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13 –21 August 2025

Project 90 update: Better data on fish weights and lengths for scientific analyses

WCPFC-SC21-2025/ST-IP-03
25 July 2025

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Executive Summary

WCPFC Project 90 arose from discussions at SC13 around the need for accurate 'conversion factor' (CF) data for target and bycatch fish species captured across the western and central Pacific Ocean (WCPO). The project in its current form is now in its sixth and final year.

This paper updates SC21 on Project 90 activities undertaken since SC20 and outlines planned actions for the remainder of 2025. We note that a final report documenting all results over the life of the project will be submitted to the WCPFC Secretariat in December this year.

The past 12 months saw progress made against items 1, 2, 4 and 5 of the 2024-25 workplan as set out in Macdonald et al. (2024) [SC20/ST-IP-04]. Efforts were focussed on six main tasks (see the Table 1 below for the current status of each, with dark green = completed, light green = in progress, yellow = to do), noting that work under item 3 is scheduled for completion prior to the December 2025 project end date.

Table 1. Status of tasks listed under the 2024-25 workplan items.

2024-25 workplan item	Task	Description	Status @ 13 July 2025
1 – Updating and expanding the CF database	**1.1**	i) Undertake additional analyses to address questions raised at SC20 on the representativeness of the sex-aggregated length-weight relationship (LWR) used for the 2024 southwest Pacific striped marlin (*Kajikia audax*) assessment (Castillo-Jordán et al. 2024).	
		ii) Estimate sex-specific LWRs for input into the 2024 assessment revision (Castillo-Jordán et al. 2025) [SC21/SA-WP-06].	
	1.2	Estimate new sex-aggregated and sex-specific LWRs for input into the 2025 southwest Pacific swordfish (*Xiphias gladius*) assessment (Day et al. 2025) [SC21/SA-WP-05].	
	1.3	Finalise development of alternative statistical methods for estimating LWRs for widely distributed, commercially targeted stocks, using Pacific bigeye tuna as a case study.	
2 – Weight CF data collection for bigeye	**2.1**	i) Define the payment strategy for observer-based data collection.	
		ii) Collect further coupled gilled-and-gutted (GG) and whole weight (WW) measurements for bigeye tuna across the WCPO to improve the GG-WW relationship ahead of the 2026 stock assessment.	
3 – Database visualisation and access	**3.1**	Refine the web-based dashboard for visualising CF relationships and improve access to the CF database.	
4 – Investigation into the size data available to WCPFC stock assessments	**4.1**	Commence WCPFC Project 127: 'Review and reconciliation of size data collected in the WCPFC-CA for stock assessment purposes'. An update on phase 1 of the project is available in Hamer et al. (2025) [SC21/ST-WP-02] and will be presented to SC21.	
5 – Length CF data collection for south Pacific albacore	**5.1**	Design and implement a data collection plan to estimate a new length-to-length CF (i.e. a 'finlet-to-fork' relationship) for south Pacific albacore tuna to support age estimation for the ongoing close-kin mark-recapture (CKMR) study (WCPFC Project 100c) (SPC and CSIRO 2025 [SC21/SA-WP-09]; CSIRO and SPC 2025 [SC21/SA-WP-14]).	

We note that all tasks listed in the 2024-25 Project 90 workplan are either completed, or progressing on schedule at the time of writing. Additional detail on the status of and key outcomes for each task is presented in section 2 and the appendices of this paper. In section 3, we outline the work programme up to December 2025, and in section 4 we provide some recommendations for future directions for WCPFC Project 90 tasks following the scheduled project end date.

We invite SC21 to:

1. review and comment on the progress made on WCPFC Project 90 tasks since SC20;
2. note that a final project report summarising all work conducted under Project 90 since its inception will be submitted to the WCPFC Secretariat in December 2025; and
3. consider the continuation of key Project 90 tasks into 2026 and beyond, either integrated within phase 2 of WCPFC Project 127 or as part of a new WCPFC project focussed on improving size data inputs for stock assessments.

1. Background

WCPFC Project 90 evolved from discussions at SC13 regarding regional estimates of purse seine and longline bycatch (Peatman et al. 2017; 2018a, b), and the need for accurate 'conversion factor' (CF) data for targeted and bycatch fish species.

Following these discussions, SC13 recommended that the Scientific Services Provider (SPC) be tasked with:

a. designing and coordinating the systematic collection of representative length measurements for bycatch species; and
b. designing and coordinating the systematic collection of length-to-length, length-to-weight and weight-to-weight CF data on all species.

These recommendations have shaped the work undertaken within Project 90 since its inception in 2019. Now in its sixth and final year, the scope of the project has expanded to incorporate analyses and modelling of the length and weight data where needed, particularly for the purposes of updating key CF relationships for WCPFC tuna and billfish stock assessments.

This paper updates SC21 on Project 90 activities over the past 12 months, focussing specifically on progress against the 2024-25 workplan items and tasks listed in Table 1 in the Executive Summary. We also outline planned activities for the remainder of 2025, noting that a final report documenting all work conducted across the life of the project will be submitted to the WCPFC Secretariat in December 2025.

2. Progress against the 2024-25 workplan

Task 1.1

Questions were raised at SC20 around the representativeness of the eye orbital fork length (EFL, a.k.a. EO) to whole weight (WW) relationship used in the 2024 southwest Pacific striped marlin (*Kajikia audax*) assessment (Castillo-Jordán et al. 2024) and the consequences of this for the estimation of key management quantities. Specifically, there were concerns regarding the potential for spatial variation in the length-weight relationship (LWR) to exist across the assessment region that was not adequately captured in the dataset from Kopf et al. (2011), upon which the EFL-WW relationship was developed last year.

Two sets of analyses were undertaken to address these issues:

i) Follow-up analyses conducted by SPC (full details available in Appendix 1) have confirmed that the dataset collected by Kopf et al. (2011) (*n* = 113 coupled length and weight records) remains the best available for estimating the EFL (in cm) to WW (in kg) relationship for southwest Pacific striped marlin. In comparison with other datasets available to SPC, including data from the New Zealand recreational fishery, the Kopf et al. (2011) dataset spans the largest range of EFL lengths, with measurements sourced across the broadest spatial domain in the WCPO. We highlight that this dataset was used to estimate the sex-aggregated LWR in the 2024 MULTIFAN-CL assessment (Castillo-Jordán et al. 2024).

ii) With the move from MULTIFAN-CL to a two-sex Stock Synthesis (SS3) model for the 2024 assessment revision (Castillo-Jordán et al. 2025 [SC21/SA-WP-06]; Ducharme-Barth et al. 2025 [SC21/SA-IP-15]), new sex-specific EFL-WW relationships were estimated for southwest Pacific striped marlin, again based on the Kopf et al. (2011) dataset (see Appendix 1, Figure A4).

The sex-aggregated and sex-specific parameter estimates for allometric equations of the form WW = $a \times \text{EFL}^b$, as estimated in i) and ii) above, are as follows:

<u>Sex-aggregated</u>
a = 5.425259e-07 (95% CI: 2.349155e-07, 1.252937e-06)
b = 3.583776 (95% CI: 3.424904, 3.742648)

<u>Females</u>
a = 4.849174e-07 (95% CI: 1.906227e-07, 1.233562e-06)
b = 3.608258 (95% CI: 3.431708, 3.784808)

<u>Males</u>
a = 1.087518e-06 (95% CI: 1.911076e-07, 6.188637e-06)
b = 3.445321 (95% CI: 3.113681, 3.776961)

Note that all '*a*' parameter estimates and confidence intervals (CI) presented above have been corrected to account for the negative bias caused by the log transformation that shifts the basis of the regression from the mean to the geometric mean.

While these parameter estimates represent the latest available, and we recommend their use for the 2024 southwest Pacific striped marlin assessment revision (Castillo-Jordán et al. 2025), our follow-up work has identified a clear need for the collection of additional representative length and weight data from across the WCPO to re-estimate these LWRs ahead of the next assessment, scheduled in 2029.

Annotated R code to reproduce these analyses is available on the SPC shared drives at 'P:/OFPEMA/Project 90/Data/2024 data/MLS_assessment_LW/MLS_length-weight_relationship', and full results will be made available in the final Project 90 report.

Task 1.2
The southwest Pacific swordfish assessment is also shifting to a two-sex SS3 model configuration in 2025. To this end, new sex-aggregated and sex-specific LWRs were estimated for this year's assessment (Day et al. 2025) [SC21/SA-WP-05] based on the most recent data available. This analysis drew on coupled measurements of lower jaw fork length (LJFL) (in cm) and whole weight (WW) (in kg) recorded by WCPO fisheries observers, with data sourced from two datasets:

obsvGEN4_LW: data collected on the 'GEN4' data form by Australian and New Zealand observers from swordfish captured in Australian and New Zealand waters between 1988 and 2008 (*n* = 3,209 after filtering steps) (Figure 1 left panel). This dataset contained no information on the sex of captured individuals.

obsvLL4_LW: data collected on the 'LL4' data form by WCPO observers from swordfish captured off New Zealand and in more tropical waters across the central WCPO between 2011 and 2023 (*n* = 3,814 after filtering steps) (Figure 1 right panel). This dataset contained information on the sex of captured individuals. We note that this dataset (minus the three most recent years of data) was used to estimate the LJFL-WW relationship for the 2021 southwest Pacific swordfish assessment (Ducharme-Barth et al. 2021a, b) [SC17/SA-IP-07, SC17/SA-WP-04].

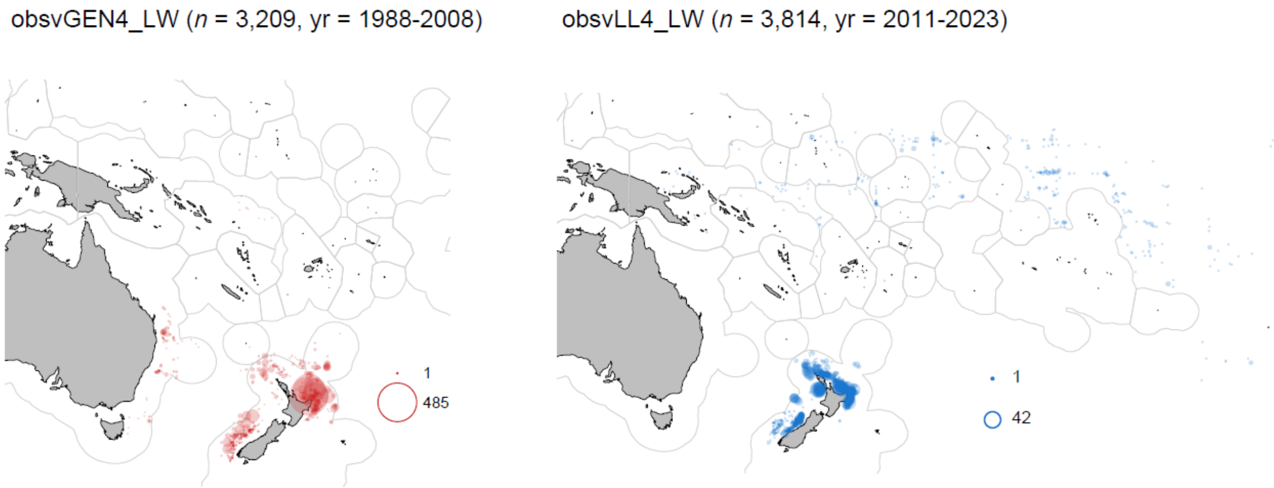

Figure 1. Spatial and temporal coverage of coupled LJFL and WW records in the obsvGEN4_LW (left, red circles) and obsvLL4_LW (right, blue circles) datasets. Circle size reflects the number of records collected at a particular location and is scaled for each dataset separately. *n*, the total sample size available per dataset after filtering, yr, period covered.

The sex-aggregated relationship of the form WW = $a \times \text{LJFL}^b$ was estimated on the obsvGEN4_LW and obsvLL4_LW datasets combined, whereas relationships for females and males separately were estimated on the obsvLL4_LW dataset alone. The parameter estimates are as follows, noting again, that all '*a*' estimates and their 95% CIs have been bias-corrected:

Sex-aggregated
a = 2.774087e-06 (95% CI: 2.511274e-06, 3.064404e-06)
b = 3.303671 (95% CI: 3.284199, 3.323144)

Females
a = 6.565533e-06 (95% CI: 5.228345e-06, 8.244715e-06)
b = 3.139509 (95% CI: 3.095440, 3.183577)

Males
a = 8.942387e-06 (95% CI: 6.448529e-06, 1.240070e-05)
b = 3.063015 (95% CI: 2.998319, 3.127711)

Key results from the sex-aggregated analysis are as follows:

- There was close agreement in mean predicted weight-at-length for the obsvGEN4_LW and obsvLL4_LW datasets across the full LJFL range; however, variability in weight-at-length was consistently higher for the obsvLL4_LW dataset (Figure 2).
- A notable difference was observed in the mean predicted weight-at-length for the new sex-aggregated LWR compared with that used in the 2021 diagnostic case (Ducharme-Barth et al. 2021b) (Figure 2). This difference was driven primarily by the inclusion of the obsvGEN4_LW dataset into the current analysis (not used in 2021), changes to filtering steps used for the obsvLL4_LW dataset (i.e. including only records where LJFL and WW were both measured directly on an individual, with no reliance on other CFs to convert measurements of other length or weight codes to LJFL or WW), and the bias-correction of the '*a*' parameter estimate undertaken for the 2025 assessment, though we note that this correction had a comparatively minor influence on the mean predicted weight-at-length.

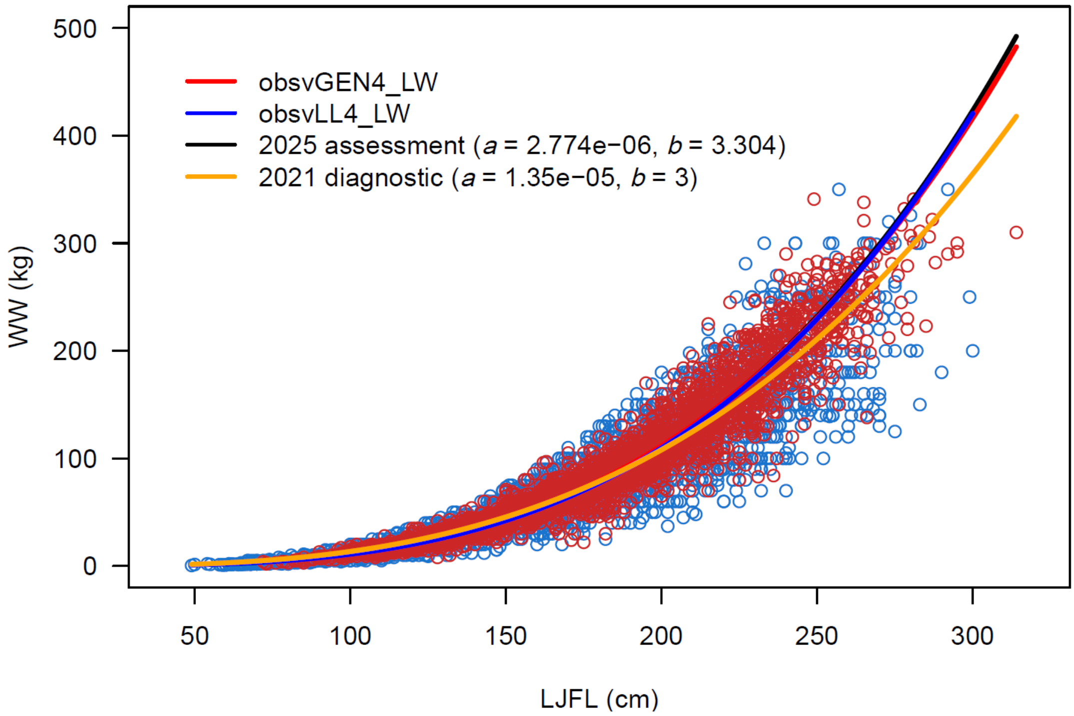

Figure 2. Comparison of sex-aggregated LJFL-WW relationships estimated for southwest Pacific swordfish from the obsvGEN4_LW dataset (red circles and line) and the obsvLL4_LW (blue circles and line) dataset. Circles are coupled LJFL and WW records and lines are the mean predictions of weight-at-length. Also shown are the mean predictions of weight-at-length (and parameter estimates in brackets) for the new sex-aggregated LJFL-WW relationship estimated for the 2025 assessment (black line) and from the 2021 diagnostic case model (orange line).

- Following discussions at the 2025 Pre-Assessment Workshop (PAW), we also assessed evidence for spatial variation in the LJFL-WW relationship for the sex-aggregated case. We found preliminary evidence of longitudinal (using the obsvGEN4_LW dataset) and latitudinal (using the obsvLL4_LW dataset) differences in the LWR parameter estimates, noting that these comparisons were likely influenced by the small sample sizes available for some strata, and/or sex and/or temporal differences not accounted for directly in the modelling that require further evaluation. Overall, the results supported the inclusion of data from across the broadest spatial area possible, which was done. This allowed us to implicitly capture any spatial variation that may be present in the sex-aggregated LWR for the 2024 assessment revision.

Key results from the sex-specific analysis are as follows:

- A significant difference was observed in the mean predicted weight-at-length between males and females as estimated from the obsvLL4_LW dataset. On average, females were always larger than males at a given length, with this difference becoming more pronounced for individuals over 150 cm LJFL (Figure 3).
- These findings support the choice of a two-sex SS3 model structure for the 2025 assessment.

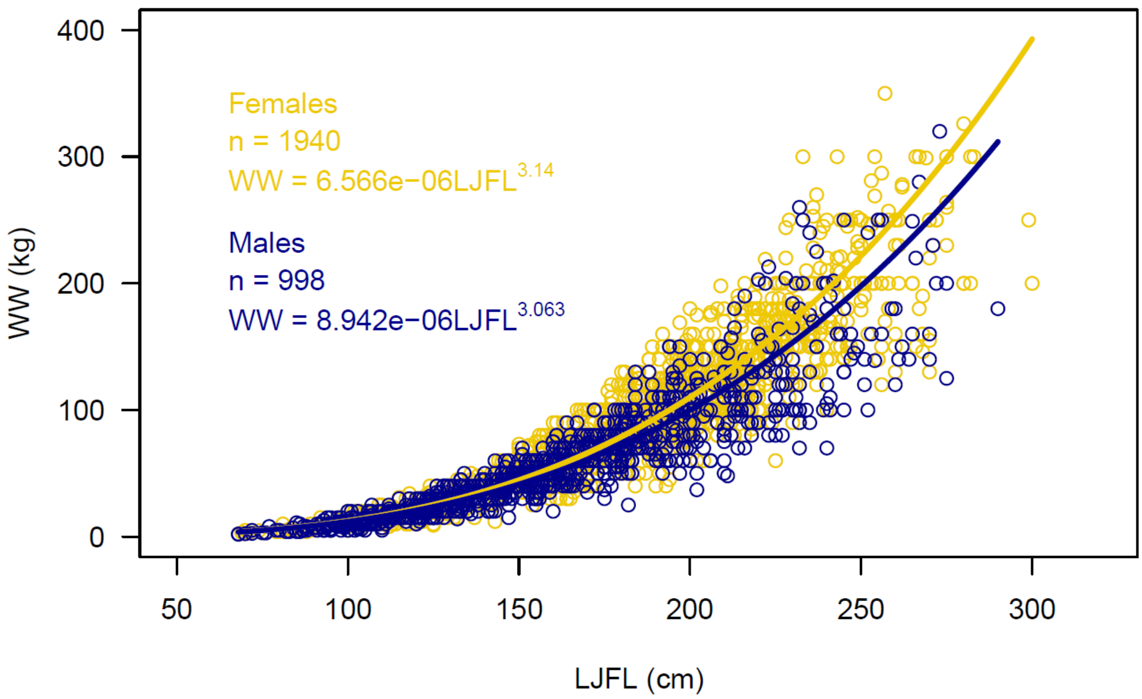

Figure 3. Comparison of sex-specific LJFL-WW relationships estimated for southwest Pacific swordfish from the obsvLL4_LW dataset. Circles are coupled LJFL and WW records and lines are the mean predictions of weight-at-length for females (gold circles, lines and text) and males (blue circles, lines and text).

Annotated R code to reproduce these analyses is available on the SPC shared drives at 'P:/OFPEMA/Project 90/Data/2025 data/SWO_assessment_LW/SWO_length-weight_relationships', and full results will be made available in the final Project 90 report.

Task 1.3

We have finalised work on an alternative statistical framework for the estimation of LWRs based on generalised additive mixed models (GAMMs). This framework was first introduced at SC19 (see Appendix 1 in Macdonald et al. 2023 [SC19/ST-IP-04]), with the modelling pipeline refined over the past two years to address common issues associated with length and weight data collection in fishery observer programs, including measurement error, protocol changes, spatial effects and observer effects.

This work has recently been submitted for publication in the journal *Fish and Fisheries*, with the paper entitled 'Reimagining the estimation of length-weight relationships through the eyes of bigeye tuna (*Thunnus obesus*) in the Pacific' by Hoyle et al. currently under peer review and available here as a pre-print. In essence, the findings highlight the advantages of more sophisticated analytical approaches than the simple power functions typically used to estimate LWRs in fisheries science. We use data on Pacific bigeye tuna for illustration in the paper; however, the methods presented are broadly applicable to other WCPO tuna and billfish stocks, offering useful insights into the sources of variation in estimated LWRs, even if the models currently used to assess WCPFC stocks cannot always incorporate all such sources of variation.

Task 2.1

i) Project 90 continues to support data collection aimed at improving the gilled-and-gutted weight (GG) to whole weight (WW) relationship for large bigeye tuna in the WCPO (see Macdonald et al. 2023 [SC19/ST-IP-04] for the most recent update to this relationship). Given the challenges in obtaining GG and WW data outside of the Philippines due to the way bigeye are typically processed at sea, SPC co-signed letters of Agreement with Tonga, the Cook Islands and the Republic of the Marshall Islands in 2024 that outlined alternative approaches for collecting the required data (i.e. involving the sampling and storage of gills-and-guts at sea, and weighing these in port at the conclusion of each trip – see here for the Terms of Reference for full details of the sampling protocol). Data collection for this project relies on fisheries observers deployed on longline vessels. MRAG, an SPC research partner, supports payments to observers for biological sampling tasks, and a process was initiated through MRAG in early 2025 that has paved the way for observers to receive a separate payment per fish for collecting GG and WW data in addition to payments for routine biological sampling tasks carried out onboard.

ii) In mid-2024, fisheries observer Iowane Koroi undertook the first at-sea data collection trip for this project onboard a longliner that unloaded in Apia, Samoa, collecting ~200 GG and WW records on bigeye. This trip highlighted some of the logistical challenges associated with collecting this type of data - particularly around limitations in storage space for heads and tails of large bigeye on commercial vessels. A presentation outlining the status and data requirements for this project was given at the inaugural Tuna Research and Applications (TRAW) Workshop, held in Nuku'alofa, Tonga, in April 2025, and this has provided impetus for a second data collection trip currently underway. Details on the outcomes of this trip and an updated GG-WW relationship for WCPO bigeye will be provided in the final Project 90 report.

Task 4.1

Following discussions with the SPC Stock Assessment and Modelling (SAM) team in the lead up to SC20, the 2024-25 Project 90 workplan (under item 4) identified an investigation into the size data available to WCPFC assessments as a priority task. Enter WCPFC Project 127: 'Review and reconciliation of size data collected in the WCPFC-CA for stock assessment purposes', a two-year project dedicated to such an investigation.

The paper by Hamer et al. (2025) [SC21/ST-WP-02] updates SC21 on results from phase 1 of this project. Hamer al. (2025) focus on the compilation of size composition data available for WCPO tunas, billfish and sharks and review the length-length, weight-weight and length-weight CFs available to the SAM team, noting their importance in the generation of reliable size data for WCPFC stock assessments. This review also highlighted the need for further scrutiny of several length-length and weight-weight CFs currently in use, particularly those for billfish. The phase 2 workplan, scheduled for 2026, will focus on further exploration of historical data quality/suitability, technical analysis of data coverage deficiencies, an appraisal of current data collection sources, and the improved statistical treatment of size data for use in stock assessments.

Clear overlaps exist between the objectives of WCPFC Projects 90 and 127. Whilst supporting the phase 2 workplan throughout the remainder of 2025, Project 90 also supports broader recommendations set out in Hamer et al. (2025) to improve documentation around reporting of size data collections for assessed stocks. These recommendations are echoed in the paper described in **Task 1.3,** both in the need for establishing standardised data collection protocols to obtain the most representative data possible for the species/stock of interest, and in promoting best practices for data exploration in the estimation of LWRs and other CFs.

Task 5.1

With the tuna genetics sampling programme now fully operational across the Pacific region, a priority has emerged to develop new CF relationships between fork length and other measurements along the fish's tail (e.g. distance from 2nd finlet to the caudal fork) for the region's key tuna stocks. These 'finlet-to-fork' relationships will allow us to estimate fork length, and hence annual age, for each fish sampled for CKMR or other genetic/ecological studies when only the tail is available for genetic sampling, noting that estimated age represents a key input for CKMR models.

Through Project 90, we have drafted a study design and data collection plan for this work (available in Appendix 2). The plan encompasses data collection for the four key tuna species targeted across the WCPO, with the current priority on south Pacific albacore in support of the ongoing CKMR study being conducted under WCPFC Project 100c (SPC and CSIRO 2025 [SC21/SA-WP-09]; CSIRO and SPC 2025 [SC21/SA-WP-14]).

Data collection is underway across the region, with required numbers of measurements already collected from New Zealand. We envisage that data collection across all ports will be completed in the coming months, with the new CF relationships to be presented in the final Project 90 report.

3. Workplan for the remainder of 2025

The following tasks will be prioritised over the next five months:

1. Update and review the CF database.
2. Complete the data collection and analytical work needed for updating the GG-WW relationship for bigeye.
3. Refine the web-based dashboard for visualising CF relationships and improve access to the CF database via the Tufman2 interface (**Task 3.1** in Table 1).
4. Support phase 2 work scheduled under WCPFC Project 127.
5. Complete the data collection and analytical work needed for developing the 'finlet-to-fork' relationship for south Pacific albacore in support of WCPFC Project 100c.
6. Collate all work conducted to date under WCPFC Project 90 and comnplete the final report due for submission to the WCPFC Secretariat in December 2025.

4. Recommendations

As alluded to in Hamer et al. (2025), there is still work to do towards obtaining the most reliable conversion factors for use in WCPFC stock assessments, particularly with regard to length-length and weight-weight relationships for billfish. These relationships are used in the conversion of the size data that go into the assessments, and ideally should be traceable, linked to their source data, inspected regularly, and updated as new data comes to hand.

To this end, though WCPFC Project 90 is due to finish in December 2025, we recommend that tasks 1 and 3 of the 2025 workplan (outlined in section 3) be continued into 2026 and beyond, potentially under the auspices of WCPFC Project 127 or as part of a new WCPFC project focussed on improving size data inputs for stock assessments.

We invite SC21 to:

4. review and comment on the progress made on WCPFC Project 90 tasks since SC20;
5. note that a final project report summarising all work conducted under Project 90 since its inception will be submitted to the WCPFC Secretariat in December 2025; and
6. consider the continuation of key Project 90 tasks into 2026 and beyond, either integrated within phase 2 of WCPFC Project 127 or as part of a new WCPFC project focussed on improving size data inputs for stock assessments.

5. Acknowledgements

We thank Rosanna Bernadette Contreras and the SFFAII team for their continued commitment to biological sampling, CF data collection and tag recovery at General Santos Port, Philippines. Thanks to the CSEPTA team at SPC, Russ Bradford at CSIRO and Mike O'Driscoll at NIWA (New Zealand) for their ongoing support on data collection required for estimating the 'finlet-to-fork' relationships. Simon Hoyle and Eric Chang are thanked for leading and contributing to the development of the Pacific bigeye LWR modelling framework.

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Appendix 1: Follow-up work on southwest Pacific striped marlin length-weight relationships

Prepared by Jed Macdonald

Background

In the search to explain the conflict observed between the size composition data and CPUE indices in the 2024 southwest Pacific striped marlin (*Kajikia audax*) assessment (Castillo-Jordán et al. 2024), questions arose during SC20 around the representativeness of the eye fork length (EFL, a.k.a. EO) to whole weight (WW) relationship used in the assessment (detailed in the WCPFC Project 90 paper presented to SC20 – Macdonald et al. 2024 [SC20/ST-IP-04]) and the consequences of this for the estimation of key management quantities. In particular, concern was raised regarding the potential for spatial variation in the length-weight relationship to exist across the assessment region that was not adequately captured in the dataset from Kopf et al. (2011), upon which the EFL-WW relationship was developed this year.

Follow-up work has now been undertaken by SPC to explore this issue. The work had four objectives:

1. To collate available information on published length-weight relationships for striped marlin across ocean basins to allow comparison of parameter estimates with those derived from the Kopf et al. (2011) data as used in the 2024 assessment.
2. To identify and explore other relevant datasets comprising coupled EFL and WW measurements for southwest Pacific striped marlin.
3. To confirm if the back-transformed '*a*' parameter estimated for the EFL-WW relationship used in the 2024 assessment has been corrected for the negative bias induced by the log transformation (Miller 1984; Hayes et al. 1995; Brodziak 2012).
4. To further explore the Kopf et al. (2011) dataset for evidence of spatial variation in the EFL-WW relationship within the WCPO. This exploration involved two components:
    a) Comparison between sampling locations – i.e. Australia, New Zealand.
    b) Comparison of the EFL-WW relationship used in the 2024 assessment with relationships derived from a larger number of coupled lower jaw fork length (LJFL) and WW records collected for the Kopf et al. (2011) study. These LJFL records come from fish captured in Australian, New Zealand and Fijian waters, and were first converted to EFL prior to fitting the EFL-WW relationships.

This document details the key results of this follow-up work.

Results

Objectives 1 and 3

Table A1 documents the results of a literature search on length-weight relationships published to date for striped marlin across all oceans. Note that only relationships confirmed as estimated directly from coupled measurements of EFL and WW made on the same fish are reported in the table. We searched the Google, Google Scholar and FishBase v. 06/2024 databases (Froese and Pauly 2024) [all accessed 18 October 2024], using search terms including “striped marlin length and weight”, “striped marlin length-weight relationship”, “striped marlin growth”. We also tracked cited references and citing references where available.

Table A1. Summary of published eye fork length (EFL) (cm) to whole weight (WW) (kg) relationships for striped marlin (*Kajikia audax*) across all oceans.

Ocean	Area	Sampling period	Sex	n	EFL range (cm)	WW range (kg)	*a*	95% CI of *a*	*b*	95% CI of *b*	R^2	References
South Pacific (WCPO)	Australia, New Zealand	2005-2008	Combined	114	107-240	9-168	Naïve: 5.3994e-07 Bias-corrected: 5.425259e-07	Naïve: 2.3380e-07, 1.2470e-06 Bias-corrected: 2.349155e-07, 1.252937e-06	3.583776	3.424904, 3.742648	0.95	Macdonald et al. (2024) [SC20 ST-IP-04] - derived from data associated with Kopf et al. (2011)
North Pacific, (EPO)	Cabo San Lucas, Mexico	1990-2015	Male	3214	122 - 204	16.1 - 81	1.96×10-5	1.64e-05, 2.34e-05	2.860	2.826, 2.894	0.91	Ortega-García et al. (2018)
“	“	“	Female	3118	114 - 209	14 - 90	1.14×10-5	9.48e-06, 1.38e-05	2.967	2.930, 3.004	0.90	“
“	“	“	Combined	6332	114 - 209	14 - 90	1.37×10-5	1.20e-05, 1.56e-05	2.930	2.905, 2.956	0.91	“
Pacific (EPO)	East of 130° W, from Pt Conception, USA, to Talcohuano, Chile	1963-1967	Combined	51	108 - 211	NR	5.5565×10-6	NR	3.0888	NR	NR	Kume and Joseph (1969), IATTC (2002)
Pacific (EPO)	San Diego, California, USA; Baja California Sur Mexico; MazaUh, Sinnloa, Mexico	1967-1970	Male	975	120 - 203	NR	9.885531e-06	NR	2.999	NR	0.877	Wares and Sakagawa (1974), Ueyanagi and Wares (1975)
“	“	“	Female	1007	110 - 215	NR	5.714786e-06	NR	3.113	NR	0.854	“
“	“	“	Combined	1982	110 - 215	NR	6.9663×10-6	NR	3.071	NR	0.864	“
Indian (equatorial western Indian Ocean)	NR	1964-1967	Male	65	143 - 193	28.6 - 68.5#	1.576396e-05*	NR	2.917	NR	NR	Merrett (1968)
“	NR	“	Female	91	120 - 196	14.1 - 85.3#	5.554761e-06*	NR	3.121	NR	NR	“
“	NR	“	Combined	156	120 - 196	NR	7.493167e-06*	NR	3.062	2.865, 3.260	NR	“
Indian	East Africa	Pre-1962	Combined	98	NR	NR	1.064916e-05*	NR	2.84448	NR	NR	Williams (1962) cited in Merrett (1968)
Northwest Pacific	Waters off Taiwan	2004-2010	Combined	1037	No length range reported. Estimated as ~90 - 220 from Fig. 1	No weight range reported. Estimated as ~5 - 130 from Fig. 1	4.68 x 10-6	NR	3.16	NR	0.91	Sun et al. (2011)

Values were originally reported in lb in Merrett (1968). These have been converted to kg here.

* The *a* parameter estimates presented in Merrett (1968) describe the EFL-WW relationship in terms of cm and lb. Accordingly, we multiplied the back-transformed (inverse log10) estimates for *a* by 0.453592 to place the relationships in terms of cm and kg.

NR = not reported.

Our Google and Google Scholar searches uncovered additional studies that reported length-weight relationships for striped marlin using alternative length measurements such as LJFL (e.g. Kopf et al. 2005, 2011), tip of snout to the caudal fork (e.g. Skillman and Yong 1974) or pectoral fork length (Setyadji et al. 2012), or weight measurements such as gilled-and-gutted weight (e.g. Koga 1967). Others did not clarify the length and/or weight measurement recorded (e.g. Ponce-Díaz et al. 1991) and these are not considered further here. Our search of FishBase returned 11 records for length-weight relationships derived from data collected in New Zealand, Indonesia, South Africa, Hawaii, the EPO and the equatorial western Indian Ocean (see https://www.fishbase.se/popdyn/LWRelationshipList.php?ID=223&GenusName=Kajikia&SpeciesName=audax&fc=419), plus the Bayesian estimates of *a* and *b* derived through the approach of Froese et al. (2014). Examination of the references underpinning these relationships revealed in most cases that either EFL was not measured directly (e.g. Merrett 1971; Skillman and Yong 1974; Holdsworth and Saul 2004; Kopf et al. 2005; Setyadji et al. 2012) or that the length code used was not clarified in the document (Torres 1991). Exceptions were relationships developed or reviewed by Kume and Joseph (1969), Wares and Sakagawa (1974) and Ueyanagi and Wares (1975) and details of these were added to Table A1.

The study by Kopf et al. (2011) is of particular interest in the context of the 2024 WCPFC southwest Pacific striped marlin assessment. Whilst Kopf et al. (2011) did not derive an EFL-WW relationship for southwest Pacific striped marlin, they did measure a total of 114 coupled EFL and WW measurements on fish captured from the Australian (n = 55) and New Zealand (n = 59) EEZs between 2005 and 2008. Following internal discussions at SPC, it was considered that these measurements represented the best available data upon which to develop an EFL-WW relationship for the 2024 assessment.

Keller Kopf kindly granted SPC access to this dataset in the lead up to SC20 and this was used to model WW as a function of EFL for 113 of the 114 records using the standard allometric equation $WW = aEFL^{b}\xi$ (Eq. 1) where ξ is a lognormally distributed multiplicative error term. Applying a natural log transformation to this equation gives $\ln(WW) = \ln(a) + b\ln(EFL) + \epsilon$, where $\epsilon = \ln(\xi)$ and is normally distributed with mean = 0 and constant variance. The *a* and *b* parameters were then estimated by linear regression and the maximum likelihood estimate of parameter *a* back-transformed from the logarithmic scale to obtain the parameter estimates on the original scale (see Macdonald et al. 2024 [SC20/ST-IP-04] for full details and a link to R code to reproduce this analysis). The parameter estimates based on the Kopf et al. (2011) dataset are reported in the first row of Table A1 and were:

a_{naive} = 5.3994e-07 (95% CIs: 2.3380e-07, 1.2470e-06)

$a_{bias\text{-}corrected}$ = 5.425259e-07 (95% CIs: 2.349155e-07, 1.252937e-06)

b = 3.583776 (95% CIs: 3.424904, 3.742648)

The above estimate of a_{naive} is given by exp(ln*a*). This estimate does not account for the negative bias caused by the log transformation that shifts the basis of the regression from the mean to the geometric mean (Miller 1984; Hayes et al. 1995; Brodziak 2012). The bias can be corrected by multiplying exp(ln*a*) by $\exp(\sigma^2/2)$ (Sprugel 1983; Miller 1984), where σ^2 is the residual variance of the regression model, which, when applied to a_{naive} above, produced $a_{bias\text{-}corrected}$ of 5.425259e-07 (see row 1 in Table A1).

To clarify what was done for the 2024 assessment, the mean prediction of weight-at-length presented in Figure 3 of Macdonald et al. (2024) used $a_{bias\text{-}corrected}$. However, a_{naive} was reported in the paper as the final estimate of *a*. Importantly, the use of $a_{bias\text{-}corrected}$ or a_{naive} had minimal influence on the predicted EFL-WW relationship for southwest Pacific striped marlin (see Figure A1), with the difference in mean predicted whole weight for a 240 cm EFL individual less than 1 kg. Nonetheless, we advise using $a_{bias\text{-}corrected}$ for future work on this assessment in the lead up to SC21.

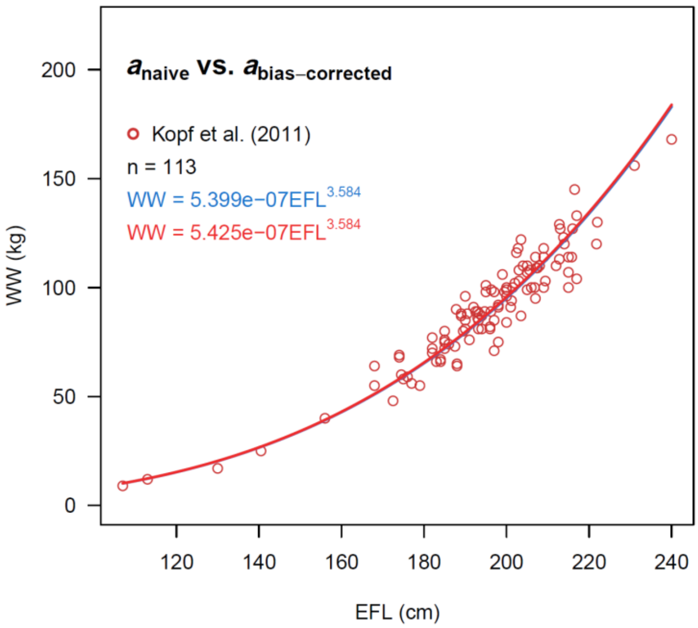

Figure A1. Comparison of EFL-WW relationships for southwest Pacific striped marlin derived using the naive estimate of the *a* parameter (a_{naive}) and the bias-corrected estimate ($a_{bias\text{-}corrected}$) Red circles are coupled EFL and WW measurements associated with Kopf et al. (2011). Equations in blue and red text denote the EFL-WW relationships that use a_{naive} and $a_{bas\text{-}corrected}$, respectively. The blue and red lines are the mean predictions of weight-at-length using a_{naive} and $a_{bas\text{-}corrected}$, respectively.

When the EFL-WW relationships identified in our review are plotted together (see Figure A2), we see that all except the Williams (1962) and Kume and Joseph (1969) curves predict similar weight-at-length for fish up to ~ 160 cm EFL. Above this size, the relationship derived from the Kopf et al. (2011) data for the 2024 assessment predicts the heaviest weight-at-length of all curves presented in Table A1.

The Sun et al. (2011) curve most closely aligns with the 2024 assessment relationship (Figure A2). This curve was based on a substantial number of fish captured in northwest Pacific waters off Taiwan, the closest region geographically to the collection locations for the Kopf et al. (2011) data of any relationship identified, and sitting within the northwestern region of the WCPO.

The three relationships from the EPO (Kume and Joseph 1969; Wares and Sakagawa 1974; Ortega-García et al. 2018) while varying in sample size, time period covered and shape of the mean curve, all predict lower weight-at-length than those from the WCPO, particularly for individuals greater than 160 cm EFL.

The two relationships presented from the Indian Ocean (Williams 1962; Merrett 1968) were based on relatively few observations and were wildly divergent in their predictions (Figure A2). At present, we place low confidence in the Williams (1962) estimates. We were unable to gain access to the original paper and had to rely on information cited within Merrett (1968) to reconstruct the Williams (1962) curve.

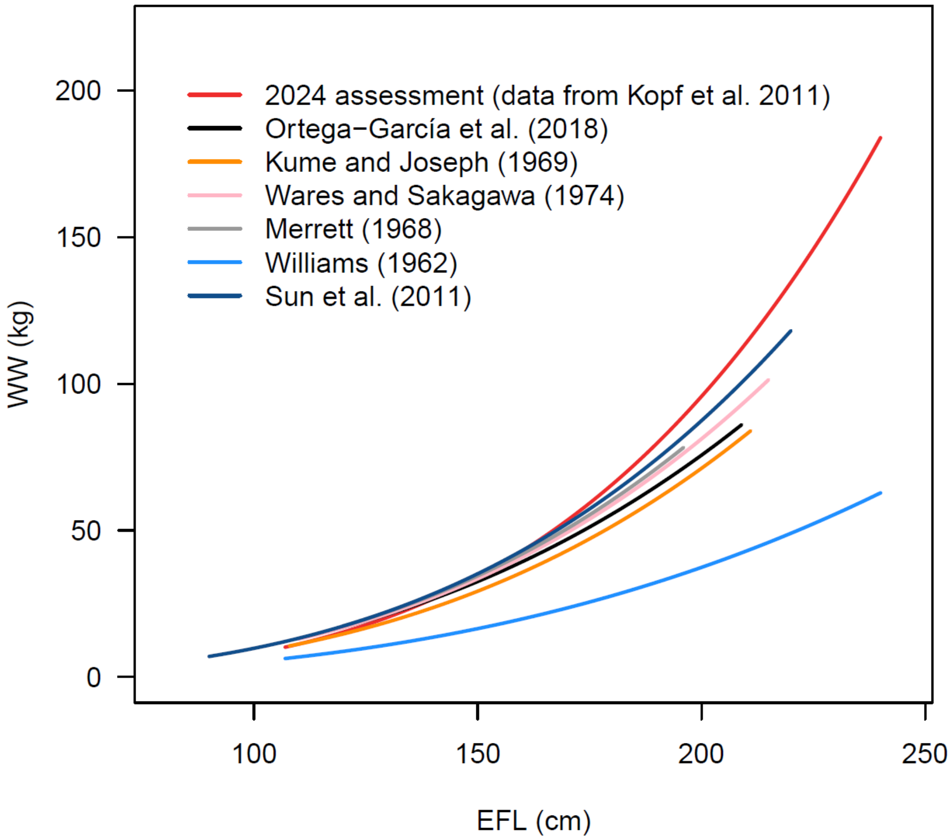

Figure A2. Mean predictions of weight-at-length from published EFL-WW relationships for striped marlin across all oceans, as reviewed in Table A1. Only relationships for both sexes combined are presented for comparison. Each relationship is plotted across the EFL range reported in that study when available. If the length range was not provided (i.e. for Williams 1962), we used the length range of the Kopf et al. (2011) data used to develop the EFL-WW relationship for the 2024 assessment.

Objective 2

John Holdsworth (Blue Water Marine Research Ltd) kindly provided SPC access to measurements (n = 542 after filtering) of EFL (in cm) and WW (in kg), by sex, recorded for striped marlin captured by the recreational fishery off New Zealand's North Island between 1985 and 2020. John confirmed that the length measurements were made using a tape measure, as were those made by Kopf et al. (2011). Therefore, we assume that any biases associated with measuring length in this manner, as opposed to using a standard measuring caliper, would be common to both datasets.

A comparison of the sex-aggregated EFL-WW relationships estimated for the 2024 southwest Pacific striped marlin assessment revision based on the Kopf et al. (2011) dataset (Castillo-Jordán et al. 2025) [SC21/SA-WP-06] and the New Zealand recreational fishery data reveals far higher variability in measured WW at a given EFL for the New Zealand data, and a very different mean predicted weight-at-length (see Figure A3).

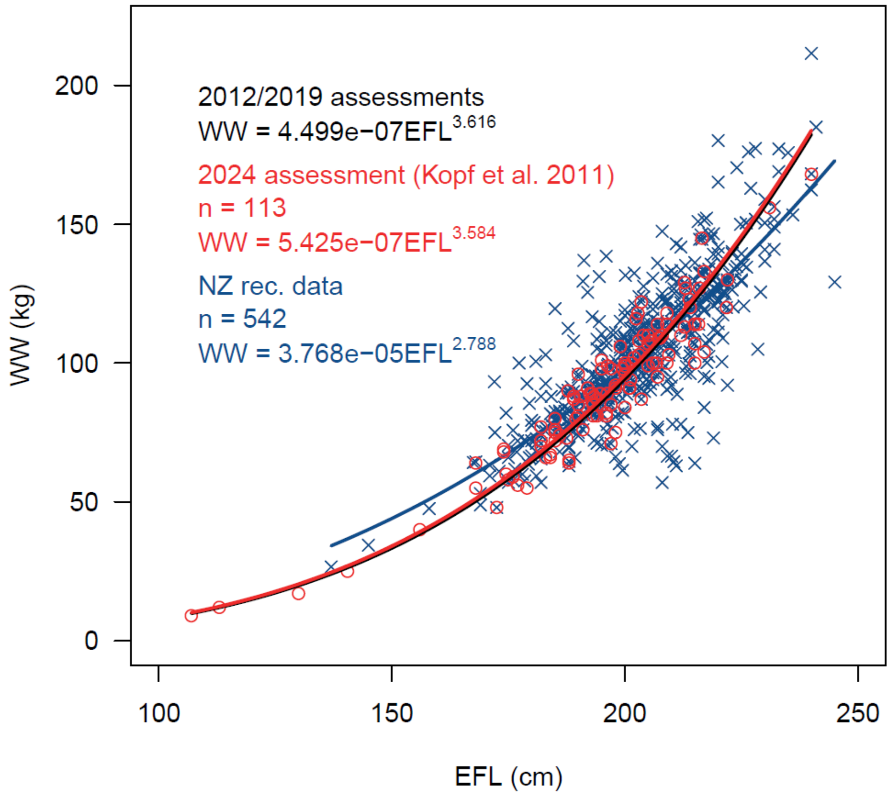

Figure A3. Comparison of sex-aggregated EFL-WW relationships estimated for the 2024 southwest Pacific striped marlin assessment revision based on the Kopf et al. (2011) dataset (red circles, line and text) and the New Zealand recreational fishery data (blue crosses, line and text). Symbols are coupled EFL and WW records and lines are the mean predictions of weight-at-length. Also shown for reference is the EFL-WW relationship used for the 2012 (Davies et al. 2012) and 2019 (Ducharme-Barth et al. 2019) assessments (black line and text).

We observe that the bulk of the New Zealand recreational fishery data was clustered around EFLs between 150 and 250 cm, which impacted the shape of the estimated relationships for males and females and made direct comparisons with the sex-specific relationships estimated from Kopf et al. (2011) rather challenging (Figure A4).

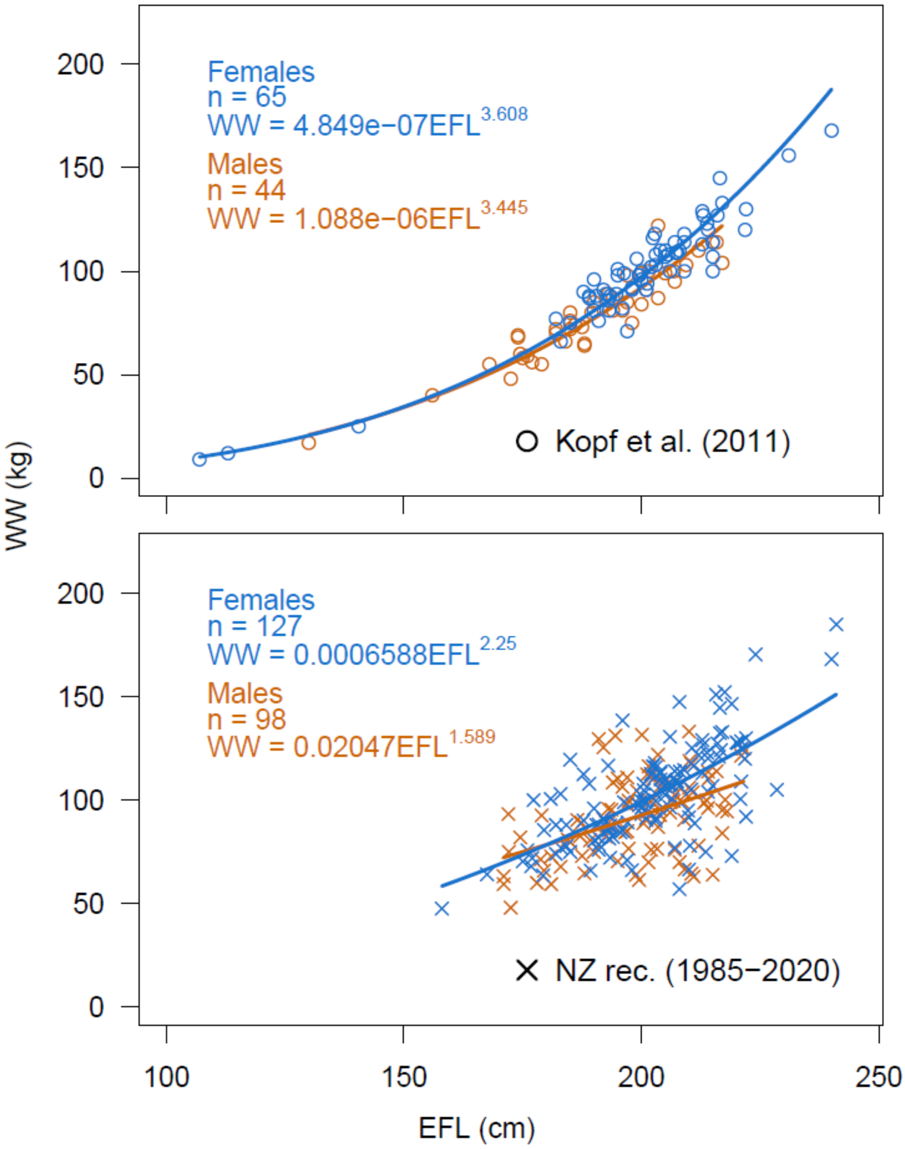

Figure A4. Comparison of sex-specific EFL-WW relationships estimated for southwest Pacific striped marlin from the Kopf et al. (2011) (top panel) and New Zealand recreational fishery (bottom panel) datasets. Symbols in each panel are coupled EFL and WW records and lines are the mean predictions of weight-at-length for females (blue symbols, lines and text) and males (gold symbols, lines and text).

Based on these results, the spatially restricted sampling coverage of the New Zealand recreational fishery data (i.e. only in North Island waters) and the lack of small EFL classes in this dataset (see Figure A4), a decision was made to continue with the Kopf et al. (2011) dataset for estimating the sex-aggregated and sex-specific EFL-WW relationships for the 2024 assessment revision. We recommend that further exploration of the New Zealand recreational fishery data (and other datasets that may become available) be carried out well before the next assessment in 2029.

Objective 4a

The Kopf et al. (2011) dataset provided us an opportunity to test for spatial variation in the EFL-WW relationship for southwest Pacific striped marlin captured in Australian and New Zealand waters. We split the data by country and fit models (i.e. Eq. 1) for each country separately (see Figure A5).

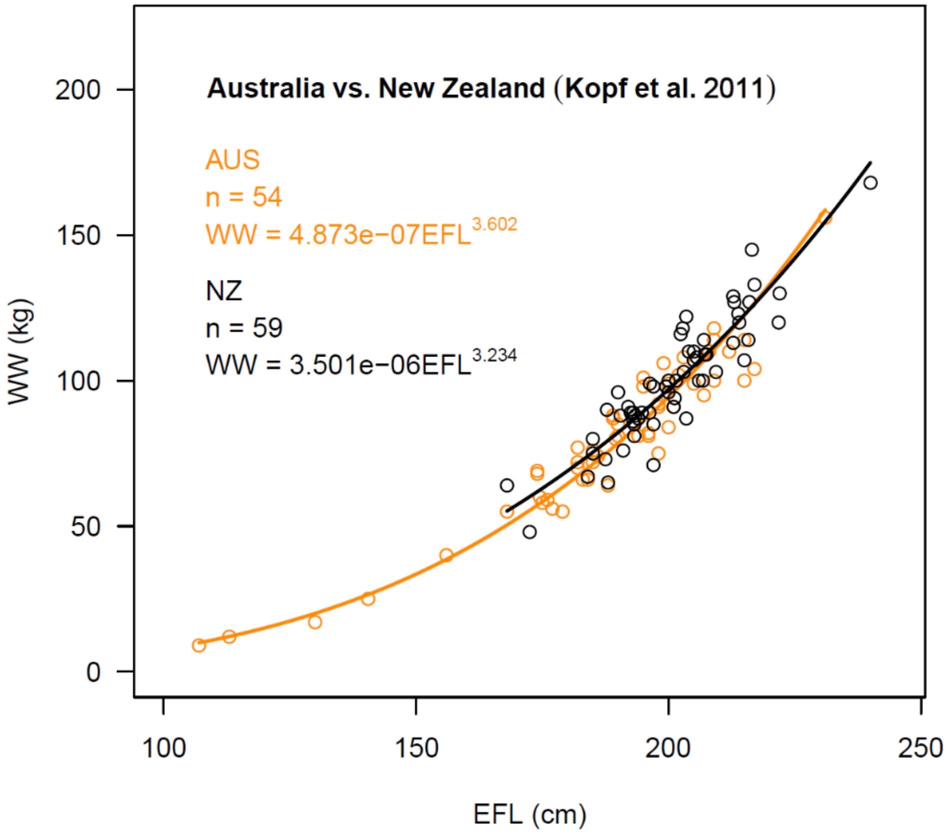

Figure A5. Comparison of EFL-WW relationships for southwest Pacific striped marlin captured in Australian (AUS) (orange text, circles and line) and New Zealand (NZ) (black text, circles and line) EEZs. Circles are coupled EFL and WW measurements associated with Kopf et al. (2011). Lines are the mean predictions of weight-at-length from each model.

With reference to Figure A5, we see that the weight-at-length measurements for the Australian and New Zealand data are very similar across the length range where data is available from both regions. Refitting the model with 'country' as an indicator variable, interacting with EFL showed that the differences in the *a* (p = 0.11) and *b* parameters (p = 0.11) estimated for the Australian and New Zealand data were not statistically significant at α = 0.05. From these results, though difficult to confirm without additional data, we suggest that the lower *b* parameter estimate for the New Zealand data is likely driven by the lack of small fish measured from New Zealand waters rather than any biological differences giving rise to variation in the length-weight relationship in space.

Objective 4b

Kopf et al. (2011) also collected coupled LJFL and WW measurements on 213 striped marlin ranging between 129 cm and 287 cm LJFL captured within Australian (n = 66), New Zealand (n = 132) and Fijian (n = 15) EEZs between 2005 and 2008. We were granted access to this data for further analysis. Making use of the LJFL measurements from Kopf et al. (2011) allowed us to expand the spatial coverage of our comparison to incorporate a small number of measurements from Fiji.

We first converted LJFL to EFL using the linear equation derived by Kopf et al. (2011) (see their Table 3) with parameters adjusted for length in cm, so EFL (cm) = 3.661 + 0.834*LJFL (cm). If measured EFL was available for a particular record, we used the measured value; if not, we used the converted value. As for *Objective 3a*, we then fitted models (Eq. 1) for each EEZ separately to assess evidence for spatial variability in the EFL-WW relationship. Finally, we fitted an 'overall' model (i.e. Eq. 1) to all 211 records (two data points from the Australian data were identified as measurement errors and excluded from further analysis) and compared the parameter estimates with those used in the 2024 assessment.

The main results are shown in Figure A6. The Australian dataset spans the greatest range of lengths, with the New Zealand data dominated by larger specimens and the Fijian measurements representing a narrower range of lengths between ~151 cm and 172 cm EFL. While the mean predictions of weight-at-length from the Australian and New Zealand data (see orange and black curves in Figure A6) were in fairly close agreement, the curve for Fiji is clearly different. Refitting the overall model with all data combined and adding 'country' as an indicator variable, interacting with EFL showed that the differences in the *a* parameter estimates among the three countries were not statistically significant at $\alpha = 0.05$, with $p = 0.06$. However, differences in the *b* parameter estimate were statistically significant ($p = 0.04$), with Fiji fish exhibiting a value outside the realms of biological plausibility (Froese 2006). While these results are interesting, the limited data available from Fiji makes it difficult to draw conclusions regarding the existence (or not) of spatial variability in the length-weight relationship between Fiji and Australia/New Zealand. Additional coupled length and weight samples from Fiji and from further afield across the PICTs are needed to address this knowledge gap.

Importantly, when comparing the mean predictions from the overall model fit to the 211 records combined from Australia, New Zealand and Fiji (grey line in Figure A6) with the relationship used for the 2024 assessment (red line in Figure A6) we found no evidence of a difference in the mean curves. The differences in the *a* parameter estimates ($p = 0.66$) and *b* parameter estimates ($p = 0.71$) were not statistically significant at $\alpha = 0.05$.

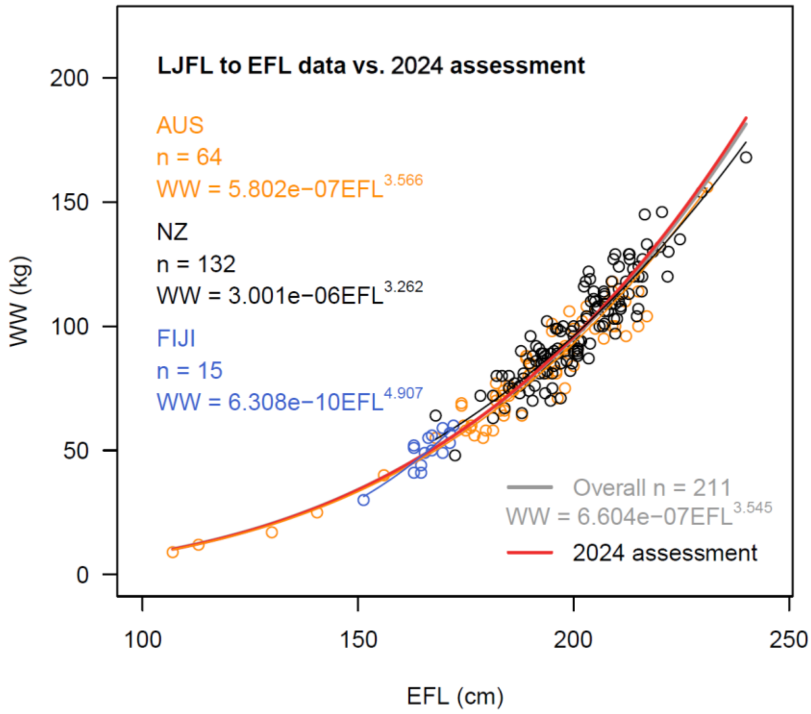

Figure A6. Comparison of EFL-WW relationships for southwest Pacific striped marlin captured in Australian (AUS) (orange text, circles and line), New Zealand (NZ) (black text, circles and line) and Fijian (FIJI) (blue text, circles and line) EEZs. Circles are coupled EFL and WW records associated with Kopf et al. (2011), with the EFL records converted from LJFL measurements made directly on the fish. Also shown is the overall model (grey text and line), in which data from Australia, New Zealand and Fiji are combined, and the mean prediction from the model used in the 2024 assessment (red line). Lines are the mean predictions of weight-at-length from each model.

Summary, conclusions, recommendations

Outcomes from this follow-up work on southwest Pacific striped marlin length-weight relationships are summarised below in relation to the three objectives outlined at the start of the document along with some final remarks.

***Objective 1*:** Above 160 cm EFL, the relationship derived from the Kopf et al. (2011) data for the 2024 assessment predicts the heaviest weight-at-length of all curves presented in Table A1 (see Figure A2). The Sun et al. (2011) curve most closely aligns with the relationship used in the 2024 assessment. This curve was based on a substantial number of fish captured in northwest Pacific waters off Taiwan, within the northwestern region of the WCPO. The three relationships reviewed from the EPO, while varying in sample size, time period covered and shape of the mean curve, all predict lower weight-at-length than those from the WCPO, particularly for individuals greater than 160 cm EFL. The two relationships presented from the Indian Ocean were based on relatively few observations and were wildly divergent in their predictions. At present, we place low confidence in the Williams (1962) estimates.

***Objective 2*:** Our exploration of the New Zealand recreational fishery records provided by John Holdsworth highlighted the limits (inherent to this fishery's characteristics) in the spatial coverage and the EFL range available. To this end, we elected to continue with the Kopf et al. (2011) dataset for estimating the sex-aggregated and sex-specific EFL-WW relationships for the 2024 assessment revision, with a view to further investigating the New Zealand recreational fishery data (and other datasets that may become available) ahead of the next assessment in 2029.

***Objective 3*:** For the 2024 assessment, the mean prediction of weight-at-length presented in Figure 3 of Macdonald et al. (2024) used the bias-corrected a parameter ($a_{bias\text{-}corrected}$). However, a_{naive} was reported in that paper as the final estimate of a for use in the assessment. Importantly, the use of $a_{bias\text{-}corrected}$ or a_{naive} was shown to have very little influence on the predicted EFL-WW relationship for southwest Pacific striped marlin (see Figure A1), with the difference in mean predicted whole weight for a 240 cm EFL individual less than 1 kg. Nonetheless, we advise using $a_{bias\text{-}corrected}$ for future work on this assessment in the lead up to SC21.

***Objective 4a*:** The weight-at-length measurements for striped marlin captured in Australian and New Zealand waters aligned well across the shared length range (see Figure A5), and the a and b parameter estimates from Eq. 1 were not significantly different between sampling locations. We suggest that the lower b parameter estimate for the New Zealand data is likely driven by the lack of small fish measured from New Zealand waters rather than any biological differences giving rise to variation in the length-weight relationship in space. Additional measurements from smaller fish captured within the New Zealand EEZ are needed to explore this idea further.

***Objective 4b*:** The exploration of the LJFL data measured by Kopf et al. (2011) and converted to EFL allowed us to expand the spatial coverage of our comparisons to incorporate a small number of coupled length and weight measurements from Fiji. The New Zealand and Fiji data span different length classes, with the only information on smaller fish below 150 cm coming from the Australian data. While the mean predictions of weight-at-length from the Australian and New Zealand data (see orange and black curves in Figure A6) showed strong agreement across the shared length range, the curve for Fiji is different, with Fijian fish exhibiting a b parameter value outside the realms of biological realism. That said, when comparing the mean predictions from the overall model fit to the 211 records combined from Australia, New Zealand and Fiji (grey line in Figure A6) and the model used for the 2024 assessment (red line in Figure A6) we found no evidence of a statistical difference in the mean curves.

Final remarks: Overall. this work has confirmed that the data used in developing the EFL-WW relationship for the 2024 WCPFC southwest Pacific striped marlin assessment, as drawn from the direct measurements of EFL and WW from Kopf et al. (2011), remains the best available, highest confidence dataset at hand for estimating this relationship. That said, data are relatively few, and the limited coverage of measurements across space and time currently limits inference regarding the existence (or not) of spatial variability in the length-weight relationship between Fiji and Australia/New Zealand. We recommend additional data be collected from Fiji and further afield across the WCPO to address this knowledge gap well ahead of the next WCPFC southwest Pacific striped marlin assessment scheduled in 2029.

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Appendix 2: Sampling design for developing finlet length-to-fork length relationships for Pacific tunas

Prepared by Jed Macdonald and the SPC and CSIRO CKMR teams

Background and rationale

With the SPC/CSIRO tuna genetics sampling programme now fully operational across the Pacific region, a priority has emerged to develop relationships between **fork length (UF)** and **other measurements along the fish's tail** for the region's key tuna stocks (i.e. south Pacific albacore [SP ALB], north Pacific albacore [NP ALB], bigeye [BET], yellowfin [YFT] and skipjack [SKJ]). These relationships will allow us to estimate fork length, and hence annual age, for each fish sampled for CKMR or other genetic/ecological studies when only the tail is available for sampling, noting that estimated age represents an important input for CKMR models.

Making use of tuna tails for genetics/genomics projects has the capacity to increase sampling rates and efficiency across the region. Put simply, sampling tails in ports where they are available will likely remove the logistical hurdles associated with handling whole fish, lessen disruption to unloading activities, speed up sample collection and so lead to higher sampling rates. Moreover, many processing facilities across the region hold tail stock, and assuming that the tails can be traced back to the vessel they came from, or the area fished, working in such facilities could further expedite the sampling process.

One tail measurement of interest is the **finlet length (FINL)** – defined as the length from the anterior insertion point of the 2nd finlet to the fork in the tail on either the dorsal or ventral side of the fish (see Figure 1). Another is the **tail width (TW)** – defined as the length between the dorsal and ventral insertion points of the 2nd finlet (Figure 1). Note that for TW, we need the linear measurement between finlet insertion points, not the curved measurement.

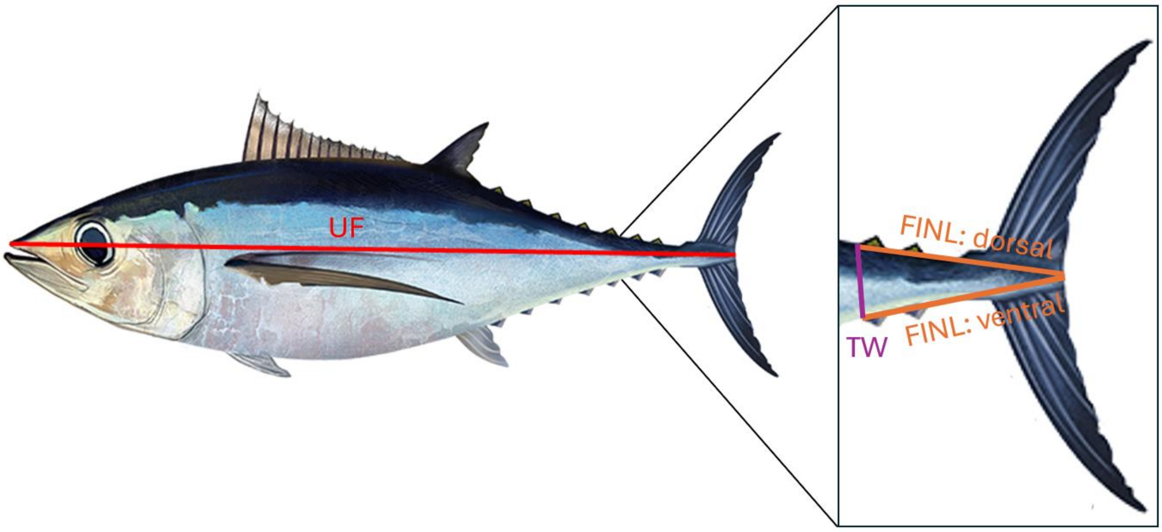

Figure 1. Measurements required to develop relationships between fork length (UF) (red line), finlet length (FINL) (orange lines) and tail width (TW) (purple line) for Pacific tunas, with SP ALB used as an example here. Images courtesy of NOAA Fisheries.

A preliminary analysis of data collected in Westport, USA during 2024 showed a strong positive linear association between FINL and UF measurements for NP ALB (Figure 2). That said, a fairly large spread of fork length observations was observed within each finlet length bin. This pattern was seen right across the range of finlet length measurements collected and indicates that the variability in fork length for each finlet length measurement can be quite high.

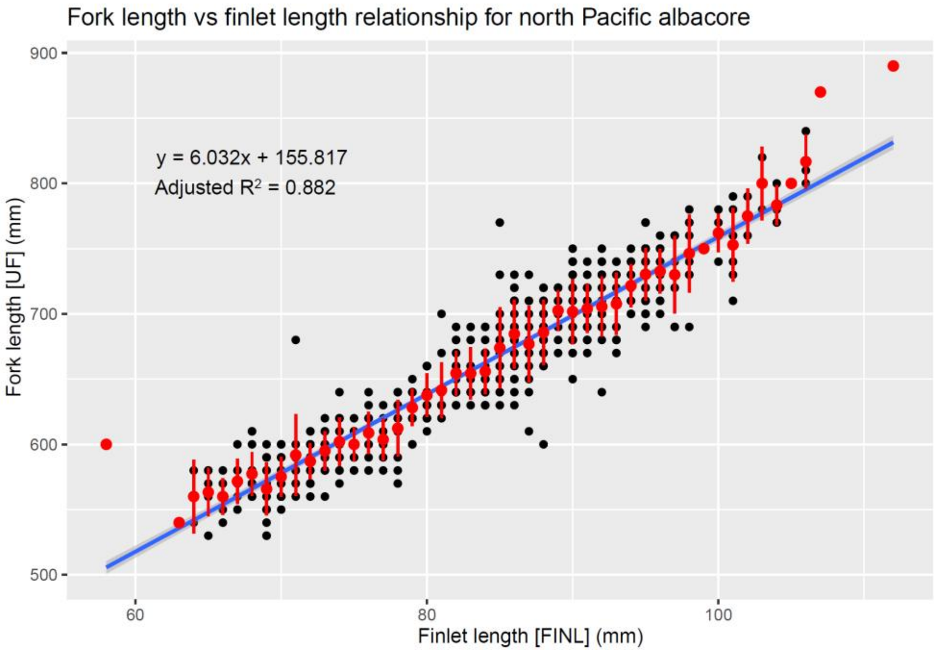

Figure 2. Relationship between fork length [UF] and finlet length [FINL] measured for north Pacific ALB from Westport, USA. Black circles are the measurements, the red dot is the mean fork length for each finlet length measurement, and red vertical lines are ± 1 standard deviation. The linear regression equation is shown and the mean prediction (blue line) overlaid with 95% confidence intervals shown in grey.

This variability can be accounted for in the CKMR model if the variability in the subsequent length-at-age estimates is not too excessive – the benefits of being able to collect a lot more tail samples should outweigh the increase in uncertainty. To test this, we drew on the von Bertalanffy growth parameters derived previously for SP ALB and compared the estimated age at estimated fork length (derived from the FINL-to-UF relationship for NP ALB in Figure 2) with the estimated age at measured fork length. Next, we compared the estimated age at estimated fork length (again derived from the equation in Figure 2) with length-at-age estimates from otolith reads for SP ALB. We note that for this analysis, the same FINL-to-UF relationship was assumed for both NP ALB and SP ALB populations. Despite some bias observed in estimated ages for the smallest and largest fish when using the finlet length to convert to fork length (Figure 3 left panel), the resulting length-at-age estimates using i) finlet length converted to fork length and ii) measured fork length and otolith readings showed good congruence (Figure 3 right panel).

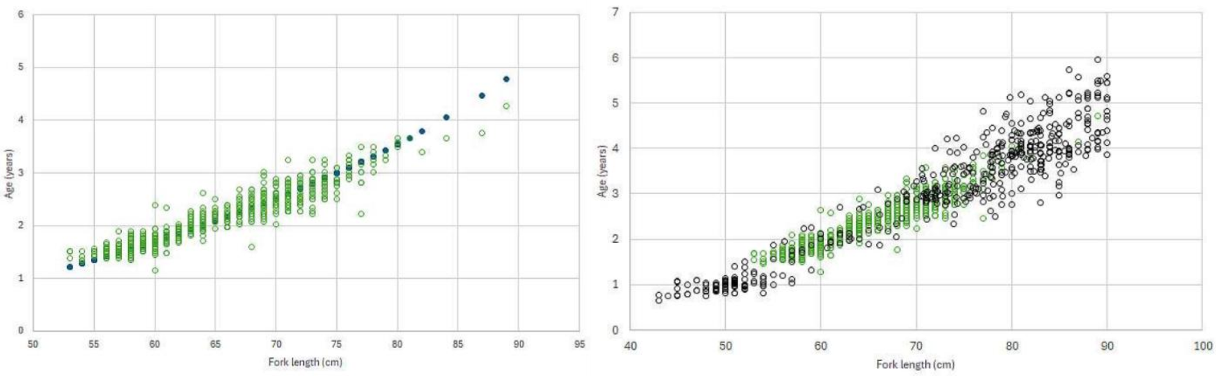

Figure 3. Left panel: estimated age at fork length of NP ALB sampled from Westport, USA, derived using von Bertalanffy growth parameters for SP ALB. Green circles = ages estimated using finlet length to estimate fork length. Blue circles = ages estimated from measured fork length. Right panel: green circles as for left panel. Black circles = length-at-age estimates derived from measured fork length and associated otolith readings from SP ALB (for fish up to 90 cm UF).

In summary, these preliminary results for NP ALB suggest that using finlet length (FINL) to obtain fork length (UF) estimates, and hence age estimates, will be acceptable from a CKMR modelling standpoint. However, further investigation into FINL-to-UF relationships across the full size range of the catch, incorporating larger sample sizes and using standard measuring tools (i.e. digital calipers) is now needed for each species. Furthermore, we are interested to see if relationships exist between tail width (TW) and UF, and if including TW measurements in the analysis can help to improve our estimates of fork length for each species.

Data collection strategy

To generate the data required to develop these relationships, we considered the following:

- factors associated with each port (i.e. number of fish unloaded in 2024, species composition of the catch, variation in length frequencies within and among ports and sampling events (see Appendix A), available personnel and logistical challenges);
- sample size (i.e. how many samples are needed to achieve acceptable power);
- whether random sampling (RS), sampling fixed numbers of fish per length bin (FS), sampling variable numbers per length bin in proportion to the length frequency in the catch (PS) or some variation on these themes is most appropriate[2] (see Appendix A);
- the potential for spatial differences in the FINL-to-UF and TW-to-UF relationships to occur in different regions;
- whether FINL measurements vary between the dorsal and ventral sides of the fish[3];
- whether FINL and TW measurements vary between sexes; and

[2] PS is often recommended for the estimation of growth parameters in fast growing species like tunas (Chang et al. 2019; Schemmel et al. 2022). Schemmel et al. (2022) showed that PS performed better than FS when the catch was representative of the true population. However, it is still unclear how robust PS designs are if biological samples were fishery-dependent because the catch and the resulting biological samples may be a poor representation of the true population. Indeed, a PS- or FS-type sampling design may not be best suited to our objectives here.

[3] If the finlet lengths differ consistently between dorsal and ventral sides, then we need to pay attention when sampling tails as to which side we measure. If the measurements don't differ, there will be no need to pay attention to which side we measure when sampling tails.

- the potential for onboard storage procedures (i.e. blast frozen vs. 'fresh') to induce different FINL-to-UF and TW-to-UF relationships.

As a key motivation here is to estimate age from the tails alone, we are most interested in getting UF, FINL and TW measurements that cover the size range of fish whose tails are cut and available for sampling across our ports. That said, having measurements across **all** size classes captured by fisheries targeting each species would be ideal and useful not just for obtaining age estimates for CKMR, but for broader ecological studies on growth variability. To this end, a variation on the RS approach[4], where all fish sampled are measured for UF, FINL and TW within a sampling event, may be an appropriate approach for our needs (see Appendix A for a justification).

With this in mind, and following an analysis of port-related factors, sample size requirements and spatial considerations, our data collection strategy is as follows:

Overall objective: For each species/stock (i.e. SP ALB, NP ALB, YFT, BET, SKJ) obtain UF, FINL and TW measurements across the full size range represented in the fishery catch across all ports.

Target fisheries: Longline, purse seine, troll.

Sampling location: Port.

Ports, target species and sample size requirements:

Country (Port)	Target species and sample sizes
Fiji (Suva)	SP ALB (n=200), YFT (n=400), BET (n=200)
Solomon Islands (Noro)	SP ALB (n=200), YFT (n=400), BET (n=400), SKJ (n=200)
FSM (Pohnpei/Kosrae)	YFT (n=200), SKJ (n=200)
RMI (Majuro)	YFT (n=200), SKJ (n=200)
Tonga (Nuku'alofa)	SP ALB (n=200), YFT (n=200)
New Zealand (Greymouth/Westport)	SP ALB (n=200)
Samoa (Apia)	SP ALB (n=200)
USA (Westport)	SP ALB (n=400), NP ALB (n=500)
New Caledonia (Noumea)	SP ALB (n=200), YFT (n=100)
French Polynesia (Papeete)	SP ALB (n=400)
Cook Islands (Rarotonga)	SP ALB (n=100), YFT (n=100)
American Samoa (Pago Pago)	SP ALB (n=100), YFT (n=100)

Protocol at each port:

Data collection for this study is designed to be done in conjunction with normal CKMR sampling events. We have created a separate DATA_FORM (available here: Finlet_to_fork_DATA_FORM.xlsx) on which to record the required length measurements and other important data for each fish. So, for a given CKMR sampling event, sampling teams record the data associated with each tissue sample in OnShore, as usual, while at the same time filling out the DATA_FORM as each fish is measured. The LABEL NO. field will allow us to match the CKMR data for each individual fish and the length measurements collected for this study.

[4] We acknowledge that if used to estimate of growth parameters from fishery catch data, RS can be biased due to size-based selectivity. However, our aim here is to get the develop the most accurate FINL-to-UF relationships possible directly from fish captured by the fishery and to obtain fork length and age estimates only for fish captured by the fishery. In this case, selectivity presents no issue and an RS-type approach may be an appropriate sampling strategy.

Key steps:

1. Enter information in the header fields at the top of the DATA_FORM.
2. Enter LABEL NO. (same as CKMR sample label) and SPECIES CODE.
3. Record UF, FINL and TW measurements on **all** fish sampled during a CKMR sampling event. We need four length measurements per fish:
    i. Record the UF (to the nearest lowest cm) [use standard 1.5 m aluminium calipers to take the measurement].
    ii. Record the FINL **on dorsal** side of fish (to the nearest lowest mm) [use handheld digital calipers to take the measurement].
    iii. Record the FINL **on ventral** side of fish (to the nearest lowest mm) [use handheld digital calipers to take the measurement].
    iv. Record the TW (to the nearest lowest mm) [use handheld digital calipers to take the measurement].
4. Enter information on SEX, if available.
5. Record in the ONBOARD STORAGE field if fish was stored blast frozen or 'fresh' (i.e. on ice or in a brine slurry).
6. Add any other COMMENTS.
7. Continue until you reach the target sample size per species/stock (see table above for guidance). Note: that reaching the targets per species/stock might require data collection across several sampling events.
8. When the target sample size per species/stock has been reached, take a picture of the completed DATA_FORM and email to me at jedm@spc.int and Marc Ghergariu (marcg@spc.int).

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Appendix A – Analysis of length frequency distributions by species, port and sampling event for all CKMR and genetics sampling conducted in 2024 across major WCPO ports.

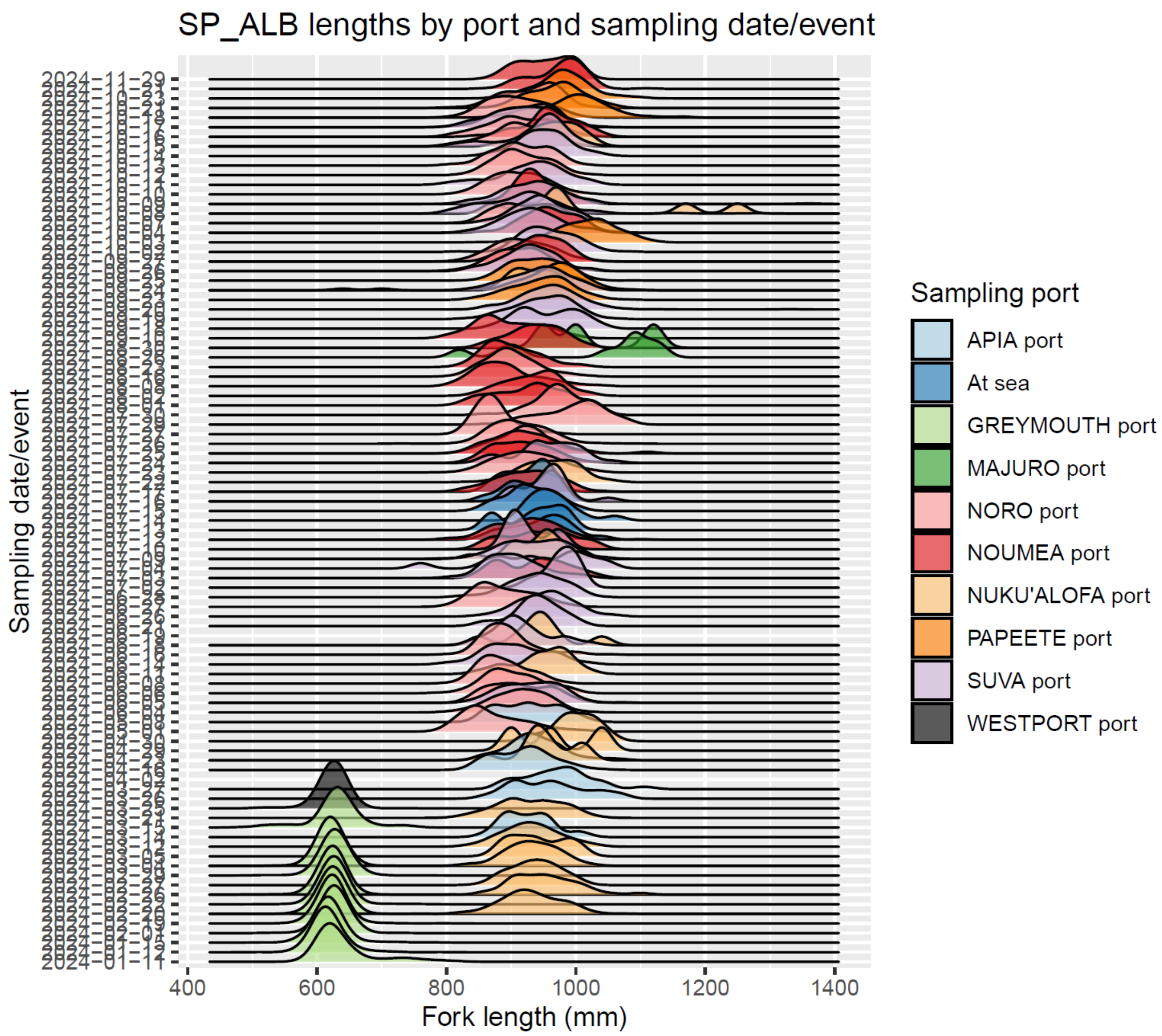

Figure A1. SP_ALB length frequency distributions by port and sampling event for all CKMR and genetics sampling conducted in 2024. Each horizontal line on the plot represents the date of the sampling event, with one sampling event typically occurring per day. Colours denote ports and histograms show the distribution of lengths measured for each sampling event.

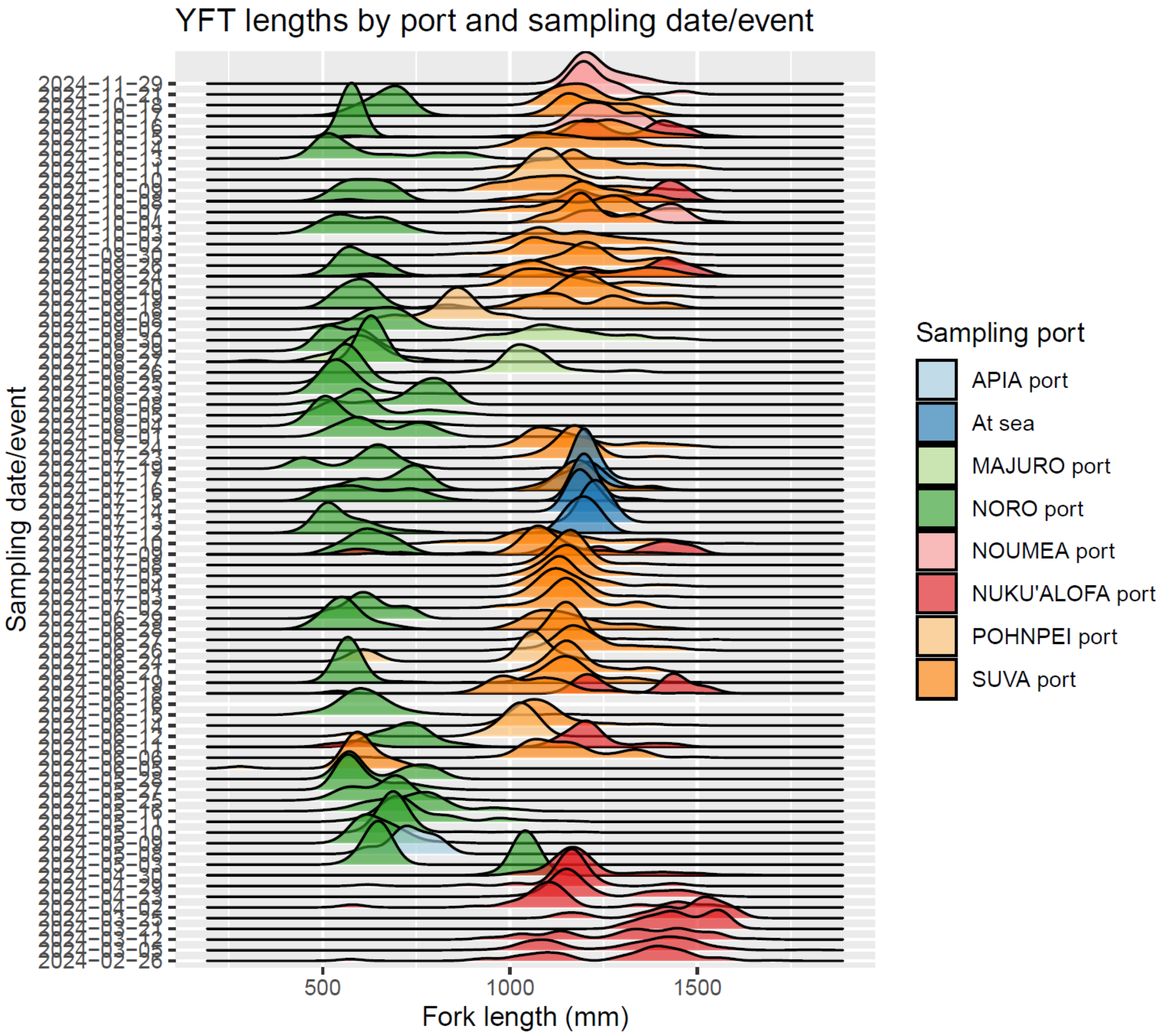

Figure A2. YFT length frequency distributions by port and sampling event for all CKMR and genetics sampling conducted in 2024. All other details as for Figure A1.

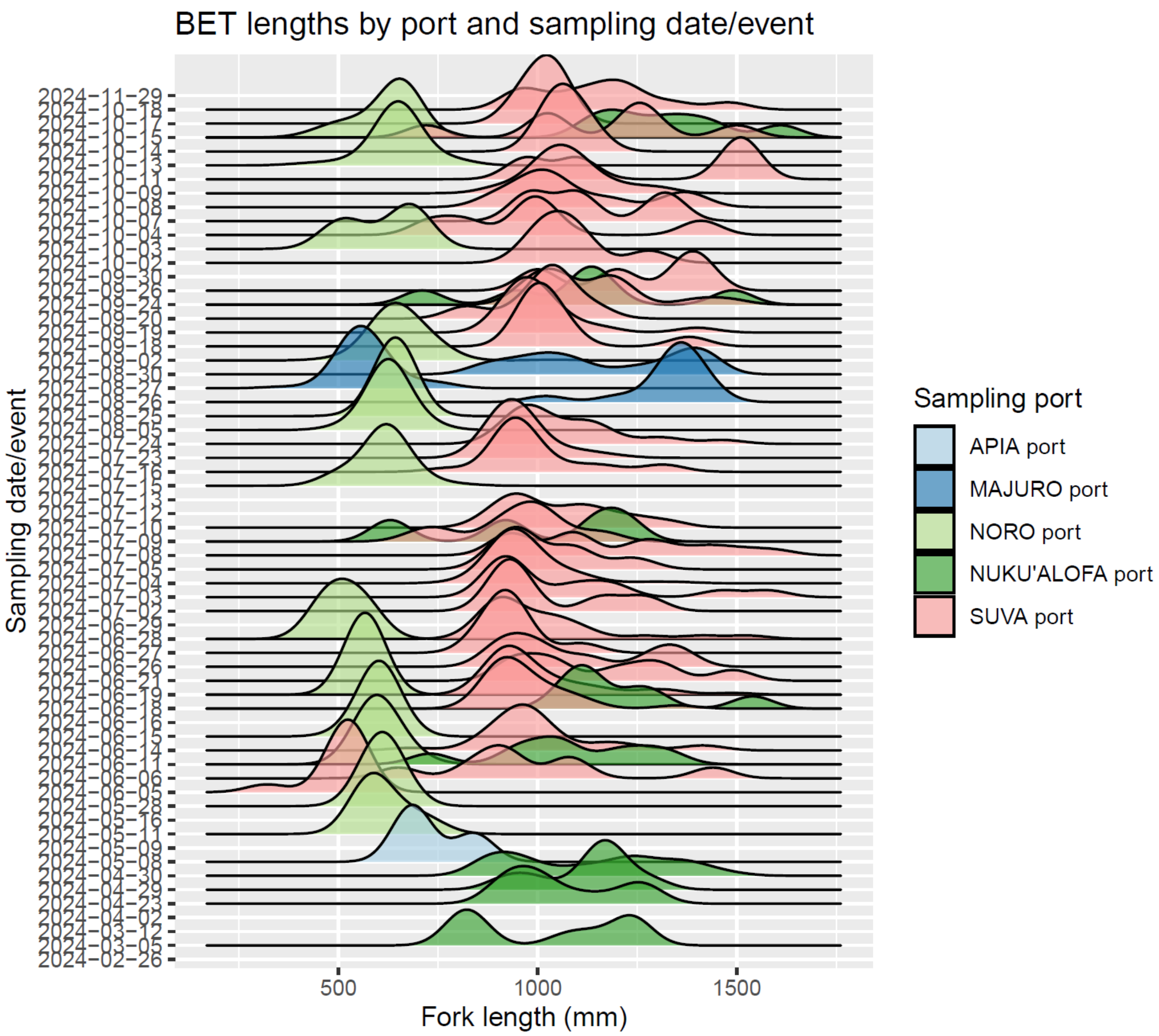

Figure A3. BET length frequency distributions by port and sampling event for all CKMR and genetics sampling conducted in 2024. All other details as for Figure A1.

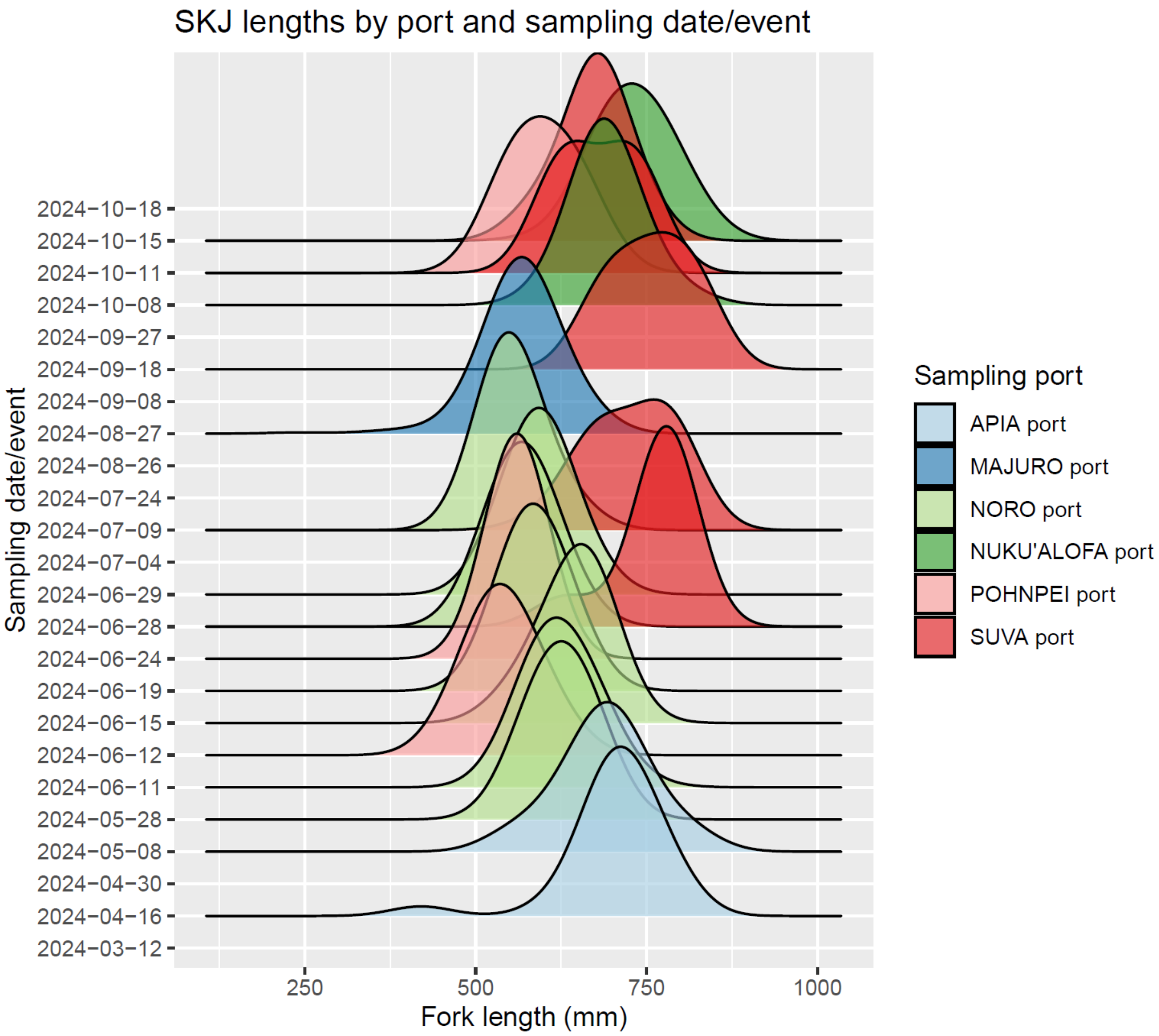

Figure A4. SKJ length frequency distributions by port and sampling event for all CKMR and genetics sampling conducted in 2024. All other details as for Figure A1.

In summary, Figures A1 to A4 show that the length range available for each species varies substantially among ports and relatively little among sampling events within a given port. For SP_ALB, YFT and BET, most individual sampling events adequately captured the size range encountered at a given port throughout the year. That said, for YFT in Nuku'alofa, we see that some sampling events early in 2024 only encountered fish around the 100-120 cm fork length mark while missing the larger individuals, with other events later in the year only measured larger individuals. A similar situation was seen for SP_ALB in Majuro, though unloading of SP_ALB there is quite rare. For SKJ, we saw smaller fish unloaded as the season progressed in Noro and Suva, but among all ports, the full SKJ length range was fairly well covered at any time period.

These results tend to support the RS-type sampling design outlined under the 'Sampling strategy' section above. The plots show that the size range available at each port will be adequately represented by getting the sampling teams to measure FINL and UF for all fish sampled for CKMR in each sampling event up until the target sample size is reached. Sampling more than one event at each port would be ideal just in case we get unlucky with any one event having an "outlying" length distribution, but it's probably not crucial since among all ports, the length range is likely to be adequately represented.