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Project 90 update: Better Data on Fish Weights and Lengths for Scientific Analyses

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EXECUTIVE SUMMARY

Project 90 developed 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 is now in its fifth year. As of 4 June 2024, in conjunction with CF data collected since 2015 through other sampling programmes, Project 90 has returned a total of 46,898 CF measurements on skipjack tuna (*Katsuwonus pelamis*), 32,443 measurements on yellowfin tuna (*Thunnus albacares*), 8,488 on bigeye tuna (*T. obesus*), 460,837 on albacore (*T. alalunga*), and 6,139 measurements on billfish and bycatch species caught by WCPO tuna fisheries.

The original objectives of Project 90 were to design and coordinate the collection of high-quality length measurements for bycatch species, and length-length (L-L), length-weight (L-W) and weight-weight (W-W) conversion factors for tunas, billfish and bycatch species. The project's scope has since expanded to analyses of these data, particularly in the context of developing and updating CF relationships for WCPFC tuna and billfish stock assessments as new data comes to hand.

This Information Paper updates SC20 on Project 90 activities undertaken since SC19 and outlines planned actions for 2024-2025. Work over the past 12 months has included the derivation of new length-weight relationships (LWRs) for south Pacific albacore and southwest Pacific striped marlin (*Kajikia audax*) in the lead up to the 2024 assessments presented in Teears et al. (2024) and Castillo-Jordán et al. (2024), respectively. For south Pacific albacore, this constitutes the first update of the LWR since Langley and Hampton (2005). Our analysis made use of all available coupled length and weight measurements from port sampling and observer records across the region (n = 824,745). The new relationship between fork length (UF - upper jaw to caudal fork) in cm and whole weight (WW) in kg follows a power function of the form $WW = a \times UF^b$ with parameter estimates as follows:

a = 1.7075e-05 (95% CIs: 1.6901e-05, 1.7251e-05); b = 3.0483 (95% CIs: 3.0461, 3.0506) so,
$WW = 1.7075e\text{-}05 \times UF^{3.0483}$

The mean predicted WW-at-UF from this 2024 model aligns closely with the mean curve used in the 2021 assessment (Castillo-Jordán et al. 2021) [originally derived by Langley and Hampton (2005)], albeit with slightly lower predicted weight-at-length for the very largest individuals.

For southwest Pacific striped marlin, we obtained coupled eye fork length (EFL) and WW measurements for individuals ranging between 107 cm and 240 cm EFL captured in New Zealand and Australian waters between 2005 and 2008 (n = 114). These data were collected as part of work presented in Kopf et al. (2011). A model of the form $WW\ (kg) = a \times EFL\ (cm)^b$ showed a good fit to the data and the parameter estimates were:

a = 5.3994e-07 (95% CIs: 2.3380e-07, 1.2470e-06); b = 3.5838 (95% CIs: 3.4249, 3.7426) so,
$WW = 5.3994e\text{-}07 \times EFL^{3.5838}$

The mean predicted WW-at-EFL from this model aligns closely with the mean curve used in each of the previous two assessments (Davies et al. 2012; Ducharme-Barth et al. 2019) which both used a = 4.4990e-07 and b = 3.6165.

In other work, efforts have continued to expand data collection for the gilled-and-gutted weight (GG) to whole weight (WW) CF for large bigeye tuna, identified as an important data gap in previous assessments. The recent signing of Letters of Agreement with Tonga, Cook Islands and RMI on alternative approaches for collecting such data on longline-caught bigeye and yellowfin in the central Pacific (i.e. involving collection and storage of gills-and-guts at sea, and weighing them in port at the conclusion of each trip – see Appendix 1 for full details of the sampling protocol) represents an important step towards filling this gap. We note that the first trial of this approach is underway involving a Cook Islands' observer onboard a longline vessel due to unload in Apia, Samoa, in late July 2024. We estimate that this first trip will yield approximately 200 new GG-WW records for bigeye, along with coupled L-L CF data. If the data collection protocol proves workable during this trial, roll out to Tonga and RMI is envisaged for later in 2024.

Most items listed in the 2023-2024 Project 90 work plan are progressing on schedule as summarised in section 2 of this report. Others require further work to meet objectives. The 2024-2025 work plan in section 3 reflects this, as well as outlining a new proposal to explore the accuracy of historical length data for future WCPFC tuna and billfish assessments.

We invite SC20 to:

1. review and comment on the progress made on Project 90 activities at this stage;
2. note that Project 90 has been selected for inclusion in the *Online Discussion Forum* at SC20, and SPC looks to that forum to table and define the priority activities proposed in this paper; and
3. consider Project 90 as an ongoing project of the WCPFC, with indicative 2025 and 2026 budgets of USD 20,000 per annum to fund tasks set out in the 2024-2025 work plan.

1. BACKGROUND

WCPFC Project 90 arose from discussions at SC13 in 2017 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 species.

Following these discussions, SC13 recommended that the WCPFC 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-length (L-L), length-weight (L-W) and weight-weight (W-W) CF data on all species.

These recommendations have shaped the evolution of tasks undertaken within Project 90 since its commencement in 2019 (see Williams and Smith 2018; SPC-OFP 2019; Macdonald et al. 2020, 2021, 2022, 2023 for details and annual updates to the SC). Now in its fifth 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 WCPO tuna and billfish stock assessments.

We note that Project 90 has been included in the *Online Discussion Forum* each year since SC16 and is again slated for inclusion at SC20. We look to this forum as a useful platform for commentary on this Information Paper which provides an update on Project 90 activities in the 12 months since SC19, and outlines planned activities for the coming year.

2. PROJECT 90 WORK TO DATE

2.1 Overview - in brief

The work conducted in Project 90 to date has included:

i) The establishment, refinement and regular updating of the CF database and associated tables, and the incorporation of new CFs as they are developed and/or published.
ii) Scoping and gap analyses to determine the priority areas for collecting CF data under Project 90.
iii) Engagement with CCMs regarding data requirements for generating accurate CFs.
iv) Development and refinement of a web-based tool for accessing SPC's CF database, available with login at: www.spc.int/ofp/preview/login.php?redirect=species_conv_factor.php or through the Tufman2 database portal accessible here.
v) Initiation and continuation of port sampling activities in the Philippines from 2019 onwards targeted towards the collection of L-L, L-W and W-W CF data, biological samples and tag recovery information for key tuna species. These data continue to contribute importantly to the CF database for tropical tunas (i.e. skipjack tuna – *Katsuwonus pelamis*, yellowfin tuna – *Thunnus albacares*, bigeye tuna – *T. obesus*), augmenting other CF data collected across the region (including for albacore tuna – *T. alalunga*) (see Tables 1, 2, and 3).
vi) The publication of training material during 2023 relevant to Project 90 tasks including a revised biological sampling manual entitled 'Biological Sampling Manual – Guide for samplers at sea and at port' (Sanchez et al. 2023) (available here) and a series of 19 training videos (available on SPC's YouTube channel: https://www.youtube.com/@spcnc1/videos). Together, these materials demonstrate techniques for best-practice biological sampling and collection of length and weight data on tunas, mahi mahi, wahoo and billfish. The materials are designed for scientists, observers, fisheries officers, fishing captains, crew and port samplers, and as teaching tools for high school and university students.
vii) Purchase of a 'WPL Industries' motion-compensated scales to augment collection of gilled-and-gutted (GG) to whole weight (WW) CF data across the region.
viii) Establishment of a dialogue with the Solomon Islands Ministry of Fisheries and Marine Resources (MFMR) and the Solomon Islands National Observers programme (SBOB) in response to a June 2021 request to SPC regarding alternative employment opportunities for Solomon Islands' observers unable to work due to COVID-19 related travel restrictions.

ix) Development of a sampling plan to address the request outlined in **viii**. The draft plan was circulated in 2021 and adapted to include onboard-observer and/or port-based collection of GG-WW CF data and other biological samples for bigeye and yellowfin tuna in the Solomon Islands. An analysis of recent catch composition revealed that Solomon Islands purse seiners were not capturing the size classes needed to fill the current GG-WW data gap in the numbers required, so data collection opportunities in other regions were explored (see **x**).

x) This led to the drafting (in early 2023) and signing (late 2023 and early 2024) of Letters of Agreement (LOA) with Tonga, Cook Islands and RMI that set out an alternative approach for collecting coupled L-L and W-W CF data for longline-caught bigeye and yellowfin in the central Pacific (see below and Appendix 1 for further details).

xi) An update of the GG-WW CF relationships and the LWRs (i.e. upper jaw to caudal fork (UF)-WW relationships) for WCPO bigeye and yellowfin for input into the 2023 stock assessments (Day et al. 2023; Magnusson et al. 2023). We created a pipeline in R (R Core Team 2023) for data extraction, screening, filtering and modelling of these LWRs that is repeatable and can be applied consistently in future updates as new data comes to hand (see Macdonald et al. 2023).

xii) An update of the LWR (i.e. UF-WW relationship) for south Pacific albacore for use in the 2024 stock assessment (Teears et al. 2024).

xiii) Confirmation of the lower jaw fork length (LJFL) - eye fork length (EFL) relationship for southwest Pacific striped marlin (*Kajikia audax*) and an update of the LWR (i.e. EFL-WW relationship) for the stock for use in the 2024 stock assessment (Castillo-Jordán et al. 2024).

xiv) Creation of processes and R code for the exchange of length and weight data with WCPFC members and other international fisheries agencies through LOA, noting also the recent establishment of the WCPFC public domain size data (https://www.wcpfc.int/public-size-data).

xv) Completion in 2023 of modelling to explore spatial and temporal variability in the bigeye tuna LWR across the WCPO using Taiwanese observer data (see Hoyle et al. 2023). A manuscript based on this work has been drafted for submission to a scientific journal in the second half of 2024.

xvi) Commencement in 2022 and continuation through 2023 of a comparative study of length measurements recorded by electronic monitoring (EM), onboard observers and port samplers for tunas and billfish captured by longliners in French Polynesia. No new data has been collected or analyses conducted since the last Project 90 update to SC19 (Macdonald et al. 2023).

xvii) Efforts to improve links between the data collected as part of Project 90 and other WCPFC projects (i.e. Project 35b: WCPFC Pacific Marine Specimen Bank; Project 42: Pacific Tuna Tagging Project; Ecosystem and climate Indicators; Project 100c: Progress towards a Close-Kin Mark-Recapture application to south Pacific albacore)

2.2 Progress since SC19 - in detail

i) - vi) Following the major updates made to SPC's CF database entries during 2020 and 2021, work over the past 12 months has focused on improving existing CFs and developing training materials to enhance biological sampling skills and the accuracy of length and weight measurements taken by observers at sea and samplers in port.

New CF data for skipjack, bigeye and yellowfin have come primarily from the ongoing collaboration with SOCSKSARGEN Federation of Fishing & Allied Industries (SFFAII) and the Bureau of Fisheries and Aquatic Resources ministry (BFAR) in General Santos, Philippines. Through the contributions of coupled L-L, L-W and W-W measurements recorded at General Santos Port in addition to other CF data collected across the region, as at 4 June 2024, we have now amassed 46,898 CF measurements on skipjack, 32,433 measurements on yellowfin, 8,488 on bigeye, 460,837 on albacore (all L-W measurements, coming mostly from Fiji) and 6,139 measurements on billfish and bycatch species since 2015 inclusive (see Tables 1-3 for breakdowns by CF type).

The 2023 signing of a four-year preferred supplier agreement with SFFAII that allows some year-to-year flexibility in project deliverables is an important step in ensuring that port sampling efforts in General Santos can be adapted to collect the most relevant CF data (under Project 90), biological samples (under Project 35b) and tag recovery information (under Project 42) needed for each tuna stock assessment. The Year 2

implementation contract between SPC and SFFAII was agreed upon and signed by both parties on 22 March 2024.

Table 1. Numbers of individual tuna and bycatch length-length (L-L) CF measurements collected between 2019 and 2024. Data updated through 4 June 2024.

Number of L-L CF measurements					
Year	Skipjack	Yellowfin	Bigeye	Albacore	Other bycatch
2019	4	17	0	0	0
2020	0	2,192	431	0	0
2021	0	2,362	267	0	0
2022	0	2,101	136	0	0
2023	0	341	49	0	0
2024	0	0	0	0	0

Notes
1. Where length is upper jaw to caudal fork (UF) and other length measurements have been recorded.
2. Source: Port sampling.
3. 2024 data for bigeye and yellowfin is forthcoming from the first trial of alternative approaches for collecting L-L and GG-WW data. This trial is being conducted by a Cook Islands' observer onboard a longline vessel due to unload in Apia, Samoa, in July 2024.
4. The SQL query to reproduce this table is 'PH_P90_len_len_cf_summaries' and is stored at: \\corp.spc.int\shared\FAME\NC_NOU\OFP\DB1\Tuna_dbs\Conv_Fact_Project90_SQL on SPC's network drives.

Table 2. Numbers of individual tuna and bycatch length-weight (L-W) CF measurements collected between 2015 and 2024. Data updated through 4 June 2024.

Number of L-W CF measurements					
Year	Skipjack	Yellowfin	Bigeye	Albacore	Other bycatch
2015	44	5	10	27,678	158
2016	1,754	50	2	56,914	113
2017	5,379	5,750	4,976	48,333	55
2018	864	8	0	17,042	50
2019	3,593	317	50	78,735	1,003
2020	13,241	6,811	780	45,556	1,015
2021	10,571	4,621	598	55,570	325
2022	6,079	4,104	416	34,622	312
2023	4,482	1,284	578	70,456	905
2024	883	65	30	25,931	2,203

Notes
1. Where length is upper jaw to caudal fork (UF) and weight is whole weight (WW) only.
2. Source: Port sampling.
3. Port sampling under Project 90 has allowed the sampling of very small tunas (< 25 cm UF) previously unavailable.
4. Further 2024 L-W data for skipjack, yellowfin and bigeye will be available soon as the year 2 implementation contract for biological sampling activities with SFFAII rolls out. This data will be entered into *OnShore* at General Santos Port and will be available in BioDaSys.
5. The SQL query to reproduce this table is 'PH_P90_len_wt_summaries' and is stored at: \\corp.spc.int\shared\FAME\NC_NOU\OFP\DB1\Tuna_dbs\Conv_Fact_Project90_SQL on SPC's network drives.

Table 3. Numbers of individual tuna and bycatch weight-weight (W-W) CF measurements collected between 2019 and 2024. Data updated through 4 June 2024.

Number of W-W CF measurements					
Year	Skipjack	Yellowfin	Bigeye	Albacore	Other bycatch
2019	4	17	0	0	0
2020	0	20	0	0	0
2021	0	840	54	0	0
2022	0	1,406	65	0	0
2023	0	122	6	0	0
2024	0	0	0	0	0

Notes
1. Where weight is whole weight (WW) and other processed weights have been recorded.
2. Source: Port sampling.
3. 2024 data for bigeye and yellowfin is forthcoming from the first trial of alternative approaches for collecting L-L and GG-WW data. This trial is being conducted by a Cook Islands' observer onboard a longline vessel due to unload in Apia, Samoa, in July 2024.
4. The SQL query to reproduce this table is 'PH_P90_wt_wt_summaries' and is stored at: \\corp.spc.int\shared\FAME\NC_NOU\OFP\DB1\Tuna_dbs\Conv_Fact_Project90_SQL on SPC's network drives.

Finally, with the expansion in 2024 of the Close-Kin Mark-Recapture (CKMR) sampling programme for south Pacific albacore to ports across the Pacific where fish are often landed in differing states of processing, the need has arisen for new CFs to ensure accurate fork length (and hence age) estimates can be obtained when only body parts such as cut and frozen tails are available for sampling. We are currently working with colleagues at CSIRO, Australia, NIWA, New Zealand and the US troll fleet to collect measurements for such CFs to apply to south Pacific albacore landed into US and Canadian ports. This is considered a priority task in the Project 90 work plan for 2024-2025.

vii) In 2021, SPC purchased a 'WPL Industries' motion-compensated scale as part of a plan to facilitate the at-sea collection of accurate W-W CF data for tunas and bycatch species across the region. This plan addressed work scheduled under *Activity 3.2 iv)* in the 2020-2021 work plan (see Table A1 in Macdonald et al. 2021 for details). The scale arrived in Noumea in late 2021; however, the unit was not calibrated correctly and was subsequently sent back to the manufacturer for re-calibration in 2022 and again in 2023. Despite being re-calibrated and returned to Noumea, substantial issues remain in terms of setup and operation that have precluded field testing to date. SPC has been given the undertaking from WPL Industries to pay for shipping of the scales back to the UK and any repairs required. Shipping is planned as soon as practicable following disruptions caused by the civil unrest currently unfolding in New Caledonia.

viii-ix) In response to a June 2021 enquiry from the Solomon Islands MFMR and SBOB regarding the possibility of alternative work opportunities for Solomon Island fisheries observers, SPC drafted a sampling plan for at-sea and in-port collection of GG-WW CF measurements to fill this important data gap for bigeye and yellowfin tuna. However, an analysis of recent catch composition conducted in early 2023 revealed that the purse seiner fleet was not capturing the target size classes in the numbers or with the regularity required to pursue the sampling plan on those vessels at this stage. Opportunities may still exist to collect relevant GG-WW data onboard longline vessels operating in the Solomon Islands EEZ, but this is contingent upon the availability of functioning motion-compensating scales (see **vii** above) and/or the development and roll out of alternative CF data collection approaches (see **x** below).

x) Tonga, Cook Islands and RMI in conjunction with SPC have recently signed LOAs that detail one such alternative approach to help fill the GG-WW gap for bigeye. The approach involves at-sea removal and storage of the gills and guts immediately following capture on longline vessels. This is followed by weighing of i) the gills and guts, and ii) the gilled and gutted fish they came from in port at the conclusion of the trip (see Appendix 1 for the detailed protocol). The first trial of this approach is underway, involving a Cook Islands' observer onboard a longline vessel due to unload in Apia, Samoa, in late July. We estimate that this first trip will yield approximately 200 new GG-WW records for bigeye, along with L-L CF data (i.e.

measurement from the upper jaw to the anterior base of second dorsal (US)-UF and from the anterior base of pectoral fin to the anterior base of second dorsal (PS)-UF records). If the data collection protocol proves workable during this first trial, roll out to Tonga and RMI is envisaged for later in 2024.

xi) *2023 update of the GG-WW CFs and LWRs for WCPO yellowfin and bigeye*

The new CF data sourced from the ongoing port sampling collaboration with SFFAII in the Philippines provided an opportunity to update the GG-WW CF relationships for bigeye and yellowfin for the 2023 stock assessments (Day et al. 2023; Magnusson et al. 2023). This was the first update of these relationships since Langley et al. (2006). The LWRs for bigeye and yellowfin were also revised for the 2023 stock assessments. This analysis made use of all coupled length and weight measurements available for each species drawn from port sampling and observer records across the region up to 1 June 2023, inclusive. We refer readers to Macdonald et al. (2023) for full details of the analytical pipeline, and links to R code, models and results for these GG-WW and LWR analyses.

xii) *2024 update of the LWR for south Pacific albacore*

As detailed below, we have recently updated the LWR for south Pacific albacore for input into the 2024 stock assessment presented in Teears et al. (2024), the first such update since Langley and Hampton (2005). We followed the general approach taken for bigeye and yellowfin in 2023, making use of all available coupled length and weight measurements drawn from port sampling and observer records across the region up to and including 29 May 2024.

Data extraction, checking and filtering

We compiled four datasets from databases maintained by the Oceanic Fisheries Programme at SPC. A brief description of each dataset is given below with the spatial and temporal coverage and sample sizes shown in Figure 1.

1. port1_LW dataset: includes L-W records for fish measured at port prior to 2015 (drawn from the 'FISH_MASTER_WORK' database).
2. port2_LW dataset: as for 1, but includes L-W records for fish measured at port after 2015 (drawn from the 'Tufman2' database).
3. obsv_LW dataset: includes L-W records from individual fish measured at sea by fisheries observers on longline vessels (drawn from the 'OBSV_MASTER' database).
4. bio_LW dataset: includes L-W records drawn from BioDaSys, SPC's biological sampling database. BioDaSys houses length and weight information on individual fish sampled by fisheries observers at sea or port samplers for which other biological material (e.g. otoliths, gonads, liver, dorsal spine, stomachs) was also collected.

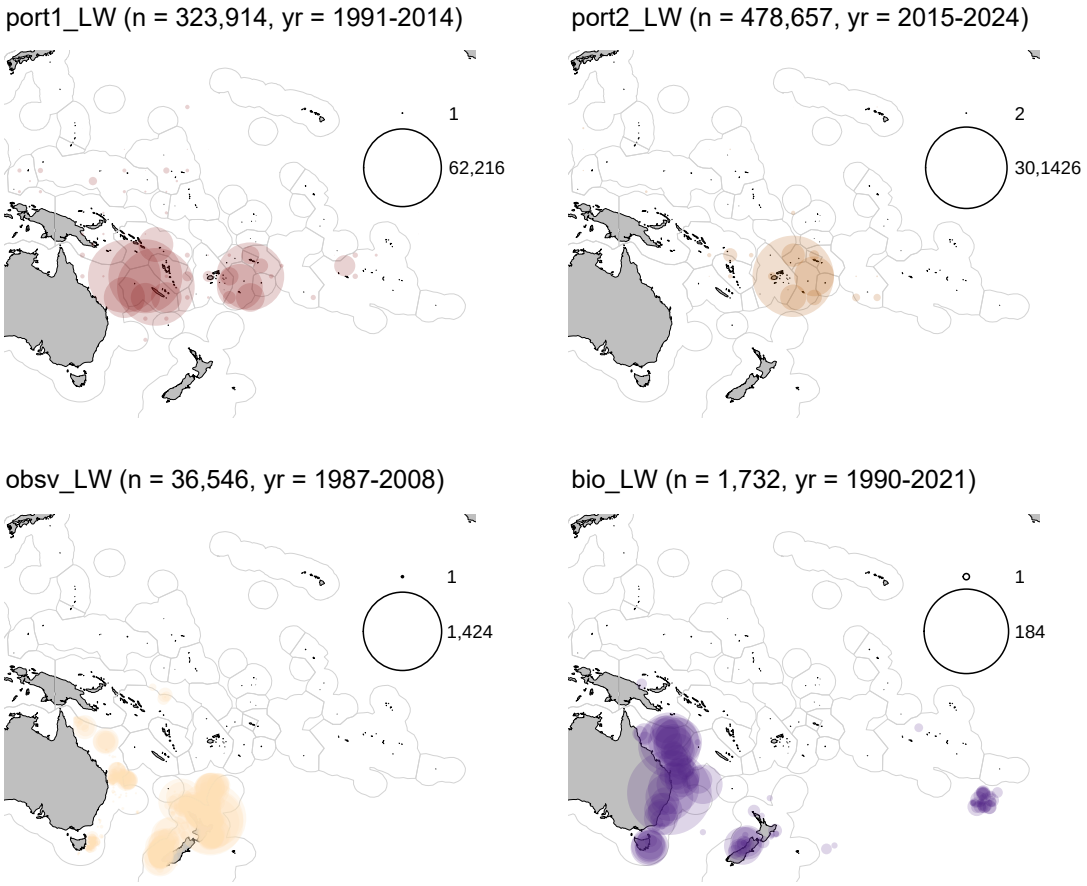

Figure 1. Spatial and temporal coverage of coupled length and weight records in each of the four datasets used to derive the LWR for the 2024 south Pacific albacore assessment. Circle size reflects the number of records collected at a particular location and is scaled for each dataset separately. n, the total sample size available per dataset prior to applying the filtering steps described below; yr, period covered.

Weights recorded for many individual fish in these datasets were processed weights (i.e. weight codes: GG, GH, GX – see Macdonald et al. 2020 Table A4 for code definitions) rather than WW, and we converted these to WW (in kg) using the preferred species-specific CF equations available from the CF database housed within the Tufman2 database.

Focussing on each of the four datasets separately, we first removed extreme outliers – i.e. those clearly outside the realm of biological plausibility. For the port1_LW and port2_LW datasets, we also removed records from north of the Equator to minimise the chance of including data from north Pacific albacore. Next, we fitted an exploratory power model of the form WW (kg) = $a \times$ UF (cm)^b to each dataset and predicted the mean weight-at-length (i.e. WW-at-UF) from this model across the full range of lengths in that dataset. Third, we applied a filtering step to define weight outliers as any value more than 70% heavier or 70% lighter than the predicted mean WW-at-UF. These values likely arise from recording errors made at port or in the SPC databases and were removed as they are not deemed biologically plausible. Fourth, we refitted the power model and flagged remaining outliers by i) using the 'simulateResiduals' and 'testOutliers' functions in the 'DHARMa' v. 0.4.6 R package (Hartig 2022), and ii) identifying records with absolute standardised residual values greater than 3. All flagged values from i) and ii) were considered potential outliers and investigated further. Decisions on whether to keep or exclude these records were based on the balance of biological reasoning and the sensitivity of the model parameter estimates to inclusion or exclusion.

Modelling

Following these filtering steps, we fitted a final power model to each dataset and an overall model to all four datasets combined. For each of these models, residual checks, extraction of parameter estimates and generation

of predictions followed the same procedures outlined for the bigeye and yellowfin LWRs in Macdonald et al. (2023). All models were fitted using the 'lm' function in the 'stats' package in R 4.3.1, with quantile residuals generated in the 'DHARMa' package. Annotated R code and data to reproduce this analysis in full is stored on the SPC network drives, here: P:\OFPEMA\Project 90\Data\2024 data\ALB_assessment_LW.

Results

The *a* and *b* parameter estimates from the models fitted to each of the four datasets are shown in Table 4.

Table 4. Parameter estimates and 95% confidence intervals (CIs) around these estimates from models of the form $WW = a \times UF^b$ fitted to each dataset.

Dataset	*a*	*a*_lower 95% CI	*a*_upper 95% CI	*b*	*b*_lower 95% CI	*b*_upper 95% CI
port1_LW	3.2756e-05	3.2115e-05	3.3410e-05	2.9156	2.9113	2.9200
port2_LW	3.0511e-05	3.0074e-05	3.0954e-05	2.9154	2.9123	2.9186
obsv_LW	2.7050e-05	2.6115e-05	2.8017e-05	2.9255	2.9174	2.9335
bio_LW	8.3423e-06	7.5212e-06	9.2530e-06	3.2080	3.1844	3.2316

We see differences among datasets in both the range of UF values represented and the spread of the observed WW values at a given fish length (Figure 2). Moreover, predictions of WW-at-UF varied to some degree among datasets, particularly for fish larger than 100 cm UF (Figure 2). With reference to the data coverage shown Figure 1, such differences may in part be attributable to spatial, temporal and/or fishery-related processes and we suggest that a deeper exploration of these factors could be a fruitful area for future modelling work (sensu Hoyle et al. 2023).

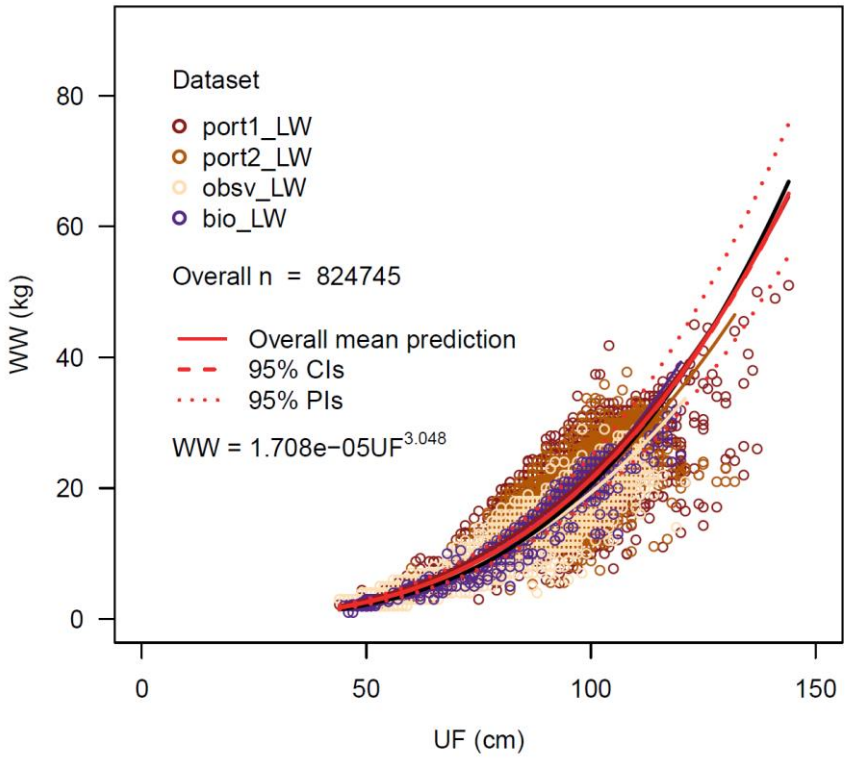

Figure 2. LWR for south Pacific albacore updated for the 2024 stock assessment. Different colour circles represent coupled UF and WW measurements from the four different datasets used in model fitting. The solid red line is the overall mean prediction from the model fitted to all four datasets combined; dashed and dotted red lines are the 95% CIs and 95% prediction intervals (PIs), respectively. The black line is the mean prediction from the LWR derived by Langley and Hampton (2005) as used in the 2021 south Pacific albacore assessment, given by $WW = 6.9587e\text{-}06 \times UF^{3.2351}$ (Castillo-Jordán et al. 2021). Other coloured lines denote the mean predictions for LWRs derived for each of the four datasets separately, with line colour matching circle colour for that dataset.

The overall model was based on a total of 824,745 records, a number dominated by port sampled measurements from the port1_LW and port2_LW datasets. The quantile residual plots revealed no evidence of model misspecification, though there were a small number of data points that fell outside the range of simulated values. These data were checked, considered to represent plausible measurements, and retained in the model. Reasonable agreement was found between observed WW and those predicted from the model (adjusted R^2 = 0.8525). The 2024 LWR for south Pacific albacore has following parameter estimates:

a = 1.7075e-05 (95% CIs: 1.6901e-05, 1.7251e-05); *b* = 3.0483 (95% CIs: 3.0461, 3.0506) so,
$WW = 1.7075e\text{-}05 \times UF^{3.0483}$

The overall mean predicted WW-at-UF from the 2024 model for south Pacific albacore aligns closely with the mean curve used in the 2021 assessment (Castillo-Jordán et al. 2021) originally derived by Langley and Hampton (2005), albeit with slightly lower predicted weight-at-length for the very largest individuals (Figure 2).

xiii) ***Confirmation of LJFL-EFL relationship and 2024 update of the LWR for southwest Pacific striped marlin***

Of the three body length measurements typically recorded for billfishes – i.e. total length from tip of the bill to tip of the tail (TL), lower jaw fork length (LJFL or LF) and eye fork length (EFL or EO), the latter two predominate in the measurements available for southwest Pacific striped marlin. Past WCPFC striped marlin assessments have used EFL as the standard currency for length measurements, and as part of model development for the 2024 assessment (Castillo-Jordán et al. 2024) there was interest in confirming the *a* and *b* parameter estimates for the linear relationship of EFL (in cm) as a function of LJFL (in cm).

The SPC CF database contains *a* and *b* parameter estimates from two sources:

1. from Kopf et al. (2011), derived from length measurements on 301 individuals (both sexes combined) captured in the southwest Pacific by recreational fishers and commercial longline vessels between 2006 and 2009; and
2. from length measurements on 498 individuals (both sexes combined) from Australian (1996-1997) and New Zealand (1990-2007) observer records provided to SPC. This is the preferred CF in the SPC database, with *a* = 0.8621 and *b* = -2.93.

Following some further investigation into the coupled LJFL and EFL data available to SPC, we decided to use the parameter estimates from source 2 for the inputs into the 2024 assessment. We propose, however, that a full revision of this and other L-L conversion factors for southwest Pacific striped marlin be undertaken in the lead up to the next assessment in 2029.

We also derived a new LWR for southwest Pacific striped marlin for input into the 2024 stock assessment. Coupled EFL and WW measurements were obtained for 114 striped marlin ranging between 107 cm and 240 cm EFL captured in New Zealand and Australian waters between 2005 and 2008. These data were kindly provided by Keller Kopf and were associated with work presented in Kopf et al. (2011). One data point was identified as a likely measurement error and was omitted, leaving n = 113 for analysis.

The modelling steps followed those described above for south Pacific albacore. Briefly, we fitted a power model of the form $WW\ (kg) = a \times EFL\ (cm)^b$ to the data. The model provided a good fit to the data, with low residual standard error = ~0.098 and an adjusted R^2 = 0.9469. The parameter estimates were:

a = 5.3994e-07 (95% CIs: 2.3380e-07, 1.2470e-06); *b* = 3.5838 (95% CIs: 3.4249, 3.7426) so,
$WW = 5.3994e\text{-}07 \times EFL^{3.5838}$

Annotated R code and data to reproduce this analysis is stored on the SPC network drives, here: P:\OFPEMA\Project 90\Data\2024 data\MLS_assessment_LW

The mean predicted WW-at-EFL from the model aligns closely with the mean curve used in the past two assessments (Davies et al. 2012; Ducharme-Barth et al. 2019) which used a = 4.4990e-07 and b = 3.6165 (Figure 3).

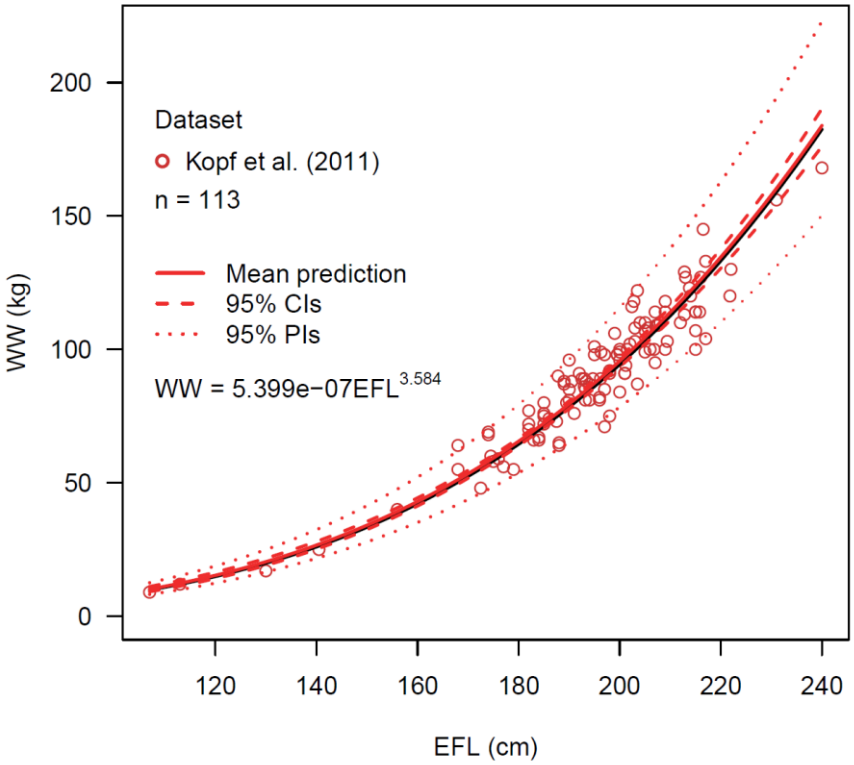

Figure 3. LWR for southwest Pacific striped marlin updated for the 2024 stock assessment. Red circles represent coupled EFL and WW measurements obtained from Keller Kopf and associated with Kopf et al. (2011). The solid red line is the mean prediction from the model; dashed and dotted red lines are the 95% CIs and 95% PIs, respectively. The black line is the mean prediction from the LWR used in both the 2012 and 2019 assessments, given by WW = 4.4990e-07× $EFL^{3.6165}$ (Davies et al. 2012; Ducharme-Barth et al. 2019), plotted for the range of lengths available in the Kopf et al. (2011) dataset.

xiv-xv) In 2021, SPC and colleagues at the National Sun Yat-sen University, Taiwan (NSYSU) entered into an agreement regarding an exchange of bigeye length and weight measurements covering all SPC and Taiwanese data holdings across the WCPO through 2021, and the subsequent collaboration on the statistical analyses of these data (see Macdonald et al. 2021 for details). A primary objective of this work was to explore spatial and temporal variability in bigeye tuna growth parameters across the WCPO, thereby addressing a key recommendation of the 2020 bigeye tuna stock assessment (Ducharme-Barth et al. 2020).

A full report detailing the methods used and results is available in Hoyle et al. (2023). In brief, a series of generalised additive models were fitted to the bigeye length and weight data, which exposed considerable variation in the bigeye LWR associated with location and season. The results highlight the importance of considering factors such as the lack of independence of individuals captured in the same set, rounding issues, and observer and gear effects when estimating LWRs, as well as exploring different error distributions. The report concludes with a set of recommendations designed to guide future approaches to modelling length and weight data for tuna (and other species) assessments that appropriately account for the abovementioned factors. This work is currently being written up for publication in a scientific journal, with a submission likely in the second half of 2024.

xvi) Following substantial progress made during 2022 and early 2023 on the EM versus observer length comparison study in French Polynesia (reported to SC19 in Macdonald et al. 2023), no further EM length data has been collected, nor analyses conducted. French Polynesia has recently ceased using EM on their tuna longline vessels, though Direction des Ressources Marines (DRM) based in Papeete has indicated

that a resumption of the EM programme is likely. Discussions between DRM and SPC around timelines for this are ongoing.

xvii) Over the past 12 months, we have continued to forge stronger links between Project 90 and a range of WCPFC-related projects. These include:

a. ongoing work on developing candidate ecosystem and climate indicators for the WCPO (SPC-OFP 2021, 2022a, 2023a, 2024a);
b. biological data and sample collection for the WCPFC Pacific Marine Specimen Bank conducted as part of WCPFC Project 35b (SPC-OFP 2022b, 2023b, 2024b);
c. tag recovery activities undertaken as part of WCPFC Project 42 (SPC-OFP 2022c, 2023c, 2024c); and
d. the development of new CFs to ensure accurate length and age estimates for the CKMR project on south Pacific albacore as part of WCPFC Project 100c (Bravington et al. 2020, 2021, SPC-OFP 2022d; SPC-OFP and CSIRO 2023, 2024).

3. SUMMARY AND WORK PLAN FOR 2024-2025

While progress continues on each of the Project 90 work areas, the following items will be prioritised over the next 12 months:

1. Updating and expanding the CF database.
2. Collection of GG-WW CF data on bigeye will continue across the region facilitated through the LOAs between SPC and Tonga, Cook Islands, RMI and potentially other member countries.
3. Refinement of a web-based dashboard for plotting CF relationships for selected species that links to SPC's CF database and is accessible on the WCPFC web site.
4. Investigation into historical length data. OFP colleagues have recently expressed interest in exploring the quality of the length data that goes into MULTIFAN-CL assessment models, in particular, the accuracy of historical length records. In response, we propose an analysis focussed on quality checks of historical length data for WCPFC tuna and billfish assessments. This analysis would be undertaken over the next 12 months and fall within the Project 90 remit. It would focus on:
    a. measurement irregularities, for example, instances of exceptionally small fish caught on longline gear and exceptionally heavy fish caught in ringnets;
    b. missing or erroneous entries for sampling location;
    c. refinement of automated filters for identifying errors highlighted in points a and b;
    d. uncertainties around spatial grid resolution;
    e. identification of areas and/or time periods with sparse records; and
    f. investigation into how rounding of length measurements has been implemented.
5. Continue work with colleagues at CSIRO, Australia, NIWA, New Zealand, and the US tuna troll fleet to collect coupled fork length and tail length measurements from south Pacific albacore. The CF developed from these measurements will allow for accurate fork length (and hence age) estimates to be derived from tail cuts alone and help support the south Pacific albacore CKMR sampling programme for fish landed into US and Canadian ports.

4. RECOMMENDATIONS

We invite SC20 to:

1. review and comment on the progress made on Project 90 activities at this stage;
2. note that Project 90 has been selected for inclusion in the *Online Discussion Forum* at SC20, and SPC looks to that forum to table and define the priority activities proposed in this paper; and
3. consider Project 90 as an ongoing project of the WCPFC, with indicative 2025 and 2026 budgets of USD 20,000 per annum to fund tasks set out in the 2024-2025 work plan.

5. ACKNOWLEDGEMENTS

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APPENDIX 1: Bigeye tuna conversion factor data collection

Background

The recently signed LOAs with Tonga, Cook Islands and RMI are exciting in that they provide an alternative pathway towards filling the GG-WW conversion data gap for large bigeye and yellowfin from the central Pacific Ocean as well as collecting useful L-L data for each species. With a current priority towards bigeye, under these LOAs, observers placed on longline and/or purse seine vessels are asked, for each captured bigeye > 70 cm UF, to:

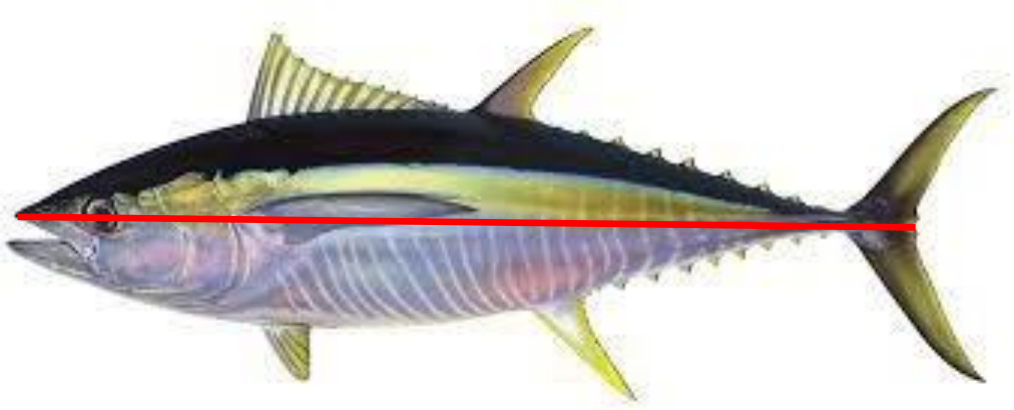
Onboard tasks

- Measure the fish's length. Record three length measurements (i.e., UF, US - upper jaw to 2nd dorsal fin, and PS - anterior base of pectoral fin to 2nd dorsal to the nearest lowest cm) on the 'GEN-4' form (see Figure A1).
- Wait for the crew to remove the gills and guts (in some cases also the head and tail).
- Place gills and guts (and head and tail, if cut off) inside a sealable plastic bag with a unique label number, and store under the same conditions as the fish is stored (e.g., blast frozen, on ice).
- Place a cable-tie coded with the same label number through the jaw of the fish.
- Record the label numbers on the GEN-4 form. This allows association of the bagged gills and guts with the relevant fish at port.

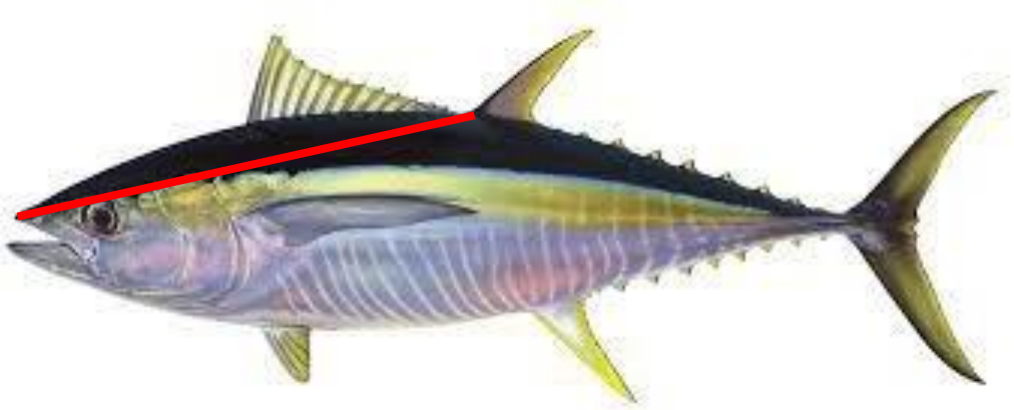
At port tasks

- If fish are brought to port GG and frozen:
    1) record the weight of the frozen gills and guts (to nearest 0.01 kg),
    2) record the weight of the frozen GG fish from which they came (to nearest 0.01 kg) identified by the same label number.
- If fish are brought to port whole and fresh:
    1) record fresh WW weight (to nearest 0.01 kg),
    2) remove gills and guts and record fresh GG weight (to nearest 0.01 kg),
    3) measure the fresh weight of the gills and guts (to nearest 0.01 kg),
    4) freeze these,
    5) measure frozen weight of the gills and guts (to nearest 0.01 kg).
- If fish are brought to port whole and frozen:
    1) record frozen WW weight (to nearest 0.01 kg),
    2) remove gills and guts and record frozen GG weight (to nearest 0.01 kg) (noting that this may be logistically challenging in some instances).
- Note down any special comments in the 'COMMENTS' section on the 'GEN-4' form.

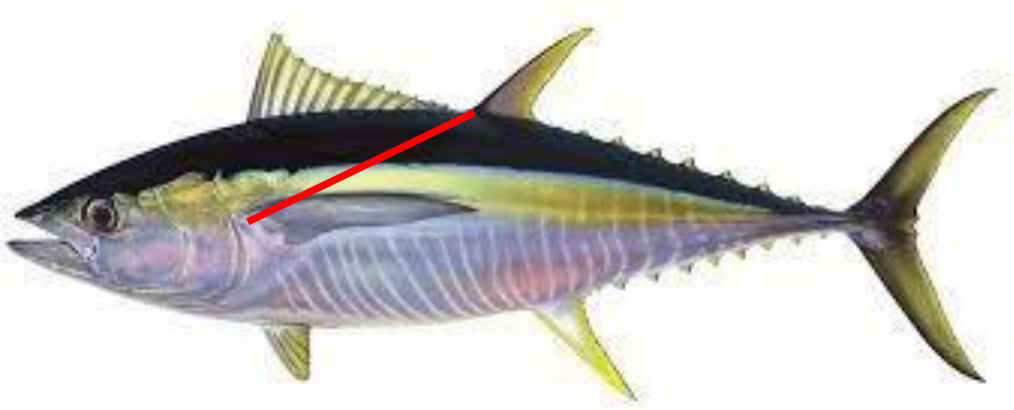
The LOAs encourage collection of these measurements for as many bigeye as possible without setting strict targets for numbers at this stage.



UF – Upper jaw to caudal fork



US (a.k.a. SD) – Upper jaw to anterior base of second dorsal



PS – Anterior base of pectoral fin to anterior base of second dorsal

Figure A1. Length measurements requested as part of observers' onboard tasks under the LOAs with Tonga, Cook Islands and RMI.