all four teams produced excellent dishes, and the results were very close.

For more information:

William Sokimi - Nearshore Fisheries Development and Livelihoods Specialist, SPC

williams@spc.int

There was no shortage of imagination in the squid dish cooking competition. Image: William Sokimi © SPC

How to catch, pose with, and prepare a diamondback squid. Images: William Sokimi, © SPC

The cooking competition: fisheries officers and SPC teamed up to see who could create the tastiest squid dish!
Images: William Sokimi © SPC

Building legal foundations for sustainable coastal fisheries management in Samoa: Training of trainers in action

Sustainable coastal fisheries management is crucial for Samoa and other Pacific Island countries and territories (PICTs). Marine resources play a central role in food security and livelihoods. Recognising this, SPC's Fisheries, Aquaculture and Marine Ecosystems (FAME) Division has adopted a "training of trainers" approach to strengthen the capacity of fisheries officers in PICTs in legislative drafting for coastal fisheries management.

Introduction

In November 2024, the first national legal workshop for coastal fisheries was conducted in Samoa, building on SPC's *Regional Legislative Drafting Course: Coastal Fisheries*. By providing training adapted to local contexts, this initiative fosters effective fisheries governance in the region and equips government officials with essential legal knowledge to address the challenges of marine resource management.

This initiative responds to the growing demand for capacity building among Pacific government officials. During the Fifteenth Heads of Fisheries meeting (HoF15) in 2023, SPC members called on FAME to "strengthen the use of both online and offline training approaches" (HoF15 Outcomes, 8.b). This effort also aligns with FAME's Business Plan 2022–2027, particularly with Key Result Areas 7.1 (designing and delivering high-quality training of regional professional training) and 4.6 (strengthening compliance with coastal fisheries laws and policies).

Regional Legislative Drafting Course: Coastal Fisheries

The *Regional Legislative Drafting Course: Coastal Fisheries*, developed with expertise from the University of California College of the Law, San Francisco (UC Law SF), was purposely designed as a hybrid course in response to the closure of SPC member states' borders during the COVID-19 pandemic. This training combines theoretical knowledge on the principles and techniques of legislative drafting – such as writing clearly and concisely, organising concepts logically, and turning policies into laws – with practical exercises, including preparing drafting instructions, crafting legal provisions, and preparing explanatory memoranda.

Between 2022 and 2024, the course trained 50 government officials across 12 PICTs, providing them with essential writing skills applicable to their work and, more specifically, for the development of laws and regulations. During the regional course, FAME's legal team trained, among others, two participants from Samoa with complementary skill sets:

Competency-based assessment of the Regional Legislative Drafting Course: Coastal Fisheries, March 2023, Noumea. Image: © SPC

- To'oto'o Glory Fuimaono, Assistant Chief Executive Officer – Legal, Ministry of Agriculture and Fisheries (MAF), and
- Su'a Ulusapeti Tiitii (aka Sapeti), Chief Coastal Fisheries, MAF Fisheries Division.

Their contributions focused on two high-quality legislative projects, demonstrating the need to sustainably manage two high value marine resources while protecting local communities' food security and livelihoods.

- Glory focused on draft sea cucumber regulations that are currently going through the internal legal process for endorsement by the Samoan government. The regulations will give legal force to the provisions of the *Sea Cucumber Management Plan 2015*[1] and its revisions.
- Sapeti initiated draft trochus fisheries regulations, addressing issues such as the lack of enforcement mechanisms for sustainable trochus harvesting, overharvesting driven by population pressure, impacts from natural disasters, and weak monitoring and surveillance.

Advancing national training in Samoa

In June 2024, Sapeti and Glory travelled to Suva, Fiji for a two-week attachment with SPC and UC Law SF to develop a training programme that aligns with Samoa's coastal fisheries and aquaculture priorities. The workshop content included interactive exercises, methods for identifying and addressing gaps in existing laws (e.g. the *Fisheries Management Act 2016*[1]) and local fisheries regulations, in accordance with the *Fisheries and Aquaculture Policy 2022–2032.*[1] This initiative empowered trainees of the *Regional Legislative Drafting Course: Coastal Fisheries* to become national trainers within their ministry, expanding legislative drafting skills to a broader audience in Samoa and enhancing local capacity in marine resource management. The complementarity of skills between a lawyer and a fisheries expert has been key in developing a legal training that meets Samoa's specific needs.

Outcomes of the Samoa Legislative Drafting Workshop

In November 2024, the first *National Legislative Drafting Workshop*: *Coastal Fisheries* took place in Samoa, gathering 23 officials from Samoa and 3 officials from American Samoa. Supported in part by a public diplomacy grant from the US Embassy, the workshop was organised by MAF in partnership with SPC and UC Law SF.[2] This training initiative aimed at strengthening Samoa's capacity in understanding the importance of clear and enforceable legislation that aligns with local policy objectives, reinforces gender equity, and respects human rights.

Competency-based assessment of the Regional Legislative Drafting Course: Coastal Fisheries, March 2023, Noumea. Image: © SPC

[1] To find existing laws and policies for Samoa, please visit the REEFLEX database: https://www.spc.int/CoastalFisheries/Legislation/country/WS

[2] Funding for the preparation of the training material and the delivery of the workshop was provided through a U.S. Embassy grant to UC Law SF, complemented by two SPC projects – PaFMaC and SCoFA – the first funded by USAID and the second by the New Zealand Ministry of Foreign Affairs and Trade with the Australian Department of Foreign Affairs and Trade.

Sapeti (left) and Glory (middle) with Solène from SPC (right) during the two-week attachment in Suva in July 2024. © SPC

Workshop participants, including MAF fisheries officers, aquaculture officers, enforcement officers, lawyers from the Attorney General's Office, and officers from American Samoa's Department of Marine and Wildlife Resources, examined the processes involved in developing national legislation, drafting bylaws, and managing case files for prosecution. Through a peer-to-peer learning approach, officials from Samoa and American Samoa were able to compare procedures and identify solutions for effective coastal resource management, building on a common understanding of legal frameworks.

Empowering PICTs fisheries agencies for lasting change

The Samoan *National Legislative Drafting Workshop* shows how government officers from fisheries agencies in PICTs can drive sustainable change through capacity building and collaboration with partners across the region and beyond. This training of trainers activity can inspire other Pacific agencies, encouraging the continued development of locally-adapted legal frameworks to protect coastal fisheries for future generations.

SPC's legal team offers dedicated support and resources to fisheries agencies' staff who have completed the *Regional Legislative Drafting Course: Coastal Fisheries* and are interested in developing a national legal training programme adapted to their country's needs. Through customised training, SPC can assist PICTs in building the skills necessary for effective legislative drafting, strengthening their capacity to develop and enforce laws and regulations that safeguard marine and fisheries resources.

For more information:

Ariella D'Andrea - SPC Legal Adviser (Coastal Fisheries and Aquaculture)
ariellad@spc.int

Solène Devez - SPC Legal Officer (Coastal Fisheries and Aquaculture)
solened@spc.int

Further reading

D'Andrea A., Devez S. and Vapnek J. 2022. Drafting coastal fisheries legislation: A new training course available online! SPC Fisheries Newsletter 167:10. https://www.spc.int/digitallibrary/get/zm63p

Pacific Community. 2024. Media release: Samoa advances coastal fisheries governance with legal training for sustainable marine resource management. https://www.spc.int/updates/news/joint-release/2024/11/samoa-advances-coastal-fisheries-governance-with-legal-training

Sauerwein A., D'Andrea A. and Vapnek J. 2021. How to draft effective coastal fisheries and aquaculture legislation. SPC Fisheries Newsletter 164:53–60. https://www.spc.int/digitallibrary/get/q6dzz

Samoa Legislative Drafting Workshop, November 2024, Apia. Image : © Ministry of Agriculture and Fisheries, Samoa.

Human rights law in coastal fisheries and aquaculture in Micronesia

SPC has recently published a comparative analysis of legislation related to gender and human rights in coastal fisheries and aquaculture in the Federated States of Micronesia (FSM), Marshall Islands and Palau.[1] The preliminary findings were shared with country counterparts and partners during a virtual workshop in June 2022. This study builds on a 2021 report covering six other Pacific Island countries.[2]

Overview

Coastal fisheries are crucial for local communities, providing food and income for up to 50% of households in the Pacific region[3]. However, the shift towards monetised economies and foreign investments is pressuring governments to open natural resources for exploitation, as recognised by the 2050 Strategy for the Blue Pacific Continent.

This legal study examines the integration of human rights in coastal fisheries and aquaculture legislation in three Micronesian countries. It compares national legislation against gender and human rights standards relevant to small-scale coastal fisheries and aquaculture, offering legal and policy recommendations to address barriers to human rights implementation.

Under international law, governments must respect, protect and fulfill human rights through all policies and legislation, prioritising human rights over environmental conservation or economic development. Given the complexity of legal systems in Pacific Island countries, which include customary laws, local ordinances and statutory legislation, the study provides an overview rather than an exhaustive analysis. Despite these limitations, it provides country-specific analyses, acknowledging positive efforts and suggesting areas for improvement in the face of climate change and globalisation.

Key findings and recommendations

While most Pacific Island countries recognise human rights, these are often limited to civil and political rights, neglecting economic and social rights, such as the right to food, the right to a healthy environment and labour rights. Environmental conservation efforts must balance biodiversity protection with human rights, particularly the right to food. Meaningful community participation in marine protected area management is crucial, requiring inclusive consultation and impact assessments on human rights.

Community-based fisheries management is being promoted, but enabling provisions often need legal reinforcement. Ensuring participation and access to remedy for marginalised groups, including women and migrants, is essential. States must also ensure health and safety at work, including for informal small-scale fishers and fish workers.

[1] Graham A. and D'Andrea A. 2024. Gender and human rights in coastal fisheries and aquaculture: A comparative analysis of legislation in the Federated States of Micronesia, Marshall Islands and Palau. Noumea, New Caledonia: Pacific Community. 100 p. https://www.spc.int/digitallibrary/get/oir28

[2] See SPC Fisheries Newsletter #164. https://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/164/FishNews164_20_DAndrea.pdf

[3] A new song for coastal fisheries pathways to change: the Noumea strategy. https://www.spc.int/digitallibrary/get/b8hvs

Coastal fisher in the Marshall Islands. Image: © Chewy E. Lin

Priority actions to be considered include: 1) amending constitutions to include economic, social and cultural rights; 2) ensuring customary practices align with international human rights law; and 3) promoting gender equality. Governments should also engage with judicial courts and customary rights holders to integrate human rights principles into local practices, thus ensuring sustainable and equitable resource management.

By implementing these actions, FSM, Marshall Islands and Palau can better protect the human rights of small-scale coastal fishers and fish workers, thereby ensuring sustainable and inclusive development in their coastal fisheries and aquaculture sectors.

For more information:

Ariella D'Andrea

Legal Adviser (Coastal Fisheries and Aquaculture)
ariellad@spc.int

Alison Graham

Independent Consultant (human rights expert)
*alison_graham2000@yahoo.co.uk_*

Leveraging Pacific Island expertise for sustainable fisheries and aquaculture: Seventh Regional Technical Meeting on Coastal Fisheries and Aquaculture

The Seventh SPC Regional Technical Meeting on Coastal Fisheries and Aquaculture (RTMCFA7) was convened as a virtual gathering – due to funding constraints – from 19 to 22 November 2024. The meeting brought together coastal fisheries scientists, fisheries officers, and technical experts from across the Pacific Islands region to address essential technical and scientific gaps, identify pressing needs and challenges, and explore emerging opportunities for advancement. The meeting addressed a broad range of critical areas, including in-depth discussions on technical challenges in aquaculture and aquatic biosecurity, and highlighted the importance of data-driven and evidence-based approaches to effective coastal fisheries management. Additionally, it explored innovative tools and technologies to reinforce food security and enhance livelihoods, focusing on sustainable development and resilience across Pacific Island communities.

The meeting was attended online by an average of 85 registered delegates each day. Forty-seven percent of registrations were from 14 SPC member countries and territories (America Samoa, Australia, Cook Islands, Fiji, French Polynesia, Guam, Kiribati, New Caledonia, New Zealand, Samoa, Solomon Islands, Tonga, Wallis and Futuna, United States of America) and 53% were observers and staff of SPC's Fisheries, Aquaculture and Marine Ecosystems Division (FAME). The actual number of participants from SPC Pacific Island countries and territories (PICTs) was difficult to determine, as several PICT fisheries agencies staff participated via a single registration through their conference or meeting room internet connection. The diverse representation included fisheries and aquaculture officers, onboard observers, civil society representatives, and nongovernmental organisations, fostering a collaborative environment for dialogue and exchange across the Pacific. The meeting was chaired by New Zealand, under the guidance of Sarah McAvinchey, Lead Adviser – Pacific Ocean and Fisheries, Pacific Regional Division, Ministry of Foreign Affairs and Trade, New Zealand.

The meeting focused on a range of areas, including:

- Progress update on RTMCFA6 outcomes and actions;
- PICT priority technical needs, issues and challenges;
- Report of the 4th Community-Based Fisheries Dialogue (CBFD4);
- Enhancing data-limited coastal fisheries health assessments in Pacific small island developing states;

Coastal fisheries data collection in (left) Honiara, Solomon Islands and (right) Port Moresby, Papua New Guinea.
Images: George Shedrawi, © SPC

Woman selling seaweed (*nama*) in Fiji.
Image: © George Shedrawi, SPC.

A plenary session focused on spat collection to support aquaculture. Shown here is a Tahitian pearl oyster spat collector with scallop spat in New Caledonia.
Image: © Antoine Teitelbaumi, SPC.

- Navigating the coastal fisheries and aquaculture monitoring, control, surveillance and enforcement future;
- Coastal fisheries activity updates:
    - An update on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) process concerning marine aquarium fishes;
    - An update on Green Climate Fund Regional Tuna Project;
    - Enhancing law and policy development for Pacific coastal fisheries and aquaculture;
- Highly instrumented fish aggregating devices (HI-FADs);
- Update on the development of the Pacific Regional Aquaculture Strategy (PRAS);
- Aquaculture updates:
    - Economic comparison of mangrove oyster longline grow-out system and traditional homemade basket system;
    - Aquaculture potential of Pacific short-fin eel *Anguilla obscura*, in a novel aquaculture system;
- Developing a regional aquaculture database: key insights from PICTs;
- Further potential of spat collection in the Pacific Islands region;
- Pacific regional assessment of climate change implications for fisheries and aquaculture – 12-year update; and
- Socioeconomic community of practice (SECoP Pasifika): What is it and how can it be useful for fisheries authorities?

The *RTMCFA7 Outcomes and Actions Report*, along with all the working and information papers and the presentations, are available on the SPC FAME RTMCFA7 website.[1]

[1] The RTMCFA7 webpage on the SPC FAME website: https://fame.spc.int/events/RTMCFA7

The *RTMCFA7 Outcomes and Actions Report* includes the agreed priority issues and needs to be actioned by SPC members, provides guidance to SPC's FAME's Coastal Fisheries and Aquaculture Programme, and identified the key recommendations to be taken to the 17th Heads of Fisheries (HoF17) meeting in late April 2025.

PICT member priorities

Prior to this virtual meeting, SPC PICT members were provided with a brief questionnaire, asking them to outline their current national coastal fisheries and aquaculture priorities and technical needs, and their challenges over the last year. Submissions were received from 11 PICT members, and their responses are captured in *RTMCFA7 Information paper 3.*[2]

The common coastal fisheries priorities included:

1. **Strengthened coastal fisheries data management and decision-making:** the need for data collection, analysis, and data management; the further use of applications (Ikasavea), databases and storage; support for socioeconomic surveys and data; and more value-chain analyses.
2. **Enhanced training and capacity building:** the need for targeted capacity-building initiatives, including training in stock assessments, fisheries-independent surveys and data analyses, certified training for fisheries officers, fisheries species identification, fish aggregating devices (FADs), and nearshore fishing techniques.
3. **Support for livelihoods, fisheries development and food security:** the need for support for all aspects of anchored FADs, including funding, deployment, fishing techniques, data, monitoring, and evaluation. Post-harvest handling, marketing and analysis of commodities, as well as supplementary or alternative livelihoods were also identified priorities.
4. **Strengthening of legislation, policies, regulations, monitoring, control, surveillance and compliance:** the need to review and update fisheries legislation, and to develop frameworks for policies and regulations for sustainable management (including community-based management), awareness and compliance.
5. **Technology:** the further promotion of technology-driven solutions, especially digital tools.

The common aquaculture priorities included:

1. **Production opportunities:** the need to improve aquaculture infrastructure and operations, develop priority species, conduct feasibility studies for farming and integrated systems, and promote local feed production.

Fresh seafood straight from the fishing boats in Fiji. Image: © George Shedrawi, SPC.

2. **Training and capacity building:** targeted training in hatchery operations, husbandry, handling, project management, feasibility studies, and site assessments was highlighted as being essential.
3. **Data and monitoring systems:** members identified the need to establish aquaculture databases, monitoring systems, and traceability systems for CITES-listed species to improve management and compliance.
4. **Governance and policy development:** the creation and implementation of standard operating procedures for biosecurity, importation, production, and management were highlighted. Members also recognised the importance of developing climate change remediation strategies for aquaculture farms.
5. **Biosecurity and infrastructure:** investments in laboratory facilities, specialised equipment, and regional demonstration facilities are needed to strengthen biosecurity and support aquaculture operations.
6. **Capacity and technical skills:** building capacity in risk assessments, disease diagnostics, site evaluations, and technical expertise for priority and emerging species was identified as a priority.
7. **Input availability:** the need to increase seed production, provide sustainable start-up support, and address water quality and supply issues, as well as to promote sustainable feed options to reduce import dependency and to lower costs.

[2] Information paper 3: https://www.spc.int/digitallibrary/get/ktbty

Fourth Community-Based Fisheries Dialogue Report to RTMCFA7

This year, the 4th Community-Based Fisheries Dialogue (CBFD4) was held (in person) in Suva, Fiji, from 12 to 13 November 2024, with a focus on the participation of community fisher representatives, civil society organisations and other non-state actors. Aydah Akao from Solomon Islands served as the convenor, and presented the *CBFD4 Outcomes and Actions Report* to RTMCFA7.[3]

In establishing the CBFD, HoF and regional fisheries ministers agreed that the full CBFD outcomes and actions report (including recommendations to HoF) be presented to RTMCFA. The RTMCFA plenary may pose questions and seek clarification in relation to the report from the CBFD, and the report will be included in the RTMCFA outcomes and actions report and transmitted unchanged to the HoF. As such, RTMCFA7 noted the CBFD4's recommendations to HoF17.

The need to review and update fisheries legislation, and to support awareness and compliance was addressed. Fisheries officers in Fiji. Image: Ariella D'Andrea, © SPC

Coastal fisheries technical sessions

Enhancing data-limited coastal fisheries health assessments in Pacific SIDS

An update was presented on the major advancements by SPC's CFAP Science and Database teams in developing innovative e-data tools designed to improve the collection, management and analysis of coastal fisheries data. These tools aim to support evidence-based management by providing accurate and reliable data, and insights for informed decision-making. The meeting also served as a platform for members to share their experiences in using these tools, discuss their practical applications, and explore upcoming capabilities being integrated into existing tools, as well as areas of importance including the use of artificial intelligence (AI) to assess fishery health and address challenges in data-limited fisheries. The meeting noted the critical need for capacity building in data-limited coastal fisheries assessments, and agreed to a number of actions and two recommendations to HoF17 to address data analysis needs in data-limited contexts.

Navigating the coastal fisheries and aquaculture monitoring, control, surveillance and enforcement future

This session emphasised the need to foster a more robust culture of compliance within coastal fisheries through monitoring, control, surveillance and enforcement (MCSE) tools, focusing on community education, stakeholder engagement, and ongoing efforts in training, partnerships, monitoring trials, and data management to support sustainable management and conservation. After participating in breakout groups, the meeting agreed on several actions and one recommendation to HoF17 to further advance SPC's efforts in strengthening coastal fisheries compliance through expanded training programmes, strategic partnerships, innovative monitoring trials, and comprehensive data management.

Coastal fisheries activity updates

SPC provided updates on the CITES proceedings for marine aquarium fish, the Green Climate Fund's Regional Tuna Project for climate resilience, and the legal and policy support for coastal fisheries management, and Pacific Small Island Developing States' negotiations on ocean and marine environmental issues, including plastic pollution from fishing gear, in collaboration with regional partners. The meeting acknowledged these updates and identified several actions and two recommendations for HoF17.

[3] Outcomes and Actions Report from the 4th Community-Based Fisheries Dialogue: https://www.spc.int/digitallibrary/get/srtip

Highly instrumented fish aggregating devices

An update was provided on the HI-FAD project, which tested satellite buoy technologies in PICTs, showing benefits including improved anchored FAD monitoring, fishing success and ocean monitoring, but also highlighting challenges such as equipment loss and the need for proper deployment practices. The meeting noted the suggestions on best practices for selecting the correct FAD design and deployment site, attaching GPS monitoring buoys to FADs, and disseminating data from electronic technologies on anchored FADs, and emphasised the importance of careful planning and recovery strategies to maximise the effectiveness of satellite buoy technologies. The meeting encouraged PICTs to explore the opportunity of repurposing equatorial purse seine fleet echosounder buoys that have been stranded in PICTs' coastal areas, as part of an effort to enhance local fisheries monitoring while managing communication costs.

Coastal fisheries produce for sale in Suva, Fiji.
Image: © George Shedrawi, SPC

Aquaculture technical sessions

The meeting acknowledged the significant contribution to Pacific aquaculture of Dr Timothy Pickering, SPC FAME Principal Aquaculture Adviser, who sadly passed away in July 2024 after a valiant 10-month fight with an illness.

Update on the development of the Pacific Regional Aquaculture Strategy

SPC provided an update on the progress of the developing PRAS, and invited participants to review the draft strategy and submit final feedback by mid-December 2024. The meeting also acknowledged SPC's effort in supporting members in developing PRAS as a comprehensive framework to guide sustainable development across the Pacific, aiming to strengthen food security, livelihoods, and economic resilience. The final draft of the strategy will be presented to HoF17 for adoption.

Aquaculture activity updates

SPC presented preliminary results from a cost-benefit analysis conducted for the Fiji Ministry of Fisheries and Forests, comparing the effectiveness of two oyster growout systems: traditional homemade baskets and longline growout baskets. The meeting highlighted the need for further analysis to optimise conditions for scaling production, ensuring that the longline system remains economically viable for larger-scale operations over time, and the need to further investigate the durability, environmental sustainability, and cost-effectiveness of various types of baskets. The meeting emphasised the importance of continued technical support and capacity building, especially for women's groups and local communities involved in oyster farming.

The preliminary results were presented from a study investigating the growth rates and survival of juvenile Pacific short-finned eels (*Anguilla obscura*) within a controlled aquaculture environment in Fiji. The meeting noted the potential to explore similar studies for species found in other PICT members, drawing on the lessons learned from the Fiji study.

Developing a regional aquaculture database: Key insights from PICTs

SPC presented the current state of aquaculture data and the need for a central database to manage aquaculture data from hatcheries and farms. After breakout group discussions, the meeting endorsed the development of a regional aquaculture database, recognising it as a crucial tool for consolidating aquaculture data across PICTs to support national and regional reporting and informed decision-making. Participants emphasised the importance of this work and emphasised several key requirements that will need to be included to maximise functionality for all users. The meeting agreed on a recommendation for HoF17 to prioritise this initiative.

Further potential of spat collection in the Pacific Islands region

Spat collection, a process of gathering juvenile shellfish such as oysters and clams from natural habitats to support aquaculture, was the focus of a plenary presentation and breakout group discussions. This low-cost, sustainable practice, already established for pearl oysters in isolated Pacific communities, could be expanded to rock and mangrove oysters, enhancing food security, environmental health, and economic resilience across the region. The meeting acknowledged spat collection as an accessible, low-cost aquaculture method with significant potential to support income generation, food security, and marine conservation for Pacific communities, but requiring further research and resource development. It was agreed that the establishment of regulatory frameworks and community agreements to clarify access rights, manage environmental impacts, and address challenges related to spat collection areas, infrastructure security, and potential navigation hazards, were important areas requiring attention. The importance of ensuring access to affordable financing and start-up capital to enable communities to actively engage in aquaculture programmes such as spat collection was highlighted.

Cross-cutting technical sessions

Pacific regional assessment of climate change implications for fisheries and aquaculture – A 10-year update

An update was provided on the Pacific regional assessment of climate change implications for fisheries and aquaculture, which is in its final stages. This comprehensive 10-year review, funded by the Australian Department of Foreign Affairs and Trade, and the New Zealand Ministry of Foreign Affairs and Trade, involves contributions from over 50 experts. The assessment examines the impacts of climate change on coastal, oceanic, freshwater fisheries, aquaculture, livelihoods, economies, food security, and blue food systems. To ensure practical and targeted outcomes, detailed summaries with recommended adaptations are being prepared for each PICT, incorporating input from national agencies, regional organisations and other stakeholders. The final publication will be presented to HoF17 in late April 2025.

Socioeconomic community of practice (SECoP Pasifika): What is it and how can it be useful for fisheries authorities?

SPC provided an update on the recently established Socioeconomic Community of Practice (SECoP Pasifika), a regional member of the Global Socioeconomic Monitoring Initiative for Coastal Management, which brings together experts and interested stakeholders to exchange insights and strategies for enhancing resource management in the Pacific. SECoP Pasifika was endorsed as a valuable platform for integrating socioeconomic insights into fisheries and coastal resource management, emphasising its role in supporting sustainable community livelihoods across the Pacific.
The meeting highlighted the importance of SECoP Pasifika in fostering collaborative learning and capacity building, providing access to resources, training, and expertise that enhance socioeconomic and gender-inclusive approaches within fisheries authorities.

Recommendations for HoF17

The meeting discussed and agreed to seven recommendations to be transmitted to HoF17 members for their consideration in late April 2025. These are included in the *RTMCFA7 Outcomes and Actions Report*[4].

Feedback

Participants were asked to complete a post-RTMCFA7 survey to rate aspects of the meeting. Only 17 participants responded to the feedback survey, a 22% response rate, representing a drop both in total participation and response rate compared to RTMCFA6 (November 2023), in which 97 participants attended the meeting and 45% responded to the post-meeting survey. It should be noted that RTMCFA6 was the first fully in-person meeting for three years, whereas RTMCFA7 was a return to a fully virtual meeting due to funding constraints.

Participants were asked to rate meeting content, opportunity for feedback, participant engagement, time allocated for the sessions, virtual meeting delivery and breakout groups facilitation. The "opportunity for feedback" and "participant engagement" received an average weighted rating under 4 points, indicating potential room for improvement for these elements for future meetings. Furthermore, all general aspects were rated between 3.8 and 4.1, indicating that the satisfaction level was good, but not high.

Participants were asked to rate the meeting sessions of RTMCFA7. The sessions receiving the highest rating were "Day 1 - Summary of PICT coastal fisheries priority technical needs, issues and challenges", "Day 1 - Enhancing data-limited coastal fisheries health assessments in Pacific SIDS" and "Day 2 - Navigating the coastal fisheries and aquaculture monitoring, control, surveillance and enforcement future", both sessions received an average rating of 4.29 out of 5. RTMCFA6 sessions received average ratings between 4.3 to 4.6, indicating a decrease in satisfaction with the agenda compared to last year's meeting.

[4] Outcomes and actions report from the 7th SPC Regional Technical Meeting on Coastal Fisheries and Aquaculture - https://www.spc.int/digitallibrary/get/6b7ek

Snapshot:

- Low response rate to the post-meeting survey (22%, only 17 out of approximately 78).
- Most respondents considered they had the opportunity to provide their inputs when they wanted to.
- Most respondents considered the sessions addressed topics relevant to their countries or territories.

Most informative: Respondents most frequently mentioned the aquaculture sessions (especially the spat collection session), the coastal fisheries MCS, and the impacts of climate change in coastal fisheries as the most informative topics discussed during RTMCFA7.

Least informative: Most respondents rated all parts of the meeting informative. A few respondents mentioned the SECoP update as least informative.

Respondents were also asked to suggest topics for RTMCFA8, as well as possible timing for RTMCFA8 to avoid conflicts with other fisheries and/or aquaculture meetings. These will be considered when planning for RTMCFA8 in 2025.

Targeted training and capacity building was highlighted as being essential, including for aquaculture operations, management and techniques. Sea cucumber hatchery in Honiara, Solomon Islands. Image: Sylvester Diake, © SPC

Conclusions

The participation rate of SPC member PICTs in RTMCFA7 was disappointing, with only 12 out of 22 PICTs attending. Only 11 PICTs completed the pre-meeting questionnaire on their priority technical needs, issues and challenges – the lowest response rate since this was initiated. Whether this was due to RTMCFA7 being a fully virtual meeting, SPC PICT members having too many fisheries or aquaculture meetings in 2024, a perceived decline in the usefulness of the RTMCFA meetings, a mix of these, or some other reasons, will need to be assessed. It is proposed that the need, value, format and timing of RTMCFA should be discussed at HoF17.

The next RTMCFA meeting is tentatively scheduled to be held in late 2025, funding permitting. Timing will depend on the decisions by HoF17 concerning RTMCFA. An official announcement will be sent out after HoF17 in late April 2025.

For more information:

Andrew Smith

Deputy Director FAME (Coastal Fisheries and Aquaculture), SPC
andrews@spc.int

Fish market at Port Moresby, Papua New Guinea. Image: George Shedrawi, © SPC

The thriller in Manila? Outcomes of the 20th annual WCPFC Scientific Committee

This year's in-person Western and Central Pacific Fisheries Commission's (WCPFC's) Twentieth Regular Session of the Scientific Committee (SC20) meeting was held in the bustling city of Manila, Philippines. Covering the wide range of issues within the SC's remit, from stock assessment to climate change, here are some of the key outcomes from SC20.

WCPFC's SC meeting is held in August each year, prior to the annual Commission meeting in December. It is attended by WCPFC's 33 member countries and territories, as well as meeting observers, and examines a range of scientific issues broken down into the four SC themes: data and statistics, stock assessments, management issues, and ecosystem and bycatch mitigation.

SPC's Oceanic Fisheries Programme (OFP) has been WCPFC's scientific services provider and data manager for the past 20 years. This means that the SC meeting is a key time for OFP scientists to present their analyses to inform SC's scientific advice for fishery management decisions taken by the Commission. This year, OFP scientists wrote 60 papers providing information and recommendations to SC20[1] across the four different themes.

SPC's Peter Williams makes sure everyone knows where the meeting is taking place. Image: Graham Pilling, © SPC

Welcome to the Philippines

SC20 was held at the Luxent Hotel in the Quezon City area of Manila from 14 to 21 August 2024. Following the unrest in New Caledonia – with the OFP team scattered across the globe due to travel restrictions – the meeting was the first time many of the team had seen each other in several months. Getting together and supporting another SC meeting felt like another step back towards normality.

Data

With good data being so critical to the scientific work of the Commission, the meeting discussed improvements to data collection frameworks. These included: 1) potential additional information for longline logbooks; improvements to information on transshipment at sea to be considered by other WCPFC bodies; and 3) further work on information gathering around fish aggregating devices.

Review the latest stock assessment results

A key element of this year's SC was the review of our latest stock assessment for South Pacific albacore. The team did a great job, with the assessment continuing to make improvements from the previous one in 2021. The stock was assessed as being "in the green" (i.e. not overfished nor subject to overfishing) and only slightly below the interim target reference point that was agreed on at WCPFC20 last year (2023). SC20 reviewed and accepted the assessment as the best scientific information available for stock status, and used the results to craft advice for consideration by fisheries managers at the Commission meeting.[2]

OFP also presented assessments of southwest Pacific striped marlin and silky shark which was led by Dragonfly Data Science in New Zealand with OFP support. The striped marlin assessment had proved technically challenging, and SC agreed that further analysis was required for presentation to next year's SC meeting (i.e. SC21). For silky shark,

[1] 20th annual WCPFC Scientific Committee: https://meetings.wcpfc.int/meetings/sc20
[2] 21st Regular Session of the Commission: https://meetings.wcpfc.int/meetings/wcpfc21

SC20 reviewed the wide range of analyses performed on this relatively data-poor stock and identified the best model to use for advice. Noting the data uncertainties, the SC highlighted the positive trend in stock status and recommended that overfishing was very unlikely to be occurring, suggesting that current mitigation measures, such as non-retention and banning wire traces, do appear to be reducing fishing impacts on silky shark populations.

Progress for tuna harvest strategies

A key focus of SC20 was the harvest strategy for South Pacific albacore, which was scheduled for agreement at the Commission meeting later in 2024. The meeting made several recommendations that progressed this work, which following the development of the 2024 assessment and leading to some significant updates that were still ongoing at the time of SC20. After a huge effort, the results of this work were delivered to the Second Science-Management Dialogue meeting[1] that was held online in September, and which provided further guidance for managers to consider at WCPFC21.

SC20 also considered the adopted harvest strategy for skipjack, in particular the monitoring strategy that tracks the performance and implementation of the management procedure and allows the Commission to check that it is working as expected and achieving the desired benefits. Noting the need for some updates, SC20 recommended it be forwarded to the subsequent Commission body meetings for further input before being considered for adoption by WCPFC21.

SPC's fisheries scientists, Paul Hamer and Claudio Castillo Jordan, enjoy some local flavours during the meeting. Image: Graham Pilling, © SPC

Target reference points for bigeye and yellowfin tuna were also scheduled for adoption at this year's Commission meeting (i.e. WCPFC21). This forms a part of the "mixed fishery" approach that considers the interactions between tuna species and the different fishing gear operating within the waters of the WCPFC. SC20 asked for some additional analyses to be provided to the Commission.

Climate change

Climate change is a key issue for WCPFC, given the direct impact on Pacific Island members and the implications for tuna stock status and spatial distribution. WCPFC adopted a resolution on climate change in 2019.[3] SC20 reviewed the latest work on developing climate indicators designed to monitor and flag changes in the western and central Pacific Ocean, and reviewed the draft climate change work plan that will be considered at the Commission meeting.

Celebrating some old hands

Keith Bigelow, who worked in OFP for a while before returning to Hawaii to work in the National Oceanic and Atmospheric Administration's Pacific Islands Fisheries Science Center, celebrated his last SC meeting this year. As head of the US delegation to the meeting, it's been great to work with him across all SC issues. James Larcombe, a long-time Australian colleague and the lucky man who took up the process of updating the Commission's harvest strategy work plan each year, also retired. We hope to see him occasionally at future meetings supporting harvest strategy discussions. Tuna work is hard to give up!

Up next

After SC20, the work level does not ease up. We have already supported WCPFC's Second Science-Management Dialogue meeting in September, presenting the work done on harvest strategies following the SC meeting, with more to do prior to the Commission meeting in December in Suva, Fiji. The OFP team was there to present the results of analyses and to inform members' decision making.

For more information:

Graham Pilling,
Head of SPC FAME's Oceanic Fisheries Programme
grahamp@spc.int

Paul Hamer,
Head of SPC FAME's Stock Assessment and Modelling Section
paulh@spc.int

[3] WCPFC Resolution 2019-01: https://cmm.wcpfc.int/resolution/resolution-2019-01

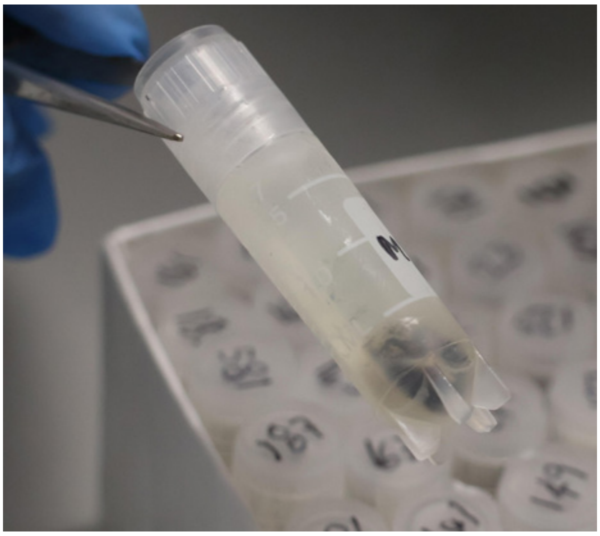
New tech for the SPC FAME genetics lab: The long and short of it (DNA reads, that is)

In April 2024, SPC's Fisheries, Aquaculture and Marine Ecosystems (FAME) Division had an official opening ceremony for its new laboratory space that supports its reference and training capacity. The expansion includes a genetics lab, scelerochronology lab (aka otolith reading), wet lab, a training and meeting room, and upgrades to the existing taxonomy lab. The ceremony made for a fun day, but the single biggest moment for our molecular capabilities happened more recently. In October, the genetics lab received a long-awaited piece of equipment: an Illumina MiSeq, a high-throughput, short-read DNA sequencer. With the MiSeq in place, the genetics lab is officially stocked for sea-to-sequence processing of genetic samples.

There are plenty of reasons to get excited about this development – some more technical than others.

Benefits of in-house sequencing

Perhaps the easiest point to boast about is that, prior to SPC FAME's acquisition of DNA sequencing machines, there was no capacity for DNA sequencing within the Pacific Islands. The only option was to send DNA samples to labs in Hawaii, New Zealand, Australia, or beyond, and trust that there would be no hiccup in air travel, delays at customs, or mix-ups of metadata in commercial-sized labs. Indeed, for many researchers and field operatives outside of the medical field, even DNA extraction (the first step of any genetic assessment) requires outsourcing. Although the SPC FAME genetics laboratory is not set up for commercial capacity or intended to relieve all genetic sequencing demands of the region, it is a critical first step in demonstrating the value of greater in-country molecular research capacity and establishing precedent for designing similar labs.



The SPC lab team can now identify, in-house, the contents of tuna stomachs genetically as well as visually. Image: Tracey Holley, © SPC

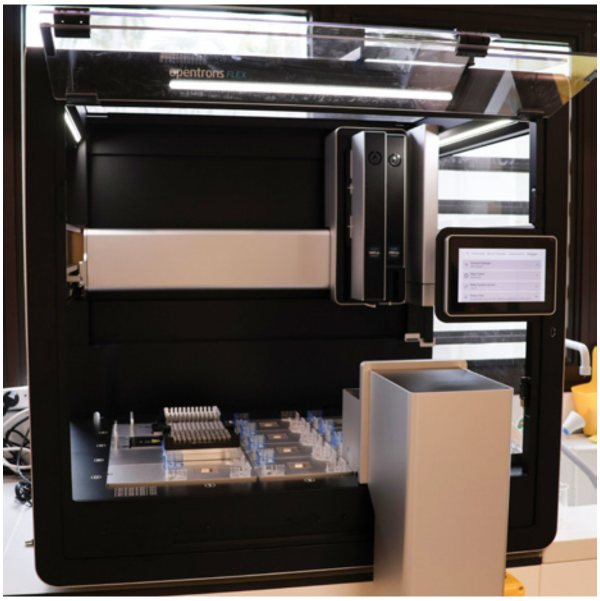
On a more functional scale, the genetics lab is already coordinating with SPC FAME's existing taxonomy lab to sequence the DNA fragments that remain in the stomachs of tuna. The concept is to make the same kinds of inferences as any traditional stomach contents study about tuna feeding behaviour, prey ecology and environmental health, but now to identify prey based on the presence of their DNA in stomachs rather than on visual identification. SPC FAME already produced one preliminary study to this effect but in that instance outsourced all DNA handling steps and collaborated on bioinformatic analyses. Now, the entire workflow is being conducted in-house, which allows for any number of protocol optimisations, repeat-samplings, and immediate study extensions based on initial results.

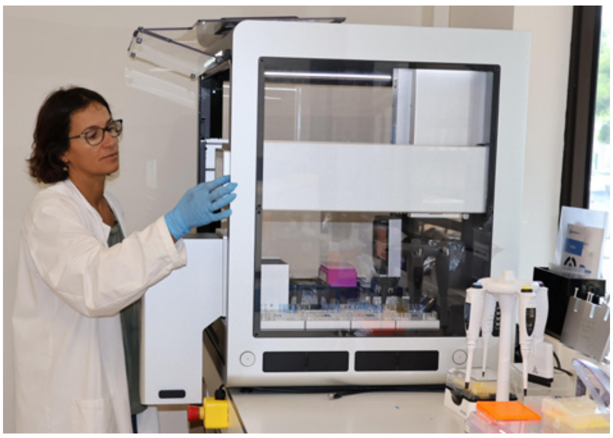
Enhancing the Pacific marine specimen DNA reference libraries

Likewise, we can now sequence specimens of interest from the Pacific Marine Specimen Bank to improve Pacific representation of species in the global mitochrondrial DNA reference libraries. A reference library is a list of DNA sequences that are known to occur only in a specific taxon; matching DNA sequences between stomach samples and the reference library indicates that the reference species was present in the stomach. Therefore, our ability to identify organisms through DNA is only as good as our reference library is inclusive. Unfortunately, there is a notorious data gap on western and central Pacific Ocean-specific species reference samples, which has previously hampered trophic level species composition studies in the region (genetic and otherwise). Similarly, when samples are submitted to the Pacific Marine Specimen Bank with some uncertainty on species identification, we can use the samples' DNA to confirm identification, thereby improving the quality control in the region's marine biodiversity biobank. These are only the first examples of work that we can now conduct in-house to improve the accuracy of science done by SPC FAME and by collaborators across the region.

On the most technical level, but the level most exciting to our genetics team, SPC FAME now has both long- and short-read sequencing capacity, represented by the Oxford Nanopore Technologies MinION and Illumina MiSeq, respectively. Together, these very different sequencing platforms cover a much broader range of research applications

The new DNA sequencing system, which will significantly enhance the lab's capacity for identifying tuna prey found in stomach samples. Image: Tracey Holley, © SPC





The new liquid handling robots (and SPC's Monica Ruibal), which will allow faster and accurate handling of complex workflows. Image: Tracey Holley, © SPC

and each helps to accommodate for weaknesses in the other. In the classic example, the MinION can process much longer strands of DNA than the MiSeq but has a higher risk of misreporting its sequence. The solution is to run the same DNA on both machines and use the MinION version as a general suggestion for how to piece together the much smaller pieces of DNA processed (with higher confidence) by the MiSeq. This kind of cross-checking has only recently become practice and is not a luxury enjoyed by most labs, but we have the option available.

Reducing human error in workflow

In a similar vein, we have robots. A perpetual challenge for molecular laboratories is the capacity for human error. Small slips in protocol can disassociate samples from important metadata, contaminate DNA, or damage inconveniently expensive and sensitive instruments. Not every lab has the luxury of automating their most labour-intensive tasks and the result is lower confidence in results, a lower productivity rate, or most likely both. The FAME genetics laboratory has only automated a few key tasks in the DNA sequencing workflow, but it is enough to greatly improve confidence (compared to an all-manual protocol) that novel observations from our data are actual biological signals and not an artefact of human error.

Tooled up and ready for evolution

The scope of FAME's genetics lab will inevitably grow and evolve as new projects and new technology arise. However, the suite of tools available in the lab now will be comfortably modern for years to come and have been organised with growth in mind. While our current projects focus mostly on species identification, the same equipment could be used for a host of other protocols that are just now being operationalised. In such a fast-paced field, it is hard to guess where and when the next breakthrough will arise. But with the tools available in the FAME genetics lab, we are well-placed to adopt current and emerging practices.

For more information:

Giulia Anderson

Fisheries Molecular Geneticist, SPC
giuliaa@spc.int

Monica Ruibal

Senior Research Officer (Genomics), SPC
monicar@spc.int

A bellyful of fishing tips: What can tuna stomachs tell us about catchability?

Pauline Machful,[1,*] Annie Portal,[1] Jed Macdonald,[1] Valérie Allain,[1] Joe Scutt Phillips[1], Joanne Potts[1] and Simon Nicol[1]

In a study we published in 2021 (see Machful et al. 2021), we presented different methods for quantifying the food ingested by fish. The preliminary results of our recent study (Machful et al. 2024) aim to better understand how the feeding behaviours of tropical tuna are influenced by ecological, fishery-related and environmental factors.

Stomach analyses are ongoing in the SPC taxonomy laboratory, with 8229 stomachs of tropical tuna species (3491 skipjack, *Katsuwonus pelamis*, 3436 yellowfin, *Thunnus albacares*, and 1302 bigeye, *Thunnus obesus*) withdrawn from the Pacific Marine Specimen Bank (PMSB) are incorporated into our current analysis compared to 8089 stomachs in our 2021 analysis

In this current article, we have furthered our analysis by diving deeper into fullness measures. Our initial fullness metric proved not to be relevant enough due to variability in the results obtained by our models. However, a simpler binary measure of empty versus non-empty stomachs offers clearer insights and more significant results. Our models explore the effects of fishing gear type, school association, and time of day on stomach fullness for each of the three tuna species.

Fishing gear

Fishing methods differ according to the behaviour of the target species. For more simplicity and robustness in our models we classified gear types into two categories: active (e.g. purse-seine) or passive (e.g. pole-and-line, handline, rod and reel, troll, and longline). Active gear types are manoeuvred to capture fish irrespective of their actions, while passive gear types are simply set in the water and fish have to engage with the gear to be caught (Fig. 2). These distinctions are thought to affect catchability and stomach fullness observations. According to our model, with active gear types, the probability of catching tuna with empty stomachs is high, regardless of species (Fig. 3A, 3H, 3O). Because feeding action is not required for the fish to be caught in purse seine nets, we might expect tunas to exhibit a wider range of stomach fullness, with no clear trend towards empty or non-empty stomachs.

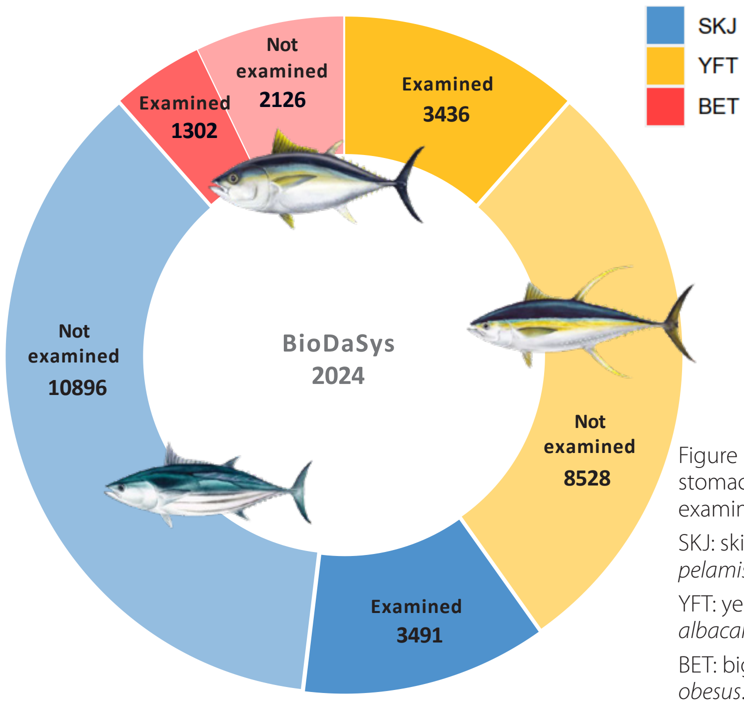


Figure 1. Summary of tuna stomachs sampled and examined.
SKJ: skipjack, *Katsuwonus pelamis*;
YFT: yellowfin tuna, *Thunnus albacares*;
BET: bigeye tuna, *Thunnus obesus*.

[1] Fisheries Ecosystem Monitoring and Analysis Section, Oceanic Fisheries Programme, Pacific Community
* Author for correspondence: paulinem@spc.int

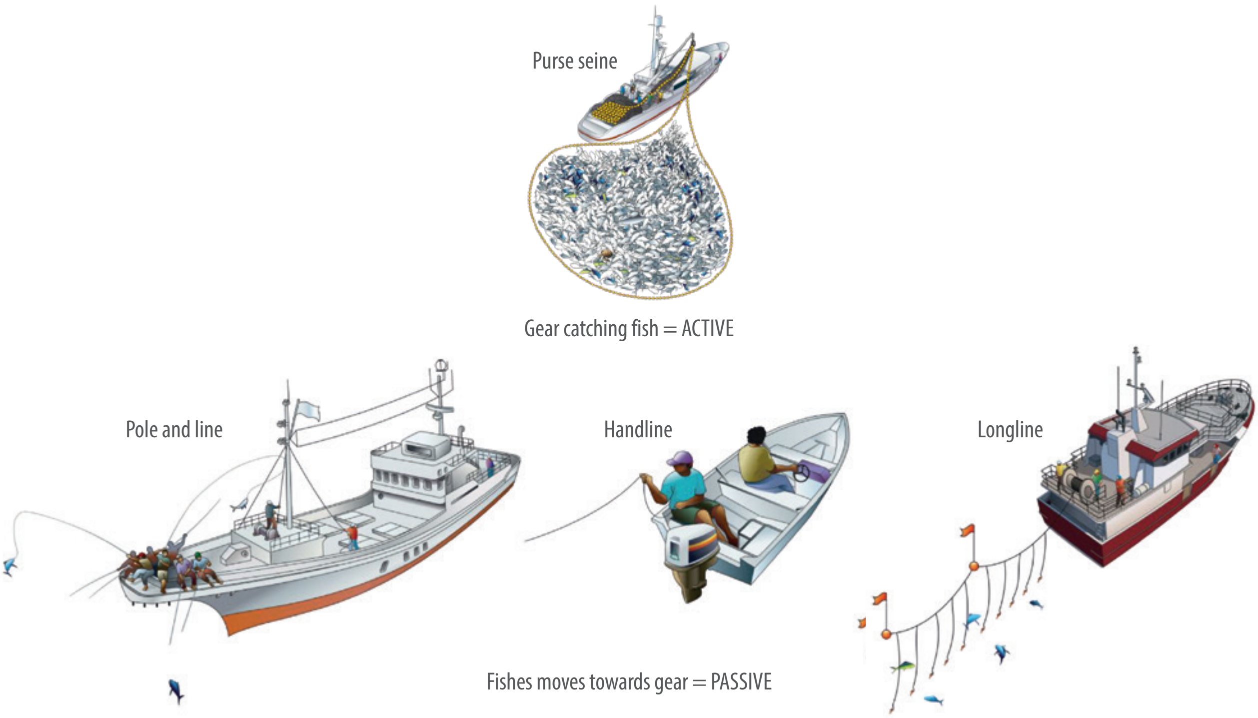


Figure 2. Two categories of fishing gear: active and passive.

The high proportion of empty stomachs in purse-seine-caught fish, however, suggests that the fishing strategy, linked to the time of day and the use of floating objects, also influences our observations.

On the other hand, passive gear types show a higher probability of capturing tunas with non-empty stomachs as they are feeding when caught (Fig. 3B, 3I, 3P). However, it is important to note that a non-empty stomach is not necessarily full. Because both pole-and-line and longline gear use bait, the chance of catching a fish depends partly on the feeding motivation of the fish (i.e. how hungry they are), and if they are actively foraging. It should also be noted that pole-and-line gear targets schools of fish that are visible and most likely actively hunting.

School association

Here we categorised the type of association into two categories, associated and free school. Associated schools refer to fish caught near anchored fish aggregating devices (FADs), drifting FADs, logs, or whales; while free schools refer to fish caught in free schools or near seamounts. The reasons for fish associating around floating objects are not clear, but FADs act as a gathering spot or refuge (Ménard et al. 2000, Leroy et al. 2013) and may be responsible for some of the patterns we observe in stomach fullness (Hallier and Gaertner 2008).

According to our results, skipjack and bigeye tuna caught in associated schools (Figure 3C and 3Q) are more likely to have empty stomachs. As purse-seine vessels target mostly fish aggregating around drifting FADs, and particularly skipjack, these results are consistent with our findings for different fishing gear.

Skipjack and bigeye tuna from free schools (Figure 3D and 3R) are more often found with non-empty stomachs, indicating that the fish were probably feeding when they were caught.

For yellowfin, there is no clear pattern regarding stomach fullness at associated or free schools (Figure 3J and 3K), suggesting that other factors such as fish size or growth stage may play a role in feeding success.

Time of day

The time of day may be linked to different feeding cycles, the availability of prey, or evasion of predators, and is likely to affect the observations of stomach fullness temporally. For this study, we grouped the times of day into three main categories. “Morning” refers to the period from dawn until the end of the morning, “noon” covers the time from late morning until the end of the afternoon, and “evening” corresponds to the period from sunset until nightfall. According to our results, empty stomachs are most commonly observed just before dawn across all species (Figure 3E, 3L,

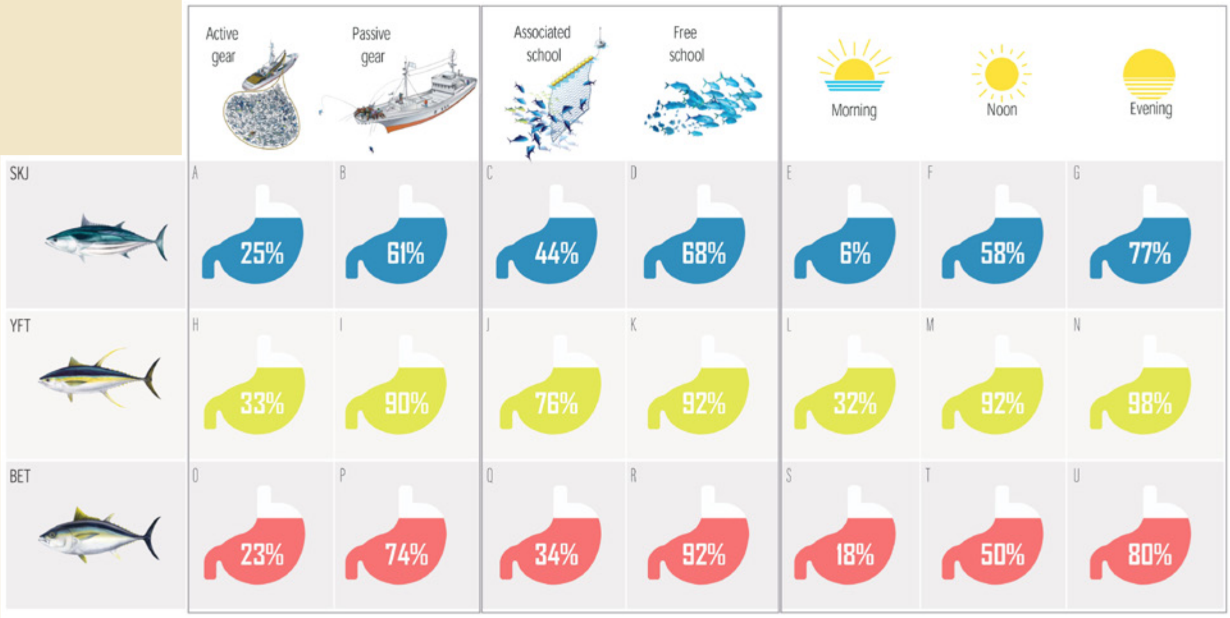


Figure 3. Plot showing the proportion of non-empty stomachs by species, gear type, school and time of day. SKJ: skipjack, *Katsuwonus pelamis*; YFT: yellowfin tuna, *Thunnus albacares*; BET: bigeye tuna, *Thunnus obesus*.

3S), with fullness increasing as the day progresses (Figure 3F-G, 3M-N, T-U). This pattern suggests a higher chance of successful feeding during daylight hours. However, due to gaps in nighttime data and limited observations, we cannot definitively conclude whether feeding occurred overnight. Information on prey-specific digestion times is lacking, and because tuna feed on a wide variety of prey types and sizes, it is difficult to know whether they may have fed on small or quickly digested prey species during the night, leaving an empty stomach at dawn.

Further work

This study has highlighted 20 years' worth of trophic data and how measuring stomach fullness can help us understand ecosystem dynamics, the influence of fisheries on tuna stomach fullness, and how to improve sampling methods for studying tuna diets. It also showed that ecological mechanisms are complex and that several interacting factors can play a role. Further work is needed to find these other key factors that affect stomach fullness in tuna. With ongoing stomach sample collection, the continued development of fullness metrics and incorporation of other data, it may be possible to more accurately characterise the true range of feeding in tuna populations. Tuna stomachs have yet to reveal all their secrets.

To read more about the study, see:
https://doi.org/10.1071/MF23174

References

Hallier J. and Gaertner D. 2008. Drifting fish aggregation devices could act as an ecological trap for tropical tuna species. Marine Ecology Progress Series 353:255–264. https://doi.org/10.3354/meps07180

Leroy B., Phillips J.S., Nicol S., Pilling G.M., Harley S., Bromhead D., Hoyle S., Caillot S., Allain V. and Hampton J. 2013 A critique of the ecosystem impacts of drifting and anchored FADs use by purse-seine tuna fisheries in the Western and Central Pacific Ocean. Aquatic Living Resources 26(1): 49–61. https://doi.org/10.1051/alr/2012033

Machful P., Portal A., Macdonald J., Allain V., Scutt Phillips J. and Nicol S. 2021. Tuna stomachs: Is the glass half full, or half empty? SPC Fisheries Newsletter 166:38–44. https://purl.org/spc/digilib/zodjm

Machful P., Portal A., Macdonald J., Allain V., Scutt Phillips J., Potts J. and Nicol S. 2024. Are tuna always hungry? A deep dive into stomach-fullness measures in the western and central Pacific Ocean. Marine and Freshwater Research 75(14). https://doi.org/10.1071/MF23174

Ménard F., Stéquert B., Rubin A., Herrera M. and Marchal É. 2000. Food consumption of tuna in the Equatorial Atlantic Ocean: FAD-associated versus unassociated schools. Aquatic Living Resources 13(4):233–240. https://doi.org/10.1016/S0990-7440(00)01066-4.

Where are the tuna larvae hiding?

Valérie Allain,[1] Hidetada Kiyofuji,[2] Atsushi Tawa,[2] Taiki Ishihara[2] and Elodie Vourey[1]

A collaborative sea voyage to discover where tuna begin their lives and how they thrive will help Pacific fisheries authorities manage their resources.

Before ending up on our plates, tuna begin their lives as tiny larvae, many of which will be eaten by other fish before reaching the juvenile stage and before becoming adults that can reproduce. Knowing where those larvae and juveniles are, and in which conditions they survive, is crucial to supporting the stock assessment science used to manage tuna resources in the Pacific Islands region.

The quest to find tuna larvae in the western and central Pacific Ocean started many years ago. Japan has been conducting larval distribution surveys since 1956, and these have helped to identify the optimal spawning temperature for skipjack, yellowfin and bigeye tuna. With climate change and greater variability in environmental conditions, new research is needed to better understand the influence of oceanographic and biological conditions on tuna larvae distribution, survival and recruitment.

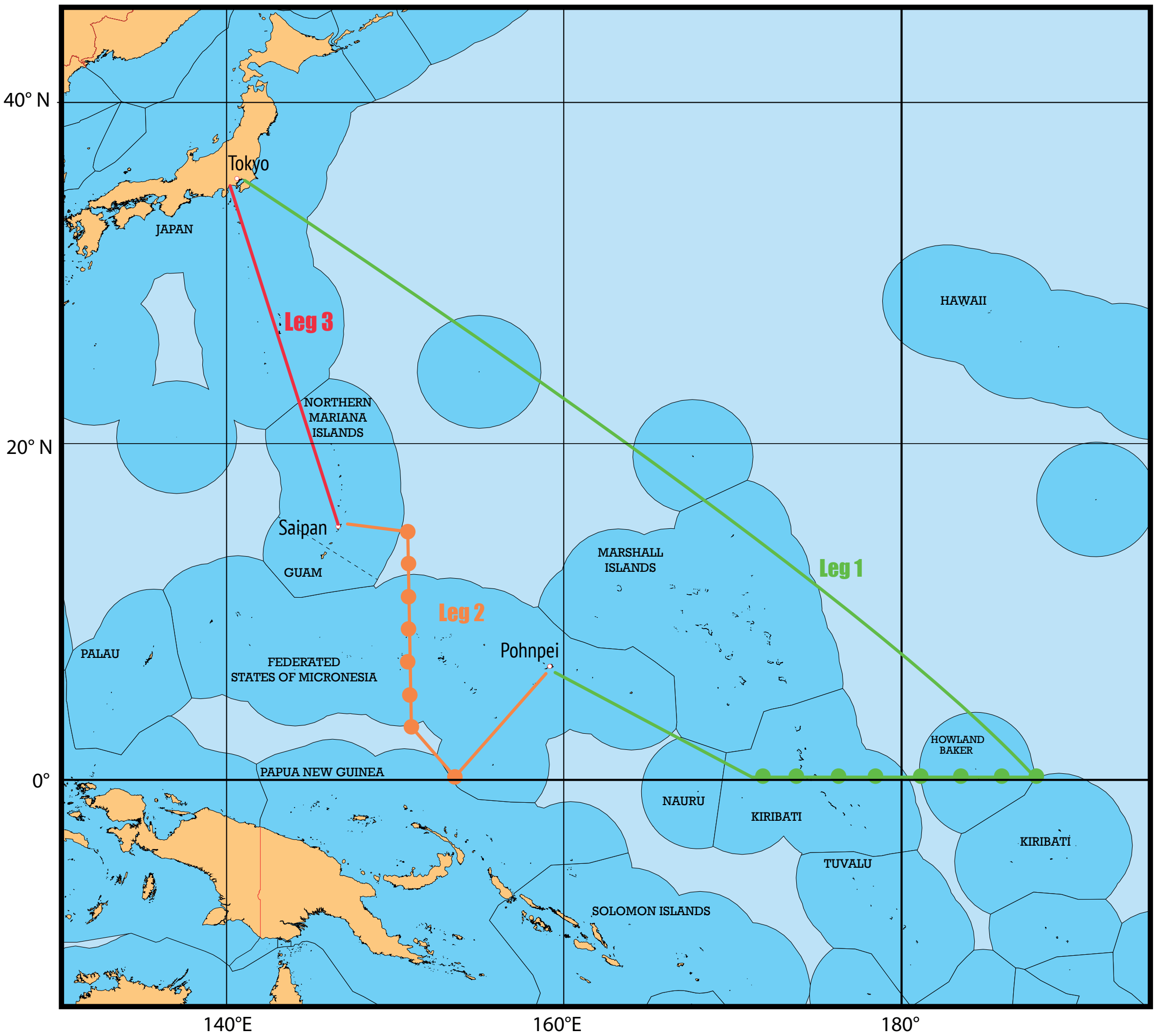
The Japanese Fisheries Resources Institute (FRI), the Fisheries Agency of Japan (FAJ) and the Pacific Community (SPC) are embarking on a new journey to explore tuna larvae distribution in relation to the environment, and allowing scientists to better characterise the pelagic ecosystem where tuna live.

Collaborative sampling effort

SPC and FRI have been collaborating for several years already, but this was the first time they literally embarked together on the same boat. FAJ made available the very recently built research vessel *Kaiyo Maru*. This 80 m-long, state-of-the-art scientific vessel – with 33 crew members and 10 scientists – roamed the seas of the western equatorial and tropical north Pacific in September and October 2024 looking for tuna larvae and juveniles in the waters of

The Fisheries Agency of Japan's scientific research vessel Kaiyo Maru, operating in the equatorial waters of the Pacific. Image: Guillaume Detandt, © IRD and SPC

[1] Pacific Community
[2] Fisheries Resources Institute, Japan Fisheries Research and Education Agency



Track of the Kaiyo Maru during September and October 2024. Each circle indicates a sampling station.
Map: Constance Odiardo, © SPC

Howland and Baker islands in Kiribati, the Federated States of Micronesia, and international waters.

During the two legs of the sea campaign, the team conducted sampling at 16 stations, during which multiple instruments were deployed both to collect tuna larvae and juveniles, and to characterise the seawater.

Tuna larvae were collected using zooplankton nets of different mesh sizes: a ring net with a mesh size of 0.3 mm, a ring net with mesh size of 1 mm, a Matsuda-Oozeki-Hu midwater trawl (MOHT) net with a mesh size 1.9 mm, and a bongo net with a mesh size of 0.3 mm. Juvenile tuna were collected with a large mid-water trawl net with a mesh size of 10 mm.

The ocean environment was characterised by monitoring the currents with an acoustic doppler current profiler instrument, by measuring temperature, salinity, oxygen and fluorescence with a conductivity, temperature and depth probe; and by collecting water from the surface down to a depth of 1500 m to analyse phytoplankton, nutrients and particulate organic matter. Zooplankton were collected with a NORPAC (North Pacific Standard) net (0.1 mm mesh size) and VMPS (multi-layer plankton sampler) net (0.1 mm mesh size), and micronekton were collected with the large mid-water trawl, allowing the biological environment to be examined. Zooplankton and micronekton were also monitored with several acoustic instruments (EK80, WBAT, TAPS and AZFP).

The hunt yields numbers

Most of the work was conducted at night when fish and other organisms were closer to the surface. When retrieved, the content of each net was carefully sorted to extract tuna larvae and juveniles that were identified in the onboard lab using a microscope. The rest of the zooplankton and micronekton was frozen for later analysis when back on land.

The larvae collected from all the nets during the voyage, included 546 skipjack, 89 yellowfin, 29 other species of

Thunnus, 13 larvae from other fish of the tuna family (Scombridae), and 5 billfish. In the mid-water trawl we collected juvenile specimens of *Thunnus* (35), other Scombridae (164) and billfish (2). These numbers might change because identification will be refined once back in the laboratory on land, and zooplankton samples will be carefully screened to ensure we did not miss any larvae.

Larvae and juveniles were not distributed equally, with 97% of the larvae found during the second leg of the scientific cruise in the western area, while only 3% were found at the equator in the central area during the first leg. As for juveniles, 68% were collected in the western part and 32% at the equator. However, a more in-depth analysis of the data will be required because these rough numbers need to be balanced by the number of trawls and the amount of water filtered.

Mission accomplished – What's next?

This scientific cruise was a fantastic opportunity for the science itself, but also for experiencing and learning how to work at sea. Over the two legs of the mission, 20 scientists joined the cruise: 9 from FRI, 2 from Kochi University in Japan, 6 from SPC, 2 from IRD, and 1 from the Pohnpei State Government. Among the scientists, two Pacific Islanders participated as well as three early-career professionals and three students. During the stopover in Pohnpei between the two legs of the cruise, there was an opportunity for a group from Pohnpei, including SPC's Micronesia regional office staff and family members, to enjoy a visit onboard the vessel.

The cruise was very successful and numerous samples and data were collected that will require many months of work in the laboratories. However, it is already time to think about the next cruise and it is likely that the quest for larvae will continue into 2025.

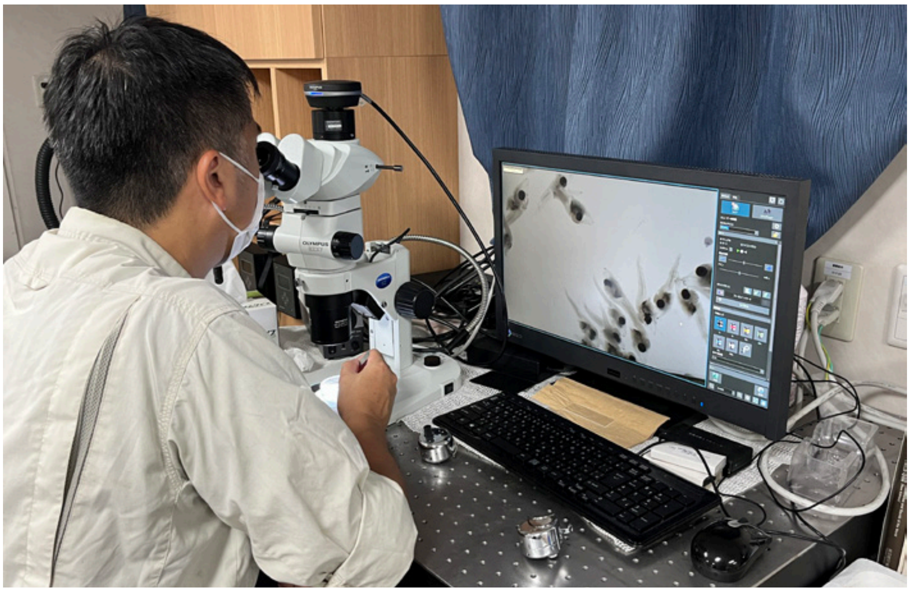
For more information:

Valérie Allain

Senior Fisheries Scientist, SPC

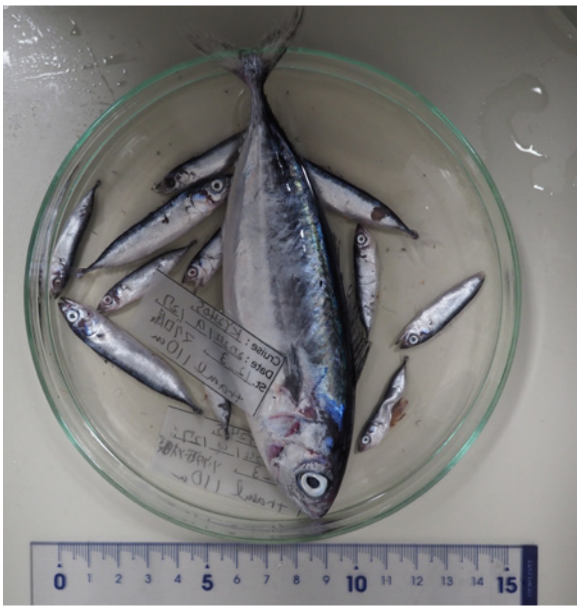
valeriea@spc.int

Sorting micronekton caught with a trawl to collect tuna juveniles. Image: Pauline Machful, © SPC



Examining collected tuna larvae under a stereomicroscope to determine the species. Image: Pauline Machful, © SPC

A ring net towed at the surface to collect tuna larvae. Image: Valérie Allain, © SPC



Juvenile tuna (left) and tuna larvae (right) collected. Left image: Atsushi Tawa, © FRI. Right image: Pauline Machful, © SPC

The passing of Hugh Walton

by Francisco Blaha

As usual in these situations, we all knew this was coming and hoped to be nearby to attend the funeral, but unfortunately, it wasn't to be in my case. As I was sitting in an FAO meeting in South Korea, the sad yet expected news of Hugh Walton's passing – a friend and mentor – arrived, making a sunny day a bit gloomier.

The significant aspect of fishing is that it has its own culture and universe. Although it isn't easy to articulate, it is one of the things that fosters deep human relationships. I often say that fisheries are more about people than fish; and as the cliché goes, it is no coincidence that the word "ship" is part of the word friendship.

Fisheries attract a variety of characters (I include myself among them), and in the Pacific, there are quite a few. Hugh was one of them and he definitely had the respect of the rest.

He led a remarkably colourful life and worked tirelessly for the major fisheries organisations in the region, including the University of the South Pacific (USP), Pacific Community (SPC) and Pacific Islands Forum Fisheries Agency (FFA). I doubt there is a Pacific Island fisheries leader who wasn't trained or assisted by Hugh over the last 40 years.

I began working closely with Hugh in Kavieng, Papua New Guinea, where he oversaw the Fisheries College for many years. There, I realised that fisheries was not merely a job for him, but his passion. In the 1970s, when several Pacific Island countries had just gained independence, little locally gained experience of industrial fishing in the region existed; the sector had to be developed from the ground up, which is easy to forget these days. What we have in the Pacific now is far beyond what existed before, and Hugh played a significant role in that transformation.

It would be hard to list all of his achievements over the past four decades, but I know he was really proud of his work at the Fisheries College in PNG and the Observer Standards he helped develop for the entire fishing fleet. He also set up the structure for evaluating the quantifications of illegal, unreported and unregulated fishing in the region, a task that will hopefully be done every five years.

Several years ago, the European Union shamed the Pacific Island fishing countries by assigning them yellow cards for our IUU-control measures. FFA had to mobilise support, and Hugh asked me to help. We managed to get the cards lifted, and the systems we developed were used as examples that were followed globally. Much of that was due to Hugh's vision.

A few years later, FFA received the International Monitoring, Control and Surveillance Network award as the most advanced organisation in preventing IUU fishing worldwide. He was a mentor and facilitator at the centre of that effort, and FFA fully deserved it. In any case, I could write about Hugh's work legacy for days and still not do it justice.

Hugh Walton. © FFA Media, FFA

I have always been very thankful to him. As an immigrant, he gave me the only thing I could not have gotten by my own efforts: "an opportunity."

We both come from operational backgrounds of fishing boats, which formed the foundation of our friendship and work perspectives. Occasionally, I would present unconventional ideas in our line of work, and he would think a bit and respond, "Yeah, we should try that... The usual hasn't worked so far."

He believed in people and trusted them, and many of our Pacific colleagues trusted him in return. He once told me that "trust is the most undervalued currency in our line of work" and that when we engage in capacity building, "it is our job to get ourselves out of a job" because at some point, if we are effective, people should no longer need us. I have never forgotten any of those lessons.

Hugh was far from perfect as a human, yet he was the first to recognise that. His heavy drinking and long-term smoking shortened his life, but he lived on his terms. A line he often quoted from his favourite poem by New Zealand author Sam Hunt evocatively describes many aspects of his life: "Beware the man that tries to fit you out in his idea of a hat."

In his later biography "*Keeping an Eye, Hugh Walton's Pacific Odyssey*"[1], I was honoured when he asked me to write the foreword, and what he wrote in the book's final paragraph is something I will treasure forever:

> ***"Yes, as my friend Francisco has said, I have tended not to follow a path in life; I have made my own; I have just been bloody incredibly lucky; these evolving experiences, so much about the upbringing I have had, taking my opportunities following my heart, and my wonderful whanau"***

Haere rā / farewell, Uncle Hugh

[1] https://www.spc.int/digitallibrary/get/d9r8w

Assessing stock abundance, size and spatial distribution of five CITES-listed sea cucumber species in Papua New Guinea

Rickson Lis[1]

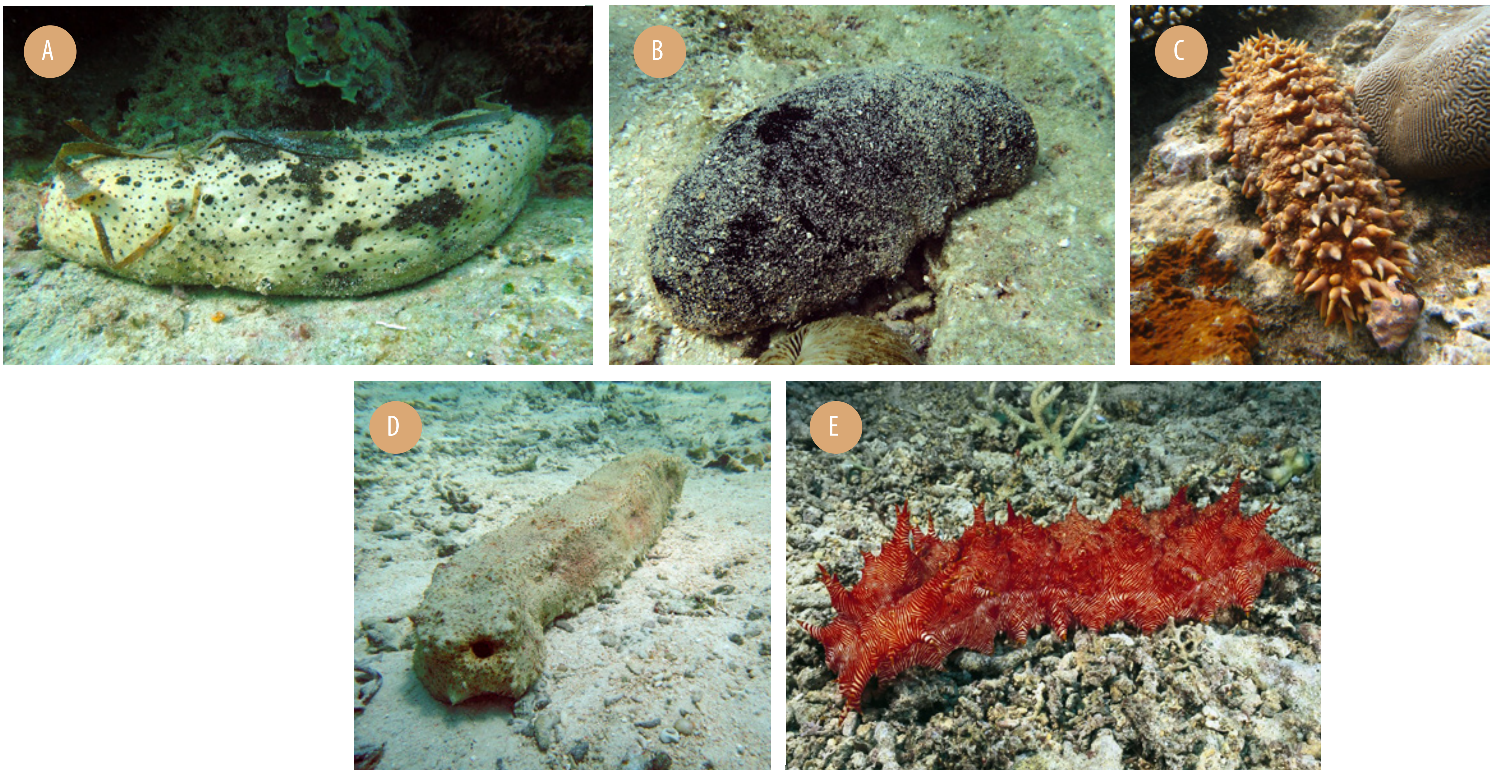
Project supervisors: Julian Burgos[2] *and Magnus Thorlacius*[2]

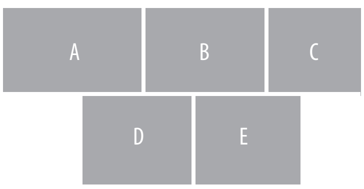
Introduction

The sea cucumber fishery plays an important role in the livelihood of coastal communities in Papua New Guinea (PNG). The fishery is extensive, conducted in most coastal and island communities, and targets more than 22 species with different market values. This is a small-scale, informal fishery with multiple landing points, carried out mostly from shore or in canoes or other small vessels. Sea cucumbers are mostly processed, dried and exported as beche-de-mer (BDM), which is an attractive source of income for coastal communities because once the sea cucumbers are processed and dried, they are shelf stable, and have a high value relative to their size (Barclay et al. 2019).

The sea cucumber fishery is economically significant in PNG, as it is the most valuable coastal fishery in the country. During the period when the fishery was active, it ranked second only to tuna as PNG's leading export product, contributing over USD 30 million in export revenue. Approximately USD 10 million from this revenue directly benefits PNG's coastal and island communities each year (NFA 2015). In essence, the sea cucumber fishery emerges as the primary coastal fishery in PNG, playing a pivotal role in generating revenue that directly supports the livelihoods of coastal and island populations.

The exploitation of sea cucumbers has a notable history in PNG. Regional markets for BDM have existed for centuries, and export records date back to at least 1870 (Barclay et al. 2019; Kinch et al. 2008b). By 1900, BDM exports reached approximately 37 tonnes (t) per year (Kinch et al. 2008a). During most of the 20th century, annual exports fluctuated below 50 t per year (Kinch et al. 2008b). Starting in the





A - White teatfish (*Holothuria fuscogilva*). © Rickson Lis
B - Black teatfish (*Holothuria whitmaei*). © Rickson Lis
C - Prickly redfish (*Thelenota ananas*). Emmanuel Tardy, © SPC
D - Amberfish (*Thelenota anax*). © Rickson Lis
E - *T. rubralineata*. © Solomon Haeremai

[1] National Fisheries Authority, Papua New Guinea. rlis@fisheries.gov.pg
[2] Marine and Freshwater Research Institute, Reykjavik, Iceland

mid-1980s, the fishery expanded greatly due to growing incomes in the main import market, China. Annual exports increased rapidly between 1985 and 1993 to 650 t per year (Hair et al. 2016). During this period, PNG emerged as a major player in the global sea cucumber industry, ranking as the third largest producer and supplying 10% of the global demand, predominantly to Asian markets (Kinch et al. 2008b; Pakoa and Bertram 2013). Between the 1990s to 2010, annual exports ranged between 400 t and 800 t. This increase was driven by increasing prices and an influx of buyers entering the market, and it was made possible by the spatial expansion of the fishery, improved harvesting efficiency, and a greater demand for lower-value and newly commercialised sea cucumber species (Hair et al. 2016, 2019). At this time, the PNG sea cucumber fishery operated in all maritime provinces of the country, supporting up to 200,000 people and providing up to 30% of annual villagers' income (Hair et al. 2018).

Sea cucumber fisheries are prone to boom-and-bust cycles, where depletion follows periods of heavy fishing (Anderson et al. 2011). Due to overfishing, in 2001 the PNG government established a management plan for beche-de-mer. The plan established a total allowable catch (TAC) for each province, enforced through the control of exports via licensing. The plan also established a closed season. The TAC was based on stock assessment data when available, or on historical catch records.

But despite these measures, the fishery still operated under a management framework that lacked robustness in monitoring, leading to extensive overfishing and localised depletions. In 2009, NFA imposed a moratorium on harvesting sea cucumbers and selling BDM. The moratorium had the objective of allowing the sea cucumber spawning populations to recover (Barclay et al. 2017), but had a large impact on the communities that relied heavily on BDM as a source of income. During the closure period, NFA conducted an annual sea cucumber stock assessment, initially in eight provinces, gradually expanding to cover other provinces. The surveys concluded that: 1) recovery had occurred for some sea cucumber species, 2) recruitment was limited for others, and 3) most sea cucumbers were below the minimum legal size (Hair et al. 2018). The seven-and-a-half-year moratorium ended in 2017, with the sea cucumber fishery re-opened with a revised Beche-de-mer Management Plan gazetted in 2016 (Hair et al. 2019).

The opening of the fishery in 2020 presented NFA with further challenges, particularly following the inclusion of white teatfish (*Holothuria fuscogilva*) and black teatfish (*Holothuria whitmaei*) in the Appendix II listing of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) during the 2019 COP18 meeting in Geneva, Switzerland. Article IV of the convention mandates the production of a non-detrimental finding (NDF) document, outlining clear guidelines and measures to ensure the sustainable management and conservation of these species (Rose 2014). After developing the guidelines, NFA drafted an NDF for these two species that served as a crucial framework for management and regulations during the 2020 fishing season (Gisawa et al. 2020). During the 19th Conference of the Parties to CITES (CoP19) meeting in Panama,[3] three additional species – prickly redfish (*Thelenota ananas)*, amberfish (*Thelenota anax)* and candy cane (*Thelenota rubralineata)* – were listed under Appendix II (CITES 2022), and as a result, PNG is required to produce NDFs to facilitate the trade of these species as well.

Methodology

Stock assessment surveys

This study uses data collected during the stock assessment surveys that were carried out to evaluate the status of sea cucumber stocks in PNG (NFA, unpublished data). The methodology is based on the stock assessment survey conducted by Kaly et al. (2007) in PNG's New Ireland Province (Kaly et al. 2007). The stock assessment data covers the period from 2010, after the moratorium was initiated, to 2023. There is a gap in the data in 2017, when the fishery was open. The surveys were carried out in eight of the 14 maritime provinces in PNG. For this report we used data from three provinces: Milne Bay, Manus, and the Autonomous Region of Bougainville (AROB) (Fig. 1).

Survey methodology

Survey locations were chosen in provinces renowned for sea cucumber harvesting. Then, areas within coastal boundaries governed by local level governments were selected within these provinces. Within these LLGs, specific sites were identified in each ward, and further selections were made based on reef habitats that have enough coverage to accommodate 10 transects, each measuring 100 metres (m) in length and 4 m in width (Fig. 2).

Each transect was surveyed by a team of three officers using a combination of scuba diving, snorkelling and reef wading. Officers recorded the number, species and length of all sea cucumbers observed, noting variations in depths and visibility conditions.

Analysis and interpretation

Time series of length distributions were compiled for each species in the three provinces. Patterns in length distributions were examined and compared with the minimum legal size as designated in the PNG National Beche-de-mer

[3] See the appendices amended at the 19th Conference of the Parties to CITES (CoP19): https://cites.org/sites/default/files/notifications/E-Notif-2023-005_0.pdf

Figure 1. Papua New Guinea, with a circle indicating the three provinces where stock assessment survey data were used for the study. Source https://www.mapsofworld.com/answers/geography/what-are-the-key-facts-of-papua-new-guinea/attachment/map-of-papua-new-guinea/#

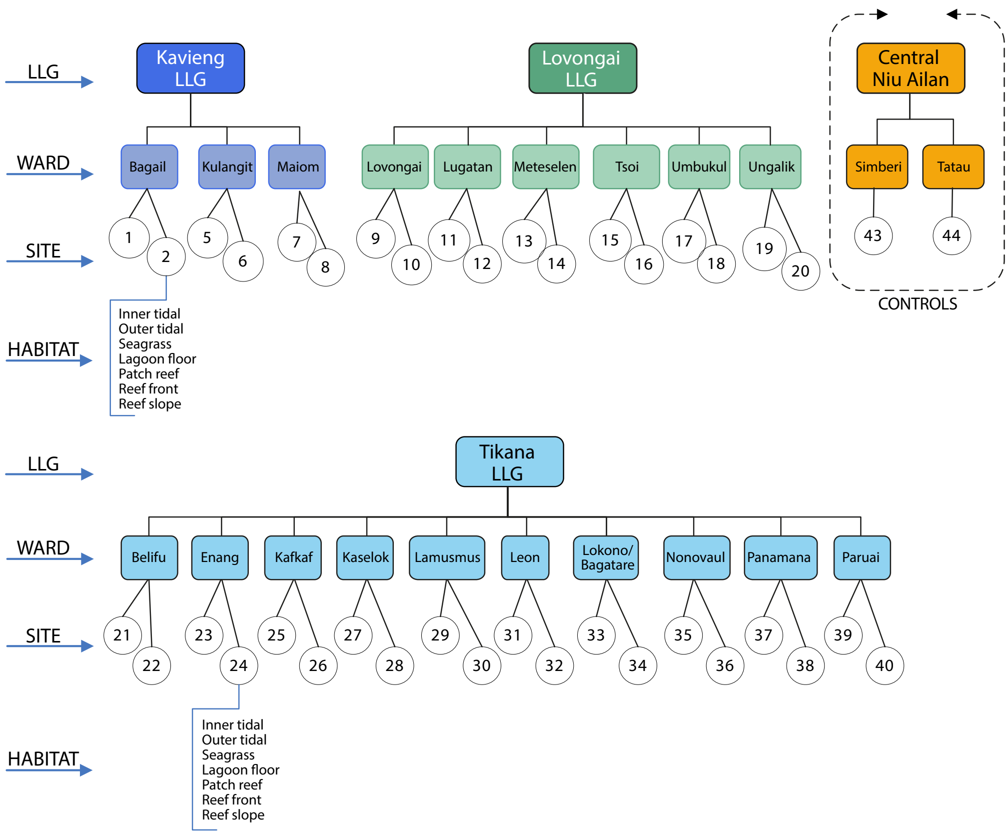


Figure 2. Stock assessment survey design adopted from the Coastal Fisheries and Development Project (Kaly et al. (2007).

Management Plan 2018, and with length at maturity estimates taken from Skewes et al. (2014) (Table 1). This analysis determines the proportion of individuals surpassing the length-at-maturity threshold, providing information on the population capable of reproduction, thereby influencing recruitment and stock recovery.

The density and abundance of each of the five species in each province was estimated using the survey data.

The mean density of each species by reef habitat (reef flat, reef slope, lagoon, and seagrass) and province was estimated following Purcell et al. (2009):

$$\overline{x}_{s,h,p} = \frac{\sum n_{s,h,p}}{nt_{s,h,p}}$$

Where $\bar{x}$ = is the mean density per transect of species *s* at habitat *h* and province *p*, $\sum n$ is the number of sea cucumbers, and *nt* is the number of transects. Density per transect was converted to area density by multiplying the density per transect by the area of each transect measured in hectares (400 m^2 = 0.04 ha).

The resulting density estimates were compared with previous studies conducted in Papua New Guinea, as compiled by Kinch (2008b). The maximum recorded mean density from Kinch's report was employed as a reference benchmark, representing density values observed when exploitation rates were low.

The total population abundance was estimated by scaling up the area density values with the total coverage of each reef habitat in each province calculated using reef habitat mapping provided by Sheppard (2015). Abundances were estimated using all observations, and using only specimens with lengths smaller than the age-at-maturity to explore recruitment patterns.

Patterns in length distribution, density and abundance were evaluated in relation with the moratorium period in the fishery. All statistical analyses were performed using R statistical software (v4.3.1; R Core Team 2023).

Results

Species density

Observed densities of white teatfish across the three provinces were at their lowest point in 2010. For instance, in Manus Province the lowest recorded mean density was 1.63 ± 0.82 individuals per hectare (ind/ha). Values were significantly lower than the reference benchmark mean density of 23 ind/ha (Kinch et al. 2008), proving that white teatfish stocks were depleted prior to the moratorium.

There was significant recovery in all habitats in the provinces of Manus and Milne Bay during the moratorium years, attaining peak level in 2016 before the opening of the fishery in 2017.

The impact of the fishery's opening is evident in the reduction of density estimates, which fell below the reference line from Kinch (2008b). This suggests that management efforts were not effective, and overfishing had occurred over the short period in which the fishery was opened.

The mean density per hectare of black teatfish shows inconsistent trends, with most values falling below the benchmark reference. The graph indicates that reef flats were the primary habitats for black teatfish, although they were also found on reef slopes and in lagoons. Across the three provinces, an average density of 13.3 ind/ha and fewer were observed in the 2015 and 2016 data (NFA, unpublished data), with a significant decrease observed after the fishery opening in 2017. Similar to white teatfish, the management strategies were not effective, and overfishing has certainly occurred.

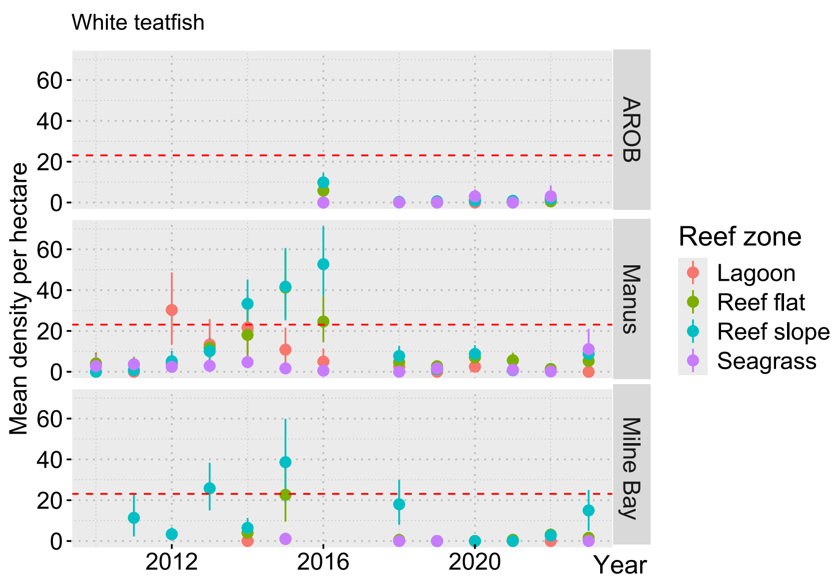


Figure 3. The mean density of white teatfish (*Holothuria fuscogilva*) across each reef zone. Red dotted lines indicate the reference value of 23 individuals per hectare.

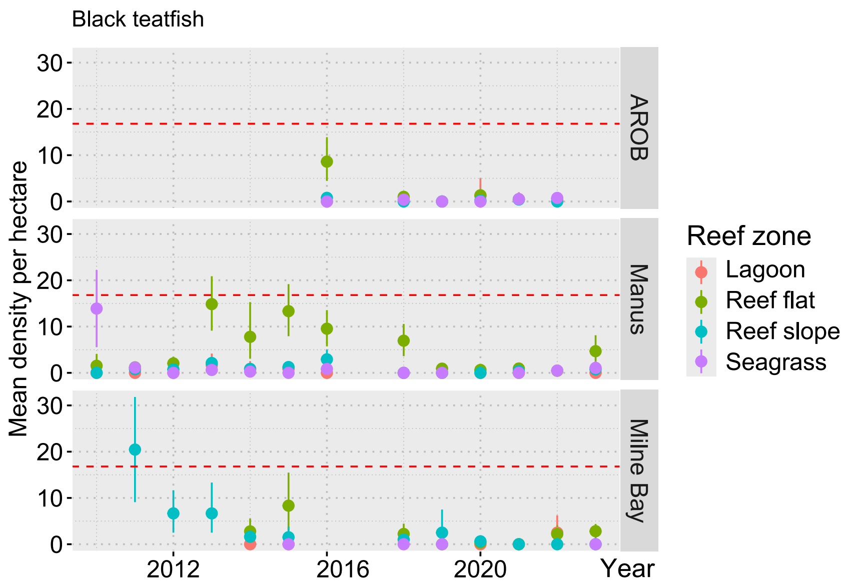


Figure 4. Average density of black teatfish (*Holothuria whitmaei*) across various reef zones within each province. Red dotted lines indicate the reference value of 16.8 individuals per hectare (Kinch et al. 2008b).

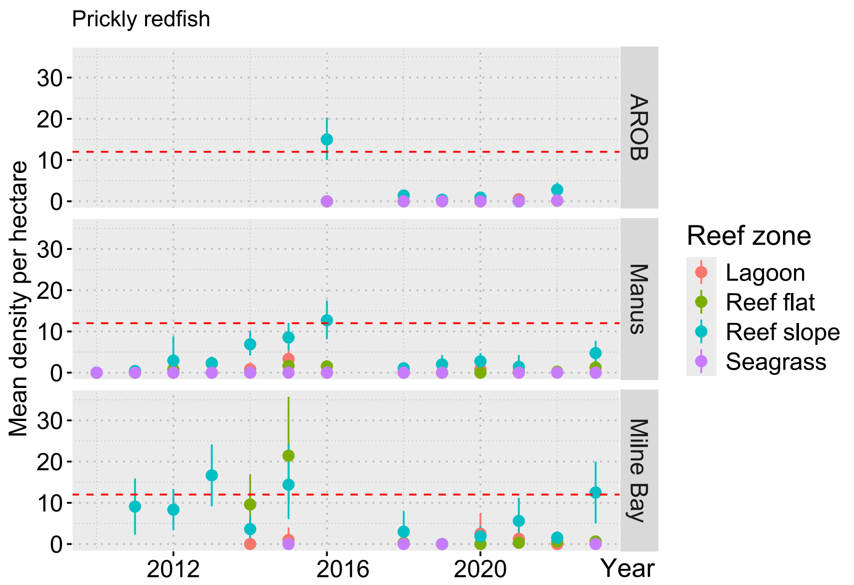


Figure 5. The mean density of prickly redfish (*Thelenota ananas*) across different reef zones. Red dotted lines indicate the reference value of 12 individuals per hectare.

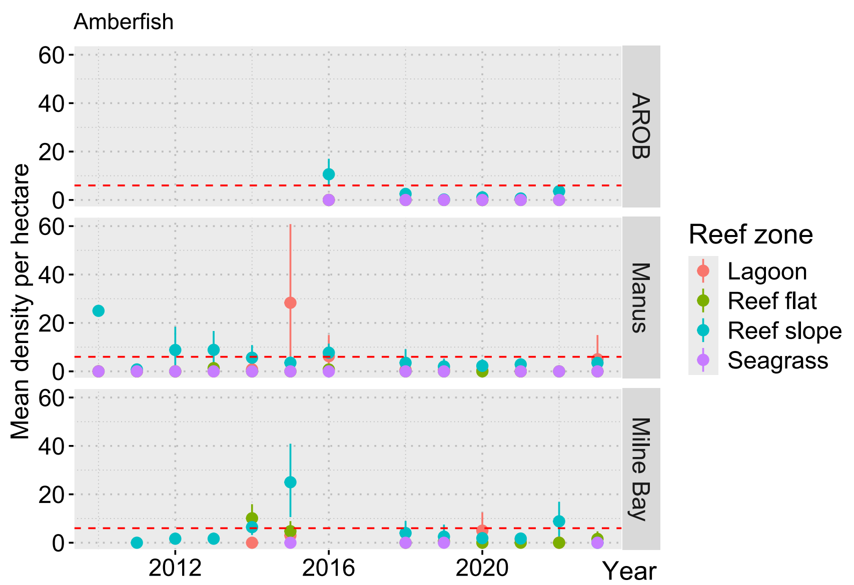


Figure 6. The mean density of amberfish (*Thelenota anax*) in each reef zone per province. Red dotted lines indicate the reference value of 6 individuals per hectare.

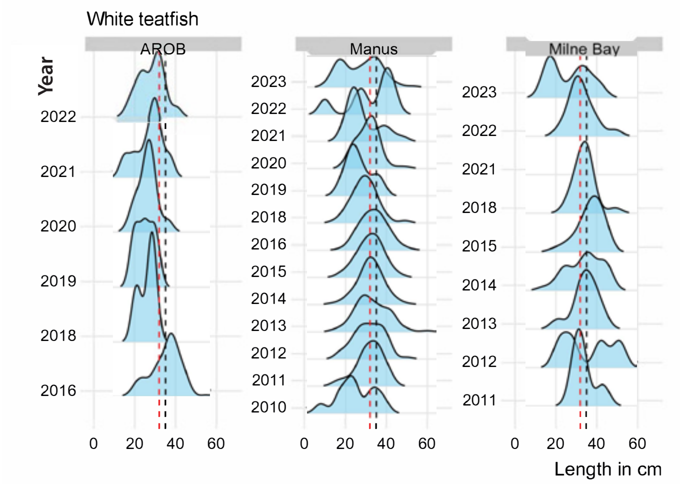


Figure 7. Live length distribution of white teatfish over time presented with the minimum legal harvestable size of 35 cm marked by a black dotted line, and size at the maturity stage of 32 cm highlighted by a red dotted line.

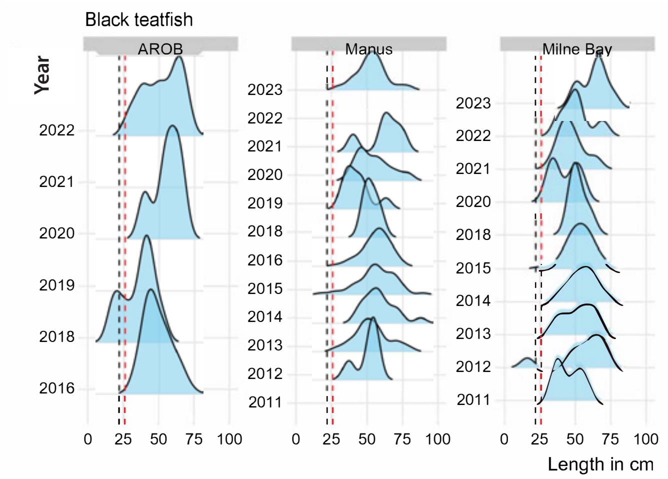


Figure 8. Live length distribution of black teatfish over time is presented, with the minimum legal harvestable size of 22 cm marked by a black dotted line and size at maturity of 26 cm highlighted by a red dotted line.

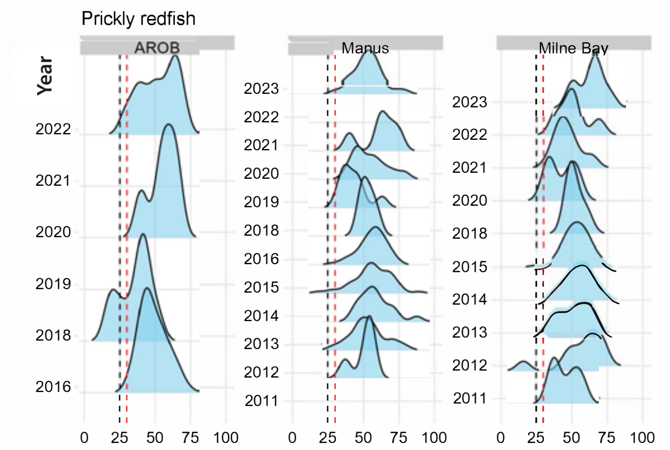


Figure 9. Live length distribution of prickly redfish overtime is presented, with the minimum legal size of 25 cm marked by a black dotted line and size at maturity of 30 cm highlighted by a red dotted line.

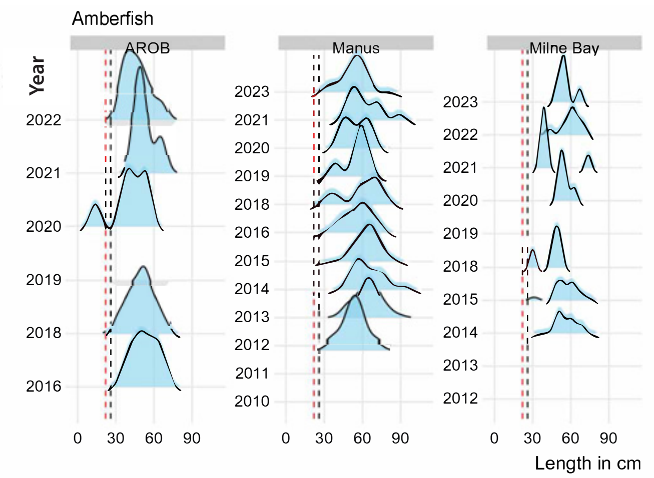


Figure 10. Live length distribution of amberfish overtime is presented, with the minimum legal harvestable size of 22 cm as per the Beche-de-mer Management Plan (NFA 2018). Size at maturity is not available.

Observed densities of prickly redfish were below the reference value at 12 ind/ha. During the entire period of this study, except during 2015 and 2016 just before the fishery was re-opened (Fig. 5). The mean density was highest in two reef zones: reef slope and seagrass areas. This species is typically found along reef slopes and passages within reef areas, extending to depths ranging from 10 m to 20 m (Kinch et al. 2008b).

The density of amberfish was observed to be below the reference value of at 6 ind/ha in most locations and years. In Milne Bay Province, the observed densities were higher in 2014–2015 the period when the fishery was closed. Notably, very high densities were observed in 2015 in Manus Province in lagoon habitats. In general, amberfish are distributed across various reef zones, and are particularly prominent on reef slopes and seagrass areas. Although commonly found on reef slopes and lagoonal passages according to Pinca et al. (2009), this research suggests a higher prevalence in seagrass habitats.

Length frequency distribution assessment

The analysis revealed that the majority of the species studied have grown to a size that meet the legal requirements set forth by the National Fisheries Authority for sea cucumber management. The sizes also align with the length at which the sea cucumbers reach maturity. The preceding graphs depict the size distribution of each sea cucumber species relative to both NFA's minimum legal-size requirements, and the size at which each species attains maturity reported by Skewes et al. (2014).

The length distribution graph for white teatfish (Fig. 7) reveals significant variability in the proportion of mature individuals reaching the size at maturity (32 cm), as reported by Skewes et al. (2014), compared with those meeting the minimum legal-size requirement (35 cm) specified in the National Beche-de-mer Plan 2018 (NFA 2018).

In the size-frequency distributions for 2015 and 2016 across the three provinces, between 50% and 70% of white teatfish were both mature and met the legal-size criteria. Remarkably, within that period, the decision was made by NFA to lift the moratorium, and the fishing season commenced in 2017. However, following the opening of the season in 2017, the length distribution shifted to the right, indicating a decrease in mature individuals and suggesting that adult populations were heavily harvested during the opening phase.

Unlike the white teatfish, the length distribution of black teatfish indicates that in most years nearly 90% of the population had reached maturity and meets the minimum legal size limit set by NFA (Fig. 8); however, there is a discrepancy: the size at maturity suggested by Skewes et al. (2014) is 26 cm, which is higher than NFA's minimum legal-size limit of 22 cm. This suggests that black teatfish were being harvested before they reached maturity and had the chance to spawn, thus hindering replenishment of the population.

The size distribution graph for prickly redfish (Fig. 9) reveals that during the surveys nearly 95% of the individuals had reached maturity and exceed the minimum legal-size requirement.

However, like the length frequency result observed for black teatfish (Fig. 10), the minimum legal size defined by NFA is lower than the size at maturity recommended by Skewes et al. (2014). This discrepancy implies that NFA's harvestable size limit may lead to fishing prickly redfish before they are mature and reproduce. Thus, this warrants setting minimum size limits above the size at maturity.

The length distribution of amberfish depicted in Figure 10, indicates that nearly 98% of amberfish surpass the minimum threshold size as designated by the regulatory framework of the Beche-de-mer Management Plan (NFA 2018). However, critical information such as age or size at maturity and maximum size is unknown (Conand et al. 2013a)

Discussion

While using stock assessment data from 2016 as a benchmark for density and abundance might not be entirely reliable, it is important due to significant changes that prompted NFA to reopen the fishery after a seven-and-a-half-year moratorium.

Population density and biomass estimates serve as fundamental components for evaluating management strategies (Purcell 2014). The stock assessment results presented in this study indicate a partial recovery of at least two species, white teatfish and prickly redfish, when compared with the reference values from Kinch 2008b. However, the findings for black teatfish show fluctuations between survey periods in comparison to the two described. In contrast, amberfish exhibits consistently low abundance densities throughout the moratorium period, with occasional peaks observed only in certain reef habitats in 2015.

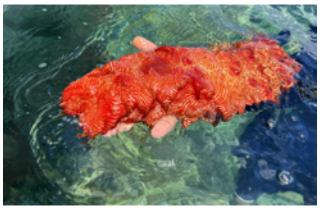
The stock abundance and density of all four species, except candy cane, have exhibited consistent growth throughout this study. AROB's trend is expected to follow this pattern, although its data starts in 2016, showing an initial peak that declined after the moratorium was lifted. This pattern is also observed for abundance, which peaked in 2016, dropping during the fishery opening, and then increasing again. Despite fluctuations, white teatfish recruitment and abundance demonstrate consistent growth. However, black teatfish and prickly redfish exhibited inconsistent recruitment levels without clear patterns, indicating variability in their abundance over time.

The 2002 stock assessment survey conducted by Skewes et al. (2002) revealed that most of the studied species were located on reef edges or slopes, with black teatfish being predominantly found on reef tops (Skewes et al. 2002). Similarly, this study observed that white teatfish, prickly redfish and amberfish were mainly situated on reef slopes across all three provinces. However, black teatfish were primarily distributed on reef flats and seagrass areas, with mean densities ranging from 8.6 ind/ha in one province to as high as 14.85 ind/ha in another.

Tropical commercial sea cucumber species are often noted for their tendency to grow to significant sizes once they reach adulthood, which is an important parameter related to reproductive fitness, when food is available (Conand 2018). The findings from the size distribution analysis indicate that most of the species examined tend to exhibit larger sizes, with many reaching maturity and meeting the legal-size requirements. This suggests that these species have attained sizes consistent with the regulations outlined by NFA in the Beche-de-mer Management Plan (NFA 2018). However, the study identified an inconsistency regarding two species: black teatfish and prickly redfish. Their size limits outlined in the management plan seem to be smaller than the size at which these species typically reach maturity (Skewes et al. 2014) and minimum recommended live length proposed by Govan (Govan 2018). The results presented on the size structure displays more of mature size than juveniles, which means more adult breeding populations.

The distribution of the studied species within the three provinces indicates clear signs of recruitment over the moratorium period. Ideally, it would be beneficial to observe a broader distribution of species across all of PNG by analysing data from other surveyed provinces.

Candy cane (Thelenota rubralineata)



Candy cane is reported to be widespread in the central Indo-Pacific region, including PNG, but rare (Conand et al. 2013b). However, the result does not show any substantial range from the research, despite its presence being noted in some provinces. The overall mean density was recorded at 0.117 ind/ha, with 7 individuals found in Manus Province, and 0.028 ind/ha in AROB.

Candy cane was identified as being rare in French Polynesia (Andréfouët et al. 2019). Historically, candy cane had limited trade activity due to its naturally sparse populations. However, it has gained commercial traction in the Indo-Pacific region, including PNG and Solomon Islands (Kinch et al. 2008b). Trade data for this species are scarce, with some countries not recording export figures at the species level. The data analysed for this report indicate a paucity of information available for the species under examination, resulting in limited discussion regarding this species.

White teatfish (Holothuria fuscogilva)

White teatfish was included in Appendix II of the CITES in 2020 and faced regulatory measures coinciding with the commencement of PNG's sea cucumber fishery opening in the same year. These measures include the implementation of an NDF, which established a harvest limit for white teatfish of 16 t across PNG, based on the 2020 stock assessment survey (Gisawa et al. 2020). Notably, white teatfish commands the highest market value among the sea cucumbers in PNG (Barclay et al. 2019).

The lowest densities of white teatfish were found in three provinces (Manus, Milne Bay and AROB) during the 2010 stock assessment survey, which was conducted during the moratorium period. The results analysed by province shows the mean density plummeted to its lowest point, reaching 1.63 ±0.82 ind/ha in Manus. Similarly, other provinces such as Milne Bay exhibited a low density of 0.847 ± 0.134 ind/ha during the moratorium phase. However, a discernible uptrend in mean densities was observed throughout the analysis, indicating a positive correlation between time and density increase. The increase was notable in 2015 and 2016, surpassing the reference benchmark (Kinch 2008b) used in this study.

Figure 3 illustrates that areas with higher mean densities are typically associated with reef slopes. The findings from Murphy et al. (2021) indicate that white teatfish density per hectare on reef slope areas varies, ranging from 0 to 2.28, with some locations reaching up to 6.9, and a highest recorded density of 17.7 ind/ha. However, it is important to note that the results in this study represented the mean density per hectare across all sites, rather than specific locations. For instance, in Milne Bay Province, the mean density was 45.3 ind/ha, while in Manus Province, it was as high as 53.4 ind/ha in 2015 and 2016. It is crucial to understand that these figures reflect the overall mean density across the entire reef slope area in these provinces, in comparison to the Torres Strait study conducted by Murphy et al (2021).

The most interesting observation in the study presented in Figure 9 shows that white teatfish mean density had recovered from depletion and surpassed the reference density of 23 ind/ha (Kinch et al. 2008b) in 2016. Additionally, it exceeded the population density limit of 40 ind/ha as cited in the proposal paper published by CITES to list the two teatfish species (CITES 2019). However, the trend shifted during the opening period of 2017, with the mean density nearly reverting back to levels observed in the 2010 stock assessment. Subsequently, there has been a gradual recovery in density due to the moratoriums implemented in 2019 and 2021 (which is still in place at the time of writing).

Length distribution of white teatfish

Skewes et al (2014) emphasised the importance of growth and age parameters as initial estimates for sea cucumber species used in population models. The authors specifically identified the size at maturity for white teatfish to be 32 cm (Skewes et al. 2014). Subsequently, NFA set the live legal-size limit at 35 cm (NFA 2018). Additionally, the Melanesian Spearhead Group (MSG) collaborated to establish a standard legal-size limit at 35 cm (Govan 2018).

In this study, an equivalent proportion of *Holothuria fuscogilva* individuals fall under two categories: those deemed undersized and those considered to be of harvestable size, reflecting whether they were below or above the legally designated size limit (Fig. 15). This distribution curve of lengths conveys a key perception that recruitment and subsequent growth within the population have transpired notably during the moratorium period.

Black teatfish (Holothuria whitmaei)

In 2020, black teatfish was also listed under the Appendix II of the CITES. Because PNG is a party to the agreement, the inclusion initiated regulatory actions, including the establishment of an NDF for both white teatfish and black teatfish in preparation for the 2020 fishing season. The NDF set specific harvest limits for black teatfish across PNG of 4 t. However, based on stock assessment data from a 2020 survey, only four provinces qualified, including Milne Bay and Manus provinces, receiving 1 t each. This regulatory measure was aimed at ensuring the sustainable harvest of black teatfish (Gisawa et al. 2020).

Black teatfish is most often observed on reef flats, and only rarely found on reef slopes and intertidal crests (Conand 2008). The mean density per hectare of black teatfish exhibits variability over the duration of the seven-year moratorium as shown in Figure 11. In this study, only one province has an abundance of reef flats although there was a notable peak (14.2 ind/ ha) in 2010 in seagrass habitats. In Milne Bay Province, black teatfish are mostly found on reef slopes, and there was an observed peak in 2011 of 21.3 ind/ha on reef slopes. The initial mean density peaks in 2010 and 2011 observed in Figure 4 may be an oversight in survey methodologies or a possibility of errors, and needs further investigation.

The mean density of black teatfish also falls below the reference benchmark density of 16 ind/ha from Kinch (2008b) used in this study, indicating that the recovery of black teatfish was not as strong as that of white teatfish. In most cases, the highest mean density of black teatfish observed in the study was 13.88 ind/ha in 2013 and 13.3 ind/ha in 2014, both falling short of the density benchmark.

Length distribution of black teatfish

Female black teatfish mature at around four years of age and at a length of 26 cm, and can attain a maximum size of 56 cm (Skewes et al. 2014). The minimum legal length as set by the Queensland Department of Primary Industries and Fisheries is 30 cm (Murphy et al. 2021), while MSG proposed a minimum legal size at 30 cm (Govan 2018).

The length distribution analysis in Figure 8 shows that most black teatfish species are above both the legal length of 22 cm set by NFA, and size at maturity recommended by Skewes et al (2014).

Although sea cucumber species typically exhibit contraction in size, a notable concern arises with the legal-size limit set for PNG at 22 cm, which is below size at maturity estimated by Skewes et al (2014). The legal threshold falls below the size at maturity for these species, indicating a considerable mismatch between legal-size requirement and the size at which these species reach reproductive maturity.

Prickly redfish (Thelenota ananas)

Prickly redfish is one of the three *Thelenota* species recently included in the CITES COP19 meeting in 2022. PNG has not developed an NDF for this species or other *Thelenota* species as yet, primarily due to the fishery remaining closed after the 2020 season. Prickly redfish is considered more common than the other two *Thelenota* species and is probably one of the largest sea cucumber species, often surpassing 5 kg in live weight (Pinca et al. 2009; Purcell et al. 2012). This species is one of the high-value sea cucumber species harvested in PNG and is commercially important (Kinch et al. 2008b).

The stock assessment survey done in 2002 records prickly redfish in 9 areas with the highest mean density recorded at 2.88 ind/ha (Skewes et al. 2002). The stock assessment survey in the province of New Ireland recorded 2.4 ind/ha in reef slopes, 0.3 on reef flats and 0.2 in lagoons (Kaly et al. 2007).

The highest recorded density of prickly redfish by Kinch (2008b) is 12 ind/ha, serving as the reference benchmark for this study. However, the observed results indicate that almost all densities fell below this benchmark in 2010 until a slight surge in 2016. Notably, the mean density appears to be highest in two reef zones: reef slopes and seagrass areas, as illustrated in Figure 5. Prickly redfish is typically found along reef slopes and passages within reef areas, in depths ranging from 10 m to 20 m (Kinch et al. 2008b).

In this study, prickly redfish is most prominent on reef slopes. Although the study by Skewes et al. (2002) in Milne Bay Province was conducted based on local level government areas, the results presented in Figure 5 represent the overall mean density abundance for the three provinces. Interestingly, the mean density in each reef habitat observed in this study is higher compared with those reported in previous studies. For instance, Murphy et al. (2021) recorded a density of 16.4 ind/ha on reef slopes, with the highest density of 55.2 ind/ha observed on barrier reefs (Murphy et al. 2021).

The mean density abundance for the 2016 survey on reef slopes was 9.86 ind/ha in AROB, 53.2 ind/ha in Manus, and 44.2 ind/ha in Milne Bay. This variation can be attributed to the effect of the moratorium, which has likely influenced the population increase of prickly redfish across the surveyed provinces.

As observed from the analysis of white teatfish and black teatfish, prickly redfish also exhibits low densities after the fishing season opening, indicating a depletion of stocks within just three years. Data from 2023 shows a surge after a further moratorium, which is a positive sign of recovery. However, there are evident gaps in management that need to be addressed to ensure the sustainability of the population.

Length distribution of prickly redfish

Prickly redfish typically reaches a maximum length of 80 cm, with an average length commonly around 45 cm. In PNG, the average fresh length of *Thelenota ananas* ranges from 45 cm to 80 cm, with an average fresh weight record at approximately 2.6 kg (Purcell et al. 2012). Skewes et al. (2014) established growth parameters for prickly redfish, setting the minimum legal size at 50 cm under Australia's Queensland Department of Primary Industries and Fisheries regulations. They indicated the size at maturity as 30 cm, with individuals reaching a maximum size of 80 cm (Skewes et al. 2014).

A further evaluation of sea cucumber fisheries by MSG advocated for standardising sea cucumber size regulations among all MSG countries. Specifically, prickly redfish was suggested to have a length limit of 45 cm. While PNG's National Beche-de-mer Management Plan enforces a legal limit of 22 cm, other MSG members – such as Solomon Islands and Vanuatu – have set theirs at 35 cm (Govan 2018; NFA 2018).

In this study, the majority of species observed across all three provinces displayed a trend similar to that of black teatfish, with most individuals reaching both the legal size and the size at maturity length. However, it is important to note that the size limit enforced by NFA is 22 cm, which is significantly below the recommended size. Furthermore, the size at maturity, set at 30 cm, exceeds the legal-size limit, highlighting a notable discrepancy between the regulatory standards and the biological requirements of the species. Changes are required to bring legal-size limits in alignment with biological parameters.

Amberfish (Thelenota anax)

Amberfish is another species of the genus Thelenota listed under the CITES recently. This species is reported to be one of the heaviest sea cucumbers with an average live weight recorded in PNG of 3.34 kg (Purcell et al. 2012; Hammond et al. 2020). Amberfish is recorded to be of low value (Kinch 2008b) and previously considered to be non-commercial but has increasingly become an important commercial species after other high-value species have become depleted (Conand et al. 2013c). Amberfish are commonly found on reef slopes and outer lagoons near passages at depths of 10–30 m (Conand et al. 2013c). In PNG's New Ireland Province, the density of this species decreased from 1.0 ind/ha in 1992 to 0.7 ind/ha in 2006 (Kaly et al. 2007). The highest density recorded in Milne Bay Province was 3.71 ind/ha (Skewes et al. 2002).

Figure 6 illustrates a significant decline in amberfish density that was particularly evident in 2011, notably in Milne Bay Province. Conversely, Manus Province recorded a density of 2.1 ind/ha in seagrass areas in 2010. Manus also experienced a peak in mean density of 28.3 in lagoon areas in 2015, followed by a decrease to 6.25 ind/ha in the same reef habitat in 2016. However, the overall density for amberfish remains below the reference benchmark, indicating that the species has not fully recovered. This is further supported by the absence of any discernible trend in recruitment abundance for, leading to its exclusion from the recruitment analysis.

To further clarify the reasons behind the notable increase observed in 2015 in Manus Province followed by a decline in 2016, the discrepancy can be traced back to habitat identification, particularly in one specific location. This also highlights the importance harmonising data records during surveys.

Length distribution analysis of amberfish

The length distribution of amberfish indicates that nearly 98%of the species surpass the minimum threshold size as designated by the regulatory framework of the Beche-de-mer Management Plan (NFA 2018). However, critical information such as age or size at maturity and maximum size remain largely unknown (Conand et al. 2013a). For trade of this species, care must be taken in applying management strategies.

Conclusion

The stock assessment results presented in this study highlight a partial recovery of two sea cucumber species, white teatfish and prickly redfish, when compared to the reference provided by Kinch (2008b), indicating a positive trend in recruitment and abundance for these species. However, the assessment also reveals fluctuations in the population of black teatfish, and inconsistent abundance patterns for amberfish during the moratorium period.

Overall, the stock abundance and density of most species showed consistent growth trends, with clear signs of recruitment over the moratorium period (2010–2016). However, the impacts of fishing seasons (2017–2018, 2020) on recruitment aspects were evident, stressing the importance of management measures such as moratoriums in sustaining sea cucumber populations.

The analysis of size distribution suggests that many individuals reached maturity, consistent with the regulations outlined by the NFA Beche-de-mer Management Plan (NFA 2018), while highlighting the discrepancies in legal-size requirements for black teatfish and prickly redfish.

Recommendations for improving management include revising size limits to align with size at maturity, enforcing minimum size limits, and setting harvest control rules based on catch and effort triggers. Additionally, there is a need for separate stock assessment studies targeting the five species in area of habitat preference.

Recommendations

Density threshold

As observed from this study, most of the species were above the density threshold from Kinch (2008b) in 2015 and 2016. These years have become focal points for the study due to the clear trend in species density surpassing previously known thresholds, which indicates a significant population growth or recovery for most species under consideration. However, black teatfish presents a contrasting narrative because it did not reach the density threshold and followed a similar trend to other species under study. It is worth noting that this study only evaluated 3 PNG provinces out of 14 maritime provinces. A broader examination including assessments from other provinces might yield a different understanding of black teatfish mean density.

Considering the aforementioned factors, it is prudent to recommend that the 2016 stock assessment data be employed as a reference point for future studies, management decisions and policy formulation.

Setting size limits

In this study, two sea cucumber species – black teatfish and prickly redfish – were found to have minimum legal-size limits established under the PNG Beche-de-Mer Management Plan, set below the size at which they typically reach maturity, as reported by Skewes (2014). It is recommended that the minimum legal size of these two species be reviewed and adjusted to ensure they align with the size at maturity, thus fostering a sustainable management of their populations.

Candy cane (Thelenota rubralineata)

Candy cane warrants a decisive prohibition from the sea cucumber fishery, primarily due to its rarity as indicated by the analysis provided in the report. Numerous studies consistently highlight its scarcity, both in terms of density and abundance. Hence, it becomes imperative to implement stringent measures to safeguard this species from any further depletion.

Catch quotas

The monitoring of TACs has been a standard practice in PNG since the inception of the initial management plan. However, its implementation has been somewhat sporadic, with limited trials conducted for species such as black teatfish and white teatfish during the 2020 season. Moving forward, it is strongly advised that, especially for CITES-listed species, TACs be allocated separately and subjected to precise monitoring. This approach ensures more targeted and effective regulation of fishing activities, thereby promoting the sustainable management of populations.

Conduct targeted stock assessments

Conduct a separate, well-defined stock assessment study, targeting the five species of sea cucumbers that are well represented throughout the country. This will provide more comprehensive data for effective management strategies.

Improve data harmonisation

Ensure uniformity in habitat identification and data collection procedures during surveys to reduce inconsistencies in findings. Additionally, establish standardised and efficient assessment sampling protocols to accurately estimate population abundance.

Conduct research into breeding seasonality

Conduct research on growth rates and breeding times of each sea cucumber species to ascertain breeding seasonality so that breeding season does not coincide with the fishery's open season.

Enhance monitoring and enforcement

Strengthen monitoring and enforcement efforts to deter illegal fishing activities and ensure compliance with size limits and regulations.

Further analysis of data from other provinces within PNG

Further analysis of the data across other provinces within PNG is essential to accurately assess the distribution and abundance of the five sea cucumber species. This can be used in informing the effective management strategy in terms of allocating TACs by species and province.

The analysis conducted in this study has shed light on significant gaps in the management of sea cucumber fisheries in PNG. Disparities in density between fishing opening periods and moratoriums highlight the need for improved management strategies to ensure the sustainability of sea cucumber populations. Addressing these gaps is crucial for the long-term health of PNG's marine ecosystems and the livelihoods of communities reliant on sea cucumber fisheries.

References

Anderson S.C., Flemming J.M., Watson R. and Lotze H.K. 2011. Serial exploitation of global sea cucumber fisheries. Fish and Fisheries 12(3):317–339. https://doi.org/10.1111/j.1467-2979.2010.00397.x

Andréfouët S., Tagliaferro A., Chabran-Poete L., Campanozzi-Tarahu J., Tertre F., Haumani G. and Stein A. 2019. An assessment of commercial sea cucumber populations in French Polynesia just after the 2012 moratorium. SPC Beche-de-mer Information Bulletin 39:8–18. https://www.spc.int/digitallibrary/get/syo7t

Barclay K., Fabinyi M. and Kinch J. 2017. Governance and the Papua New Guinea beche-de-mer value chain. SPC Beche-de-mer Information Bulletin 37:3–8. https://www.spc.int/digitallibrary/get/bgidj

Barclay K., Fabinyi M., Kinch J. and Foale S. 2019. Governability of high-value fisheries in low-income contexts: a case study of the sea cucumber fishery in Papua New Guinea. Human Ecology 47:381–396. https://doi.org/10.1007/s10745-019-00078-8

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). 2019. Consideration of Proposals for Amendment to Appendices I and II. Eighteenth meeting of the Conference of the Parties, Geneva, Switzerland: Convention on the International Trade in Endangered Species of Wild Fauna and Flora. Available at: https://cites.org/cop/18/proposals_for_amendment

CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). 2022. Consideration of Proposals for Amendment of Appendices I and II. Panama. Nineteenth meeting of the Conference of the Parties, Panama: Convention on the International Trade in Endangered Species of Wild Fauna and Flora. Available at: https://cites.org/eng/cop/19/amendment-proposals

Conand C. 2008. Sea cucumbers, class Holothuridea. p. 687–1396. In: FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 2. Cephalopods, crustaceans, holothurians and sharks. Carpenter K.E. and Niem V.H. (eds). Rome, Italy: Food and Agriculture Organization of the United Nations.

Conand C. 2018. Tropical sea cucumber fisheries: Changes during the last decade. Marine Pollution Bulletin 133:590–594. https://doi.org/10.1016/j.marpolbul.2018.05.014

Conand C., Gamboa R. and Purcell S. 2013a. Thelenota ananas. The IUCN Red List of Threatened Species 2013: e.T180481A1636021. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T180481A1636021.en

Conand C., Gamboa R. and Purcell S. 2013b. Thelenota rubralineata. The IUCN Red List of Threatened Species 2013. e.T180285A1610697. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T180285A1610697.en

Conand C., Purcell S. and Gamboa R. 2013c. Thelenota anax. The IUCN Red List of Threatened Species 2013: e.T180324A1615023. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T180324A1615023.en

Gisawa L., Kinch J., Ugufa S., Shedrawi G., Lis R. and Pakop N. 2020. Non-Detrimental Finding (NDF) for two teatfish species Holothuria witmaei and Holothuria fuscogilva in Papua New Guinea. Port Moresby, PNG: National Fisheries Authority.

Govan H. 2018. A review of sea cucumber fisheries and management in Melanesia. Fisheries Newsletter 154:31–36.

Hair C., Foale S., Kinch J., Yaman L. and Southgate P.C. 2016. Beyond boom, bust and ban: The sandfish (Holothuria scabra) fishery in the Tigak Islands, Papua New Guinea. Regional Studies in Marine Science. 5:69–79. https://doi.org/10.1016/j.rsma.2016.02.001

Hair C., Kinch J., Galiurea T., Kanawi P., Mwapweya M. and Noiney J. 2018. Re-opening of the sea cucumber fishery in Papua New Guinea: A case study from the Tigak Islands in the New Ireland Province. Beche-de-Mer Information Bulletin 38:3–10. https://www.spc.int/digitallibrary/get/ybxzq

Hair C., Foale S., Kinch J., Frijlink S., Lindsay D. and Southgate P.C. 2019. Socioeconomic impacts of a sea cucumber fishery in Papua New Guinea: Is there an opportunity for mariculture? Ocean and Coastal Management 179:104826. https://doi.org/10.1016/j.ocecoaman.2019.104826

Hammond A., Meyers L. and Purcell S. 2020. Not so sluggish: Movement and sediment turnover of the world's heaviest holothuroid, Thelenota anax. Marine Biology 167:60. https://doi.org/10.1007/s00227-020-3671-5

Kaly U., Preston G., Opnai J. and Aini J. 2007. Sea cucumber survey: New Ireland Province. Port Moresby, PNG: CFMDP and PNG National Fisheries Authority.

Kinch J., Purcell S.W., Uthicke S. and Friedman K. 2008a. Population status, fisheries and trade of sea cucumbers in the western central Pacific. p. 7–55. In: Sea cucumbers: A global review of fisheries and trade. Toral-Granda M.V., Lovatelli A. and Vasconcellos M. (eds). Rome, Italy: Food and Agriculture Organization of the United Nations.

Kinch J., Purcell S.W., Uthicke S. and Friedman K. 2008b. Papua New Guinea: A hotspot of sea cucumber fisheries in the western central Pacific. p. 57–77. In: Sea cucumbers: a global review of fisheries and trade. Toral-Granda M.V., Lovatelli A. and Vasconcellos M. (eds). Rome, Italy: Food and Agriculture Organization of the United Nations.

Murphy N.E., Plaganyi E., Edgar S., Salee K. and Skewes T. 2021. Stock survey of sea cucumbers in east Torres Strait. Final report. Canberra, Australia: Commonwealth Scientific and Industrial Research Organization. 138 pp.

NFA (National Fisheries Authority). 2015. Management of the PNG Beche-de-mer Fishery. Port Moresby, PNG: NFA

NFA (National Fisheries Authority). 2018. The National Beche-de-mer Fishery Management Plan. Port Moresby, PNG: Government Printing Office.

Pakoa K. and Bertram I. 2013. Management state of Pacific sea cucumber fisheries. Beche-de-mer Information Bulletin 33:49–52. https://www.spc.int/digitallibrary/get/z56bi

Pinca S., Kronen M., Friedman K., Magron F., Chapman L., Tardy E., Pakoa K., Awira R., Boblin P. and Lasi F. 2009. Regional assessment report: Profiles and results from survey work at 63 sites across 17 Pacific Island Countries and Territories. Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C/CoFish). Noumea, New Caledonia: Secretariat of the Pacific Community (SPC). https://www.spc.int/digitallibrary/get/f2z4c

Purcell S.W. 2014. Value, market preferences and trade of beche-de-mer from Pacific Island sea cucumbers. PLOS ONE 9(4):e95075. https://doi.org/10.1371/journal.pone.0095075

Purcell S. and Tekanene M. 2006. Ontogenetic changes in colouration and morphology of white teatfish, *Holothuria fuscogilva*, juveniles in Kiribati. Beche-de-mer Information Bulletin 23:29–31. https://www.spc.int/digitallibrary/get/edzwq

Purcell S., Gossuin H. and Agudo N. 2009. Status and management of the sea cucumber fishery of La Grande Terre, New Caledonia. Penang, Malaysia: The WorldFish Center.

Purcell S.W., Samyn Y. and Conand C. 2012. Commercially important sea cucumbers of the world. Rome, Italy: Food and Agriculture Organization of the United Nations.

R Core Team. 2023. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/

Rose M. 2014. Non-Detriment Findings in CITES (NDFs). Version 1.2. Vienna, Austria: Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management.

Sheppard S. 2015. Mapping of reef habitats in PNG for National Fisheries Authority, Port Moresby, Papua New Guinea: Data compilation and analysis report. Version 2. Port Moresby, Papua New Guinea: National Fisheries Authority.

Skewes T., Kinch J., Polon P. and Dennis D. 2002. Research for the sustainable use of beche-de-mer resources in the Milne Bay Province, Papua New Guinea. DOI: https://doi.org/10.13140/RG.2.1.3823.0560

Skewes T., Plagányi E., Murphy N., Pascual R. and Fischer M. 2014. Evaluating rotational harvest strategies for sea cucumber fisheries. Brisbane, Australia: Fisheries Research and Development Corporation.

Managing coastal fisheries in Tuvalu: Lessons learned from a maturity study to establish minimum size limits in Funafuti

Lotokufaki Paka Kaitu,[1,] Aimée F. Komugabe-Dixson,[1,2] Filipo Makolo,[1] Paeniu Lopati,[1] Maani Petaia,[1] Hetoa Taula,[1] Sione Falesene,[1] Iakoba Italeli,[1] Lale Petaia,[1] Matapua Falani,[1] Lavata Nivaga,[1] Semese Alefaio[1] and David J. Welch[3]*

Introduction

Coastal fisheries play an essential role in the livelihoods, food security and cultural practices of Tuvalu's people. Despite its modest land area of just 26 km^2, Tuvalu's nine atoll islands are surrounded by an expansive exclusive economic zone (EEZ) that spans nearly 1 million km^2 (Fig. 1) and provides a vast marine resource base that is central to Tuvalu's identity and survival (United Nations 2024). Tuvalu has a population of approximately 11,000 people, over half of whom reside in the capital, Funafuti (United Nations 2024). Population growth on Funafuti, and peoples' increasing reliance on coastal fisheries, have raised concerns about the sustainability of coastal fisheries resources.

Fishing in Funafuti primarily targets reef and lagoon species using a variety of methods, such as spearfishing, gill nets and handlines. Increasingly, fishers are landing juvenile fish and exerting greater effort to maintain catches by traveling farther, which means that there is growing pressure on coastal ecosystems (Makolo et al., 2017; Tuvalu Fisheries Department 2023). There are also several challenges such as habitat degradation and climate change, which further strain these resources, undermining their ability to sustain the community over time (Makolo et al. 2017).

To better assess and manage coastal resources, the Tuvalu Fisheries Department has implemented monitoring programmes, such as creel (landing) surveys to track key indicators of fishery health. Between 2015 and 2024, over 5300 creel surveys were conducted across the islands, including 1300 in Funafuti, yielding data from 110,000 samples (50,000 from Funafuti), (Tuvalu Fisheries Department 2023). These surveys have provided insight into catch composition, gear use, and fishing pressure. Notably, the percentage of fish smaller than the estimated size at maturity (Lm), catch per unit effort (CPUE), and spawning potential ratio (SPR) serve as critical indicators of overfishing and resource health: high proportions of undersized fish indicate depleted stocks, while declining CPUE highlights reduced fishery abundance. These data are summarised annually, and published in the creel report cards on the Fisheries Department website.[4]

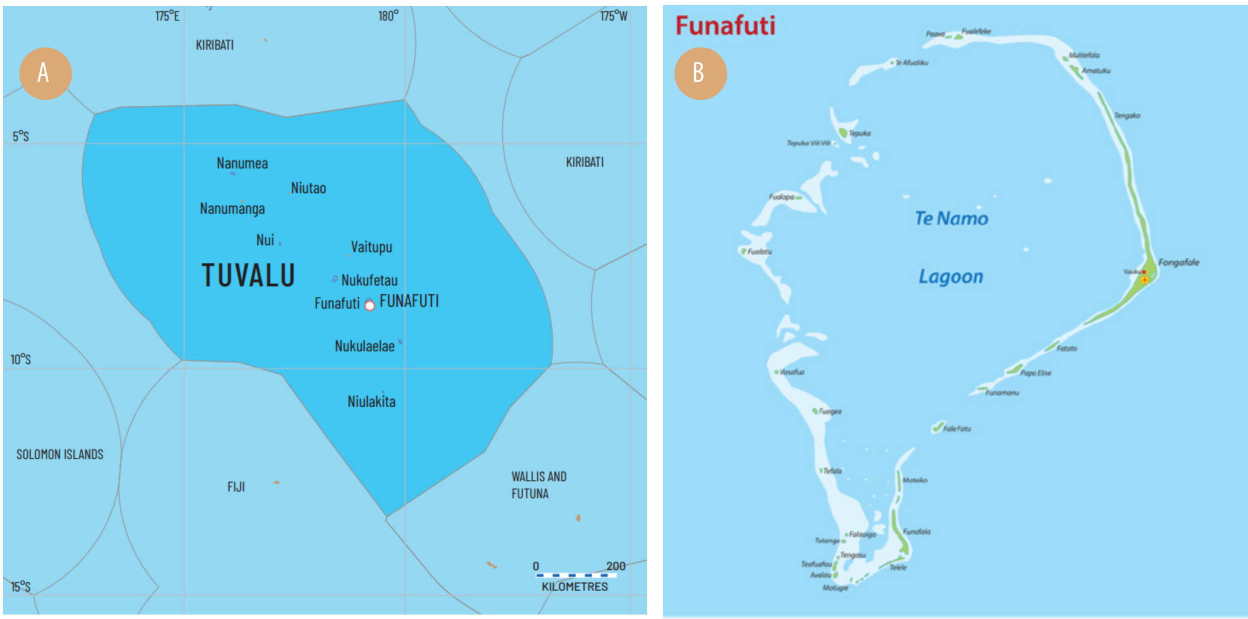


Figure 1. (A) Tuvalu, showing the atolls and extent of the country's exclusive economic zone; (B) Funafuti Atoll.
Source: Pacific Community

[1] Tuvalu Fisheries Department, Vaiaku, Tuvalu
[2] Felicity & Wainhouse Consulting
[3] C2O Fisheries, Cairns, Australia
[4] https://tuvalufisheries.tv/library/
* Author for correspondence: lotokufakip@tuvalufisheries.tv

Recent data have revealed troubling trends, particularly in Funafuti. In 2021 and 2022, over 60% of landed fish were below breeding size (Tuvalu Fisheries Department 2023), suggesting that current management measures are insufficient for reducing overfishing and protecting spawning populations. These management measures include no-take zones (e.g. Funafuti Conservation Area) and a gill net mesh size limit. This underscores the need for management action to reverse these trends, as ideally, the percentage of undersized fish that are caught should approach zero.

In Tuvalu, the responsibility for managing fisheries within 12 nautical miles of the coastline, lies with the *falekaupule*, the traditional governing assembly on each island, under the Falekaupule Act. Tuvalu's vast coastal areas are locally managed, and the *falekaupule*'s decisions are executed by the *kaupule*, or island councils. In Funafuti the Fisheries Department has been working with the Funafuti *kaupule* on draft bylaws that include the introduction of minimum size limits, which is a core management strategy under the Funafuti Reef Fisheries Stewardship Plan. In order to achieve this, the Fisheries Department undertook a study to determine the size at maturity for 28 key finfish species in Funafuti to inform the establishment of locally appropriate size limits (unpublished data).

This paper presents the methods and findings of this study and its role in advancing coastal fisheries management in Funafuti. We discuss the challenges and opportunities faced during this study, and hope that the lessons learned can be helpful for other Pacific Island countries seeking to improve coastal fisheries sustainability through size limit measures.

Methodology

The Tuvalu Fisheries Department engaged a technical consultant, funded through the World Bank's Pacific Regional Oceanscape Project (PROP), to provide fisheries staff training on conducting fish maturity and spawning seasonality studies, including fish sampling, dissection, data collection and analysis. The two-week training was initially planned to be in-person, but due to COVID-19-related travel restrictions, it ended up being delivered (along with a followup workshop) via Zoom. Despite these challenges, the training was successful even without the physical presence of the technical consultant. The consultant provided comprehensive resource materials (e.g. manuals and videos) that guided the staff through the practical sessions. Staff were able to access further guidance through the exchange of emails and a series of video calls.

Study location

The study, which was conducted in Funafuti, Tuvalu, targeted reef fish species that are commonly caught within the atoll's waters. Funafuti was selected because of its significance as the main settlement for the majority of Tuvaluan people, and because it provided a central and strategic point for research purposes. Funafuti is geographically located at 8°31'0"S and 179°13'0"E in the Pacific Ocean (Fig.1).

Target species

The research focused on 28 of the most commonly caught reef fish species in Funafuti (Table 1). Key species were prioritised based on the most common local catches and species vulnerability, and was informed by local creel survey

Table 1. The 28 most commonly caught reef species in Funafuti. Species are listed in order of priority.

	Common name	Species name	Tuvaluan name
1	camouflage grouper	*Epinephelus polyphekadion*	gatala pulepule
2	fringelip mullet	*Crenimugil crenilabis*	fuakanase
3	ambon emperor	*Lethrinus amboinensis*	noto
4	highfin grouper	*Epinephelus longispinis*	gatala moeo
5	humpback red snapper	*Lutjanus gibbus*	taea
6	orange-striped emperor	*Lethrinus obsoletus*	tanutanu
7	common bluestripe snapper	*Lutjanus kasmira*	savane
8	bluespine unicornfish	*Naso unicornis*	ume,tupotupo
9	sabre squirrelfish	*Sargocentron spiniferum*	tamalau
10	yellowlip emperor	*Lethrinus xanthocheilus*	gutula
11	lined surgeonfish	*Acanthurus lineatus*	pone lolo, pone matagi
12	squaretail mullet	*Liza vaigiensis*	kafakafa,baibue
13	convict surgeonfish	*Acanthurus triostegus*	manini,koinava
14	orangespine unicornfish	*Naso lituratus*	manini lakau,umalei
15	bigscale soldierfish	*Myripristis berndti*	malau puku,te mon
16	blue lined squirrelfish	*Sargocentron tiere*	malau loa,malau gutu loa
17	longface emperor	*Lethrinus olivaceus*	filoa,rou,kapatiko
18	blacktail snapper	*Lutjanus fulvus*	tagau,takape
19	streamlined spinefoot	*Siganus argenteus*	maiava
20	honeycomb grouper	*Epinephelus merra*	gatala liki
21	humpnose big-eye bream	*Monotaxis grandoculis*	muu fatu
22	bignose unicornfish	*Naso vlamingii*	taitifi,tativi
23	spotted unicornfish	*Naso brevirostris*	pokapoka,ume pokapoka
24	gray unicornfish	*Naso caesius*	pokapoka,ume
25	Pacific longnose parrotfish	*Hipposcarus longiceps*	ulafi
26	scarlet soldierfish	*Myripristis pralinia*	malau puku
27	snubnose grouper	*Epinephelus macrospilos*	gatala
28	shoulderbar soldierfish	*Myripristis kuntee*	malau,malau po

data for Funafuti for the period 2015–2020 (Tuvalu Fisheries Department 2020).

Sample collection and processing

Fish were caught by local fishers and based on their catches (fishery-dependent sampling), with fish purchased from fishers using the Fisheries Department and project funds. Fish were dissected straight away upon receipt, and excess fish samples were stored in a freezer. A dissection timetable was drafted to be followed by dedicated staff, and data were recorded on a datasheet (Fig 2).

The process of fish dissection and data recording required the following equipment: dissecting scissors for cutting the fish cavity open; tweezers, to hold body cavity for better dissection; scalpel, if available (or similar small sharp blade or scissors), to start the process of cutting fish; measuring board or ruler to measure fish length; weighing scale (approximately 0.01 g – 10 kg) to measure fish weight and gonad weight; datasheet to record information; and a pencil for writing information on the data sheet. The field guide that was developed by the consultant (unpublished) was a useful resource for the team. It provided clear guidance on identifying different fish maturity stages and sex during laboratory work.

During dissection, a cut was made on the ventral side of the fish from the anus to behind the gills and forward of the pelvic fins (Fig. 3). An upward cut continued through the side of the belly flap and just behind the pectoral fin. The belly flap was then cut and pulled forward towards the head, ensuring not to damage the guts, allowing the internal organs to be exposed. The final step was locating and removing the gonads for weighing, and determining maturity and sex.

Determining maturity

A female gonad can be distinguished from a male gonad by colour and shape: female gonads are yellow, orange or pink, while male gonads are always white. Also, female gonads are

Figure 2. Fish samples dissected for gonad inspection (left); processing the samples and recording the data (right). Images: © Rickard Abom (left), © Lotokufaki Paka Kaitu (right)

Figure 3. Female gonads are identifiable by their yellow, orange or pink hue, and sausage-like, tubular shape. © Rickard Abom

sausage-like, tubular and saclike, whereas male gonads are usually elongated in a thread-like, triangular shape.

Stage of maturity can be determined by looking at some of the distinct features between male and female gonads. Mature females have enlarged ovaries with distinct blood vessels and visible eggs. Mature male gonads have identifiable testes and visible milt oozes. On the other hand, the gonad of an immature fish is always small, often clear and thread-like, with indistinct blood vessels. Part of the training highlighted the difficulty in differentiating immature gonads from inactive mature gonads, with some tips for minimising this challenge (e.g. sampling only during known spawning times).

Data analysis

An Excel master file was pre-prepared by the consultant for easy analysis, whereby data was inserted into the appropriate fields, and macros ran the analysis and generated size at maturity estimates and data plots. The key data input fields were the number of mature and number of immature individuals by sex, if there were sufficient data. The spreadsheet accommodated different size-class groupings, depending on the size of the species and the number of samples collected. The analysis fits a logistic regression model to data on the proportion of fish in the total number sampled that are mature, in relation to body size. The analysis estimated the size at which 50% of the population was likely to be mature for that species (L_{50}), as well as 95% (L_{95}). Data were also collected to calculate the gonadosomatic index (GSI) for each species to determine their spawning seasonality. A spreadsheet tool made this a simple process. However, these results are not presented here because the team only collected data over a four-month period rather than throughout the year.

Results

We were able to determine the maturity of 2077 samples taken from 40 different species (see Table 2). Of these samples, 52% were female, 35% male, and the rest (13%) were immature and, therefore, sex could not be determined using our current methodology. One of the challenges was obtaining sufficient numbers of samples for each individual species (Table 2). These data collections, however, provided preliminary estimates of size at maturity for three species: *Lutjanus gibbus, Lutjanus kasmira* and *Lethrinus amboinensis*.

For three fish species we were able to obtain a sufficient number of mature and immature samples across a range of sizes to provide preliminary estimates of the length at 50% and 95% maturity (see Fig. 4A–C).

For each of these three species, the maturity estimates were:

Lethrinus amboinensis: L_{50} = 18.3 cm fork length (FL); L_{95} = 21.8 cm FL.

Lutjanus gibbus: L_{50} = 23.4 cm FL; L_{95} = 33.1 cm FL

Lutjanus kasmira: L_{50} = 18.4 cm FL; L_{95} = 21.6 cm FL

For these species – and for most other species included in the study – the analysis step highlighted where data were lacking. For example, for *Lethrinus amboinensis*, samples were obtained across a large size range (15.8–39.5 cm FL), which is desirable (Fig. 4a). Also, there were a sufficient number of samples of larger mature individuals as indicated by most of the larger size classes showing that 100% of the fish were mature. However, insufficient sample numbers in several size classes meant that the model did not fit closely to the data points. Ideally, the data points would sit on or close to the smooth logistic curve generated by the model. For example, the number of samples obtained across the sizes where maturity appears most likely to occur (~17–22 cm) were generally low (4–11 samples). Further, while the smallest size classes suggest that we are close to estimating when maturity first starts, the sample numbers in these size classes are also very low (1 and 4). Finally, low sample numbers in some size classes have also generated "outliers" (size class midpoints of 28.5 cm and 29.5 cm).

Similar patterns can be seen in the plots of *L. gibbus* and *L. kasmira* (Fig. 4B and 4C), which provide guidance on further sampling needed to improve the fit of the model to the data and, therefore, obtain accurate estimates of size at maturity. For many of the species in the study, overall sample numbers were very low, and it may take some time to collect a sufficient number of samples to estimate maturity. Although current data collected for many other species is not sufficient to provide maturity estimates, good progress has been made and, with targeted sampling, maturity estimates will soon be possible. An example of this is *Lethrinus harak*, for which many samples were obtained (n = 280). However, the size range is limited and very few immature individuals have been obtained (Fig. 5). While maturity estimation is not possible, targeted sampling of smaller individuals is likely to achieve this with relatively little effort.

Size frequencies

Examination of the size frequency of the samples collected for the three species, when compared with the preliminary estimate of L_{50}, is also informative. For all three species, assuming that the sample collections were representative of the usual local catch, current catches include immature fish (Fig. 6). Although data are preliminary, this is variable for each species and most notable for *Lethrinus gibbus* (Fig. 6). However, these plots vindicate the decision of the Tuvalu Fisheries Department to conduct this study with the purpose of introducing size limits for key species.

Table 2. Summary of the samples collected by species

Species	Sample size*	Sex/stage			Size range (cm)**
		F	M	Immature	
Acanthurus lineatus	165	72	74	19	18.0–23.9
Acanthurus triostegus	359	163	174	15	6.3–15.5
Anyperodon leucogrammicus	14	10	2	2	32.0–41.0
Aphareus furca	6	3	2	1	18.9–27.0
Crenimugil crenilabis	1	1	0	0	31.0–31.0
Epinephelus fuscoguttatus	18	4	11	3	26.4–46.0
Epinephelus hexagonatus	1	1	0	0	17.1 (TL)
Epinephelus howlandi	1	0	1	0	30.1 (TL)
Epinephelus longispinis	7	7	0	0	31.0–41.0 (TL)
Epinephelus macrospilos	1	1	0	0	21.5 (TL)
Epinephelus maculatus	38	28	10	0	27.0–42.0 (TL)
Epinephelus melanostigma	1	1	0	0	30.0 (TL)
Epinephelus merra	9	7	2	0	14.0–21.0 (TL)
Epinephelus polyphekadion	24	12	9	1	25.0–48.3 (TL)
Epinephelus quoyanus	2	1	1	0	17.0–17.5 (TL)
Epinephelus tauvina	1	0	1	0	33.0 (TL)
Lethrinus amboinensis	71	41	12	18	15.8–39.5
Lethrinus genivittatus	137	74	59	2	16.0–23.5
Lethrinus harak	280	138	134	8	15.0–23.5
Lethrinus obsoletus	33	15	15	3	20.4–29.4
Lethrinus olivaceus	12	8	2	2	15.5–44.2
Lethrinus rubrioperculatus	72	53	15	3	17.0–31.0
Lethrinus xanthochilus	17	11	3	3	25.6–37.0
Liza vaigiensis	168	91	56	15	21.0–42.0
Lutjanus fulvus	95	57	31	6	18.8–29.9
Lutjanus gibbus	192	97	14	74	16.0–34.7
Lutjanus kasmira	133	62	28	40	16.0–29.8
Lutjanus quinquelineatus	38	27	11	0	16.5–21.5
Monotaxis grandoculis	15	3	7	3	16.2–41.5
Monotaxis heterodon	4	1	1	1	15.5–18.2
Myripristis adusta	2	2	0	0	18.0–20.5
Myripristis berndti	7	5	2	0	13.5–20.0
Myripristis murdjan	3	1	2	0	13.0–13.0
Myripristis violacea	27	15	12	0	12.0–17.0
Naso lituratus	72	35	11	24	20.6–29.0
Naso unicornis	18	6	11	1	22.3–52.6
Naso vlamingii	8	5	0	2	34.5–41.0
Sargocentron spiniferum	14	1	2	7	15.0–28.0
Sargocentron tiere	9	1	7	1	15.2–19.5
Sargocentron violaceum	2	0	0	2	16.5–17.0

* Sample size includes unclassified samples (samples with maturity stage unknown)
** Size range in fork length (FL) unless otherwise indicated (TL : total length)

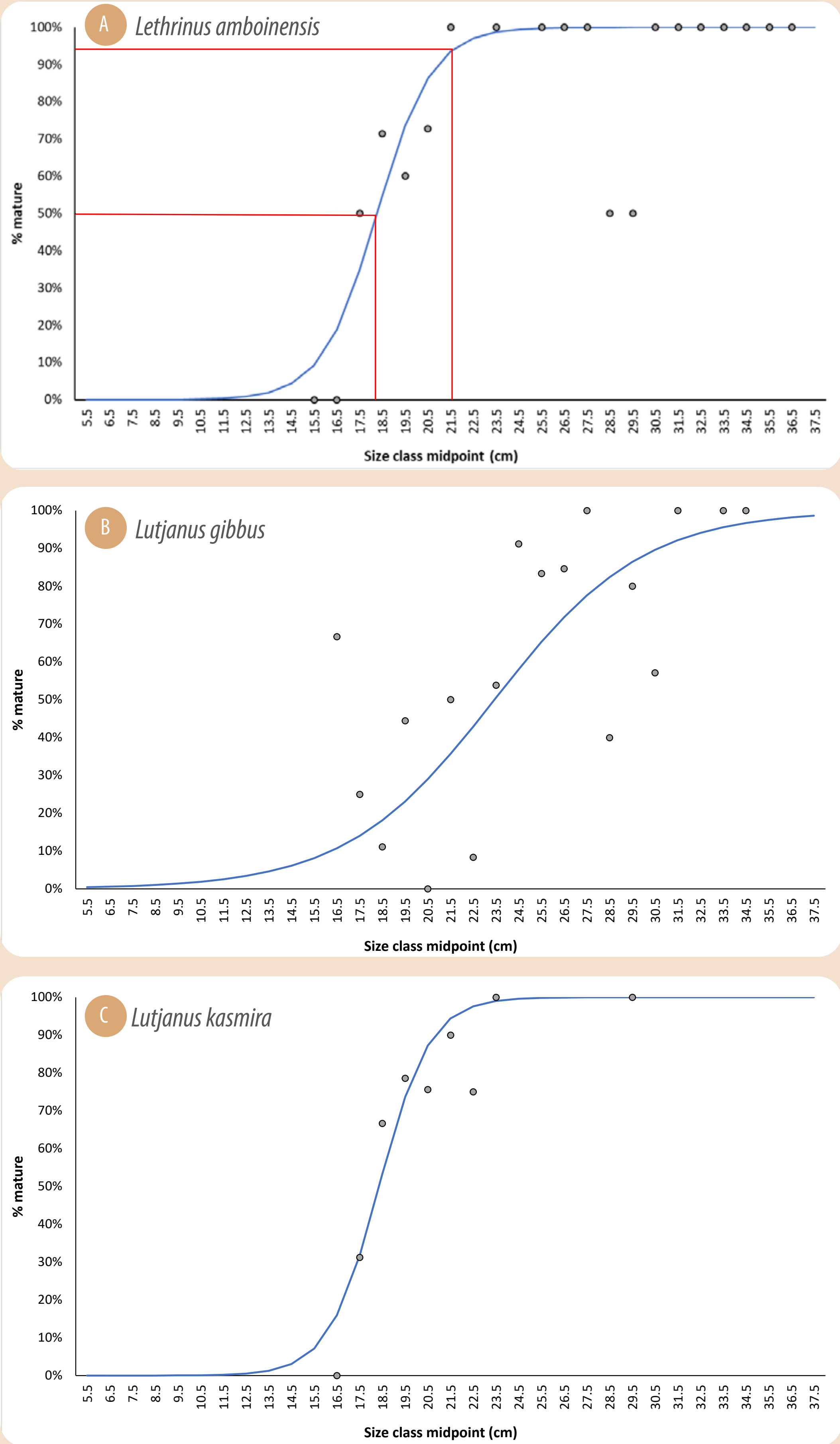
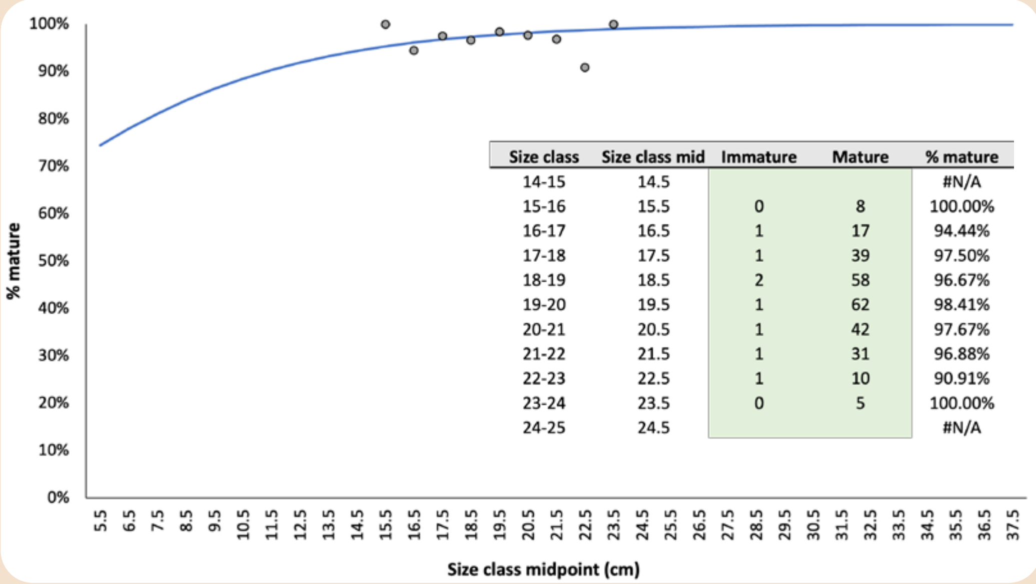


Figure 4. Plots showing the logistic curve (blue line) fitted to the data (% mature by size class; grey dots) for the three species with the best model fits. A) *Lethrinus amboinensis*. The lines on the plot for 50% and 95% of mature individuals demonstrate how the model estimates the corresponding size for estimating when maturity occurs, on average.



Size class	Size class mid	Immature	Mature	% mature
14-15	14.5			#N/A
15-16	15.5	0	8	100.00%
16-17	16.5	1	17	94.44%
17-18	17.5	1	39	97.50%
18-19	18.5	2	58	96.67%
19-20	19.5	1	62	98.41%
20-21	20.5	1	42	97.67%
21-22	21.5	1	31	96.88%
22-23	22.5	1	10	90.91%
23-24	23.5	0	5	100.00%
24-25	24.5			#N/A

Figure 5. Plot of maturity data for *Lethrinus harak* and the poor model fit, due to the lack of samples in the smaller immature size classes as shown by the data and evident in the plot.

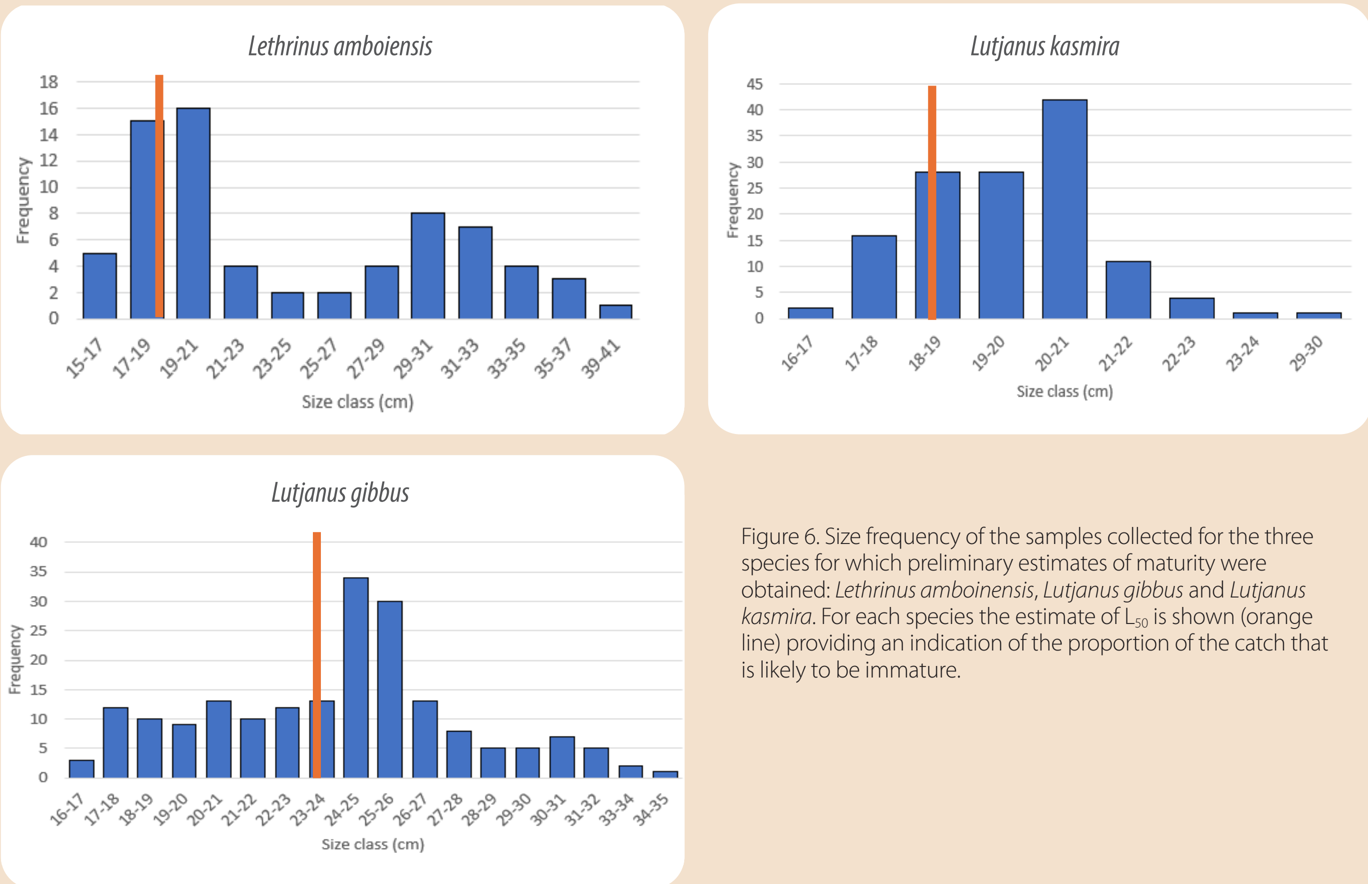


Figure 6. Size frequency of the samples collected for the three species for which preliminary estimates of maturity were obtained: *Lethrinus amboinensis*, *Lutjanus gibbus* and *Lutjanus kasmira*. For each species the estimate of L_{50} is shown (orange line) providing an indication of the proportion of the catch that is likely to be immature.

Discussion

This study is the first to estimate the size at maturity for key target reef species of Tuvalu, and significantly advances the capacity for informed fisheries management. These findings are essential in determining minimum size limits for the management of coastal reef fish, marking a crucial step toward ensuring sustainable fisheries in Tuvalu, particularly for the Funafuti community. While it is acknowledged that further sampling is required, the implementation of these size limits for the first time will help alleviate the pressures of overfishing and promote the long-term viability of marine resources in the region.

Comparison of size at maturity estimates

The estimated size at maturity for the reef species in Tuvalu provides valuable insights. Table 3 shows a comparison of the results with studies from other Indo-Pacific regions. Tuvalu's maturity estimates align with those from nearby locations at similar latitudes, such as Solomon Islands and Papua New Guinea (PNG). However, there are some differences, with species that are at higher latitudes generally reaching maturity at larger sizes.

Table 3. Comparison of fish size at maturity with other parts of the Pacific and Indonesia.

Species	Location	Latitude	L_{50} (cm)*	Reference
Lethrinus amboinensis	Tuvalu	8° S	18.3	This study
	Indonesia	6° S	27 TL	Wibisono et al. 2019
Lutjanus gibbus	Tuvalu	8° S	23.4	This study
	Morobe, PNG	7° S	18-23 female, 14 male	Longenecker et al. 2011
	Solomon Islands	8° S	20.9	Prince et al. 2020
Lutjanus kasmira	Tuvalu	8° S	18.4	This study
	Morobe, PNG	7° S	12 female, 14 male	Longenecker et al. 2011
	Solomon Islands	8° S	17.4	Prince et al. 2020

* Fork length unless otherwise stated. TL: total length

Importance of the study for Tuvalu

The findings of this study are particularly important for Funafuti, the main population centre, which faces increasing pressure on its coastal fisheries due to overfishing and growing population. The adoption of size limits is, therefore, crucial for ensuring sustainable fisheries management. This research also has broad relevance across Tuvalu, as the eight outer islands have already highlighted the implementation of size limits as a key priority in their coastal fisheries management plans. Therefore, the results of this study not only address the immediate needs of Funafuti but also provides a foundation for extending size limit strategies to the outer islands.

Translating results to management actions

The results from this maturity study provide insights for developing effective management strategies to ensure the sustainability of coastal fisheries in Funafuti. Following the estimation of the size at maturity for key species, with additional data collections, the next step is the implement minimum size limits to prevent overfishing and allow fish populations to replenish.

To support the gradual adoption of these measures, minimum size limits will be developed for an initial five key species for which estimates of maturity are considered robust. Size limits will be set for *Acanthurus lineatus*, *Lethrinus amboinensis*, *Lutjanus gibbus*, *Lutjanus kasmira* and *Naso lituratus*, based on a multiple of the size of maturity using 1.2 times the L_{50} to preserve 20% SPR as per Prince (2021) and Prince and Hordyk (2018).

This approach allows for a smooth transition and ensures that the community is adequately prepared to comply with the new regulations. To further ensure the long-term success of these management actions, the plan is to continue adding five more species to the bylaw schedule at annual intervals. This phased approach will allow for the careful monitoring of each species' response to size limit measures, while also providing ample time for the local fishing community to adapt to the changes.

This strategy not only supports the sustainable management of marine resources but also fosters greater community buy-in by allowing stakeholders to gradually adjust to the new regulations. Over time, as more species are incorporated into the schedule, these measures will contribute to the resilience of fisheries and help ensure that they continue to provide vital food security and livelihoods for Tuvalu's people.

Lessons learned

1. **Undersampling.** The use of fishery-dependent sampling methods meant we did not have much control over the sizes caught, and we ended up undersampling the smaller sizes for most species. For many species, undersampling larger individuals was also a factor. This resulted in insufficient data to reliably estimate size at maturity for a number of species. Future sample collection will need to ask fishers to target the size classes lacking for certain species, or to conduct some fisheries-independent sampling.
2. **Oversampling.** We ended up collecting data on 40 species instead of the planned 28 species. It was hard to control the sample selection as this was outsourced to local fishers. While this potentially adds value to the project, it created additional resource requirements than was planned in terms of staff to process samples and their storage.
3. **Clear communication and guidelines for sample collection**. One solution to oversampling is to give the fishers (or those collecting samples) accurate species names and clear identification guidelines to avoid the inclusion of non-target species.
4. **Precision in measurement.** Accurate and precise length and weight measurements are important to generate reliable data. Our weighing scales were initially not accurate enough to measure gonad weights and we had to order precision balances to ensure we could measure weights under 1 g. It is also important when recording fish gonad data (gender, maturity), to be willing to record data as "blank" when it is uncertain. For example, identifying immature individuals with certainty is often not possible, and it is better to record nothing than to make an error.
5. **Challenges in identifying maturity stages.** Identifying the various stages of maturity was a bit challenging, especially knowing the difference between a mature-inactive stage and an immature male gonad for some of the fish species. The technical nature of this type of work requires education and patience, acknowledging that with experience the ease and accuracy of data collection will only improve.
6. **Leadership**. Leading the study required considerable effort and high capacity to maintain a smooth and constant pace. High support from the rest of the team was also essential.
7. **Sex differences**. During the course of this work, the team learned some of the distinct physical differences between males and females in some fish species. For example, *Naso lituratus* can be distinguished by looking at the forked tail, a male has a longer tail and female has a short tail.

Recommendations

1. **Develop a sampling and dissection plan**. Having a well-defined sampling and dissection plan helps ensure consistency of data collection. Having a structured plan with, for example, weekly, fortnightly or monthly targets will ensure reliable and cost-efficient data collection, and prevent confusion. A data collection plan that includes both fisheries-dependent and -independent sampling is also recommended.
2. **Fish identification resources**. Have fish identification books available during the dissection process to verify species names and avoid misidentification.
3. **Timely data entry.** Entering data straightaway after dissection is important for avoiding damage or loss. Leaving data unattended for long periods on your desk may increase the risk of errors or incomplete records.
4. **Clear roles and responsibilities.** Assign specific roles and delegate tasks among a dedicated team to fast track the process and ease the workload.
5. **Adequate budget**. Have an adequate budget to buy enough fish from fishers on the spot to avoid delays. Underestimating costs can lead to insufficient sample collection.
6. **Proper equipment.** Ensure all supplies and tools needed for fish dissection are procured and tested beforehand and are sufficient to carry out the work.
7. **Sufficient number of team members.** Having additional team members helps to speed up the work.

Conclusions

Once the results of the Funafuti study are finalised with robust estimates of maturity for as many of the study species as possible, they will be published and integrated into the Funafuti Regulation of Marine Resources. Results for the size limit study could be compared with similar studies of other islands across the Pacific with the same latitudes. Funafuti regulation will have to undergo a formal legal ratification process before it is officially effective and strongly enforced with the public.

Acknowledgements

This study was funded by the World Bank Pacific Islands Regional Oceanscape Program (PROP), the New Zealand bilateral support (Tuvalu Fisheries Support Programme), and Tuvalu Government. We would like to thank Jeremy Prince for initial discussions and support on length-based maturity estimates from Tuvalu creel data.

References

DeMartini E.E., Langston R.C. and Eble J.A. 2014. Spawning seasonality and body sizes at sexual maturity in the bluespine unicornfish, *Naso unicornis* (Acanthuridae). Ichthyological Research 61(3):243–251. https://doi.org/10.1007/s10228-014-0393-z

Longenecker K., Langston R., Bolick H. and Kondio U. 2011. Reproduction, catch, and size structure of exploited reef-fishes at Kamiali Wildlife Management Area, Papua New Guinea. Honolulu, Hawaii: Bishop Museum Technical Report.

Makolo F., Taula H., Petaia L., Paka L., Petaia M., Taufilo M., Stuart M., Finauga, M., Lopati P., Fepuali P., Alefaio S., Italeli S. and Kaly U. 2017. Funafuti Lagoon Reef Fisheries Management Plan: Optimising our use and benefits from fisheries. Tuvalu: Department of Fisheries, Ministry of Natural Resources. 35 p.

Prince J. 2021. Chapter 9: Reforming the management of small-scale fisheries with LBSPR assessment. p. 5-36. In: The Barefoot Ecologist's Toolbox. https://biospherics.com.au/wp-content/uploads/2021/04/BE_C9_FINAL.pdf

Prince J. and Hordyk A. 2019. What to do when you have almost nothing: A simple quantitative prescription for managing extremely data-poor fisheries. Fish and Fisheries 20(2):224–238. https://doi.org/10.1111/faf.12335

Prince J., Smith A., Raffe M., Seeto S. and Higgs J. 2020. Spawning potential surveys in Solomon Islands' Western Province. SPC Fisheries Newsletter 162:58–68. https://www.spc.int/digitallibrary/get/pb5b3

Tuvalu Fisheries Department. 2023. Funafuti creel report card. Tuvalu: Department of Fisheries, Ministry of Natural Resources.

Tuvalu Fisheries Department. 2020. All islands creel report card. Tuvalu: Department of Fisheries, Ministry of Natural Resources. 4 p. https://tuvalufisheries.tv/?sdm_process_download=1&download_id=4163

United Nations 2024. https://pacific.un.org/en/about/tuvalu (accessed December 2024)

Wibisono E., Mous P. and Humphries A. 2019. Using a collaborative data collection method to update life-history values for snapper and grouper in Indonesia's deep-slope demersal fishery. Cold Spring Harbor, New York: Cold Spring Harbor Laboratory. https://doi.org/10.1101/655571

Original text: English

Pacific Community, Fisheries Information Section, BP D5, 98848 Noumea Cedex, New Caledonia
Telephone: +687 262000; Fax: +687 263818; spc@spc.int; http://www.spc.int