Collect. Vol. Sci. Pap. ICCAT, 81(2), SCRS/2024/046: 1-11 (2024)

CONVERSION FACTORS FOR TROPICAL TUNAS CAUGHT WITH PURSE SEINE IN THE ATLANTIC OCEAN UPDATE OF THE ARTICLE "CONVERSION FACTORS UPDATE FOR TROPICAL TUNAS CAUGHT WITH PURSE SEINE IN THE ATLANTIC OCEAN"

Théotime Fily[1] and Antoine Duparc[1]

SUMMARY

In this paper, we proposed an update of the length weight relationship of major and neritic tunas caught by the tropical tuna purse seine fisheries for which the conversion was not revised for more than 40 years. Based on previous study "Conversion factors update for tropical tunas caught with purse seine in the Atlantic Ocean", we further tested for an additional predictor, the fishing mode and performed sensitive analyses on spatio-temporal predicators to demonstrate the robustness of the new estimated relationship. Although the fishing mode was significantly selected, its effect on prediction was marginal and the lowest of all the predictors conserved in the optimal model. Sensitive analyses demonstrated the robustness of the estimates for the length weight relationship (LWR) of major tuna species even with a strict filtering minimum of 50 data by 5° square and year. The LWR parameters estimate in the simple linear model remained unchanged whatever the filtering intensity. Regarding the predictions of the two models, their relative differences were also very small. Consequently, the authors recommend the use of simple length-weight relation to convert length to weight for the purse seine tropical fisheries.

RÉSUMÉ

Dans ce document, nous avons proposé une mise à jour de la relation longueur-poids des principaux thonidés néritiques capturés par les pêcheries de senneurs ciblant les thonidés tropicaux pour lesquels la conversion n'a pas été révisée depuis plus de 40 ans. Sur la base de l'étude précédente "Conversion factors update for tropical tunas caught with purse seine in the Atlantic Ocean (mise à jour des facteurs de conversion pour les thonidés tropicaux capturés à la senne dans l'océan Atlantique)", nous avons testé un prédicteur supplémentaire, le mode de pêche, et effectué des analyses de sensibilité sur les prédicteurs spatio-temporels afin de démontrer la robustesse de la nouvelle relation estimée. Bien que le mode de pêche ait été sélectionné de manière significative, son effet sur la prédiction était marginal et le plus faible de tous les prédicteurs conservés dans le modèle optimal. Des analyses de sensibilité ont démontré la robustesse des estimations de la relation longueur-poids (LWR) des principales espèces de thonidés, même avec un filtrage strict de 50 données au minimum par carré de 5° et par année. L'estimation des paramètres LWR dans le modèle linéaire simple est restée inchangée quelle que soit l'intensité du filtrage. En ce qui concerne les prévisions des deux modèles, leurs différences relatives étaient également très faibles. Par conséquent, les auteurs recommandent l'utilisation d'une simple relation longueur-poids pour convertir la longueur en poids pour les pêcheries de senneurs tropicaux.

RESUMEN

En este documento, se propone una actualización de la relación talla-peso de los principales túnidos y de los túnidos neríticos capturados por las pesquerías de cerco de túnidos tropicales, cuya conversión no se revisaba desde hacía más de 40 años. Basándonos en el estudio previo "Actualización de los factores de conversión para los túnidos tropicales capturados con red de cerco en el océano Atlántico", hemos probado un predictor adicional, la modalidad de pesca, y hemos realizado análisis sensibles sobre los depredadores espaciotemporales para demostrar la solidez de la nueva relación estimada. Aunque la modalidad de pesca se seleccionó de forma significativa, su efecto sobre la predicción fue marginal y el menor de todos los predictores

[1]MARBEC, Univ Montpellier, CNRS, IFREMER, IRD, Sète, France. antoine.duparc@ird.fr

conservados en el modelo óptimo. Los análisis de sensibilidad demostraron la solidez de las estimaciones de la relación talla-peso (LWR) de las principales especies de túnidos, incluso con un filtrado estricto de un mínimo de 50 datos por cuadrícula de 5° y año. La estimación de los parámetros LWR en el modelo lineal simple no varió con independencia de la intensidad del filtrado. En cuanto a las predicciones de los dos modelos, sus diferencias relativas también fueron muy pequeñas. En consecuencia, los autores recomiendan el uso de la relación simple talla-peso para convertir la talla en peso para las pesquerías tropicales de cerco.

KEYWORDS

Length-weight relationship, Yellowfin, Skipjack, Bigeye, Little tuna, Frigate tuna, Bullet tuna

1. Introduction

Paper SCRS/2023/148 (Fily and Duparc 2023) was presented to the tropical tuna species group meeting of ICCAT in 2023 with the aim to propose a full review of major tunas length weight relationship (LWR). The study bases on a large time series biological dataset clearly demonstrated the necessity of update parameters of major tropical tuna caught by the purse seine fisheries in Atlantic Ocean. Spatial, temporal and marginally sex effects have been demonstrated significant but with very limited size effect compared to a simple linear relationship. The present paper presents an update of the previous study to answer the points raised by the working group. First sensitive analyses on spatio-temporal effect were performed to estimate robustness of the output and give advice on common critical points of the data collection. The working group recommended testing for the fishing mode effect on LWR, as it is well known that body condition of the tuna can differ among school type due to variable trophic conditions (Hall et al. 1992, Hallier and Gaertner 2008, Dupaix et al. 2023). Indeed, we expected tunas to be bigger for a given size in free school than in school under FOB resulting from a better nutrient intake link to activities or ecological trap effects. Finally, we extend the methodology of the previous study to neritic tunas for which a consequent dataset was available.

2. Materiel and methods

2.1 Data

The data uses for this study come from the Tunabio database (Guillou et al. 2022). Datasets and filtering procedure are described in Paper SCRS/2023/148 (Fily and Duparc 2023, **Table 1**).

The fish were sampled in routine at Abidjan port on EU tropical purse seine fisheries (France and Spain) through the Data Collection Framework (Reg 2017/1004 and 2021/1167) funded by both IRD and the European Union. Fish were store in brine in wells during the trip and were unfrozen before measurement and weight.

2.2 Modelling

The allometric relationships are commonly modeled using a power function (Eq1), log transformed in its linear form (Eq2) to simplify the modeling approach ((Keys 1928, Le Cren 1951, Pélabon et al. 2014).

$$W = aL^b \qquad \text{Equation (1)}$$

Where, W is the whole-body wet weight (kg), L is the fish length (here Fork length, cm), a and b the parameters.

$$\log(W) = \log(a) + b\log(L) \qquad \text{Equation (2)}$$

Following the recommendations of Froese et al. (2011) and Pélabon et al. (2014), we aim to compare two linear models. The "simple model" is defined as the direct relationship between the response variable (W) without any other covariable than the length (L), whereas the full model included the sex of each individual, the 5° square id (CWP) as spatial predictors, fishing months and fishing year, as temporal predictors. All predictors were in interaction with the length considering that the allometry relationship can vary. No interaction between space and time was included to ovoid overparameterization issues.

Regarding the full model, predictor selection was performed using backward selection based on Akaike's information criterion (AIC). Two models with more than two values of AIC (ΔAIC) were considered significantly different (Anderson and Burnham 2002). When ΔAIC between two models was inferior to two, the simplest model in terms of degrees of freedom was selected. The best-fit model was referred to as the "optimal model".

2.3 Sensitive analysis on spatial-temporal effect

We tested whether the LWR were sensitive to the sampling effort. Data have been aggregated by CWP (5°) and year. The dataset has been reduced by keeping data in each group CWP-year according to minimum thresholds of 10, 20, 30 and 50 data respectively. For each filtering, we estimated the adjusted R^2 of the optimized model and the size effect of every selected predictor using estimated marginal means.

We also computed the simple model coefficients of the LWR and the relative error between the two models similarly to the paper SCRS/2023/148 (Fily and Duparc 2023).

2.4 Fishing mode analysis

Fishing mode effect was studied separately because this information is available for a limited part of the sets. The dataset was unbalanced. Indeed, there were more FOB data than FSC's and the FSC fish were not present in the smaller size ranges, or only to a limited extent (**Figure 1**). So, we kept, for each species, the same size range for both fishing mode. We tested this revised dataset with the same modeling approach previously described and with the addition of the fishing mode as predictors. Similarly, we performed variable selection and computed the size effect of the fishing mode variable.

Fishing mode effect have been tested only on major tuna species due to the lack of presence of this information for neritic tunas.

3. Results and discussion

3.1 Sensitive analyses

Predictor selection remained similar whatever the minimum numbers of data by 5° square – year tested, except for the BET for which year effect was not observed for the strongest filtering (50 data). With such a high filtering, data from several years disappear completely which can explain this result (**Table 2**). Similarly, size effects were in the same order of magnitude and kept the same relative importance among predictors (table not shown here). For instance, fishing months and CWP (5° square) remained the major variable selected in all models. Sex differences were consistently observed for YFT only.

Accordingly, the R^2 were stable and high (>0.99) for all species and all filtering levels. These results were not surprising for YFT and SKJ considering the large amount of data available even for strong filtering (Respectively 3115 and 2160 measures, **Table 3**). More surprising BET with only 387 data kept a high R square value of 0996. Relative error between models (simple and optimized) also remained very small (< 1%), meaning that even with reduce data set, simple model was reliable compared to complex one. Moreover, parameters of the LWR from the simple model did not significantly differ among filtering intensity, which demonstrated the robustness of the estimated relationship (**Table 3**).

3.2 Fishing mode

Fishing mode was always selected in optimal models as, spatial and temporal variables. Sex is only selected for YFT as in the previous analyses accounting for all dataset but without fishing mode.

However, the size effect of the fishing mode was the lowest effect of all predictors with less than 1% of variation for YFT and SKJ and less around 2% for BET. In comparison, Spatio-temporal predictors had effects 2 to 10 times higher (**Table 4**).

More surprisingly, no strong pattern of bigger fish under FSC was observed (**Figure 2**). Spatial and temporal factor could have a confounding effect as free schools and associated schools are not homogeneously distributed all over the fishing ground.

4. Conclusion and recommendations

In the light of the study of the article SCRS/2023/148 and with the additional analyses presented in this paper, authors strongly recommend use of simple model approach to estimate new LWR relationship to convert length to weight of the majors and neritic tuna species caught by tropical tuna purse seine fisheries during the period 2010 to 2030. The validity of this relationship could certainly be extended to a larger period in the future years after checking.

Authors also strongly recommend a similar analysis based on similar data collection to estimate the LWR for other fisheries and to improve the understanding of the allometric relation at the stock level.

It is important to note that considering the freezing process undergone by fish in purse seine fisheries, weight of individual could be biases due to the gain or lost of water. LWR relationships in **Table 5** are so not usable before correction of this weight variation. Further research is needed to estimate this variation.

However, conclusion relative to methodology and impact of variables remained correct as the bias is constant over all individuals. Authors recommend measure on fresh fish to avoid any bias.

References

Anderson, D. R., and K. P. Burnham. 2002. Avoiding Pitfalls When Using Information-Theoretic Methods. The Journal of Wildlife Management 66:912–918.

Dupaix, A., L. Dagorn, A. Duparc, A. Guillou, J.-L. Deneubourg, and M. Capello. 2023. No evidence from long-term analysis of yellowfin tuna condition that Drifting Fish Aggregating Devices act as ecological traps. Marine Ecology Progress Series:1–18.

Fily, T., and A. Duparc. 2023. Conversion factors update for tropical tunas caught with purse seine in the Atlantic ocean. Col.Vol.Sci.Pap. ICCAT:1–12.

Froese, R., A. C. Tsikliras, and K. I. Stergiou. 2011. Editorial Note on Weight–Length Relations of Fishes. Acta Ichthyologica Et Piscatoria 41:261–263.

Guillou, A., N. Bodin, E. Chassot, A. Duparc, T. Fily, P. Sabarros, M. Depetris, M. Amandè, J. Lucas, E. Augustin, N. Diaha, L. Floch, J. Barde, P. Pascual-Alayón, J. C. Báez, P. Cauquil, K. Briand, and J. Lebranchu. 2022. Tunabio: biological traits of tropical tuna and bycatch species caught by purse seine fisheries in the Western Indian and Eastern Central Atlantic Oceans. Biodiversity Data Journal 10:e85938.

Hall, M., M. Garcia, C. Lennert-Cody, P. Arenas, and F. Miller. 1992. The association of tunas with floating objects and dolphins in the eastern Pacific Ocean: a review of the current purse-seine fishery. Pages 87–194 Proceedings of the international workshop on the ecology and fisheries for tunas associated with floating objects.

Hallier, J.-P., and D. Gaertner. 2008. Drifting fish aggregation devices could act as an ecological trap for tropical tuna species. Marine Ecology Progress Series 353:255–264.

Keys, A. B. 1928. The Weight-Length Relation in Fishes. Proceedings of the National Academy of Sciences 14:922–925.

Le Cren, E. D. 1951. The Length-Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (*Perca fluviatilis*). Journal of Animal Ecology 20:201–219.

Pélabon, C., C. Firmat, G. H. Bolstad, K. L. Voje, D. Houle, J. Cassara, A. L. Rouzic, and T. F. Hansen. 2014. Evolution of morphological allometry. Annals of the New York Academy of Sciences 1320:58–75.

Table 1. Summary of time series used for LWR modeling per species.

Species	*effective*	*min FL*	*max FL*	*min W*	*max W*	*min year*	*max year*
YFT	5,123	36	173	0.96	111.4	2010	2022
BET	1,054	39.3	172.6	1.3	117.25	2014	2022
SKJ	2,745	30.3	71	0.5	9.2	2008	2022
BLT	348	31.2	45.6	0.58	1.87	2021	2022
FRI	292	30	46	0.49	2.01	2021	2022
LTA	140	32.2	52	0.65	3.11	2021	2022

Table 2. Model selection per major tuna species according various minimum numbers of data per 5°square – year.

Species	*filter*	*formula*	*df*	*AIC*	*R_sq*
YFT	All	log_weight ~ log_fl * cwp5 + log_fl * sex + log_fl * fishing_month + log_fl * fishing_year	6238	-17434	0.997
	10	log_weight ~ log_fl * cwp5 + log_fl * sex + log_fl * fishing_month + log_fl * fishing_year	6161	-17198	0.997
	20	log_weight ~ log_fl * cwp5 + log_fl * sex + log_fl * fishing_month + log_fl * fishing_year	5834	-16237.2	0.997
	30	log_weight ~ log_fl * cwp5 + log_fl * sex + log_fl * fishing_month + log_fl * fishing_year	5184	-14551.2	0.997
	50	log_weight ~ log_fl * cwp5 + log_fl * sex + log_fl * fishing_month + log_fl * fishing_year	4171	-11614.9	0.997
SKJ	All	log_weight ~ log_fl + cwp5 + fishing_month + fishing_year + log_fl:cwp5 + log_fl:fishing_month	2674	-6830.1	0.987
	10	log_weight ~ log_fl * cwp5 + log_fl * sex + log_fl * fishing_month + log_fl * fishing_year	2653	-6799.3	0.987
	20	log_weight ~ log_fl + cwp5 + fishing_month + fishing_year + log_fl:cwp5 + log_fl:fishing_month + log_fl:fishing_year	2599	-6671.8	0.987
	30	log_weight ~ log_fl + cwp5 + fishing_month + fishing_year + log_fl:cwp5 + log_fl:fishing_month + log_fl:fishing_year	2427	-6223.1	0.987
	50	log_weight ~ log_fl + cwp5 + fishing_month + fishing_year + log_fl:cwp5 + log_fl:fishing_month + log_fl:fishing_year	2096	-5360.5	0.987
BET	All	log_weight ~ log_fl + cwp5 + fishing_month + fishing_year + log_fl:cwp5 + log_fl:fishing_year	993	-2938.5	0.998
	10	log_weight ~ log_fl + cwp5 + fishing_month + fishing_year + log_fl:cwp5 + log_fl:fishing_month + log_fl:fishing_year	940	-2832.4	0.998
	20	log_weight ~ log_fl + cwp5 + fishing_month + fishing_year + log_fl:cwp5 + log_fl:fishing_month + log_fl:fishing_year	695	-2075.2	0.998
	30	log_weight ~ log_fl + cwp5 + sex + fishing_month + fishing_year + log_fl:cwp5 + log_fl:fishing_month	554	-1646.1	0.997
	50	log_weight ~ log_fl + cwp5 + sex + fishing_month + log_fl:cwp5 + log_fl:fishing_month	366	-1032.3	0.996

Table 3. Variation of the parameters in the LWR simple linear model according various minimum numbers of data per 5°square – year.

Species	*Filter*	*N*	*FL min*	*FL max*	*intercept*	*intercept_IC95*	*slope*	*slope_IC95*	*Adj R^2*
YFT	0	5123	36	173	2.02E-05	[1.97e-05 ; 2.06e-05]	3.004	[2.999 ; 3.009]	0.996
	10	5044	36	173	2.02E-05	[1.97e-05 ; 2.07e-05]	3.004	[2.999 ; 3.008]	0.996
	20	4716	36	173	2.02E-05	[1.97-05 ; 2.068e-05]	3.003	[2.998 ; 3.008]	0.996
	30	4067	36	172	2.00E-05	[1.95e-05 ; 2.05e-05]	3.006	[3.001 ; 3.011]	0.996
	50	3115	36	172	1.93E-05	[1.88e-05 ; 1.99e-05]	3.013	[3.007 ; 3.019]	0.996
SKJ	0	2745	30.3	71	5.52E-06	[5.18e-06 ; 5.88e-06]	3.352	[3.335 ; 3.368]	0.983
	10	2733	30.3	71	5.55E-06	[5.21e-06 ; 5.92e-06]	3.35	[3.333 ; 3.367]	0.983
	20	2673	30.3	71	5.67E-06	[5.31e-06 ; 6.05e-06]	3.345	[3.328 ; 3.361]	0.983
	30	2501	30.3	71	5.63E-06	[5.26e-06 ; 6.02e-06]	3.346	[3.329 ; 3.364]	0.983
	50	2160	30.3	70.5	5.72E-06	[5.32e-06 ; 6.14e-06]	3.343	[3.324 ; 3.361]	0.983
BET	0	1054	39.3	172.6	2.22E-05	[2.13e-05 ; 2.32e-05]	3.006	[2.996 ; 3.015]	0.997
	10	1010	39.3	172.6	2.21E-05	[2.12e-05 ; 2.31e-05]	3.007	[2.997 ; 3.017]	0.997
	20	749	39.3	171.8	2.20E-05	[2.09e-05 ; 2.32e-05]	3.007	[2.995 ; 3.02]	0.997
	30	593	39.3	171.3	2.26E-05	[2.12e-05 ; 2.41e-05]	3.002	[2.987 ; 3.016]	0.996
	50	387	43	166	2.16E-05	[1.96e-05 ; 2.38e-05]	3.011	[2.988 ; 3.034]	0.994

Table 4. Size effect of selected predictors in the optimal models and according three fork length size (FL) of individual.

Species	*FL*	*mn_W*	*mx_W*	*mu_W*	*SD*	*CV*	*predictor*
YFT	107.8	25.5	25.9	25.7	0,2849	0,0111	sex
	131	45	46	45.5	0,7205	0,0158	sex
	144	59.2	60.8	60	1,0891	0,0181	sex
	107.8	25	26.4	25.7	0,4319	0,0168	month
	131	44.6	46.8	45.5	0,6902	0,0152	month
	144	58.5	62.1	60	1,0262	0,0171	month
	107.8	24.6	27.2	25.7	0,6524	0,0254	year
	131	43.2	47.2	45.5	1,2502	0,0275	year
	144	56.5	61.8	60	1,939	0,0323	year
	107.8	23.5	29	25.7	0,901	0,0351	cwp5
	131	42.4	48	45.5	1,0619	0,0233	cwp5
	144	56.4	62.8	60	1,2927	0,0215	cwp5
	107.8	25.6	25.8	25.7	0,1344	0,0052	fishing_mode
	131	45.3	45.6	45.5	0,2379	0,0052	fishing_mode
	144	59.8	60.2	60	0,3139	0,0052	fishing_mode
SKJ	42	1.4	1.6	1.5	0,0533	0,0347	month
	46	1.9	2.2	2.1	0,0846	0,0406	month
	51	2.6	3.1	2.9	0,1431	0,0487	month
	42	1.4	1.7	1.5	0,0894	0,0581	year
	46	1.9	2.3	2.1	0,1211	0,0581	year
	51	2.7	3.2	2.9	0,1709	0,0581	year
	42	1.4	1.7	1.5	0,0572	0,0372	cwp5
	46	2	2.3	2.1	0,0724	0,0348	cwp5
	51	2.7	3.2	2.9	0,1128	0,0384	cwp5
	42	1.5	1.5	1.5	0,0039	0,0025	fishing_mode
	46	2.1	2.1	2.1	0,0121	0,0058	fishing_mode
	51	2.9	3	2.9	0,0281	0,0096	fishing_mode
BET	63.2	5.3	6.3	5.9	0,2795	0,0471	month
	81.2	11.1	13.1	12.3	0,582	0,0471	month
	112	28.4	33.7	31.7	1,4932	0,0471	month
	63.2	5.3	6.9	5.9	0,5381	0,0904	year
	81.2	11.3	13.7	12.3	0,7404	0,0599	year
	112	30.3	32.6	31.7	0,7895	0,0249	year
	63.2	4.3	6.9	5.9	0,6282	0,1053	cwp5
	81.2	9.7	14	12.3	1,0112	0,0816	cwp5
	112	27.6	35.5	31.7	1,814	0,0572	cwp5
	63.2	5.8	6.1	5.9	0,2289	0,0386	fishing_mode
	81.2	12.1	12.6	12.3	0,3052	0,0247	fishing_mode
	112	31.5	31.8	31.7	0,2175	0,0069	fishing_mode

Table 5. Final length weight relationship per tuna species from simple linear model for the purse seine fleet in the Atlantic Ocean.

Species	*Effective*	*Min FL*	*Max FL*	*Intercept*	*Intercept 95IC*	*Slope*	*Slope 95IC*	*Adj R^2*
YFT	5,123	36	173	2.016e-05	[1.97e-05; 2.06e-05]	3.004	[2.999; 3.009]	0.996
SKJ	2,745	30.3	71	5.52e-06	[5.18e-06; 5.88e-06]	3.352	[3.335; 3.368]	0.983
BET	1,054	39.3	172.6	2.22e-05	[2.13e-05; 2.32e-05]	3.006	[2.996; 3.015]	0.997
BLT	348	31.2	45.6	1.19e-05	[7.87e-06; 1.80e-05]	3.139	[3.026; 3.251]	0.897
FRI	292	30	46	6.52e-06	[4.69e-06; 9.07e-06]	3.299	[3.209; 3.389]	0.947
LTA	140	32.2	52	2.73e-05	[1.64e-05; 4.55e-05]	2.901	[2.765; 3.037]	0.928

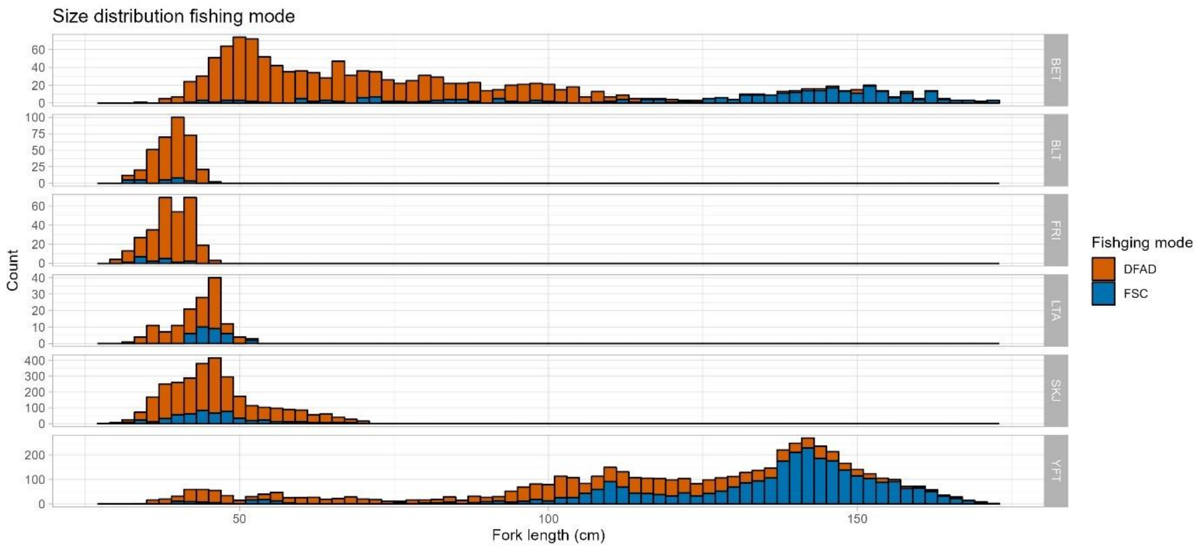

Figure 1. Size distribution per fishing mode and tuna species caught by the tropical purse seine fisheries for the period 2008-2022. The period slightly varies among species.

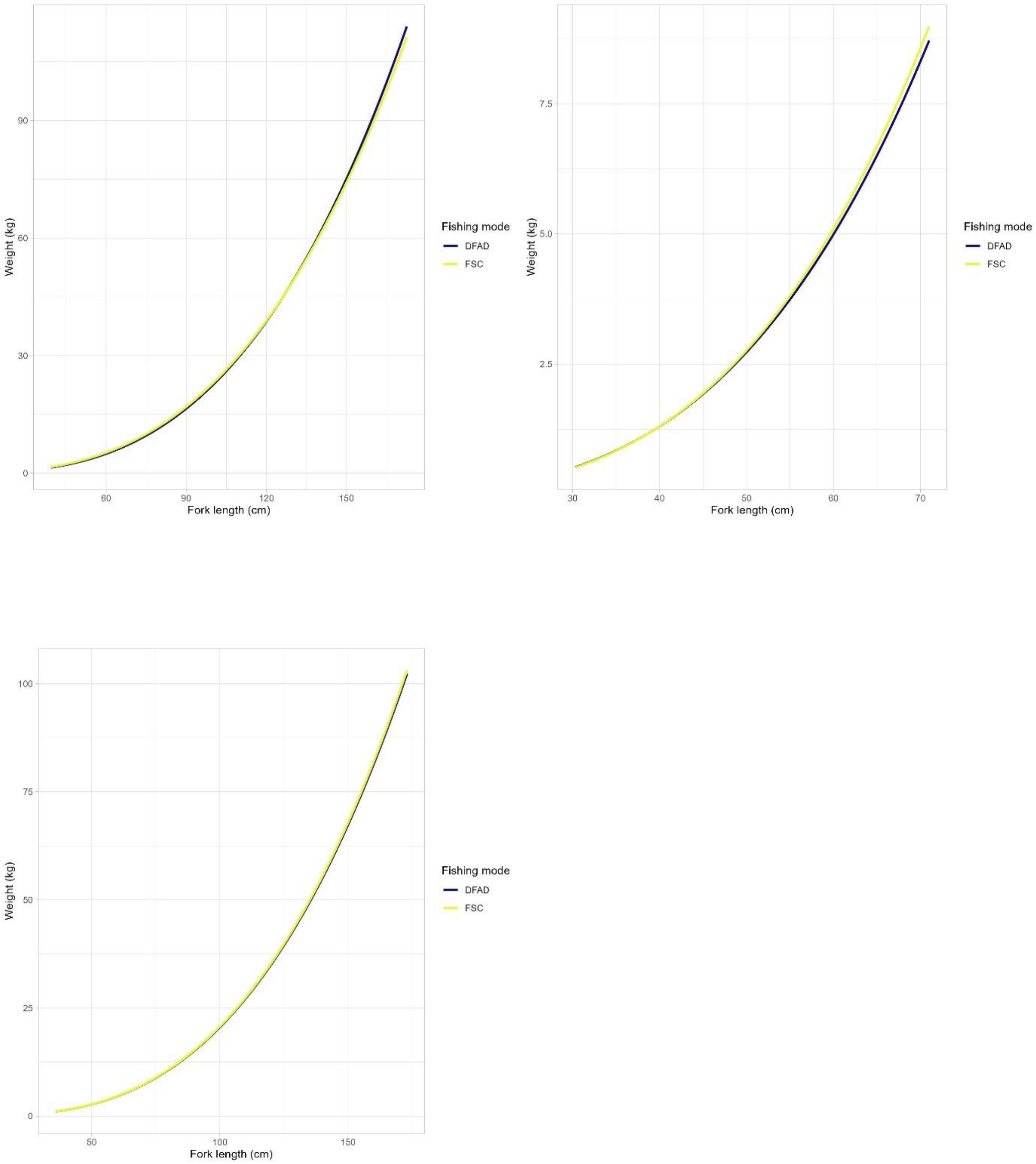

Figure 2. Fitted LWR according the fishing mode for BET, SKJ and BET species (top left, right and bottom left respectively). DFAD = floating object (drifting FAD), FSC = free school.