**SCIENTIFIC COMMITTEE**
**TWENTIETH REGULAR SESSION**

Manila, Philippines
14 – 21 August 2024

# REPRODUCTIVE BIOLOGY OF WCPO YELLOWFIN TUNA

**WCPFC-SC20-2024/SA-IP-11**

**SPC-OFP**
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**Executive Summary**

Baseline reproductive research on WCPO tunas is critical for improving reproductive potential and spawning biomass estimates used in stock assessments and related analyses. This document summarises the current availability of yellowfin tuna samples from the WCPO for reproductive studies, identifies spatial and other gaps in the existing data, and outlines a project timeline for obtaining additional biological samples for planned histological and other analyses.

The Pacific Marine Specimen Bank (PMSB) currently houses around 3000 gonad-otolith paired samples from females over 60 cm fork length (FL), the length below minimum size at maturity. The majority of samples were collected during the period 2014 to 2024. While the spatial coverage across most of the WCPO is good, fewer samples are available from the northern and eastern central Pacific region. Temporal analysis indicates there are also fewer samples from fish ≥60 cm FL in the first and last quarter of the year. This paper discusses potential strategies for additional sampling effort to improve the data gaps.

The project will undertake histological and fecundity analyses on the gonad samples, as well as explore the potential application of emerging proteomic techniques to classify the maturity status of individuals using otoliths. These analyses are briefly outlined along with an initial timeline for the project.

**Recommendations**

SC20 is invited to:

- Note the commencement of the project examining the reproductive potential of WCPO yellowfin tuna.
- Note the current availability and spatiotemporal coverage of biological samples for these analyses, with the identified gaps across spatial, seasonal and size-based dimensions.
- Support additional sampling effort to ameliorate these gaps, leveraging other WCPO tuna research projects where possible.

## Background

The need for updated baseline measures of reproductive potential for WCPO tropical tunas has been recognized as critical for improving the precision of spawning biomass estimates used to assist management decision making (OFP-SPC, 2023).

Previous studies in the WCPO have indicated significant spatial variation in spawning potential for some tuna species (e.g., yellowfin and albacore tuna - (Farley et al. 2013; Farley et al. 2014; Itano 2000), while information is limited for others (e.g. bigeye and skipjack tuna - (Farley et al. 2018). Gaining an improved understanding of reproductive biology data across the WCPO is essential for improving stock assessment models and projections, thereby facilitating informed decisions for more effective and sustainable fisheries management. Additionally, given the potential impacts of increasing climate variability on the spawning potential of tropical tunas, establishing current baseline levels is crucial for identifying future changes.

In 2023, the WCPFC Scientific Committee initiated a project to study the reproductive biology of WCPO tropical tunas, to commence in 2024 (OFP-SPC 2023). The present information paper presents an initial assessment of the samples available in the Pacific Marine Specimen Bank (PMSB) for their capacity to provide an appropriate range of seasonal, spatial and size-based coverage to fully examine the reproductive biology of WCPO yellowfin tuna (*Thunnus albacares*). Areas of low sample number are identified, and recommendations for improving coverage across these dimensions are recommended. A brief overview of the anticipated histological and related analyses is also provided.

## Available Data

The PMSB contains over 7,000 gonads from WCPO yellowfin tuna, macroscopically identified as female, with matching otoliths available for almost all individuals.
Seasonally, ovary samples were available throughout the year, although fewer samples from fish between 60 and 120 cm FL were present, especially in the first and last quarter of the year (Figure 1). Note that this size range is likely to be the crucial transition from immature to mature females. Also, the largest number of samples overall exist for individuals between 40 and 60 cm fork length, which are generally considered immature (Itano 2000). These samples will largely be excluded from histological analyses, reducing the sample size from 7,000 to 3,000 for fish larger than 60 cm FL. However, otoliths from juveniles less than 60 cm fork length will be important for validation of non-maturity using emerging proteomic and microchemical techniques (see below). These smaller individuals follow a spatial distribution similar to those included in the histological analysis, with the majority sampled in Solomon Islands in 2022.

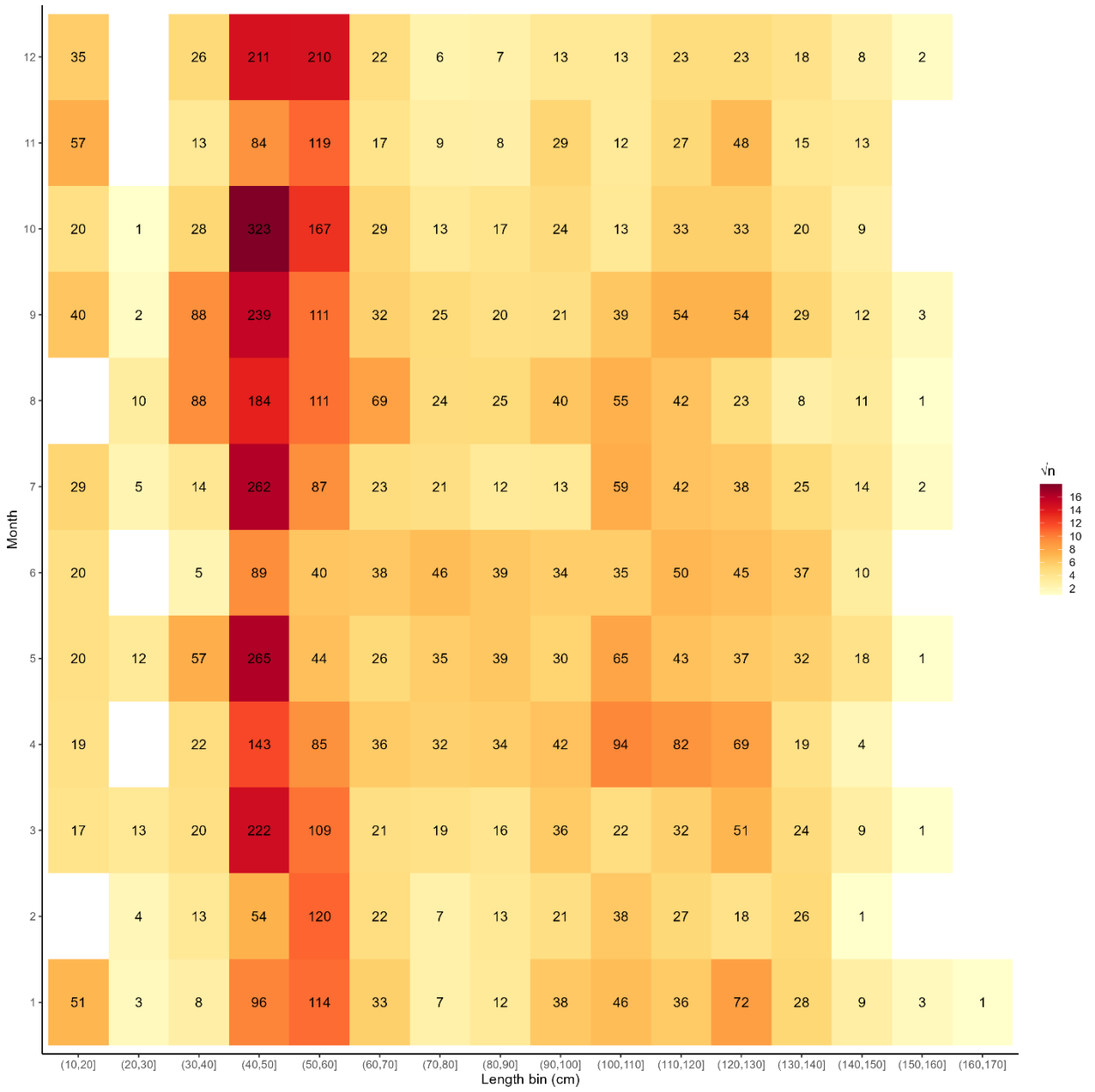


*Figure 1 Length structure heatmap of the number of samples from female yellowfin tuna available for analysis by month*

Temporally, samples are sporadically available from 2005 sparse coverage initially (Table 1). The numbers increase substantially from 2014 onwards, albeit with a notable decrease in 2018 and the most recent two years. This temporal range provides historical context to investigate potential reproductivity plasticity over time (Table 1).

*Table 1Monthly Distribution of Female Yellowfin Gonad Samples from fish larger than 60 cm fork length by Year*

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 2009 | 0 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 4 | 1 | 0 | 0 | 12 |
| 2010 | 0 | 0 | 6 | 22 | 0 | 0 | 22 | 1 | 2 | 0 | 0 | 0 | 53 |
| 2011 | 65 | 0 | 4 | 84 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 169 |
| 2012 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 12 |
| 2013 | 0 | 0 | 0 | 23 | 22 | 5 | 1 | 3 | 19 | 8 | 24 | 5 | 110 |
| 2014 | 13 | 22 | 21 | 34 | 50 | 40 | 22 | 63 | 54 | 22 | 14 | 11 | 366 |
| 2015 | 38 | 31 | 42 | 54 | 68 | 34 | 27 | 16 | 26 | 20 | 26 | 22 | 404 |
| 2016 | 17 | 22 | 27 | 15 | 42 | 118 | 32 | 48 | 26 | 9 | 15 | 16 | 387 |
| 2017 | 34 | 11 | 11 | 14 | 9 | 1 | 7 | 10 | 17 | 18 | 1 | 14 | 147 |
| 2018 | 0 | 0 | 2 | 3 | 11 | 33 | 8 | 15 | 1 | 5 | 2 | 7 | 87 |
| 2019 | 13 | 2 | 19 | 25 | 12 | 2 | 45 | 32 | 15 | 16 | 8 | 17 | 206 |
| 2020 | 3 | 3 | 11 | 23 | 31 | 23 | 21 | 31 | 43 | 47 | 26 | 6 | 268 |
| 2021 | 53 | 46 | 25 | 35 | 27 | 38 | 44 | 36 | 53 | 26 | 27 | 27 | 437 |
| 2022 | 26 | 30 | 47 | 55 | 32 | 23 | 18 | 39 | 13 | 16 | 29 | 7 | 335 |
| 2023 | 11 | 1 | 10 | 25 | 3 | 15 | 0 | 4 | 4 | 3 | 4 | 3 | 83 |
| 2024 | 12 | 5 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 |

Spatially, the highest numbers of yellowfin tuna gonads and otoliths are from the archipelagic area around the Solomon Islands and Papua New Guinea. Substantial numbers are also available throughout the warm-pool region from 25ºS to 15ºN, and 115-175ºE (Figure 2).

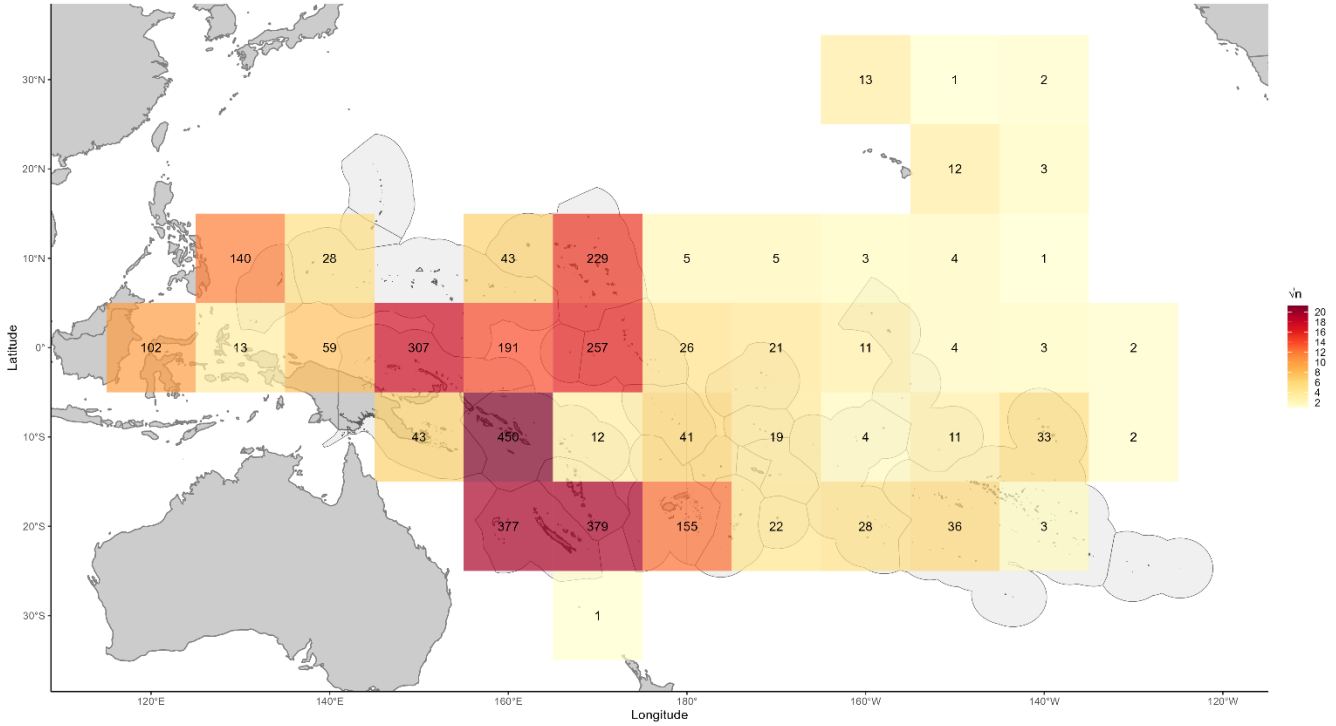


*Figure 2 Spatial distribution of the available female gonads from fish larger than 60 cm fork length. Aggregated to 10-degree squares.*

**Additional Sampling Effort**

Significant gaps have been identified in the available samples. These include:

i. A need for more samples between 60 and 120 cm FL to capture the crucial transition from immature to mature fish.
ii. A notable shortage of samples from regions south of 25°S, east of 170°E, and north of 15°N, which would enhance data robustness and geographic coverage.
iii. Insufficient samples from the first and last quarters of the year, which may correspond to potential peak spawning periods.

To address these gaps, several opportunities are proposed:

i. Forging collaborations to pool resources for sample collection:
    a. Leveraging sampling effort from the Close Kin Mark-Recapture (CKMR) project, which is a genetics-based initiative focusing on WCPO tropical tunas to estimate absolute biomass and other demographic parameters, may provide an opportunity to ensure an increased spatial and temporal coverage of samples for reproductive biology analyses (SC20-SA-WP-09).
    b. A study on the reproductive biology of three tropical tuna species (yellowfin, bigeye and skipjack tuna) is currently underway in Indonesia (BRIN) in collaboration with Australia (CSIRO). The samples were collected over two years in waters south of Java and east of Sulawesi (Davies et al. 2023). Just over 400 yellowfin tuna ovaries were collected for histological analysis and the reading protocol will be consistent with the methods being proposed in the current study. The information and samples collected from this project could be highly complementary to our efforts. By coordinating with this project, we can enhance our understanding of tuna reproductive biology in the region.
ii. Developing port sampling initiatives in underrepresented areas.
iii. Deploying personnel for biological sampling campaigns.
iv. Focusing on purse seiners operating in eastern regions and around Japan, as well as longliners with broader geographical coverage that tend to target larger fish, could effectively strengthen representation across fish size ranges.

## Planned Analyses

*Histological assessment*

Ovaries will be prepared and assessed using modern histological methods following (Brown-Peterson et al. 2011) and protocols specifically developed for tuna by Farley et al. (Farley et al. 2013; Farley et al. 2014; Farley et al. 2022). Histological assessment provides high-resolution data on gonadal development stages, allowing for precise determination of maturity status, spawning frequency, fecundity as well as spawning areas and seasons. This is crucial for developing accurate maturity ogives, estimates of total annual fecundity and estimating spawning biomass. Additionally, by standardizing the histological protocols, comparisons across different studies and regions can be undertaken (e.g., with research on yellowfin tuna reproduction currently underway in Indonesia), contributing to a more comprehensive understanding of species' reproductive biology across their range.

*Otolith Proteomics*

A team at the University of Melbourne has been actively investigating new techniques to estimate a fish's maturity using the biochemical and proteomic data naturally stored in otoliths (Thomas et al. 2019, Thomas et al. 2020). This novel maturity assay is based on estimating an individual's size- and age-at maturity from determining the presence and location of reproductive proteins trapped in otoliths. They recently discovered that otoliths archive hundreds of biomineralizing and non-biomineralizing proteins during daily increment deposition (Thomas et al. 2019). Further, they have shown that the location, and thus timing of expression, of specific proteins can be determined through immunohistochemical (i.e. antibody) staining techniques (Thomas et al. 2020). Development of this approach can reduce the need to directly observe and assess fish gonads, creating opportunities to streamline how maturity data is collected and allowing for the reconstruction of maturity and spawning time series based on already archived otolith collections. The potential for further developing and testing this method, in parallel to the planned histological assessment, will be explored using paired otolith-gonad samples in this project.

**Timeline**

| Activity | 2024 | | | | 2025 | | | | 2026 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| PMSB Audit | | | | | | | | | | | | |
| Additional Sampling | | | | | | | | | | | | |
| Inventory and Collation of existing samples | | | | | | | | | | | | |
| Preparation and processing of gonads and otoliths for histology and proteomics/chemical compounds analysis | | | | | | | | | | | | |
| Data analysis/Parameter estimation | | | | | | | | | | | | |
| Reporting | | | | | | | | | | | | |
| Final Report | | | | | | | | | | | | |

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