DETERMINATION OF A LENGTH-WEIGHT EQUATION APPLICABLE TO ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*) DURING THE PURSE SEINE FISHING SEASON IN THE MEDITERRANEAN

Simeon Deguara[1], Ana Gordoa[2], José L. Cort[3], Raffik Zarrad[4], Noureddine Abid[5], Pedro G. Lino[6], Saadet Karakulak[7], Ivan Katavic[8], Leon Grubisic[8], Mark Gatt[9], Mauricio Ortiz[10], Carlos Palma[10], Juan José Navarro Cid[11], Francesco Lombardo[12]

SUMMARY

An important use of the length-weight (L-W) equation for Atlantic bluefin tuna, Thunnus thynnus, is to convert the straight fork length (SFL) measured with stereocameras during the caging of BFT to catch weight (RWT). The literature and other available data indicated that using the most recent ICCAT L-W relationships overestimate the RWT attributed to a particular SFL, which would result in a significant overestimate of the actual catch weight. A review of published L-W relationships, and an analysis of some new data, was carried out with the final objective of providing a L-W equation to be used to convert SFL data of BFT caught during the purse seine fishing season and transferred to cages to RWT. A new equation applicable to the Mediterranean Sea during the months of May and June was determined: RWT = (2.8684x10^{-5}) x (SFL)$^{2.9076}$. This equation is more representative of the equations found in the literature than those proposed by the current ICCAT equations, and it is recommended to use this new equation for the conversion of stereocamera SFL data to RWT.

RÉSUMÉ

*Une utilisation importante de l'équation longueur-poids (L-W) pour le thon rouge de l'Atlantique (*Thunnus thynnus*), consiste à convertir en poids vif (RWT) la longueur droite à la fourche (SFL) mesurée par des caméras stéréoscopiques pendant la mise en cage du thon rouge. Les publications et d'autres données disponibles ont indiqué que l'utilisation des dernières relations L-W de l'ICCAT surestime le RWT attribué à une SFL particulière, ce qui entraînerait une surestimation importante du poids réel de la capture. Un examen des relations L-W publiées et une analyse de certaines nouvelles données ont été réalisés dans le but final de fournir une équation L-W qui servirait à convertir en RWT les données SFL du thon rouge capturé pendant la saison de pêche à la senne et transféré dans des cages. Une nouvelle équation applicable à la Méditerranée au cours des mois de mai et juin a été déterminée : RWT = (2,8684x10^{-5}) x (SFL)^{2,9076}. Cette équation est plus représentative des équations trouvées dans les publications que celles proposées par les équations actuelles de l'ICCAT et il est recommandé d'utiliser cette nouvelle équation pour la conversion en RWT des données SFL obtenues par caméras stéréoscopiques.*

RESUMEN

Un uso importante de la ecuación talla-peso (L-W) para el atún rojo del Atlántico, Thunnus thynnus, *es convertir la longitud a la horquilla recta (SFL) medida con estereocámaras durante*

[1] Federation of Maltese Aquaculture Producers (FMAP), 61, St. Paul Street Valletta VLT12l2 Malta; Email: simeon.deguara@um.edu.mt
[2] CEAB-CSIC. Acc. Cala St. Frances 14. 17300 Blanes. Girona Spain.
[3] Instituto Español de Oceanografía, Centro Oceanográfico de Santander. Apdo. 240, 39080 Santander, Spain.
[4] Institut National des Sciences et Technologies de la Mer (INSTM-Mahdia), BP 138 Mahdia 5199, Tunisia.
[5] Center Régional de L'INRH á Tanger/M'dig, B.P. 5268, 90000 Drabed Tanger, Morocco.
[6] Instituto Português do Mar e da Atmosfera - I.P./IPMA, Avenida 5 Outubro s/n, 8700-305 Olhão, Portugal.
[7] Faculty of Fisheries, Istanbul University, Ordu Cad. Nº 200, 34470 Laleli, Istanbul.
[8] Institute of Oceanography and Fisheries, Šetalište I. Meštrovića 63, 21000 Split, Croatia.
[9] Department of Fisheries and Aquaculture, Ghammieri, Ngiered Road, Marsa. MRS 3303, Malta.
[10] ICCAT Secretariat. Corazón de Maria 8, Madrid 28002, Spain.
[11] Grupo Balfegó, Polígono Industrial - Edificio Balfegó, 43860 L'Ametlla de Mar, Tarragona, Spain.
[12] OCEANIS Srl, Via Marittima, 59 Napoli 80056 Ercolano *(NA)*, Italy.

la introducción en jaulas del atún rojo a peso vivo (RWT). La bibliografía y otros datos disponibles indican que utilizando las relaciones L-W más recientes de ICCAT se sobrestima el peso vivo atribuido a una SFL particular, lo que podría tener como resultado una importante sobrestimación del peso real de la captura. Se llevó a cabo un examen de las relaciones L-W publicadas y un análisis de algunos datos nuevos con el objetivo final de proporcionar una ecuación L-W para utilizarla en la conversión a peso vivo de datos de SFL de atún rojo capturado durante la temporada de pesca de cerco y transferido a jaulas. Se determinó una nueva ecuación aplicable al Mediterráneo durante los meses de mayo y junio: RWT = $(2{,}8684x10^{-5}) \times (SFL)^{2{,}9076}$. Esta ecuación es más representativa de las ecuaciones halladas en la bibliografía que las propuestas por las actuales ecuaciones de ICCAT y se recomienda utilizar esta nueva ecuación para la conversión a peso vivo de datos de SFL de las estereocámaras.

KEYWORDS

Bluefin tuna, L-W relationships, stereocamera, caging, RWT

1. Introduction

It is important to have a suitable length–weight equation since it is an essential component for the purpose of carrying out stock assessments for the Atlantic Bluefin tuna (BFT). In addition, the L-W equation is used when converting the straight fork lengths (SFL) determined by stereocamera (SC) measurements to round weight (RWT) for the purpose of determining quota allocations and potential over-catches (leading to the requirement of the release of fish from the cages) of purse seine (PS) fish caught in the Mediterranean and then transferred to farms. PS catches accounted for 90% of the BFT catches in the Mediterranean in 2015.

Comparison of the L-W equations currently available on the ICCAT website, which pertains to the East Atlantic BFT stock (Rodriguez-Marin et al., 2015) to other equations available in the literature has led to the discussion as to the suitability of the current ICCAT equations for the purpose of converting the SC-determined SFLs to RWT, as they appear to overestimate the RWT caught. Although comparatively small, this difference does translate into a significant total RWT difference when the whole PS catch (transferred to cages) is calculated (Gordoa, 2016).

In order to further analyse the differences noted, a review was carried out of the various L-W equations provided by many scientists over many years, for many gears and over the Mediterranean area where the purse seine activities are concentrated. The main objectives of this analysis were to determine if there is an alternative L-W equation specifically applicable to the conversion of SC SFL data to RWT.

2. Methodology

A review was carried out of some of the literature available in which various authors have presented equations for L-W relationships of BFT caught by various gears in different parts of the Mediterranean. For the purpose of the analysis, equations relating to fish caught in months including May and June (corresponding to the current PS fishing season) were used.

For comparative purposes, the L-W equations provided by the various authors were used to calculate the RWT of a fish of 200cm SFL. In addition, some new data was provided and similarly analysed, where possible using only data for fish caught during the period 26 May to 24 June.

Only equations using data requiring no conversions (for example, from GG to RWT) were used. The Fulton's Condition Factor K was calculated for this size of fish and data in which K was <1.4 or >2.6 removed as outliers (Cort et al., 2013).

In addition to the above, the data used for the calculation of the equations for the East Atlantic stock (Rodriguez-Marin et al., 2015) was used to obtain a new equation applicable to the Mediterranean only (excluding East Atlantic fish data) for the months of May and June (non converted and K-filtered).

3. Results and Discussion

Table 1a and b summarises information about the various L-W equations from the literature including the current ICCAT equations (Rodriguez-Marin *et al*., 2015). The table is split into three sections, big fish (fish range average over 100cm), small fish (fish range average lower than 100cm) and new data provided for this paper. **Table 1b** also includes a calculation of the difference, in kg and as a %, between the predicted RWT of the different equations in the literature and the average May/June weight predicted by the current ICCAT East Atlantic stock equations.

From the RWTs for a 200cm fish predicted by the various L-W equations, there appears to be some differences between different authors with predicted values ranging from 123.6 to 174.3kg, although there are a greater number of equations predicting a lower RWT than that of the current ICCAT equations for the months of May and June. The overall average difference between the equations from the literature and the average May/June weight predicted by the current ICCAT East Atlantic stock equations was 9.8% less, i.e. the current equations overestimated the weight of fish by 9.8%.

The Mediterranean May/June equation (N = 4208, SFL 52-282cm, 1998-2011, various gears) obtained is:

$$RWT = (2.8684x10^{-5}) \times (SFL)^{2.9076}$$ (**Figure 1)**

When this Mediterranean equation is used, a 200cm SFL fish is predicted to have a RWT of 140.6kg. When the predictions for a 200cm SFL fish provided by the equations in the literature (Table 1) are compared to that by the new Mediterranean equation, the overall difference is only 2.1% less, i.e. the equation overestimates the weight of fish by 2.1%, which is significantly lower than the 9.8% found above.

Figures 2a and 2b present all the equations in **Table 1** and the new Mediterranean equation. The new equation better represents the data present in the literature and it is recommended that this equation be applied to convert SC-SFL data to RWT.

It is also recommended that there be an increased and concerted effort to obtain new SFL and RWT data from the BFT fisheries in the Mediterranean by all CPCs. At the same time, efforts will be made to recover the raw data from which the equations reproduced in Table 1 were obtained so as to increase the data set available for the determination of an updated L-W equation applicable to the Mediterranean.

References

A lot, E., Ortiz de Urbina, J. M., Rodriguez-Marin, E., Gomez, J. M., Rioja, P., Ruiz, M. de la Serna, J. M. & Macias, D. 2011. Some biometric relationships of East Atlantic bluefin tuna (*Thunnus thynnus*). Col. Vol. Sci. Pap. ICCAT, 66: 1268-1275.

Arena, P. 1988. Rilevazini e studi sulle affluenze del tonno nel Tirreno e sull'andamento della pesca da parte delle "tonnara volanti" nel quadriennio 1984-1988. E.S.P.I. Ente Siciliano per la Promozione Industriale-Palermo Unita' Operativa No. 5, 66pp.

Ceyhan, T. 2001. A study about Bluefin tuna fishing with purse seines in Aegean Sea. M.Sc. Thesis, Ege University, Graduate School of Natural and Applied Sciences, Turkey, 63pp.

Chang, S. K. 1999. Taiwan Bluefin tuna fishery in the Mediterranean Sea with preliminary investigation on the catch information. Col. Vol. Sci. Pap. ICCAT, 49: 153-156.

Cort, J.L., Deguara, S., Galaz, T., Melich, B., Artetxe, I., Arregi, I, Nielson, J. Andrushchenko, I., Hanke, A., dos Santos, M.N., Estruch, V., Lutcavage, M., Knapp, J., Compean-Jimenez, G., Solana-Sansores, R., Belmonte, A., Martinez, D., Picinetti, C., Kimoto, A., Addis, P., Velasco, M., de la Serna, J.M., Godoy, D., Ceyhan, T., Oray, I., Karakulak, S., Nootestad, L., Lopez, A., Ribalta, O., Abid, & N., Idrissi, M. 2013. Determination of Lmax for Atlantic Bluefin tuna, Thunnus thynnus (L.), from meta-analysis of published and available biometric data. Reviews in Fisheries Science, vol. 21, pp. 181–212.

Di Natale, A., Addis, P., Cau, A., Celona, A., Cingolani, N., Deflorio, M., De Metrio, G., Fuggetti, C., Garibaldi, F., Mangano, A., Marano, G., Palandri, G., Pastorelli, A. M., Piccinetti, C., Relini Orsi, L. & Valastro, M. 2005a. Pilot study report on tuna sport fishing activity in Italy. Col. Vol. Sci. Pap. ICCAT, 58: 1360-1371.

Di Natale, A., Mangano, A., Asaro, A., Bascone, B., Celona, A., Navarra, A., Valastro, M. & Zava, B. 2005b. Bluefin tuna (*Thunnus thynnus*) catch composition in the Tyrrhenian Sea and in the Straits of Sicily in 2002 and 2003. Col. Vol. Sci. Pap. ICCAT, 58: 1296-1336.

El Tawil, M., El-Kebir, K., Ortiz de Urbina, J.M., Valeiras, J. & Abad, E. 2004. Length-weight relationships for Bluefin tuna (*Thunnus thynnus L.*) caught from the Libyan trap fishery in 1999-2002. Col. Vol. Sci. Pap. ICCAT, 56: 1192-1195.

Farrugio, H. 1978. Estimation de la composition demographique au thon rouge en Mediterranee Francaise. Col. Vol. Sci. Pap. ICCAT, 7. 352-354.

Gordoa, A. (in press). Possible consequences of the use of Atlantic Bluefin tuna population biometrics in the algorithms of stereocameras. Document SCRS/2016/131.

Hattour, A. 2003. Relation taille-poids des captures de thon rouge (*Thunnus thynnus*) en Tunisie. Col. Vol. Sci. Pap. ICCAT, 55: 217-223.

Hossucu, H., Ceyhan, T., Akyol, O., Unal, V., Ozekinci, U. & Ayaz, A. 2001. Tuna fishing with purse-seines in the Aegean Sea. Workshop on Technological Developments in Fisheries, 19-21 June, Izmir, 212pp.

Karakulak, S. 1999. Fishery and biology of Bluefin tuna (*Thunnus thynnus* L. 1758) in Turkish waters. Ph.D. Thesis, Universitesi Fen Bilimleri Enstitusu, Istanbul, Turkey, 168pp.

Lombardo, F., Baiata, F., Oliveri, A. & Pignalosa, P. 2016. Length/weight relationship for bluefin tuna caught by longliners in central Mediterranean Sea. Col. Vol. Sci. Pap. ICCAT, 72: 1815-1822.

Lombardo, F., Baiata, P., Pignalosa, P., Apr, M., Maradonna, F. & Carnevali, O. (in press). An update on the length/weight relationship for bluefin tuna caught by longliners in Mediterranean Sea. Document SCRS/2016/190.

Percin, F. & Akyol. O. 2009. Length-weight and length-length relationships of Bluefin tuna, *Thunnus thynnus*, in the Turkish part of the eastern Mediterranean sea. J. Appl. Icththyol., 25: 782-784.

Rodriguez-Marin, E., Ortiz, M., Ortiz de Urbina, J. M., Quelle, P., Walter, J., Abid, N., Addis, P., Alot, E., Andrushchenko, I., Deguara, S., Di Natale, A., Gatt, M., Golet, W., Saadet, K., Kimoto, A., Macias, D., Saber, S., Santos, M. N. & Zarrard, R. 2015. Atlantic bluefin tuna (*Thunnus thynnus*) biometrics and condition. PLos One 10(10):e0141478. doi:10.1371/journal.pone.0141478.

Sella, M. 1929. Migrazioni e habitat del tonno (*Thunnus thynnus*) studiati col metodo degli ami, con osservazioni sull'accrescimento, sul regime delle tonnare, ecc. Memorie, R. Comitato Talassografico Italiano, 159: 1-24.

Sinovcic, G., Franicevic, M., Zorica, B. & Cikes-Kec, V. Length0weight and length-length relationships for 10 pelagic fish species from Adriatic Sea (Croatia). J. Appl. Ichthyol., 20: 156-158.

Tzoumas, A., Ramfos, A., De Metrio, G., Correiro, A., Spinos, E., Vavassis, C. & Katselis, G. 2010. Weight growth of Atlantic bluefin tuna (*Thunnus thynnus*, L. 1758) as a result of 6-7 months fattening process in the central Mediterranean. Col. Vol. Sci. Pap. ICCAT, 65: 787-800.

Zarrad, R. 2014. Biometric relations of wild and fattened *Thunnus thynnus* (L. 1758) caught offshore Tunisia (Ionian Sea, Central Mediterranean) in 2012. Col. Vol. Sci. Pap. ICCAT, 70: 225-231.

Table 1a. Summary of L-W equations from published works and new data provided.

	Larger fish					
Equat.	**Area**	**Gear**	**Years**	**Months**	**SFL range**	**N**
1	Levantine	PS	1996-998	Sep-Jun	99-218	1288
2	Levantine	PS	2003	Mar-Jun	114-256	363
3	Aegean	PS	2000	Feb-Jun	120-240	76
4	Aegean	PS		Feb-Jun	120-242	76
5	Central/Levantine	LL/PS/Trap	1998-2008	May-Jun	60-294	416
6	Libya	Trap	1999-2002	May-Jul	100-315	790
7	Tunisia	PS	2001		113-283	171
8	Tunisia	PS	2012	June	114-242	170
9	Central/West Med	LL	1995-1998	Apr-Jul	100-300	5957
10	Straits of Sicily/Tyrrh	HNDL	2002, 2003		50-310	
11	Straits of Sicily/Tyrrh	PS	2002, 2003		50-310	
12	Straits of Sicily/Ionian/Tyrrh	LL	2015	15May-30Jun	111-271	413
13	Straits of Sicily/Ionian/Tyrrh	LL	2016	15May-15Jun	112-257	345
14	Italy	Trap	1920s		64-254	1500
15	Tyrrhenian Sea	PS	1984-1988	June	86-295	8372
16	Sardinia	Trap	1992-1995	Apr-Jun	100-305.2	2586
17	West Med	PS	1975, 1976		>130	100
18	Spain (Med only)	All gears	1998-2009	All year	44-280	2295
19	East Atl/Med	Various		May		
20	East Atl/Med	Various		June		

	Smaller fish					
Equat.	**Area**	**Gear**	**Years**	**Months**	**SFL range**	**N**
21	Eastern Adriatic	PS	1998-2003		2.5-63	534
22	West Med	PS	1975, 1976		60-130	574

	New data					
Equat.	**Area**	**Gear**	**Years**	**Months**	**SFL range**	**N**
23	Balearic	LL	2010	26may-24jun	130-281	187
24	Balearic	PS	2010-2015	26may-24jun	124-253	124
25	Turkey	PS	2003-2006	26may-24jun	55.5-280	250
26	Central Adriatic	PS	2011, 2012, 2016	26may-24jun	72-120	216

Table 1b. Summary of L-W equations from published works and new data provided. Diff current was calculated as reference RWT for a 200cm fish less the RWT for a 200cm fish predicted by the average current ICCAT May and June equations (152.6kg). % Diff is calculated as the Diff current as a % of the average current ICCAT May and June equations (152.6kg)

	Larger fish						
Equat.	**a**	**b**	**RWT200cm**	**K**	**Reference**	**Diff current**	**%Diff**
1	0.000047	2.79	123.6	1.54	Karakulak (1999)	-29.0	-19.0
2	0.0000028	3.34	135.7	1.70	Percin and Akyol (2009)	-16.9	-11.1
3	0.000017	2.99	131.3	1.64	Ceyhan (2001)	-21.3	-14.0
4	0.000017	2.99	129.0	1.61	Hossucu *et al.* (2001)	-23.6	-15.5
5	0.000059	2.75	125.5	1.57	Tzoumas *et al.* (2010)	-27.1	-17.8
6	0.00004	2.82	123.3	1.54	El Tawil *et al.* (2004)	-29.3	-19.2
7	0.00002	2.96	129.4	1.62	Hattour (2003)	-23.2	-15.2
8	0.000052	2.79	136.7	1.71	Zarrad (2014)	-15.9	-10.4
9	0.00055	2.36	148.2	1.85	Chang (1999)	-4.4	-2.9
10	0.00002	2.97	136.5	1.71	Di Natale *et al.* (2005a)	-16.1	-10.6
11	0.00006	2.76	134.6	1.68	Di Natale *et al.* (2005b)	-18.0	-11.8
12	0.000098	2.68	145.1	1.81	Lombardo *et al.* (2016a)	-7.5	-4.9
13	0.000055	2.76	123.9	1.55	Lombardo *et al.* (2016b)	-28.7	-18.8
14	0.000019	2.97	129.7	1.62	Sella (1929)	-22.9	-15.0
15	0.000018	3.03	165.4	2.07	Arena (1988)	12.8	8.4
16	0.000050	2.79	132.2	1.65	Addis *et al.* (1997)	-20.4	-13.4
17	0.000016	3.03	150.1	1.88	Farrugio (1978)	-2.5	-1.7
18	0.000037	2.90	174.3	2.18	Alot *et al.* (2011)	21.7	14.2
19	0.000035	2.89	154.1	1.93	Rodriguez *et al.* (2015)	1.5	1.0
20	0.000035	2.88	151.1	1.89	Rodriguez *et al.* (2015)	-1.5	-1.0

	Smaller fish						
Equat.	**a**	**b**	**RWT200cm**	**K**	**Reference**	**Diff current**	**%Diff**
21	0.00002	2.96	129.4	1.62	Sinovcic *et al.* (2004)	-23.2	-15.2
22	0.00002	2.97	136.5	1.71	Farrugio (1978)	-16.1	-10.6

	New data						
Equat.	**a**	**b**	**RWT200cm**	**K**	**Reference**	**Diff current**	**%Diff**
23	0.000047496	2.80	133.4	1.67	Gordoa (present study)	-19.2	-12.6
24	0.000060597	2.77	141.6	1.77	Gordoa (present study)	-11.0	-7.2
25	0.000031322	2.89	140.6	1.76	Karakulak (pres. study)	-12.0	-7.8
26	0.000067607	2.71	119.0	1.49	Katavic & Grubisic (present study)	-33.6	-22.0

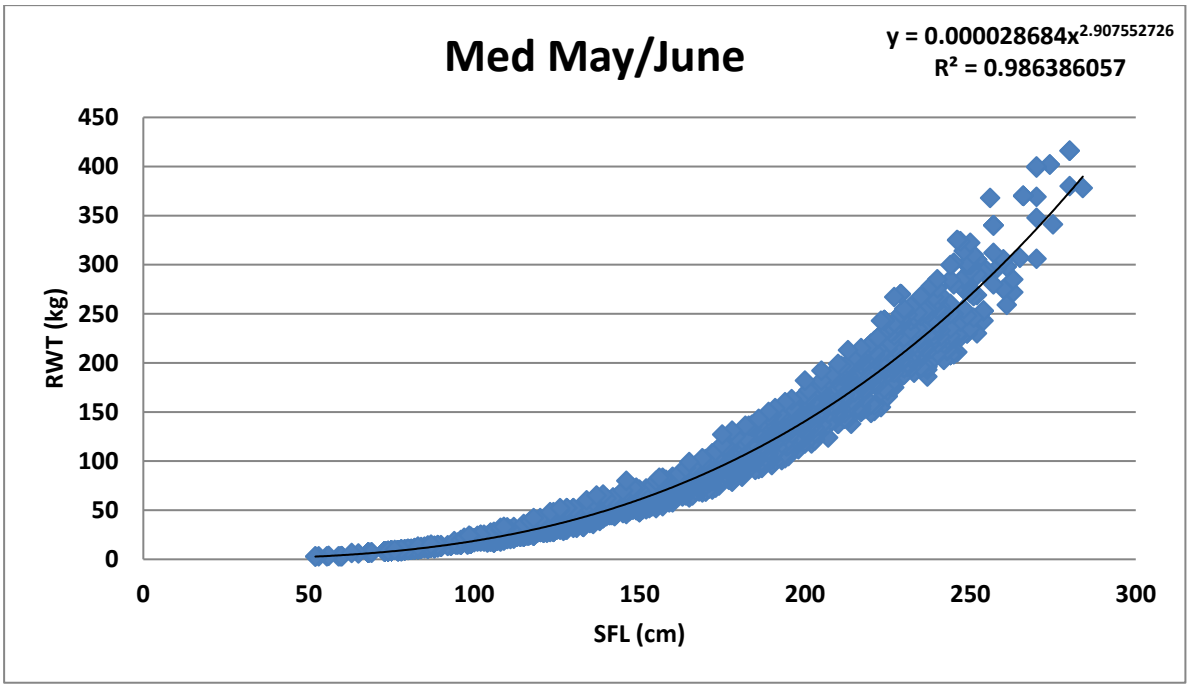

Figure 1. Length (SFL) versus weight (RWT) for Mediterranean bluefin tuna in the months of May and June.

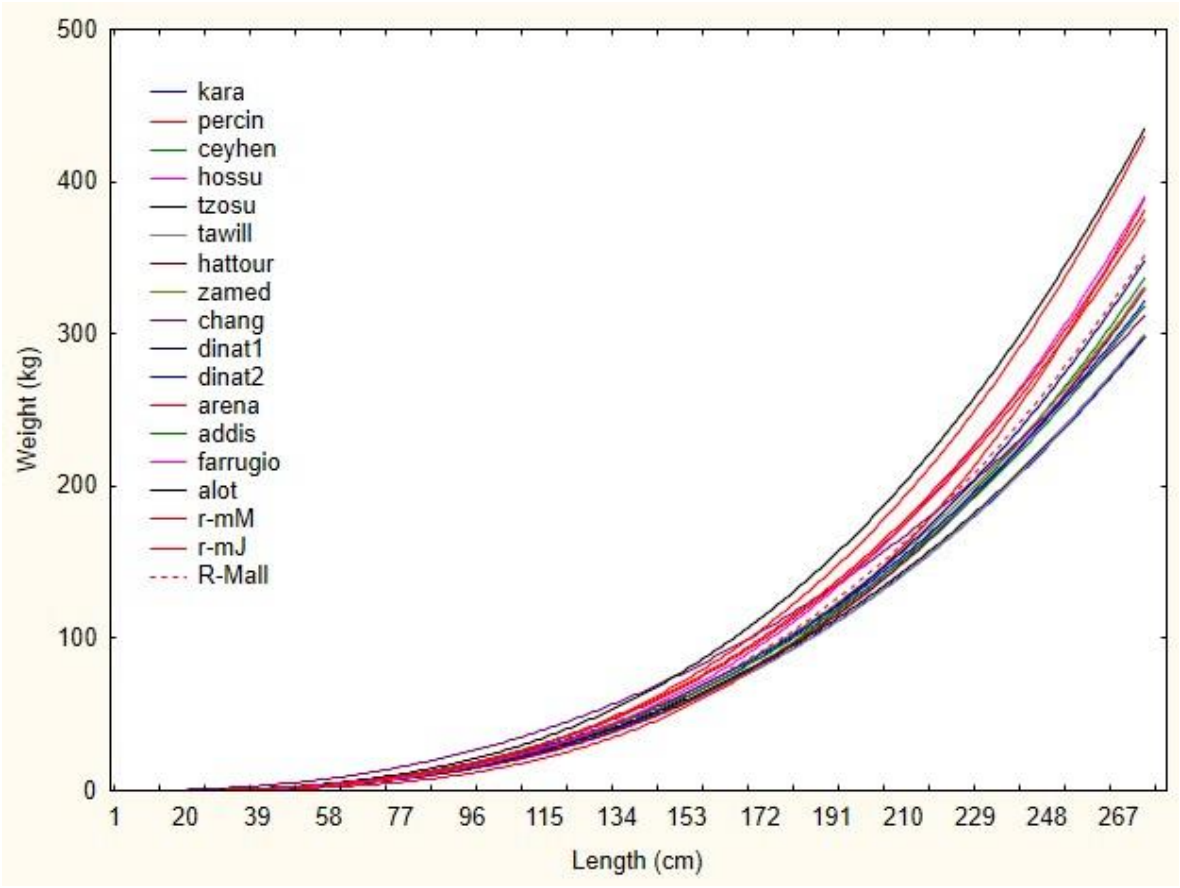

Figure 2a. Length (SFL) versus weight (RWT) curves for the various equations presented in **Table 1** (section: larger fish) and the new Mediterranean equation (R-Mall). The current ICCAT May and June equations are also included (r-mM and r-mJ).

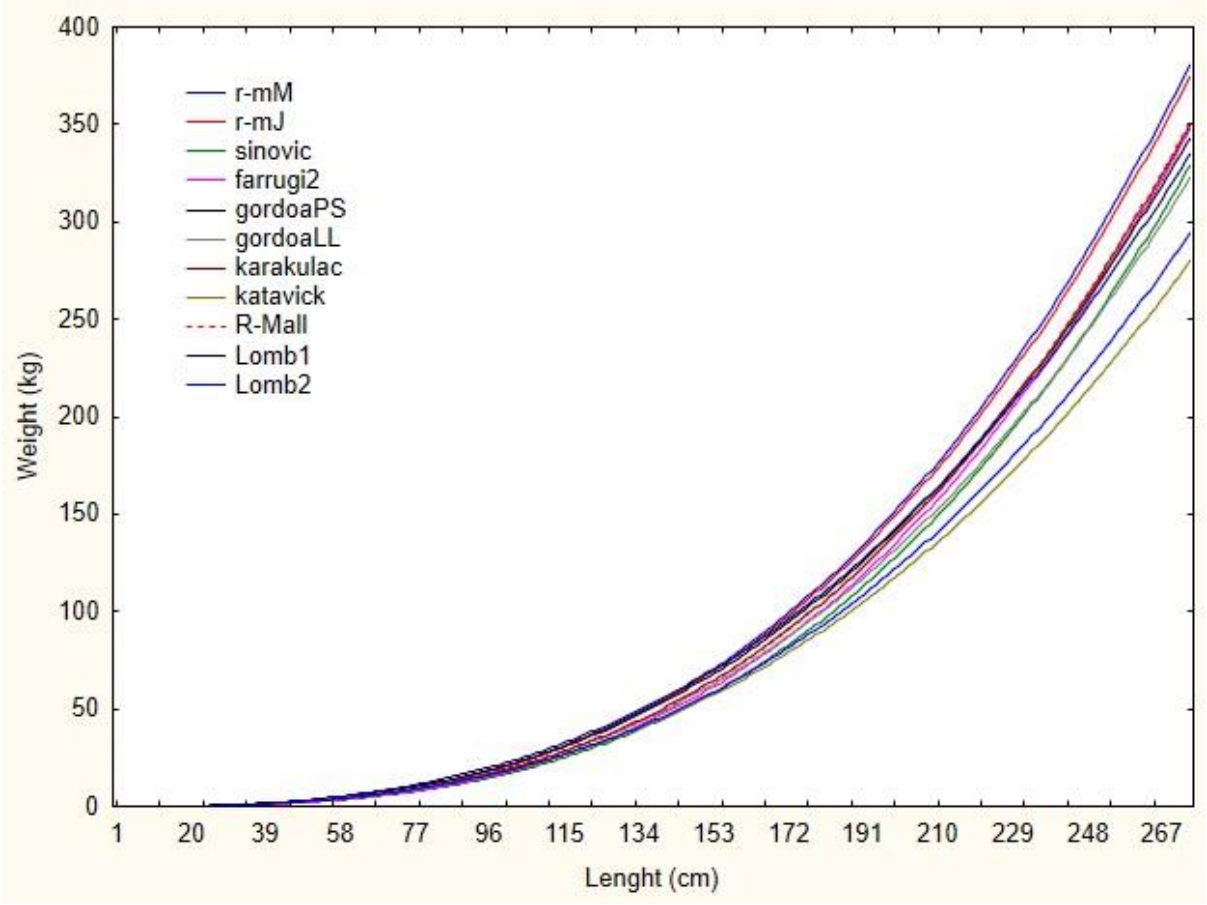

Figure 2b. Length (SFL) versus weight (RWT) curves for the various equations presented in **Table 1** (section: smaller fish, new data) and the new Mediterranean equation (R-Mall). The current ICCAT May and June equations are also included (r-mM and r-mJ).