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LENGTH-WEIGHT RELATIONSHIPS AND MORPHOMETRIC CONVERSION FACTORS BETWEEN WEIGHTS FOR THE BLUE SHARK (*PRIONACE GLAUCA*) AND SHORTFIN MAKO (*ISURUS OXYRINCHUS*) CAUGHT BY THE SPANISH SURFACE LONGLINE FLEET IN THE ATLANTIC OCEAN

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SUMMARY

Length-weight relationships and conversion factors between different weight types are presented for the blue shark (Prionace glauca) *and shortfin mako* (Isurus oxyrinchus) *which are the two of the most prevalent by-catch species in the surface longline fleets. The conversion factors RW-GW and RW-DW obtained for blue shark range, respectively, from 1.1946-1.2219 and 2.4074-2.5052 and from 1.1525-1.1577 and 1.4369-1.4575 for shortfin mako. Linear equations for conversion between different weight types are also presented for both species. The predicted weights from length-weight relationships obtained using nonlinear modeling do not differ from some of the previous length-weight relationships reported by other authors for both species.*

RÉSUMÉ

Les relations longueur-poids et les coefficients de conversion entre différents types de poids sont présentés pour le requin peau bleue (Prionace glauca) *et le requin taupe bleue* (Isurus oxyrinchus) *qui sont les espèces accessoires dominantes des flottilles palangrières de surface. Les coefficients de conversion RW-GW et RW-DW obtenus pour le requin peau bleue s'inscrivent, respectivement, dans la gamme de 1,1946-1,2219 et 2,4074-2,5052 et entre 1,1525-1,1577 et 1,4369-1,4575 pour le requin taupe bleue. Des équations linéaires pour la conversion entre les différents types de poids sont également présentées pour ces deux espèces. Les poids prédits à partir des relations longueur-poids obtenues à l'aide de modèles non-linéaires ne diffèrent pas de certaines relations longueur-poids antérieures déclarées par d'autres auteurs pour ces deux espèces.*

RESUMEN

Se presentan relaciones talla-peso y relaciones de conversión entre diferentes tipos de peso para las especies tiburón azul (Prionace glauca) *y marrajo dientuso* (Isurus oxyrinchus) *las cuales son especies de las más prevalentes como captura incidental en las flotas de palangre de superficie. Los factores de conversión RW-GW y RW-DW para el tiburón azul estarían respectivamente dentro de estrechos rangos 1.1946-1.2219 y 2.4074-2.5052 y entre 1.1525-1.1577 y 1.4369-1.4575 para el marrajo dientuso. Las diferentes ecuaciones de conversión entre diferentes tipos de peso son también suministradas para ambas especies. Las predicciones de peso a partir de las relaciones talla-pes, obtenidas usando ajustes no lineales, no difieren de las previamente descritas por otros autores para ambas especies.*

KEY WORDS

Blue shark, shortfin mako, length-weight relationships, conversion factors.

1. Introducción

One of the scientific tasks of the RFOs is to determine the biometric relationships and conversion factors between the different length or weight types of the landings of fishery products that may be presented by the different fleets. The estimation of some of these basic data for the scientific monitoring of the fisheries often depends on the availability and reliability of these relationships. Moreover, conversion factors need to be defined not only from a scientific standpoint, but sometimes even to enforce regulations or to ensure compliance.

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The ICCAT has traditionally considered the availability of the relationships to be a top-priority task in the case of tuna and tuna-like species. Their updated field manuals include a wealth of biometric relationships and conversion factors recommended for the different species in their areas of competence. However, this catalogue of biometric relationships is not usually updated by most RFOs and over the years they have been known to fall into a kind of inertia, overlooking relationship data submitted by different authors.

Up until only a few years ago, the study of pelagic sharks has not been considered a priority by ICCAT and other RFOs. However, the scientific literature includes an abundance of information on fork length-weight relationships and conversion factors related to these species of pelagic sharks (BUENCUERPO *et al.,* 1998; CASTRO & MEJUTO, 1995; FITZMAURICE *et al*., 2005; GARCÍA-CORTÉS & MEJUTO, 2002; HAZIN *et al.,* 1991; KOHLER *et al*., 1995, 1996; NAKANO & SEKI, 2003; STEVEN *et al*., 2005; among others[2]). Nevertheless, there are very few descriptive reports on the biometric relationships used by each fleet to carry out the basic statistical tasks. Given the fact that each fleet has its own criteria when it comes to gutting and preparing fish, conversion factors need to be developed for each fleet and these factors must be validated among the fleets before being able to assume a general recommended value that may be applied to each species. Moreover, the availability and accuracy of some of the relationships reported have been limited by the large size of the specimens and the difficulties entailed when recording this type of information at sea

Over the years the presentation of the landings of these pelagic shark species has changed. In the 1980s, the Spanish fleet would land only a small portion of the blue shark catches, and these landings were largely carried out in gutted weight. During this period, catches of shortfin mako were usually landed in round or gutted weight, depending on the port and the area of origin of the catch. Thanks to the available data on these two species during this period, it was possible to describe the existing bycatch fishery and to estimate the landing-discard levels of pelagic sharks from some important fractions of the longline fleet in addition to developing fork length-round weight relationships (FL-RW) by sex for shortfin mako and porbeagle (MEJUTO & GONZÁLEZ-GARCÉS, 1984; MEJUTO, 1985). Later, with the installation of on-board freezing systems in the vessels of this fleet, most of the catches of these species are now able to be landed in dressed weight, although the other presentations are still common in the more traditional artisanal boats. *Prionace glauca* and *Isurus oxyrinchus* are the two most prevalent species of pelagic sharks in the catches of the Spanish Atlantic surface longline fleet, accounting for 86%-89% and 9%-11% of the annual bycatch of pelagic sharks, respectively, from 1997 to 1999 (CASTRO *et al*., 2000; MEJUTO *et al*., 2002).

2. Material and methods

Fork length (FL) and weight (round RW, gutted GW and dressed DW) were specifically recorded during two scientific trips carried out in the Atlantic between 1996 and 1997. In both cases the criteria used for gutting and dressing the specimens followed the commercial standards employed by each vessel, without the intervention of the scientific staff in this process. The data on blue shark, from the NE Atlantic, were obtained during a trip targeting the scientific tagging of swordfish. Data on shortfin mako were recorded during a commercial trip in the South Atlantic. Fork length was measured to the lowest centimeter in a straight line and the weight was recorded in kilograms down to an estimated accuracy of roughly 250 gr.

The relationships between length and the different weight types were obtained using a nonlinear regression model. The conversion factors among the different types of weight were derived from several different methods. The first (1) took the sum of the respective weights by species-trip to calculate the conversion factors among these weights, which were applied to the trip as a whole. This conversion factor would provide a rough estimate of the weighted average of the catch taken. The second method (2) used the conversion factors between the weights obtained for each individual specimen and then averaged these weights to obtain an individual mean factor. In the third method (3) a linear regression modelling was applied, either (3.1) assuming a = 0 or (3.2.) estimating the two constants that define the straight line.

3. Results

A total of 119 blue shark specimens ranging in fork length from 93 to 254 cm FL (1.6-50 kg DW) and 34 shortfin mako specimens from 95 to 222 cm FL (6-85 kg DW) were analyzed **(Table 1)**.

[2] For more details http://www.iccat.es/Documents/SCRS/Manual/CH2/2_2_1_1_BSH-ENG.pdf

For *Prionace glauca* the conversion factors between RW-GW and RW-DW were in a narrow range: 1.1946-1.2219 and 2.4074-2.5052, respectively. For *Isurus oxyrinchus* the conversion factors between RW-GW and RW-DW were in the narrow range of 1.1525-1.1577 and 1.4369-1.4575, respectively. **Table 2** and **Figures 1 and 2** show the different conversion factors between weights and the biometric relationships obtained for the transformation between the different weight types by species and the method used.

The fork length-weight relationships obtained by species and weight type are given in **Table 3**. **Figures 3 and 4** show the linear fit of the data and their confidence intervals (95%). **Table 4** and **Figure 5** show the fork length-round weight relationships previously obtained for the species *Isurus oxyrinchus* and *Lamna nasus* (MEJUTO & GONZÁLEZ-GARCÉS, 1984). A comparison of the relationship reported by these authors for *Isurus oxyrinchus* (sexes combined) with the one obtained in this document revealed that the estimations of round weight by fork length are practically identical, despite the fact that there is a substantial difference in the number of observations **(Figure 6)**. Both equations were derived from the fish caught in the Atlantic, but in very different years. The fork length-round weight equation obtained for *Prionace glauca* was compared with another one that was reported previously for the NW Atlantic using 4,529 fish of both sexes and a broad range of sizes (KOHLER *et al*., 1995; 1996), with the results being virtually identical in the prediction of weight by fork length **(Figure 7)**. These equations compared for blue shark were obtained from eastern and western regions of the North Atlantic, respectively. However, abundant information from tagging recapture supports that this individuals pertain to the same stock and they cross the North Atlantic throughout large migrations. So equal biometric relationships should be expected.

Similarly, a comparison of the fork length-dressed weight relationships obtained with those reported by other authors for the Atlantic regions (GARCÍA-CORTÉS & MEJUTO, 2002) showed identical results in terms of predicting dressed weight by fork length. The results for both species would appear to be in keeping with other relationships described earlier.

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Table 1. Ranges, mean values and number of observations available for analyses of fork length FL (cm) and weight type (kg) for each species analyzed: *Prionace glauca* (PGO) and *Isurus oxyrinchus* (IOO).

PGO	*FL*	*RW*	*GW*	*DW*	*IOO*	*FL*	*RW*	*GW*	*DW*
Min.	93	5	4	2	Min.	95	12	9	6
Max.	254	119	95	50	Max.	222	122	107	85
Average	184	50	42	21	Average	169	57	49	40
N	119	119	119	119	N	34	34	34	34

Table 2. Factors and conversion equations found between the different weight types (RW, GW, DW) for the species *P. glauca* (PGO), *I. oxyrinchus* (IOO), according to the method used for the calculation.

Species	*Type Method*	*Method*	*Factor / Equation*	*N*	R^2
PGO	1	SUM (RW/GW)	RW= GW*1.1946	119	-
PGO	2	Average (RW/GW)	RW= GW*1.2219	119	-
PGO	1	SUM (RW/DW)	RW= DW*2.4074	119	-
PGO	2	Average (RW/DW)	RW= DW*2.5052	119	-
PGO	3.1	Linear fit (a=0), GW-RW	GW= 0.8422*RW	119	0.9883
PGO	3.2	Linear fit, GW-RW	GW= 0.8547*RW–0.8823	119	0.9886
PGO	3.1	Linear fit (a=0), DW-RW	DW= 0.4192*RW	119	0.9692
PGO	3.2	Linear fit, DW-RW	DW= 0.4288*RW–0.6767	119	0.9698
PGO	3.1	Linear fit (a=0), DW-GW	DW= 0.4973*GW	119	0.9741
PGO	3.2	Linear fit, DW-GW	DW= 0.5000*GW–0.1588	119	0.9741
IOO	1	SUM(RW/GW)	RW= GW*1.1527	34	-
IOO	2	Average(RW/GW)	RW= GW*1.1577	34	-
IOO	1	SUM (RW/DW)	RW= DW*1.4369	34	-
IOO	2	Average (RW/DW)	RW= DW*1.4577	34	-
IOO	3.1	Linear fit (a=0), GW-RW	GW= 0.8674*RW	34	0.9957
IOO	3.2	Linear fit, GW-RW	GW= 0.8668*RW+0.0401	34	0.9957
IOO	3.1	Linear fit (a=0), DW-RW	DW= 0.6983*RW	34	0.9939
IOO	3.2	Linear fit, DW-RW	DW= 0.7093*RW–0.760	34	0.9942
IOO	3.1	Linear fit (a=0), DW-GW	DW= 0.8050*GW	34	0.9964
IOO	3.2	Linear fit, DW-GW	DW= 0.8176*GW–0.7573	34	0.9967

Table 3. Estimation of constants (b0 and b1) which define the relationship between fork length (FL cm) and weight in kg (RW, GW, DW) using the nonlinear regression model, for both species analyzed: *Prionace glauca* (PGO) and *Isurus oxyrinchus* (IOO).

PGO P.glauca	*IOO I.oxyrhinchus*
Formula: RW ~ b0 * FL^ b1 Parameters: Value Std. Error t value b0: 7.66984e-006 3.13086e-006 2.44975 b1: 2.97678e+000 7.54461e-002 39.45570 Residual standard error: 5.58695	**Formula: RW ~ b0 * FL^ b1** Parameters: Value Std. Error t value b0: 4.67098e-006 3.2986e-006 1.41605 b1: 3.16457e+000 1.3474e-001 23.48640 Residual standard error: 5.74193
Formula: GW ~ b0 * FL^ b1 Parameters: Value Std. Error t value b0: 3.59388e-006 1.63047e-006 2.2042 b1: 3.08533e+000 8.38092e-002 36.8137 Residual standard error: 5.08588	**Formula: GW ~ b0 * FL^ b1** Parameters: Value Std. Error t value b0: 3.79001e-006 2.33367e-006 1.62405 b1: 3.17756e+000 1.17475e-001 27.04870 Residual standard error: 4.34245
Formula: DW ~ b0 * FL^ b1 Parameters: Value Std. Error t value b0: 0.000001209 6.66273e-007 1.81458 b1: 3.157890000 1.01772e-001 31.02910 Residual standard error: 3.02125	**Formula: DW ~ b0 * FL^ b1** Parameters: Value Std. Error t value b0: 2.56783e-006 1.85331e-006 1.38554 b1: 3.21031e+000 1.37675e-001 23.31810 Residual standard error: 4.08056

Table 4. Length (FL)-weight (RW) parameters for shortfin mako (*I. oxyrinchus*) and porbeagle (*L. nasus*), "a" and "b" constants of the equations RW= a * FL^b, n = number of pairs of values, r = correlation coefficient. Intervals: L= length range. W = weight range. (Table from Mejuto & Gonzalez-Garcés, 1984).

		b	a	r	n	Interval	Interval
Isurus oxyrinchus	♂	3.004706	0.0000101	0.98574	597	(82≤ L ≤ 262)	(6≤ W ≤ 213)
	♀	3.033177	0.0000088	0.98536	283	(75≤ L≤ 267)	(5≤ W≤ 215)
Lamna nasus	♂	2.395817	0.0002770	0.94147	39	(136≤ L 248)	(31≤ W≤124)
	♀	3.207000	0.0000039	0.98254	26	(116≤ L≤ 210)	(12≤ W≤ 174)

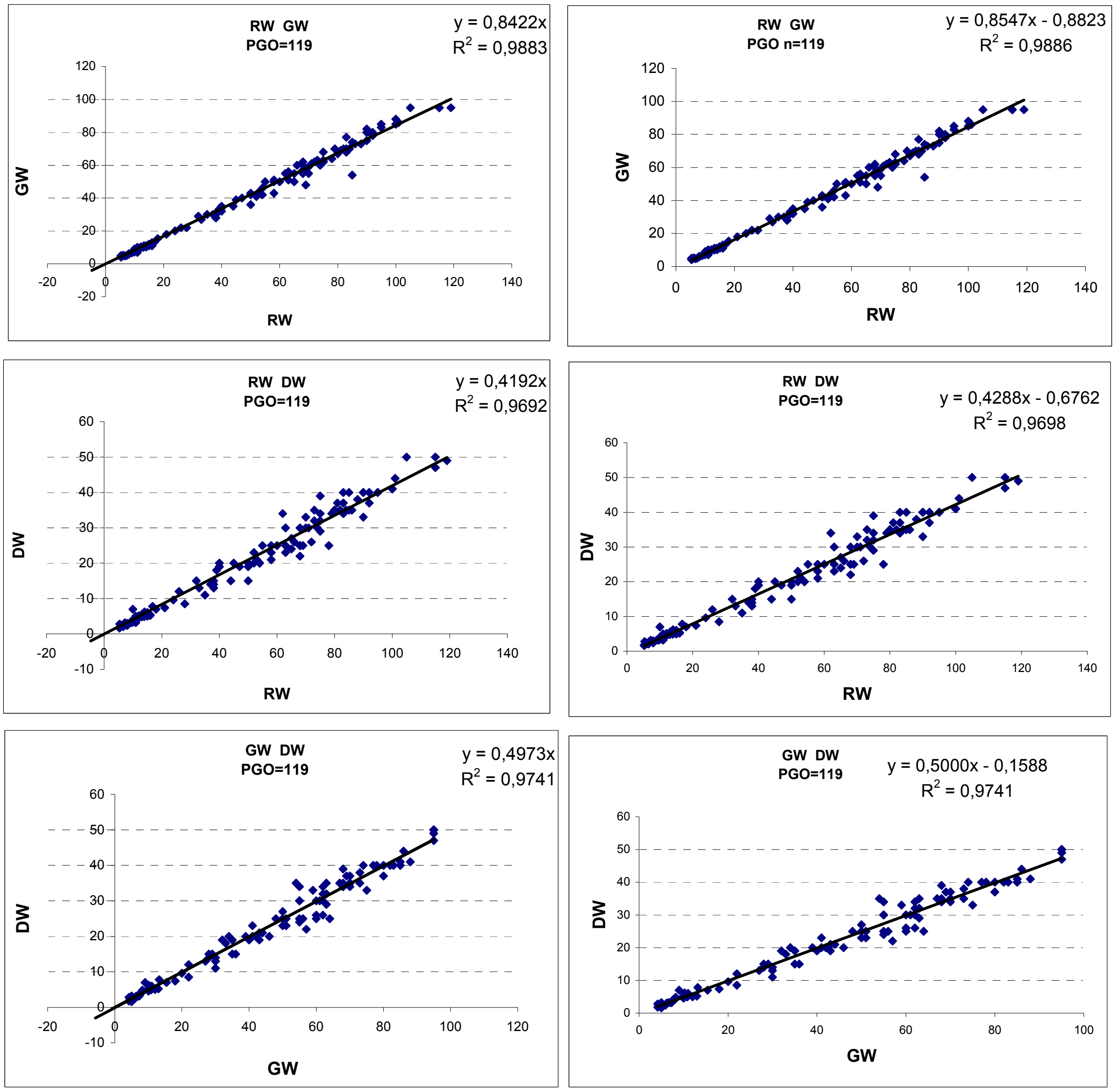

Figure 1. Biometric relationships for *Prionace glauca* between different weight types: round weight (RW), gutted weight (GW) and dressed weight (DW).

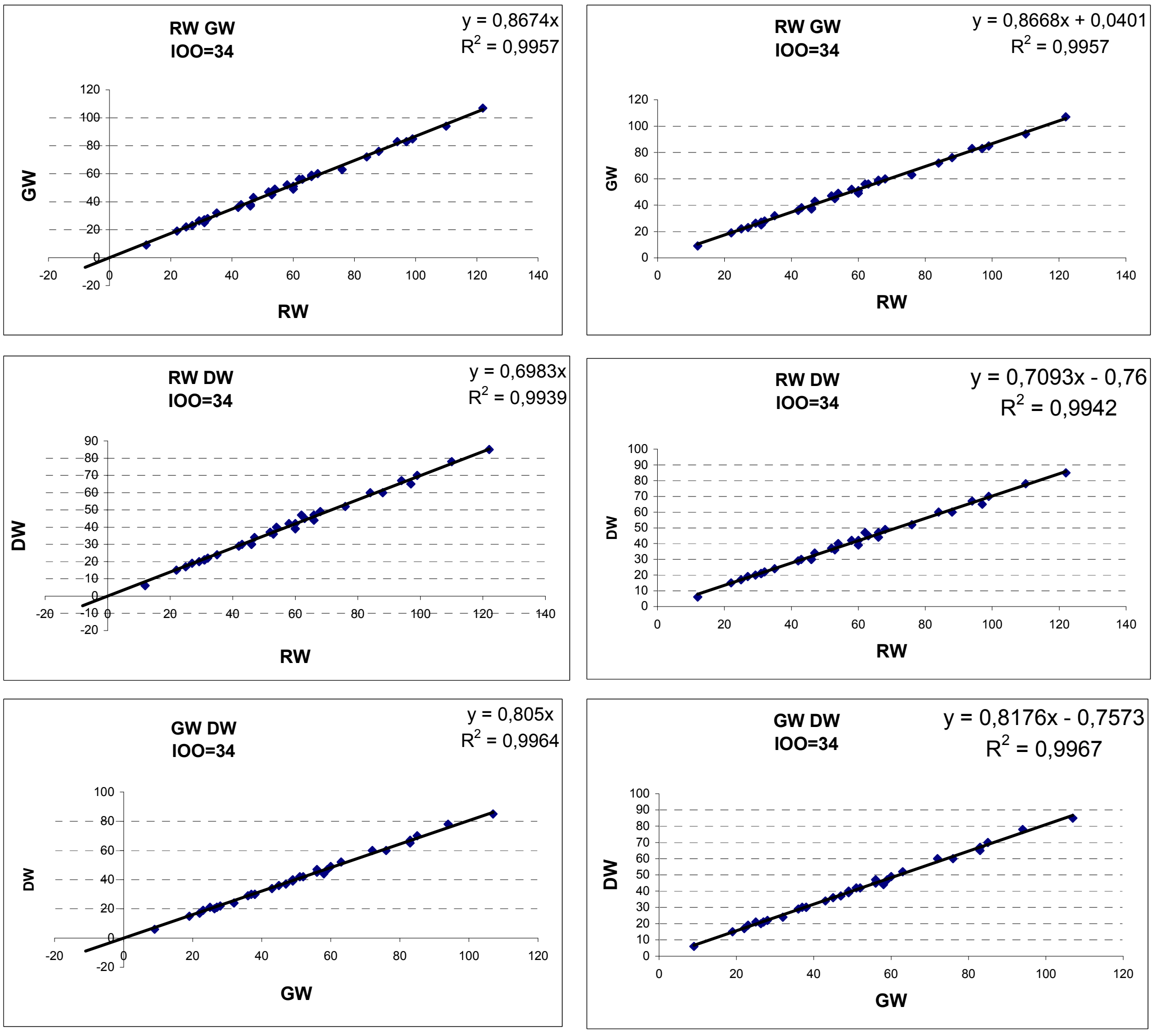

Figura 2. Biometric relationships for *Isurus oxyrinchus* between different weight types: round weight (RW), gutted weight (GW) and dressed weight (DW).

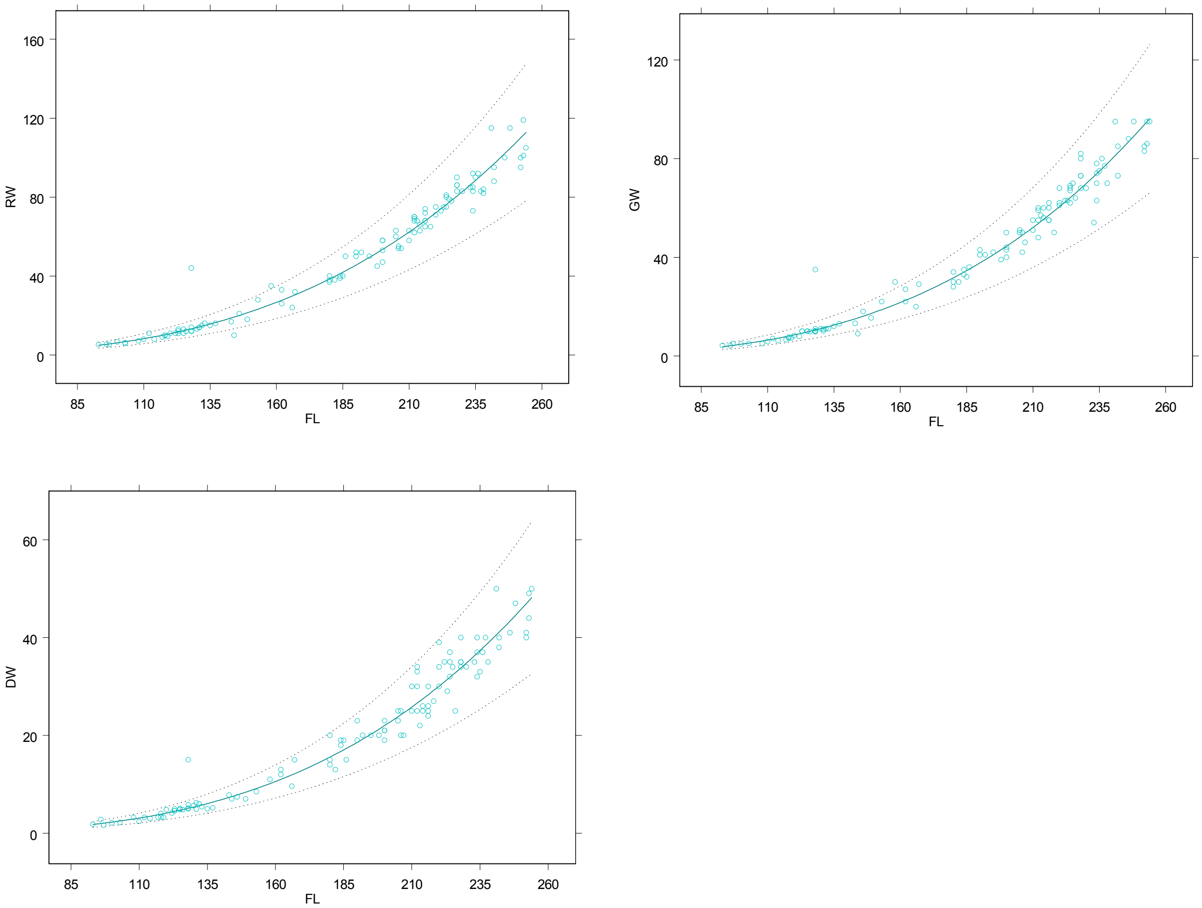

Figure 3. Power curve fits between the fork length (FL cm) and weights (RW, GW, DW in kg) for the blue shark (*Prionace glauca*) and 95% confidence intervals (see Table 3 for nonlinear fit results).

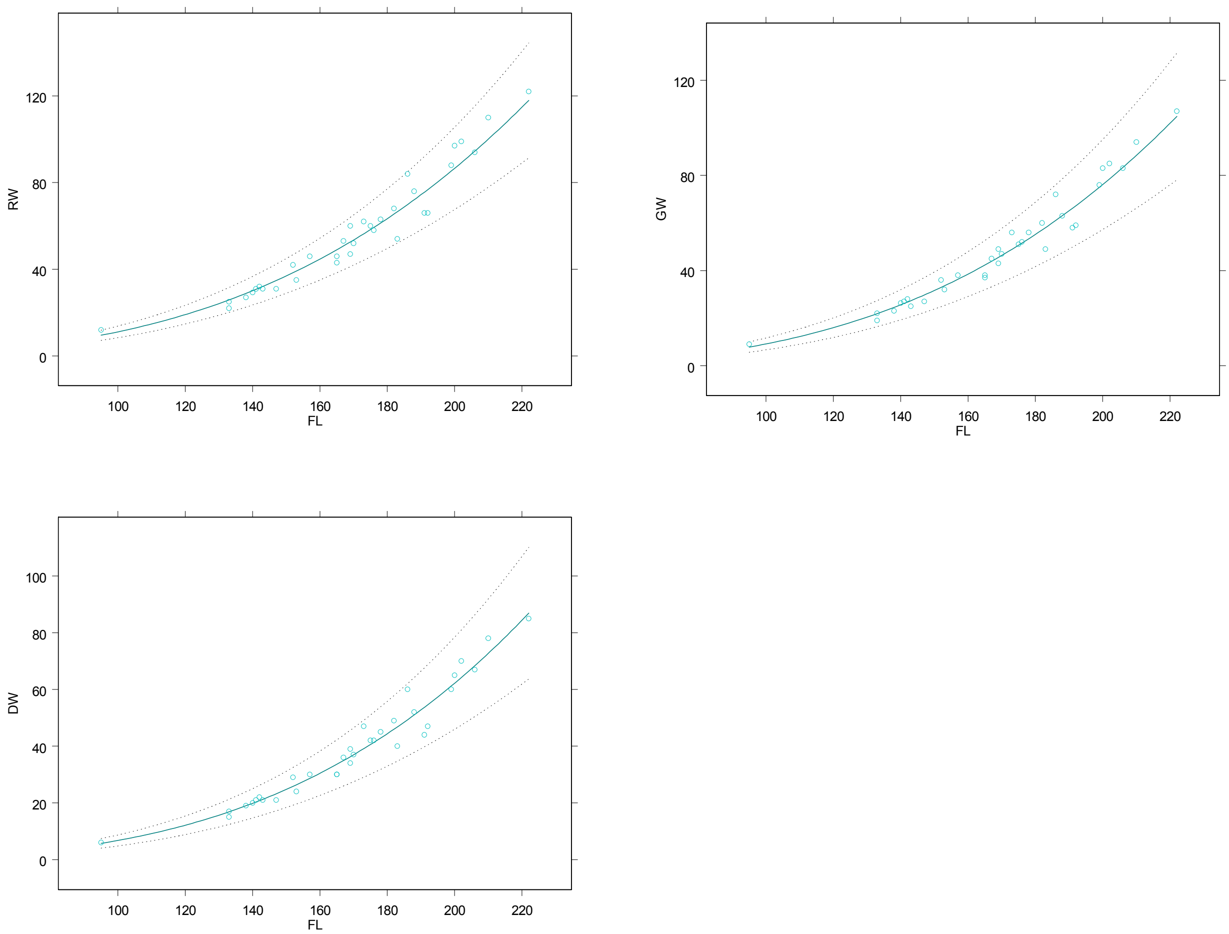

Figure 4. Power curve fits between the fork length (FL cm) and weights (RW, GW, DW in kg) for the shortfin mako shark (*Isurus oxyrinchus*) and 95% confidence intervals (see table 3 for nonlinear fit results).

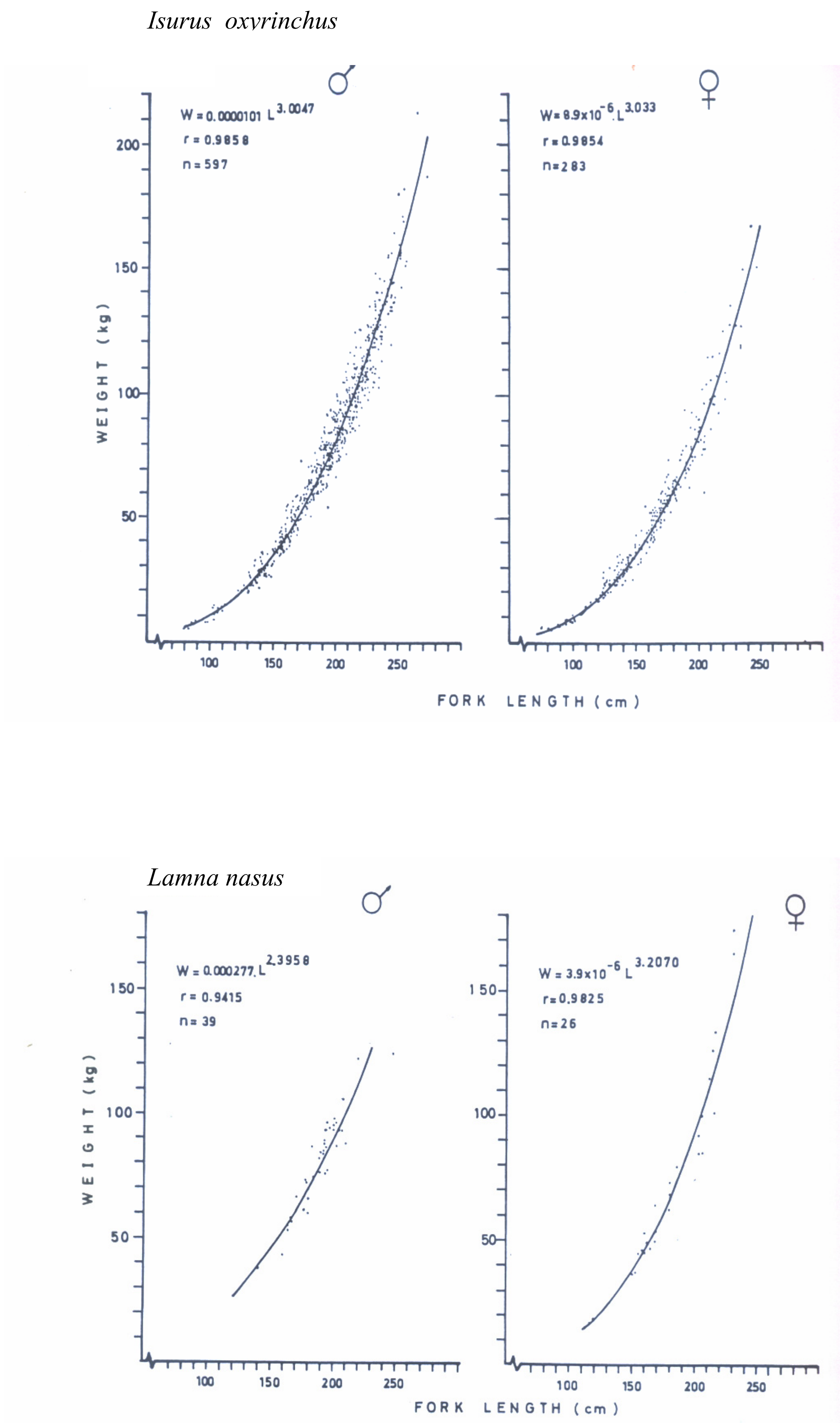

Figure 5. Length (FL)-round weight (kg) relationships by sex for the shortfin mako and porbeagle. (Figures from Mejuto & González-Garcés, 1984).

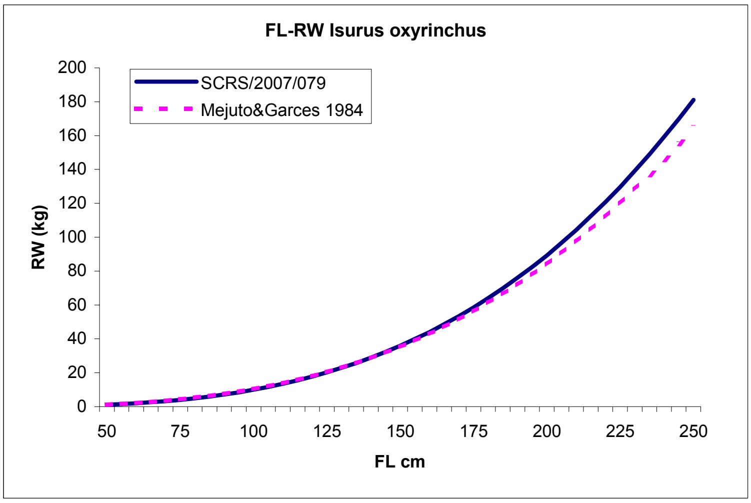

Figure 6. A comparison between the fork length (FL) and round weight (RW) relationship obtained in this work (SCRS/2007/079) for *I. oxyrinchus* and one described earlier (sexes combined) for the Spanish surface longline fishery in the NE Atlantic (Mejuto & González-Garcés, 1984).

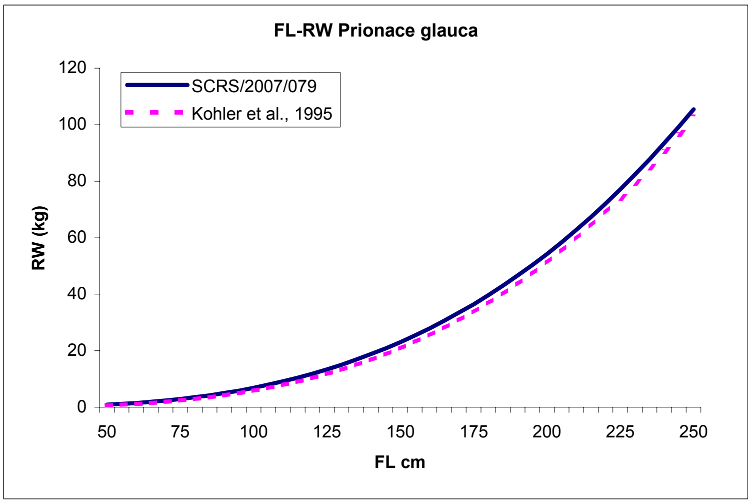

Figura 7. A comparison between the fork length (FL) and round weight (RW) relationship obtained in this work (SCRS/2007/079) for *P. glauca* and one described earlier (sexes combined) in the NW Atlantic (Kohler *et al.,* 1995; 1996).

Figure 8. Specimens of *Prionace glauca* in gutted weight (top left) and dressed weight (top right). Specimens of *Isurus oxyrinchus* in round weight (bottom left) and dressed weight (bottom right).