Biometric relationships and conversion coefficients of large pelagics collected in Reunion (Indian ocean)

Galadriel Guillén[1], Blandine Brisset[2], Hugues Evano[2], Yoann Aumond[2], Louis Wambergue[2], Jérémie Chanut[3], Anne Elise Nieblas[3], Marine Jaspers[1], Sylvain Bonhommeau[2]

[1]*Direction of the South Indian Ocean Sea (DMSOI) – Le Port - Reunion*

[2] *Ifremer DOI – Le Port – Reunion*

[3] *Company for Open Ocean Observations and Logging – Saint Leu – Reunion*

Abstract

As an outermost region (OR) of the European Union, Reunion Island is subject to the common fisheries policy (CFP) which aims to promote sustainable and economically viable fishing and aquaculture activities, in particular by encouraging the transformation products resulting from their activities. The control of the sectors by the follow-up of the traceability and the financial support makes it possible to meet its objectives. Conversion coefficients for each processing and for each species or group of species of fish marketed are used in the tools for monitoring fisheries (fishing declaration and purchasing obligations) and in the calculation of the amount of aid allocated to the sectors by the European Maritime, Fisheries and Aquaculture Fund (FEAMPA). The scale of coefficients currently applied in Reunion is inconsistent and does not comply with the CFP control regulations. A consolidated list of conversion factors for the different fish processing is proposed here for application in the Reunion region.

Résumé

En tant que région ultrapériphérique (RUP) de l'Union européenne, la Réunion est soumise à la politique commune de la pêche (PCP) qui vise à promouvoir des activités de pêche et d'aquaculture durables et économiquement viables, notamment en favorisant les produits de transformation issus de leurs activités. Le contrôle des filières par le suivi de la traçabilité et le soutien financier permet d'atteindre ses objectifs. Des coefficients de conversion pour chaque transformation et pour chaque espèce ou groupe d'espèces de poissons commercialisés sont utilisés dans les outils de contrôle de la pêche (déclaration de pêche et obligations d'achat) et dans le calcul du montant des aides allouées aux secteurs par le Fonds européen pour la pêche maritime et l'aquaculture (FEAMPA). L'échelle des coefficients actuellement appliquée à la Réunion est incohérente et ne respecte pas les règles de contrôle de la PCP. Une liste consolidée des coefficients de conversion pour les différentes transformations du poisson est proposée ici pour une application dans la région de la Réunion.

Introduction

Conversion or transformation coefficients are factors which make it possible to estimate a whole weight of fish (gross weight) from a processed weight (net weight), for a species or a group of species, and by type of processing.

As pelagic fish are often processed onboard (gutted, gilled, headed, …), conversion factors from processed weight to whole weight are critical to correctly estimate landings and catch that can be reported to IOTC. The conversion factors used stem from either EU code or other source of information that can be derived from other oceans. Given the importance of these coefficients in the catch estimates, it is critical to have robust estimates derived from local information.

Here we present the results of these estimates from the collation of different sampling programs that have been developed in Reunion island over the last 5 years.

Table 1 : Table of conversion coefficients for fresh fish, applicable to Reunion under the EMFF (2014-2020). Some coefficients are part of the EU code, the rest of the coefficients have been proposed by ARIPA (fishers' association) based on estimates made by fishing professionals. These coefficients do not comply with the CFP control regulation, since they are neither validated by the EU, nor by RFMO, nor by the Member State. At this stage, there are no coefficients for the "gutted and gillless (GUG)" and "skinless fillet (FIS)" processing.

🟥 UE code R 404/2011

🟨 If UE code is not available, the code from Franch National administration DMSOI / FAM (FranceAgriMer) is used since 2011.

	Species	Scientific name	FAO code	WHL (whole)		GUT (gutted)		GUG (gilled and gutted)		GUH (gutted and headed)		GHT (Gutted headed, and tailed)		FIL	
				UE	FR	UE	FR	UE	FR	UE	FR	UE	FR	UE	FR
Pelagic species	Albacore	Thunnus alalunga	*ALB*	1		1,11					1,16				2,9
	Bigeye tuna	*Thunnus obesus*	*BET*	1		1,1				1,29					2,58
	Striped bonito	*Sarda orientalis*	*BIP*		1		1,3				1,3				
	Balck / striped marlin	*Makaira indica / Kajikia audax*	*BLM/MLS*		1		1,3				1,3				2,16
	Blue marlin	*Makaira mazara*	*BUM*	1			1,3				1,3				2,16
	Bonitos	*Sarda spp*	*BZX*		1		1,3				1,3				
	Thazard rayé	*Scomberomorus commerson*	*COM*		1		1,3				1,3				
	Dolphinfish	*Coryphaena hippurus*	*DOL*		1		1				1,3				2,89
	Dogtooth tuna	*Gymnosarda unicolor*	*DOT*		1		1,18				1,3				2,6
	Kawakawa	*Euthynnus affinis*	*KAW*		1		1,3				1,3				
	Spanish mackerel	*Scomberomorus spp*	*KGX*		1		1,3				1,3				
	Sailfish	*Istiophorus Platypterus*	*SFA*		1		1,18				1,3				2,16
	Skipjack tuna	*Katsuwonus pelamis*	*SKJ*		1		1,3				1,3				
	Shortfin mako	*Isurus oxyrinchus*	*SMA*		1		1				1				1,66
	Shortbill spearfish	*Tetrapturus angustirostris*	*SSP*		1		1,3				1,3				3,25
	Swordfish	*Xiphias gladius*	*SWO*	1		1,11				1,31					2,17
	Wahoo	*Acanthocybium solandri*	*WAH*		1		1,3				1,3				2,6
	Yellowfin tuna	*Thunnus albacares*	*YFT*		1		1,1				1,16				2,32
Other species					1		1,3				1,3				2

Materials and methods

In the context of the TRANSFO project, only type I processing recognized by the EU is taken into account (Table 2): from whole to filleting without skin. The data used in the TRANSFO project to update the grid of coefficients, applied to Reunion Island, only concern fish from the Reunion fishery. Imported fish are not taken into account.

Table 2 : Extract from the alpha-3 codes (implementing regulation (EU) n° 404/2011 of the European Commission) for the presentation of the products of the control regulation.

Alpha-3 code for processing types	Processing
FIL	Fillet
FIS	Fillet without skin
FSB	Fillet with skin and bones
FSP	Fillet with bones
GHT	Gutted, Headed, and Tailed
GUG	Gutted and gilled
GUH	Gutted and Headed
GUL	Gutted with liver
GUS	Gutted, head without skin
GUT	Gutted
HEA	Headed
WHL	Whole

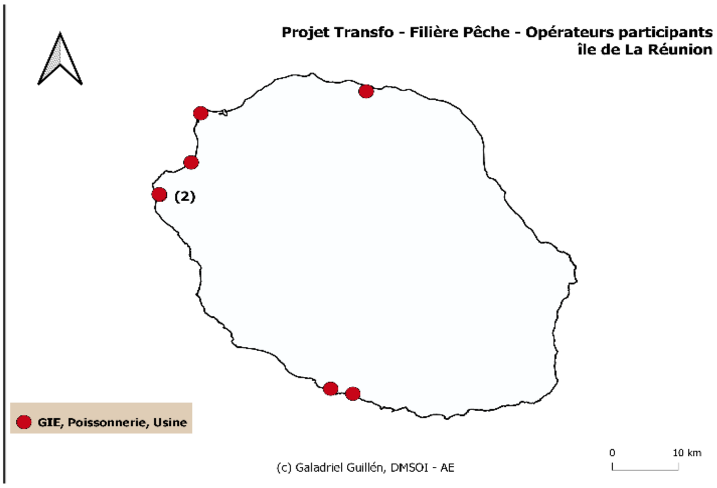


Figure 1: Location of factories, processing places, and fishmongers participating in the TRANSFO project over the period March - June 2022, for the fishing part. Due to the sensitivity of the information, their names are not disclosed.

A collection of data on the weight of large pelagic fish before and after processing in factories, GIEs (economic interest groups) and fishmongers, was carried out over the period March - June 2022. The targeted operators are the first buyers of fresh fish, that is to say any person who buys from a professional fishing vessel fishery products intended to be placed on the market. Of the 27 first declaring buyers in Reunion, 10 were contacted for the collection of data on fish processed into fillets with (FIL) and without skin (FIS). 7 operators finally took part in the TRANSFO project (Figure 1).

Filleting a fish is a more technical method than gutting or heading. How to lift a fillet (with or without skin) may depend on both the experience of the processing employee and the customer (end buyer) request. For the calculated coefficient to be sufficiently representative of what is done in Reunion, the priority was to sample from different operators. This, taking care to consider the differences in transformation that may exist, for the same EU presentation code, according to the working methods of the operators and according to customer demand. Here, the belly (ventral part of the fish) is not taken into account in the weight of the fillets, only the loins. If some professionals further cut the loins and remove the ends (considered too sinewy), the weight of the ends is considered for "FIL" and "FIS" weight.

Weight measurements are made from fish cuts made exclusively by professionals from participating factories, economic interest groups and fishmongers. The fish are weighed directly by the operators, on their usual certified scales. Before the first weighing and between each weighing the scale is tared (0 grams/kilos displayed on the scale before weighing the fish). In order to be as accurate as possible, the fresh fish (not frozen) is weighed free of other external elements (e.g. ice), and not touching any surface other than the scale plate. Measurements and weighing of fish are carried out in compliance with Regulation (EU) No 2017/1004 on the establishment of an EU framework for the collection, management and use of data in the fishing industry. fisheries and support for scientific advice on the common fisheries policy. To obtain a statistically robust transformation coefficient grid, a minimum of 30 measurements per species and per presentation is required.

Large pelagic fish are gutted on board (GUG) or even headed (GUH) for billfish (Marlins, Swordfish, etc.). Thus, the initial weight collected in the factory, EIG and fishmonger is not the whole weight, but the weight of fish having already undergone a first transformation.

Additional data

The collection of data from different operators could only be carried out over a short period, and concerned for large pelagic species of fish already processed. In order to complete the data set, weight data before and after processing from several projects carried out by Ifremer were used: the ACCOBIOM programs and the DCF program. The fish sampled in this context come from mini long-line and long-line fishing boats or from traditional boats.

The multiannual DCF program (Data collection framework), is a common European protocol for the collection and management of fisheries data, to support the common fisheries policy (CFP) through scientific advice. This program allows, in particular, the assessment of fish stocks within each regional fisheries organization (RFMO). The main contributor to this program, Ifremer has been collecting biometric data (size and weight) on large pelagics on Reunion since 2017 on landing of Reunionese longliners (before processing in the factory). Over the 2017-2022 period, different weights were collected by Ifremer agents and factory employees: "whole weight (WHL)", "gutted and gillless (GUG)" and "gutted and headless (GUH)” (Bonhommeau et al., 2018). The main species sampled are: albacore (*Thunnus alalunga*), bigeye tuna (Thunnus obesus), yellowfin tuna (*Thunnus albacares*), blue marlin (*Makaira nigricans*), sailfish (*Istiophorus platypterus*), dolphinfish (*Coryphaena hippurus*) and swordfish (*Xiphias gladius*).

The ACCOBIOM project is common to several overseas territories for the acquisition of knowledge on the biological parameters of marine resources exploited in Overseas France, and was carried out in Reunion over the period June 2021-May 2022. In this framework, weight data (WHL, GUT and GUG) were also collected on a few large pelagic species, by observation with or without the purchase of fish: dolphinfish (*Coryphaena hippurus*), stripe-bellied bonito (*Katsuwonus pelamis*) , banana tuna (*Acanthocybium solandri*), yellowfin tuna (*Thunnus albacares*).

In total, data from 916 large pelagic fish sampled and processed over the period June 2017-May 2022 will be used to establish the GUG and GUH coefficients for different large pelagic species.

Calculation of coefficients

The objective of this project is to establish a coefficient by species or group of species which makes it possible to find the live weight (whole) of a fish from a measurement of processed weight (gutted fish, without head, without tail, fillet). Biometric relationships are ideal for converting these measurements since one can clearly predict the correlation between the value of the transformed weight and the value of the whole weight. Relations for large pelagics have recently been proposed as a conversion method, for stock assessment and to improve the quality of data collected at sea, on landing and in the factory (DCF program mentioned above) (Bonhommeau et al. , 2018). For large pelagic species, there are today for the same fish stocks in Réunion, different conversion coefficient bases: coefficients defined only by Ifremer, the IOTC, scientific articles or FishBase and used for the stock assessment and other scientific purposes; and coefficients validated by the National Monitoring Committee (CNS) of the EMFF for the instruction of aid to the sector. It seems necessary to standardize these two reference systems. We have some or all of the weight data that was used to establish these biometric relationships. In addition to being able to pool databases, it is also important to keep the same calculation method. Thus, within the framework of the TRANSFO project, the conversion coefficients for fish from fishing and farming, were established on the basis of biometric relations by linear regression (performed on the R software (4.0.2)), according to the following formula :

$$WHL = a\ W$$

where WHL is the whole weight, a the conversion factor and W the processed weight

Special case

In the protocol for additional data collection on large pelagic fillets, the initial weight is already a processed weight (“gutted and gillless (GUG)” or “gutted and headless (GUH)”). However, the conversion coefficients are coefficients allowing the conversion from a transformed weight to a whole weight, and not from transformed to transformed. Thus, the full weight of this additional collection was estimated from the coefficients established for the GUG and GUH transformations on the basis of the data collected as part of the Ifremer program.

Example :

	Estimated whole weight (kg)	GUG (kg)	FIL (kg)	FIS (kg)
Thon albacore (YFT)	**1,09** * 14,8	14,8	8	7,6

WHL/GUG coefficient for YFT using previous conversion factors

The coefficients for the "fillets with skin (FIL)" and "fillets without skin (FIS)" transformations are then calculated by biometric relationships between the estimated "whole weights (WHL)" and the associated FIL and FIS data collected. in factories, economic interest groups and fishmongers.

Results

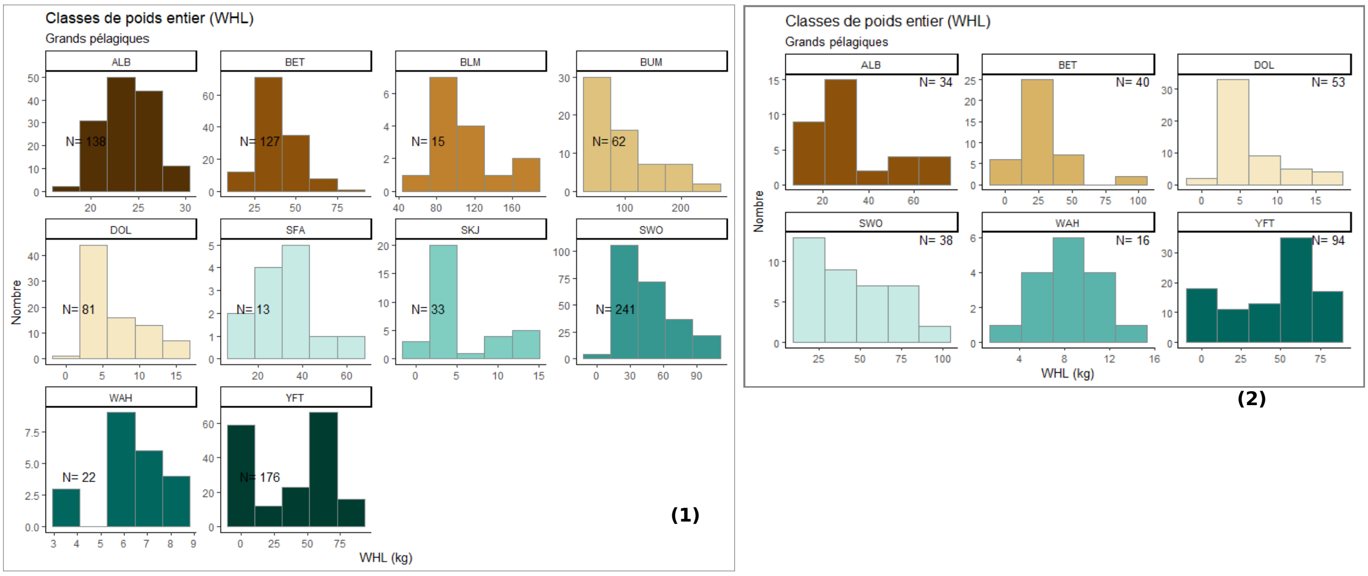
For the majority of large pelagic species, a sufficient number of fish was sampled (N>30), except for Wahoo, Black Marlin, and Sailfish (N<30) (Table 3 and 4). In general, the weight classes have a wide ranges (Table 3 and 4, Figure 5), consistent and sometimes complementary between the two sampling lots (Figure 5 (1) and (2)). For example, for Albacore (ALB), sampling (1) shows fish weighing no more than 30 kg, while the maximum weight of sampling (2) exceeds 70 kg. The range of weights sampled in tunas (ALB, BET and YFT) and swordfish (SWO) is relatively wide and varied (high standard deviation), ranging from less than 10 kg to more than 100 kg (Table 3 and 4, Figure 5). The marlins (BLM and BUM) sampled have a very high average weight and range of weights, unlike the dolphinfish (DOL), wahoo (WAH) and skipjack tuna (SKJ). For example, the minimum weight for the Blue Marlin is 49.30 kg for an average weight exceeding 100 kg, while the maximum weight for the Dolphinfish is 16.40 kg for an average weight less than 10 kg (Table 3 and 4). The Blue Marlin presents the greatest dispersion of value (Table 3 and 4).

Table 3: Description of the data used to calculate the conversion coefficient for large pelagic fish, from the additional collection (March-June 2022). The full average weight is the weight estimated using the method described in “Special case of calculating conversion coefficients from data from the additional collection”.

Species	FAO code	N	Mean WHL weight (kg)	Std (kg)	Min WHL weight (kg)	Q 25%	Median (kg)	Q 75%	Max WHL weight (kg)
Albacore	ALB	34	32,30	16,72	16,52	20,55	24,65	42,36	71,93
Bigeye	BET	40	27,58	20,02	3,77	13,04	25,70	33,66	98,08
Dolphinfish	DOL	53	6,16	4,29	1,53	3,06	4,30	8,64	18,08
Swordfish	SWO	38	44,72	24,74	13,99	19,47	41,27	65,65	90,22
Wahoo	WAH	16	8,48	2,77	2,96	6,68	8,11	10,16	14,10
Yellowfin	YFT	94	44,88	26,45	3,60	16,52	51,92	66,70	83,11

Table 4 : Description of the data used to calculate the conversion coefficient for large pelagic fish, from the collection of the DCF and ACCOBIOM programs carried out by Ifremer (June 2017 – May 2022).

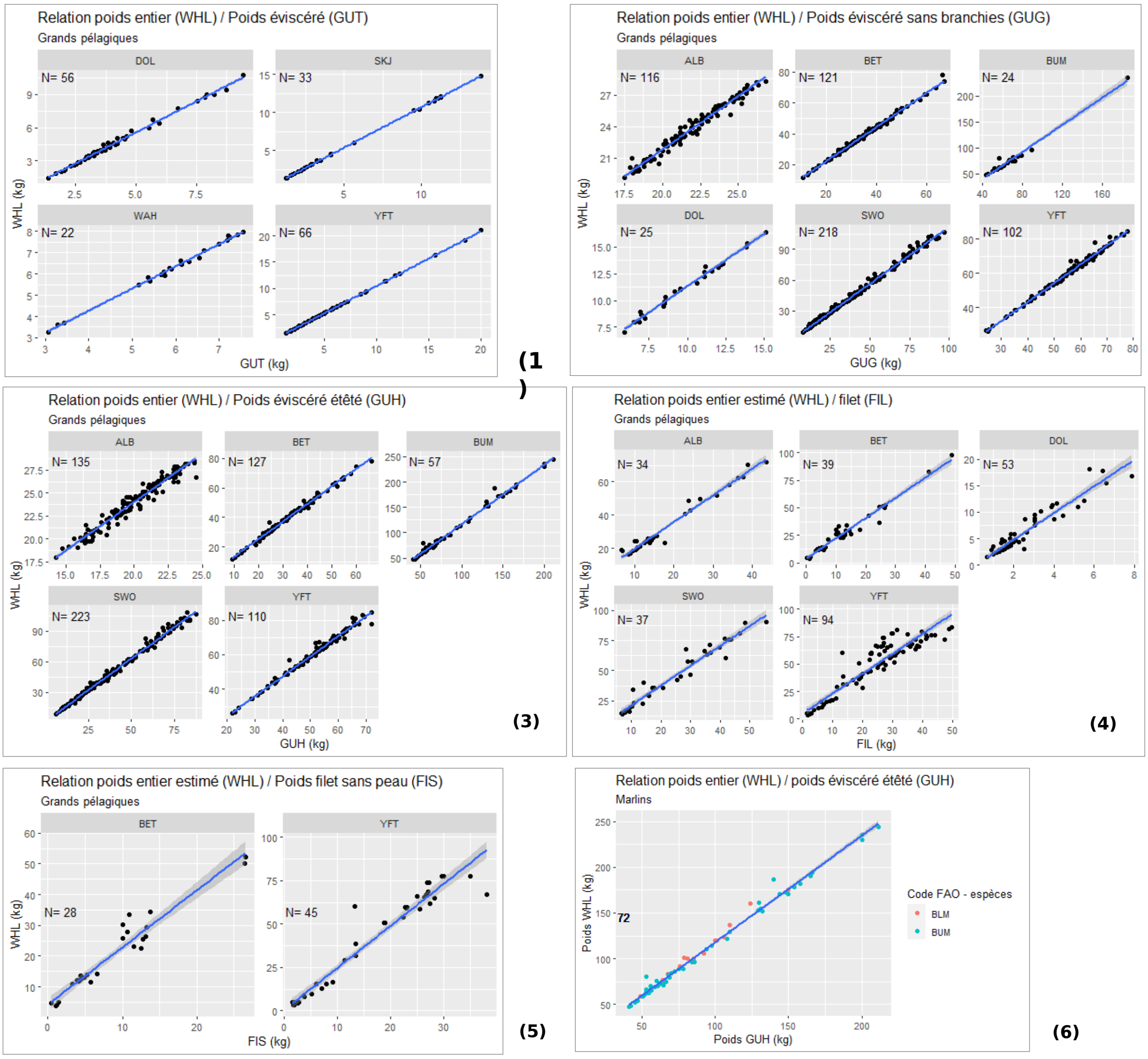
Species	FAO code	N	Mean WHL weight (kg)	Std (kg)	Min WHL weight (kg)	Q 25%	Median (kg)	Q 75%	Max WHL weight (kg)
Albacore	ALB	138	23,87	2,64	16,90	22,15	24,00	26,00	28,50
Bigeye	BET	127	38,36	12,59	11,40	29,95	35,50	45,88	78,00
Black marlin	BLM	15	108,40	31,82	59,00	87,03	101,00	121,6	175,00
Blue marlin	BUM	62	102,85	53,17	47,30	65,10	75,90	140,50	243,90
Dolphinfish	DOL	81	6,52	3,80	1,46	3,46	4,67	9,02	16,40
Sailfish	SFA	13	33,12	12,48	8,50	29,4	31,50	39,60	58,00
Skipjack	SKJ	33	5,24	4,23	1,36	2,23	3,17	10,21	14,77
Swordfish	SWO	241	45,42	24,72	9,20	25,70	40,00	61,50	108,30
Wahoo	WAH	22	6,26	1,35	3,25	5,85	6,36	7,34	7,95
Yellowfin	YFT	176	39,01	28,13	1,44	5,44	48,85	63,65	84,50



(1) **(2)**

Figure 5: Distribution of the weight of large pelagic fish sampled as part of the Accobiom - DCF (1) and Transfo (2) programs, over the period June 2017 – June 2022. The whole weight classes (WHL) presented for the harvest of additional data (2), is an estimated whole weight (see Special case of the calculation of conversion coefficients from data from the additional collection). Care must be taken when interpreting this figure: the x-axis do not have scales because they are adjusted to each species.

The different biometric relationships of weight before and after processing of large pelagic fish are presented in Figure 6 and Table 5. For each of the species, there is a significant positive relationship (p-value < 0.05 ***) between the whole weight and the various processed weights: "GUG", "GUH", "FIL" and "FIS". The fit of the linear model to the data is relatively good, with few outliers (Figure 6) and more than 95% of the variance of the whole weight can be explained by the transformed weight (coefficient of determination R² close to or equal to 1 at rounded to hundredths) (Table 5). However, the relation of bigeye tuna (BET) for transformation into “skinless fillet (FIS)” (figure 6.5) presents several centered data. The uncertainty of the coefficient resulting from this relationship is the highest ± 0.20 and the associated R² is the lowest but remains particularly high (= 0.95) (Table 5). The shares of dispersion (figure 6) and the uncertainties of the coefficients (table 5) are relatively low for all the species, and increase as soon as the transformation into a “net (FIL and FIS)” occurs. The more we progress in the transformation, the more there is loss of material and the more the conversion coefficient increases (table 5). The coefficient and the associated uncertainty of the dolphinfish in “FIL” transformation is particularly high (=2.45 ± 0.12) compared to the other species (Table 5).



(1) (2) (3) (4) (5) (6)

Figure 3 : Relationships between whole weight processed weight of large pelagic species for processing: whole (WHL) - gutted (GUT) (1), whole (WHL) - gutted and gillless (GUG) (2), whole (WHL) - gutted and head off (GUH) (3), whole (WHL) – fillet with (FIL)(4) and without skin (FIS)(5). The biometric grouping relationship of marlins for processing whole (WHL) - gutted and headless (GUH) is presented in (6). The blue line is the regression line of the linear model applied and the gray areas around this line represent the part of the dispersion of the data with respect to the line.

Table 5 : coefficients (a) with uncertainty for the different weight-weight relationships of large pelagic species: whole (WHL) - gutted (GUT), WHOLE (WHL) - gutted and gillless (GUG), whole (WHL) - gutted and headless (GUH), whole (WHL) – fillet (FIL), whole (WHL) – skinless fillet (FIS). N corresponds to the sample size, a to the coefficient on the right and R² to the proportion of the variance of the whole weight that is explained by the transformed weight.

Relation	Species	FAO code	N	a	Uncertainty	R²
WHL - GUT	Dolphinfish	DOL	56	**1,12**	± 0,01	1,00
WHL - GUT	Skipjack	SKJ	33	**1,07**	± 0,00	1,00
WHL - GUT	Wahoo	WAH	22	**1,06**	± 0,01	1,00

WHL - GUT	Yellowfin tuna	YFT	66	**1,05**	± 0,00	1,00
WHL - GUG	Albacore	ALB	116	**1,08**	± 0,00	1,00
WHL – GUG	Bigeye	BET	121	**1,11**	± 0,00	1,00
WHL – GUG	Blue marlin	BUM	24	**1,14**	± 0,04	0,99
WHL – GUG	Dolphinfish	DOL	25	**1,13**	± 0,02	1,00
WHL – GUG	Swordfish	SWO	218	**1,13**	± 0,01	1,00
WHL – GUG	Yellowfin tuna	YFT	102	**1,09**	± 0,00	1,00
WHL - GUH	Albacore	ALB	135	**1,20**	± 0,01	1,00
WHL – GUH	Bigeye	BET	127	**1,24**	± 0,01	1,00
WHL – GUH	Blue marlin	BUM	57	**1,17**	± 0,01	1,00
WHL – GUH	Swordfish	SWO	223	**1,26**	± 0,01	1,00
WHL - GUH	Yellowfin	YFT	110	**1,18**	± 0,01	1,00
WHL - GUH	Blue / black marlin	BLM / BUM	72	**1,18**	± 0,01	1,00
WHL - FIL	Albacore	ALB	34	**1,76**	± 0,06	0,99
WHL – FIL	Bigeye	BET	39	**2,02**	± 0,09	0,98
WHL – FIL	Dolphinfish	DOL	53	**2,45**	± 0,12	0,97
WHL – FIL	Swordfish	SWO	37	**1,79**	± 0,07	0,99
WHL – FIL	Yellowfin	YFT	94	**1,97**	± 0,07	0,97
WHL - FIS	Bigeye	BET	28	**2,37**	± 0,20	0,95
WHL - FIS	Yellowfin	YFT	45	**2,76**	± 0,14	0,97

Table 6 : Table of the New conversion coefficients for fresh fish

COEFFICIENT DE CONVERSION pour la filière pêche – FRAIS

Legend :
🟥 Coefficients from UE code UE R 404/2011
🟦 Coefficients estimated from the Transfo prject
🟩 Mean coefficients estimated from a species of the same family/genus

	Species	Nom scientifique	FAO code	WHL		GUT		GUG		GUH		FIL		FIS
				UE	TRANSFO	UE	TRANSFO	UE	TRANSFO	UE	TRANSFO	UE	TRANSFO	TRANSFO
Pélagiques	Albacore	*Thunnus alalunga*	ALB	1		1,11			1,08		1,20		1,76	
	Bigeye	*Thunnus obesus*	BET	1		1,10			1,11	1,29			2,02	2,37
	Bonito	*Sarda orientalis / Sarda spp / Euthynnus affinis*	BIP/ BZX / KAW		1		1,07							
	Striped / black marlin	*Istiompax indica / Kajikia audax*	BLM/MLS						1,14		1,18			
	Blue marlin	*Makaira nigricans*	BUM	1	1				1,14		1,17			
	Spanish mackerels	*Scomberomorus commerson / Scomberomorus spp*	COM / KGX											
	Dolphinfish	*Coryphaena hippurus*	DOL		1		1,12		1,13				2,45	
	Dogtooth tuna	*Gymnosarda unicolor*	DOT											
	Sailfish	*Istiophorus platypterus*	SFA											
	Skipjack	*Katsuwonus pelamis*	SKJ		1		1,07							
	Shortfin mako	*Isurus oxyrinchus*	SMA											
	Shortbill spearfish	*Tetrapturus angustirostris*	SSP											
	Swordfish	*Xiphias gladius*	SWO	1		1,11			1,13	1,31			1,79	
	Wahoo	*Acanthocybium solandri*	WAH		1		1,06							
	Yellowfin tuna	*Thunnus albacares*	YFT		1		1,05		1,09		1,18		1,97	2,76

The updated conversion coefficients for large pelagic fresh fish from the fishing sector are presented in Table 6. Swordfish, Albacore and Bigeye are species that have one or more coefficients validated under EU code R 404/2011 (in red in Table 6). Although data is available for updating these coefficients (Table 5), the coefficients in red are not subject to change. In the current grid (Table 1), concerning processing before netting for the fishing sector, a coefficient of 1.3 was applied for the majority of species and groups of species. The coefficients proposed here for the same transformations (“GUT”, “GUG”, “GUH”) are all less than 1.3.

Discussion

Thanks to the compilation of data sets (ACCOBIOM, DCF, TRANSFO), the samples of large pelagic fish pooled are encompassing a wide range of weights (Figure 5) and representative of the diversity of morphologies of the species sampled (Evano, 2021). This made it possible to ensure sampling consistency and representativeness of intra- and interspecific morphological diversity, which are important for establishing coefficients representative of fishing in Réunion.

A. Limits of the new table

Updating the conversion coefficient table for the fishing sector is a complex task, carried out over a limited period of time. Also, the grid proposed here (Table 6) has certain limitations.

Insufficient or no data

The low sampling (N<30) of wahoo (WAH) in “gutted (GUT)” processing, blue marlin (BUM) and dolphinfish (DOL) in “gutted and gilled (GUG)” processing, and of bigeye tuna (BET) in “skinless fillet (FIS)” processing, was decided sufficient to establish a conversion coefficient (Table 5).

Individually, the number of data for the black marlin (BLM) and the striped marlin (MLS), are insufficient or even non-existent for MLS. Given the good fit of the model to the pooled Blue Marlin and Black Marlin data (Figure 6.6), it was proposed to apply an average coefficient to Black Marlin (BLM) and Striped Marlin (MLS) for the transformation “gutted and headed (GUH)” (Table 5). Regarding the "GUG" transformation, it was proposed to apply the Blue Marlin coefficient to Black Marlin (BLM) and Striped Marlin (MLS) (Table 6). The lack of data available for MLS has been a difficulty encountered for several years. It would possibly be confused with the Blue Marlin (BUM) during declarations due to misidentification. The advisability of a reminder on the modalities of differentiation between the blue marlin and the striped marlin was discussed during the feedback meeting of the Transfo project.

Similarly, different bonitos species are present in the current coefficient grid (Table 1): BIP, BZX, KAW, for which no sufficient data could be collected. For the “gutted (GUT)” processing, it was proposed to apply the skipjack coefficient SKJ (=1.07) for the other bonitos present in the table (Table 6).

Several large pelagic species had a lower number of samples than the set limit (20<N<30) (see Materials and methods): wahoo (WAH), blue marlin (BUM), dolphinfish (DOL), and Bigeye (BET) (Table 5). Given the need of updating the current table, the coefficients for these species were still deemed sufficient to be integrated into the new coefficient table for the fishing sector. In the case of acquisition of additional data on these species, the coefficients proposed here (Table 6) may be reassessed.

Despite sampling over several years, it is not yet possible to consolidate robust coefficients for all the species and all the transformations of the grid. Data are insufficient to calculate coefficients for the following large pelagic species: Atlantic king mackerel (COM), Bigeye skipjack (DOT), King mackerels (KGX), Indo-Pacific sailfish (SFA), Shortfin mako (SMA), the Shortbill spearfish (SSP). Moreover, it is impossible to link, scientifically, these species to families for which the data are sufficient. Also, additional exchanges will be necessary between public actors and representatives of the fishing industry to agree on the methodology to be adopted for these species.

Possible biases and errors

The first possible bias is related to the precision of the weight measurements. The scales used for weighing are all approved but not being of the same precision nor in identical conditions (e.g. different ambient temperatures), the precision may be different. Moreover, the balance is not the only measuring instrument used. The use of load cells for large pelagic fish is also possible in the collection of DCF data. It would have been interesting to evaluate the differences in precision of the measuring instruments used. It should be noted that a difference may exist between the "GUG" empty weights recorded by IFREMER and in the factories. Indeed, within the framework of the ACCOBIOM project, the heart is not removed, whereas it is removed by some operators. There may therefore be a difference of several grams, possibly not significant. It is the same for the variation in weight depending on: the place of the cut of the gut (more or less high), whether the blood line is removed or not, whether there is cutting of the extremities of the fillet and if so, the size of the pieces removed.

Despite these possible biases, the coefficients obtained for the “GUG” and “GUH” processing for large pelagics (Table 5) seem to be consistent with the coefficients presented by the Working Party on Billfishes (WPB) of the IOTC (2006) based on Indonesian data. However, we must remain cautious in the comparison, since for the same species there may be variations in weight between different regions of the Indian Ocean (see Factors that can influence a conversion coefficient) (Nikolic et al., 2015).

Filleting, carried out on land in factories, in economic interest groups and in fishmongers, is by far one of the type I processing operations liable to introduce the most variations in weight. Indeed, in addition to lifting the fillets from the carcass, several additional cuts are made on the fillets: the blood line and the nerve parts are removed. As previously stated (see Materials and Methods), the precision of these cuts depends on the experience of the processor employee and on customer demand. In practice, it is difficult to be able to take into account these differences in filleting techniques between operators and even if they were considered, the information would be far too sensitive given the competitive aspect present within the sector.

The calculation of the conversion coefficients for the "FIL" and "FIS" transformations of large pelagic fish is not direct and first requires the estimation of a whole weight on the basis of a coefficient established beforehand (cf. Special case of the calculation of conversion coefficients from data from the complementary collection). This can lead to error propagation. It would have been more accurate to obtain a coefficient more directly: on the same fish, from the "whole (WHL)" presentation to the downstream presentations ("FIL" and "FIS") and not through intermediate presentations (“GUG” or “GUH”). However, within the framework of the complementary collection, it was not possible to work on fish from the whole to the fillet for several reasons. Primary processing is carried out at sea (and not on land) and boarding fishing vessels to collect primary processing data was impossible due to the limited time and authorizations required for the application of such a protocol. Buying more expensive fish in order to encourage professionals to sell it whole and carrying out filleting in the laboratory after the event was also impossible for budget reasons. In addition, the filleting method is complex to perform. The coefficients must be representative of what is achieved every day by the sector. Threading should therefore only be carried out by professionals.

B. Variations if application of the new coefficients

For the fishing sector, the coefficients proposed here are for the most part lower than those of the current tables 1 and 6. The introduction of these new conversion coefficients (Table 6) will necessarily have consequences on the volumes of fish landed and on the amount of EMFAF aid allocated to the sector, based on the live weight equivalent (LPE).

The application of new coefficients will also have consequences for the management of species subject to quotas. In Réunion, yellowfin tuna (*Thunnus albacares*) is the only species subject to a quota set in 2022. The modification of the conversion coefficient for this species will bring changes to the management of the quota. During a comparative study of the conversion coefficients used to estimate the live weight of the catches of the fishing fleets of the European Union (Cofrepêche, 1996), the following equations were proposed to simulate the consequences of the modifications of the conversion coefficients on the quotas: $D=QCf$

with *Q* the quota of the species (in live weight equivalent – EPV), *D* the theoretical landings and *Cf* the conversion coefficient. By modifying the conversion coefficient *Cf'*, the theoretical landings become: $D'=QCf'$. By the difference D-D', it is possible to obtain the theoretical variation of the total weight authorized for landing for the species subject to the quota. As an example, for “gutted (GUT)” processing, the coefficient currently used for Yellowfin tuna is equal to 1.3 (Table 1) and the one proposed is 1.05 which means a 25% in whole weight estimated from "GUT" to WHL landings.

The application of the new table of conversion coefficients for the fishing sector (Table 6) could also have an impact on reporting obligations. Indeed, no coefficient for the "gutted and without gills GUG" processing was proposed so far, yet the only processing carried out to gut a fish in the Reunionese sector. The coefficients used until now to declare gutted fish were those set for the “gutted (GUT)” processing. Certainly this has misled the professionals in their declaration, since a significant number of fish are declared "GUT", yet gutted and without gills. Thus, by applying the proposed grid (Table 6), professionals could be encouraged to declare gutted fish more accurately, corresponding to “GUG” and not “GUT” processing. Better declarations will thus allow better monitoring of the traceability of the sector.

By modifying the volumes landed (in EPV) and by encouraging a more accurate declaration of these volumes, updating the conversion coefficients can therefore not only have a positive or negative impact on the amount of aid allocated to the fishing industry, but also has a significant impact on the means of management and conservation of fisheries resources. Indeed, catch and purchase declarations ensure the traceability of products in the sector. By having a more accurate view of what is landed, it is possible to assess in real time the impact of fishing on exploited resources and to adjust fisheries management measures, particularly for species subject to quota. (closure of the fishery when the quota is reached) (Colinet et al., 2013). Useful for fisheries controls and support for the sector, the conversion coefficients are an integral part of the means implemented under the CFP and FEAMPA to strengthen the fisheries and aquaculture sectors, from an economic and environmental point of view (European Parliament , 2013, 2021; DMSOI, 2020).

Factors that can affect a conversion factor

In fisheries science, biometric relationships are already used in the conversion of fish measurements taken during landings (gutted fish, with or without head) for biomass estimation, stock assessment and for other scientific purposes (Bonhommeau et al., 2018). The calculation of the conversion coefficient from whole weight - processed weight biometric relationships was therefore the validated method, in consultation with the Ifremer Indian Ocean delegation and the CITEB, for this project to update the table. However, this is not the only possible method. The coefficients can be obtained by arithmetic mean or by weighted mean by taking into consideration the various factors of variation (Cofrepêche, 1996). The various following factors can influence the value of the conversion coefficients established for the fishing sector: the size and sex of the fish, the time of year, the geographical area, the inter-annual variations in the environment, the method of processing , as well as the catching gear (Cofrepêche, 1996).

Since the length-weight relationship is significantly positive for large pelagics (Bonhommeau et al., 2018), it can be assumed that the compilation of several datasets made it possible to obtain a diversity of sizes.

Sex-related weight variations may be related to sexual dimorphism. For example, in the dolphinfish, the male has a much larger head than the female (Serazin et al., 2021), which may possibly vary the value of the coefficient for the "gutted and headless (GUH)" processing. Male albacore are also larger and heavier than females (Nikolic et al., 2015). Other biological parameters may differ by sex, such as growth and age of first reproduction (Weatherley, 1987; Wootton, 1991; Cofrepêche, 1996; Nikolic et al., 2015). In the Transfo project, gender is an unknown variable in the available data. Here, data collection was done at the rate of landings. The samples could therefore reflect the sex composition of the catches.

Depending on the time of year when the fish are sampled, variations in weight may exist. Indeed, the gonado-somatic ratio during the reproductive period can have its influence, since this ratio of females can be higher than that of males (Cofrepêche, 1996). For example, Reunion is supposed to be an active breeding area for Albacore, which in this period have large gonads, especially for females (Nikolic et al., 2015). In addition, fish are subject to different conditions during the year: the availability of resources (quantity/quality) may be non-uniform over the year. Large pelagics are affected by a variation in weight depending on the season. Indeed, it has been shown that in Réunion, albacore caught in the austral winter are smaller than those caught in the austral summer (Nikolic et al., 2015). Given the significant relationship between weight and height, this could therefore have an influence on weight and on the conversion coefficient (Bonhommeau et al., 2018).

In Reunion, the types of fishing are mainly hooks (trollers and longliners) which target fish in search of food. The capture gear is not a key factor to consider in this work.

For large pelagics, the method of gutting on board or on land can be considered to be practically identical from one fisherman to another. However, variations may exist in the topping. Two types of cut exist: straight or circular (Cofrepêche, 1996). Strictly speaking, two types of coefficients should be calculated, but applying a different coefficient according to the two cutting methods would be too complex.

These various factors may or may not have a significant influence on the variation in weight and therefore on the conversion coefficient. For migratory species, these factors may also depend on the geographic sampling area within the Indian Ocean. Here, several species of large pelagics from the grid are considered highly migratory by the Convention on the Law of the Sea (Annex I, UN, 1998): Albacore, Bigeye, Yellowfin, Black Marlin, Striped Marlin, Blue Marlin, Sailboat, Swordfish, Dolphinfish, Oriental tunny and Skipjack tuna. Regarding these species, what could be significant in the case of sampling in Reunion could be insignificant in other regions of the Indian Ocean and vice versa. This was demonstrated for Albacore by Nikolic et al. (2015): in the Reunion area, females have a significantly greater weight than males, while the opposite phenomenon is observed in the Seychelles area.

Working with biometric data such as weight is very complex, as it involves a large number of biological and non-biological factors which are not always practical to consider in the calculation of conversion coefficients. In the case of the Transfo project, taking these numerous parameters into consideration in the calculation of the coefficients was considered too cumbersome in view of the small set of data available and not practical for the application of the coefficients for the traceability of the sector and the instruction aids. The objective of updating the grid is to establish coefficients by species or group of species and by processing, applicable at any time of the year and by the entire sector. With regard to the objectives of applying the conversion coefficients, the time available for updating the grid and the limits linked to the collection of data from different professionals so as not to slow down their production, it was deemed satisfactory here to not consider than the weight before and after transformation without taking into account any factor that could influence the value of the coefficient.

Conclusion

Initiated from the request of professionals in the fishing sector, the TRANSFO project has made it possible to propose coefficients that are initially reliable and in the process of being correctly defined as required by the CFP control regulations.

For their perfect application, the table presented here must be validated either by an RFMO or by the Member State. To make it possible to propose a maximum of updated coefficients in a limited time, several databases from different programs supported by Ifremer (ACCOBIOM and DCF) were used.

At the crossroads between issues of conservation of exploited resources, political and economic issues of the fishing and aquaculture sectors, the TRANSFO project has brought together different actors: DMSOI, Réunion Region, Ifremer, CITEB, ARIPA and industry operators. It meets the objectives of the CFP and FEAMPA for the development of sustainable and economically viable fishing and aquaculture activities. Indeed, updating the conversion coefficient grid for the fishing sector and the proposal of a first grid for the aquaculture sector contributes to:

- improving chain traceability, monitoring fishing activities and their impact on exploited resources by adjusting declared tonnages (declarative obligations),

- financial support for the fishing and aquaculture sectors by promoting the processing of products resulting from their activities (examination of aid provided by FEAMPA),

- the consistency and standardization of the coefficients used for the assessment of stocks by the various RFMOs in the Indian Ocean, with the coefficients used for the management of fisheries, in particular the use of quotas. In the absence of information on biometric relationships, some RFMOs such as the IOTC use relationships from other oceans or close species, which is not scientifically satisfactory. The work carried out here therefore makes it possible to overcome this problem by proposing to RFMOs new biometric relationships specifically applicable to the Indian Ocean.

By promoting data collection, this project also responds to one of the action frameworks of the strategic document for the South Indian Ocean maritime basin 2020-2026 concerning the sustainable development of the fishing sector (CMUB, 2019).

The coefficient table for the fishing industry nevertheless has some limitations. Data remain insufficient or even non-existent for certain species. Additional data collection over a longer period should be considered, taking into account all periods of the year. The temporal distribution of capture could be an interesting element to take into account to improve the efficiency of sampling.

The TRANSFO project, carried out over the period January-July 2022, only involved updating the processing coefficient grid for fresh fish. In Reunion, a grid exists for frozen fish and could also benefit from an update according to a similar protocol.

References

Bonhommeau, S., Evano, H., Huet, J., Chapat, M., Varenne, F., Le Foulgoc, L., Richard, E., Tessier, E., Chanut, J., Nieblas, A.-E., 2018. Biometric and allometric relationships for large pelagic species collected in Reunion Island : contribution to an IOTC database?

CMUB, C. ultra-marin du bassin S. océan I., 2019. Document stratégique de bassin maritime Sud océan Indien 2020-2026.

Cofrepêche, 1996. Étude comparative des coefficients de conversion utilisés pour estimer le poids vif des captures des flottilles de pêche de l'Union. Rapport final pour la Commission des Communauté Européennes et la Direction générale des pêches.

Colinet, L., Gaunand, A., Département Efpa, ., Asirpa (analyse Socio-économique Des Impacts de La Recherche Publique Agronomique), ., 2013. Appui aux politiques de conservation du saumon atlantique : définition de taux autorisés de capture (Technical Report). auto-saisine.

Commission européenne, 2011. Règlement d'exécution (UE) n° 404/2011 de la Commission du 8 avril 2011 portant modalités d'application du règlement (CE) n° 1224/2009 du Conseil instituant un régime communautaire de contrôle afin d'assurer le respect des règles de la politique commune de la pêche.

Conseil de l'Union européenne, 2009. Règlement (CE) n° 1224/2009 du Conseil du 20 novembre 2009 instituant un régime communautaire de contrôle afin d'assurer le respect des règles de la politique commune de la pêche, modifiant les règlements (CE) n° 847/96, (CE) n° 2371/2002, (CE) n° 811/2004, (CE) n° 768/2005, (CE) n° 2115/2005, (CE) n° 2166/2005, (CE) n° 388/2006, (CE) n° 509/2007, (CE) n° 676/2007, (CE) n° 1098/2007, (CE) n° 1300/2008, (CE) n° 1342/2008 et abrogeant les règlements (CEE) n° 2847/93, (CE) n° 1627/94 et (CE) n° 1966/2006.

CTOI, 2006. IOTC-2006-WPB-INF01 report.

DMSOI, 2020. Plan de compensation des surcoûts du secteur de la pêche et de l'aquaculture de la Réunion.

Evano, H., 2021. Guide d'identification des principales espèces marines pêchées à La Réunion.

Legifrance, 2022. Arrêté du 5 avril 2022 portant sur la répartition de certains quotas de pêche accordés à la France pour l'année 2022.

Nikolic, N., Puech, A., Chouvelon, T., Munschy, C., Bodin, N., Brach-Papa, C., Potier, M., West, W., Knoery, J., Zudaire, I., Dhurmeea, Z., Degroote, M., Cedras, M., Evano, H., Bourjea, J., 2015. Rapport final du projet GERMON (GEnetic stRucture and Migration Of albacore tuNa - Structure génétique et migration du thon Germon).

ONU, 1998. Convention des Nations Unies sur le droit de la mer et accord relatif à l'application de la partie XI de ladite convention.

Parlement européen, 2021. Règlement (UE) 2021/1139 du Parlement européen et du Conseil du 7 juillet 2021 instituant le Fonds européen pour les affaires maritimes, la pêche et l'aquaculture et modifiant le règlement (UE) 2017/1004.

Parlement européen, 2014. Règlement (UE) n° 508/2014 du Parlement européen et du Conseil du 15 mai 2014 relatif au Fonds européen pour les affaires maritimes et la pêche et abrogeant les règlements du Conseil (CE) n° 2328/2003, (CE) n° 861/2006, (CE) n° 1198/2006 et (CE) n° 791/2007 et le règlement (UE) n° 1255/2011 du Parlement européen et du Conseil.

Parlement européen, 2013a. Règlement (UE) n° 1303/2013 du Parlement européen et du Conseil du 17 décembre 2013 portant dispositions communes relatives au Fonds européen de développement régional, au Fonds social européen, au Fonds de cohésion, au Fonds européen agricole pour le développement rural et au Fonds européen pour les affaires maritimes et la pêche, portant dispositions générales applicables au Fonds européen de développement régional, au Fonds social européen, au Fonds de cohésion et au Fonds européen pour les affaires maritimes et la pêche, et abrogeant le règlement (CE) n° 1083/2006 du Conseil.

Parlement européen, 2013b. Règlement (UE) n° 1380/2013 du Parlement européen et du Conseil du 11 décembre 2013 relatif à la politique commune de la pêche, modifiant les règlements (CE) n° 1954/2003 et (CE) n° 1224/2009 du Conseil et abrogeant les règlements (CE) n° 2371/2002 et (CE) n° 639/2004 du Conseil et la décision 2004/585/CE du Conseil.

Parlement européen, n.d. Règlement (UE) 2017/1004 du Parlement européen et du Conseil du 17 mai 2017 relatif à l’établissement d’un cadre de l’Union pour la collecte, la gestion et l’utilisation de données dans le secteur de la pêche et le soutien aux avis scientifiques sur la politique commune de la pêche, et abrogeant le règlement (CE) no 199/2008 du Conseil 21.

Serazin, J., Varenne, F., Chapat, M., Fry, L., Passoni, S., Wambergue, L., Brisset, B., Bonhommeau, S., Evano, H., 2021. Fiche espèces. Les grands pélagiques pêchés à La Réunion. Ifremer. https://doi.org/10.13155/83458

Weatherley, A.H., 1987. The biology of fish growth. Academic Press, London ; Orlando.

Weiss, J., Demaneche, S., Evano, H., Guyader, O., Reynal, L., Mansuy, E., Berthou, P., Leonardi, S., Rostiaux, E., Leblond, E., 2018. Action OBSDEB (Observation des marées au débarquement) : Synthèse 2017 de l’observation des efforts et débarquements des pêcheries côtières.

Wootton, R.J., 1991. Fish Ecology. Springer Science & Business Media.