Length-weight relationships, conversion factors and analyses of sex-ratio, by length-range, for several species of pelagic sharks caught in experimental cruises on board Spanish longliners in the South Western Indian Ocean during 2005

by

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# SUMMARY

This paper presents the results based on data obtained by observers on board Spanish longliners regarding allometric relationships and sex ratio of the more abundant species of pelagic sharks belonging in captures during the Pilot Action (AP) undertaken by these vessels in 2005. During this AP, two ships performed 539 sets and worked 531916 hooks of 5 different kinds, baited with mackerel and squid, or squid-like species. From the total tons of fishes caught (75 species or groups of species), sharks and rays correspond to 45% of round weight (521t): 11039 individuals. The main species caught, in number of individuals, was the blue shark (Prionace glauca), 60.3%, and the short-fin mako (Isurus oxyrinchus), 10.7%; the rest correspond to another species of sharks and rays.

Observers weighed 35% of blue sharks (2311 individuals) and also obtained length data. Analyses of these data have resulted in a total length – round weight relationship, described by the equation  $W = 1.331 \times 10^{-6} \times TL^{3.204}$  if both sexes are taken into account. This is also described for males and females, though no significative differences have been found between sexes.

The same equation is presented—combined sex—for 390 individuals of silky shark (Carcharhinus falciformis), 93 specimens of whitetip shark (Carcharhinus longimanus), 377 individuals of crocodile shark (Pseudocarcharias kamoharai), 503 individuals of shortfin mako and 15 specimens of scalloped hammerhead (Sphyrna lewini).

Comparing the fork length – round weight equations obtained for four of these six species of sharks with those ones proposed by another authors in Atlantic and Indian oceans, the results are very similar to the relationship that is actually agreed by the IOTC and two more equations for whitetip shark and crocodile shark are proposed. The relationship between length (total and fork) and dressed or carcass weight are also obtained for the four species more commercialized and some conversion factors between lengths and weights are proposed.

Scientific observers on board have reported the sex and size (total length: TL) of 5990 individuals of blue shark (90% from total data capture) from direct observation of gonads. Thus, 17% of individuals are females, which points to less than 50% in practically all length classes and involves all three-month periods of 2005. Only for some ranges of size few representative (smaller than 100 cm and higher than 345 cm), females were over 50%. This percentage is significatively low from April to June (3%). However, 60% of 1058 specimens of shortfin mako were females, with over 50% for most of the length classes and similar values in the quantity of females during all the quarters of the year.

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### 1. Introduction

Spanish Fisheries Administrations are encouraged to carry out experimental fishing plans or pilot programs (AP), including participation and scientific monitoring by the *Instituto Español de Oceanografía* (IEO), the purpose of which is to test new fishing gears, manoeuvres, fishing technologies, and so on. In this case, new kinds of baits and hooks are tried out.

At the meeting of the Scientific Committee of the Indian Ocean Tuna Commission (IOTC) in November 2004, information was provided about the experimental campaign, AP-8/2004, being carried out by the IEO on two surface longliners in the international waters of the South Western Indian Ocean (Ariz *et al.*, 2004).

The main purpose of this AP was to put into effect experiments with circular hooks and different kinds of baits, in order to minimize frequent catches of marine turtles resulting from these longline fisheries. For AP programme development and monitoring, six scientific observers, directed by IEO, took part and one of them was always on board both participating vessels from the onset. For all the sets, observers collected detailed information about ship activities, data capture and biological parameters of all the species caught.

Several species of pelagic sharks, family *Istiophoridae* or tuna are often bycatch by the Spanish surface longline fleet which target species is the swordfish. In this AP, not only swordfish but also pelagic sharks were target species. Many of these sharks are gutted on board to be commercialized, so the data registered on ports are usually in dressed weight. This paper presents various equations that let calculate the length of the shark form its dressed weight or the round weight from carcass weight, in addition to information about their sex-ratio. It is also proposed an equation to convert the total length into round weight. The results are compared with previous length-weight relationships and conversion factors found in the Indian and Atlantic Ocean for several species of sharks (Amorim *et al.* 1997, Anon. 1999, Campana *et al.* 2005, García-Cortés & Mejuto 2002, Kohler *et al.* 1996, Mejuto *et al.* 2002, Stevens 1983).

Data are taken from within the geographical limits of the AP and, consequently, they are representative of different species depending on the stock structure to which they belong.

Other allometric relationships between body weight and fin weight, for pelagic sharks, were presented to the Inter-American Tropical Tuna Commission (Ariz *et al.* 2006).

# 2. Material and Methods

The biological data analyzed in this paper were obtained, in 2005, by two Spanish surface longliners: *Beata Teresa Jornet* (IOTC-000207) and *Zumaya Dous* (IOTC-000844). The working area was located in international waters of the South Western Indian Ocean, between 25°S-35°S and 30°E-50°E. **Figure 1** shows the geographical distribution of the 539 sets performed for both vessels during this AP.

Both vessels had a setline carrying 960 hooks (480 baited with mackerel and 480 baited with squid or squid-like species), as equipment for the fixed part of the long line. Specifically, 240 units of each type of hook were used, alternately varying sequences of 60 hooks of each type baited, with different kinds of bait. The variable part of the long line, which use depended on the criteria of the ship's skipper, had a maximum of 240 and a minimum of 60 hooks. These hooks had the same sequence as the fixed part—60 hooks of each type with only one kind of bait per sequence. The variable part was required to be exactly the same for both boats when undertaking joint sets (to measure and standardise the fishing efficiency of each vessel).

Longline configuration and hook distribution for fixed and variable parts was as follows (Figure 2):

- Hooks between buoys: 5
- Distance between hooks: 87 m
- Hooks between radio beacons: 60 hooks of each kind.
- Number of hooks per section: 240 (4 types of hooks) with the same kind of bait.
- Each snood drops to 18 metres to the meeting point with the setline. From here 14.6 m of line extends to where the electrical or chemical light is positioned and a further 3.6 m to the hook (approximately 10

cm, including anchoring).

• Approximate distance between radio beacons: 5220 m, reaching the fixed part of the gear at a distance of 84 km from the head to the end of the longline.

In the experiment, mainly four types of hooks (and occasionally a fifth type of hook) and two types of baits were used for the "basic or fixed longline" and for the variable or "optional" part of the longline.

Information was collected about environmental parameters (including depth and temperature data using depth registers located on the longline), fishing boats, biological (sex, etc.) and morphological (size and weight) and predation data, opportunistic tagging (spaghetti-type) and catches per type of bait and hook.

Owing to that numerous samples were gutted and cut off on board to get the carcass (body without head, gills, guts or fins), the weight of each specimen before and after this process (Round weight – RND and Dressed or Carcass weight – DWT respectively) was recorded whenever was possible. The weight was calculated directly from spring balances (100 kg, 200 gr precision) placed on board. The specimen was hanged by the caudal peduncle, so in many cases the stomach contents drained out (water and food) before weighing.

The total length (TL) and the fork length (FL) were also recorded (**Figure 3**) by making use of 1.5 metres-long callipers, always considering the lowest centimetre.

In order to convert the individual weights into length, four non-linear equations  $(W=aL^b)$  were determined for each species considering the relationship between round weight – total length, round weight – fork length, carcass weight – total length and carcass weight – fork length.

By visual inspection of the reproductive system, scientific observers reported sex, determining males, females or undetermined individuals. There was no selection of individuals to determine sex, so the entire process was made at random.

For the adjustment of the size-weight ratio, weights were allocated to the size corresponding to the average point of the interval: 0.5 cm. For the sex ratio, sizes were grouped into 5 cm intervals for results presentation.

Although there is space-time stratification for sampling in the prospected area, it was not taken into consideration for this document. Joint analysis has been made for all the specimens sampled since activities began (539 sets) for the entire area.

# 3. Results

Scientific observers identified in the 539 sets (531916 hooks) 28106 specimens of several species and taxonomic groups with a total round weight corresponding to 1162.2 tons. In the case of the sharks and rays, 11039 fish were caught (521 t), which suppose the 45% of total capture. The blue shark (*Prionace glauca*, Linnaeus 1758 – BSH) was the main capture of this group (6656 specimens, 396 t), followed by the shortfin mako (*Isurus oxyrinchus*, Rafinesque 1810 – SMA) with 1181 specimens (65.6 t), the silky shark (*Carcharhinus falciformis*, Müller y Henle 1839 – FAL) with 616 specimens (11 t) and the crocodile shark (*Pseudocarcharias kamoharai*, Matsubara 1936 – PSK) with 534 specimens (2.4 t). The other sharks were captured in lower quantity, for example the whitetip shark (*Carcharhinus longimanus*, Poey 1861 – OCS) with 255 specimens, the smooth hammerhead (*Sphyrna zygaena*, Linnaeus 1758 – SPZ) with 115 specimens and the scalloped hammerhead (*Sphyrna lewini*, Griffith y Smith 1834 – SPL) with 29 specimens (**Table 1**).

A quantity of 2268 (20%) specimens of this group was discarded depending on trade criteria (mainly the silky shark) or belonged to bycatch (mainly the rays).

# **3.1. Length-weight relationships**

The allometric length-weight equations  $(WT=aL^b)$  established for the major target and bycatch species of sharks by different authors in various areas of the Atlantic and Indian Ocean (**Table 2**) were compared with some of the expressions described in this paper for the relationship between round (RND) or carcass (DWT) weight and fork (FL) or total (TL) length. The morphometric <u>relationship between RND-TL</u> presented has been compared, for *I. oxyrinchus*, with the data presented by Stevens (1983) (**Figure 4**).

As it is shown, the relationships between FL-RND (**Figure 5**) have been compared with the theoretical data obtained with the equation proposed by another authors (Anon. 1999, Campana *et al.* 2005 and Kohler *et al.* 1996) for some species (*P. glauca, C. falciformis, I. oxyrinchus* and *S. lewini*). The results indicate that the length-weight data are adjusted to these equations and, in addition, two new equations for *C. longimanus* and *P. kamoharai* are presented.

Similarly, the relation between TL-DWT (**Figure 6**) was compared with the equations proposed for *P. glauca* by Amorim *et al.* (1997) in Brazilian waters and, in this case, the results obtained in this AP were similar. The present study also shows three more equations for the sharks: *C. falciformis*, *C. longimanus* and *I. oxyrinchus*.

For the relation between FL-DWT, (**Figure 7**) the data obtained in these experimental cruises for *P. glauca* were compared to the equation proposed by Campana *et al.* (2005) in the Canadian Atlantic and no significative adjustment was found. They have been also compared to the results obtained by García-Cortés & Mejuto (2002) in Indian Ocean for *P. glauca, C. falciformis, C. longimanus* and *I. oxyrinchus.* The present study proposes equations for *P. glauca, C. falciformis, C. longimanus* and *I. oxyrinchus.* 

The **Table 3** shows the results of length-weight adjustment to a  $WT = aL^b$  type equation, as well as characteristics of the data used in each adjustment (number of data pairs, range of weights and sizes) for the most frequently caught species of pelagic sharks. These data are presented for all the sampled specimens (both sexes and undetermined) and by sex.

# 3.2. Conversion factors length-length and weight-weight

# **3.2.1.** Length-Length conversion

The linear regressions of fork length to total length determined by various authors for some species of sharks in the Atlantic Ocean are presented in **Table 4**.

The graph and data pairs used in the adjustment of fork length – total length conversion are given in **Figure 8**, taking into account both sexes, for seven species of sharks (*P. glauca, C. falciformis, C. longimanus, P. kamoharai, I. oxyrinchus, S. lewini* and *S. zygaena*). Four of them (*P. glauca, C. falciformis, I. oxyrinchus* and *S. lewini*) were compared with the conversion factors proposed by another authors (Campana *et al.* 2005, Kohler *et al.* 1996, Stevens 1975) and the results were very similar to that proposed by Kohler *et al.* (1996) and accepted by the IOTC (Anon. 2006). **Figure 9** shows the linear regressions obtained for these species of sharks in the present study and by different authors.

The resulting linear regressions obtained with their corresponding regression coefficients, sample sizes, size ranges and geographical area are compiled in **Table 5**. Correlation coefficients are higher than 0.97 in six of the seven equations obtained; only *P. kamoharai* has a lower  $r^2$ : 0.85.

# **3.2.2.** Weight-Weight conversion

The factors to convert processed weight (DWT) into round weight (RND) published by different authors for some sharks in the Atlantic Ocean are shown in **Table 6**. These factors have been compared with those ones obtained in the present study for four species (*P. glauca*, *C. falciformis*, *C. longimanus* and *I. oxyrinchus*) and the results are adjusted to the regression proposed by Mejuto *et al.* (2002) in the case of *P. glauca* and *I. oxyrinchus* (**Figure 10**).

 Table 7 compiles the conversion factors and variables of the relationship between RND-DWT obtained in the present study.

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3.3. Sex ratio

The sex of 5990 blue shark individuals was recorded (90% of number of blue sharks caught) so as to establish the sex ratio by length class in the prospected area. **Table 8** gives the sex ratio per size interval, as well as the percentage of females obtained for *P. glauca*. A general predominance of males was observed for this species, since they were present in practically all size intervals. The females were mainly under the 20% per interval of 5 cm TL (**Figures 11 and 12**). This criteria is similar to the data registered by Mejuto and García-Cortés (2005) in the Indian Ocean (21.29% were females) and differs from the 45.8% of females found in the Atlantic Ocean by another authors (Arocha *et al.* 2005).

The scientific observers on board determined the sex of 1058 individuals of SMA (**Table 9**). In this case, the females are predominant for most of the length ranges (**Figures 11 and 12**).

The percentage of female for blue shark and shortfin mako per quarter was calculated (**Figures 13 and 14**), in order to corroborate this finding. It is difficult to draw more conclusions for the other species, owing to the small number of specimens sampled.

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Species Code	Scientific name	n	RND (t)
BSH	Prionace glauca	6656	396
SMA	Isurus oxyrinchus	1181	65.6
FAL	Carcharhinus falciformis	616	11
PSK	Pseudocarcharias kamoharai	534	2.4
OCS	Carcharhinus longimanus	255	11.9
SPZ	Sphyrna zygaena	115	8.7
SPL	Sphyrna lewini	29	1.7

**Table 1.** Total capture of sharks analysed in this paper in number of specimens (*n*) and round weight (*RND*) in tons

**Table 2.** Length – Weight equations  $(WT=aL^b)$  established for the major target and bycatch species of sharks by different authors in various areas of the Atlantic and Indian oceans. The regression coefficient  $(r^2)$ , the sample sizes (N) and the length and weight ranges are indicated

Species	Equation	$\mathbf{r}^2$	Reference	N	Length range (cm)	Weight range (cm)	Area
BSH (Blue shark) (Prionace glauca)	$RND = 1.41 \times 10^{-6} (FL)^{3.2884}$	0.99	Anon. (1999)	18	?	?	South-western Indian Ocean (Chagos Archipielago)
	$RND = 3.2x10^{-6} (FL)^{3.128}$	0.97	Campana <i>et al.</i> (2005)	720	?	?	North-western Atlantic (Canada)
	$RND=3.18x10^{-6}(FL)^{3.1313}$	0.95	Kohler <i>et al.</i> (1996)	4259	52-288	1-174	North-western Atlantic (North America)
	$DWT=2.81x10^{-5}(TL)^{2.52}$	0.67	Amorim <i>et al.</i> (1997)	110	203-302	11-60	South-western Atlantic (Brazil)
	$DWT = 1.7 \times 10^{-6} (FL)^{3.205}$	0.98	Campana <i>et al.</i> (2005)	382	?	?	North-western Atlantic (Canada)
	$DWT = 1.6x10^{-6}(FL)^{3.099}$	0.95	García- Cortés&Mejuto (2002)	289	150-260	?	West Indian Ocean
FAL (Silky shark) (Carcharhinus falciformis)	$RND = 1.54 \times 10^{-5} (FL)^{2.9221}$	0.97	Kohler <i>et al.</i> (1996)	85	73-212	4-88	North-western Atlantic (North America)
	$DWT = 1.1 \times 10^{-5} (FL)^{2.915}$	0.97	García- Cortés&Mejuto (2002)	411	50-220	?	West Indian Ocean
OCS (Whitetip shark) (Carcharhinus longimanus)	DWT=2.98 <sup>-5</sup> (FL) <sup>3.154</sup>	0.93	García- Cortés&Mejuto (2002)	567	65-215	?	West Indian Ocean
SMA (Shortfin mako) (Isurus oxyrinchus)	$RND = 5.24 \times 10^{-6} (FL)^{3.1407}$	0.96	Kohler <i>et al.</i> (1996)	2081	65-338	2-531	North-western Atlantic (North America)
	$RND = 4.83 \times 10^{-6} (TL)^{3.1}$	?	Stevens (1983)	91	58.2-343	?	South-western Pacific (New South Wales)
	$DWT = 1.4 \times 10^{-5} (FL)^{2.882}$	0.93	García- Cortés&Mejuto (2002)	171	105-235	?	West Indian Ocean
SPL (Scalloped hammerhead) (Sphyrna lewini)	$RND = 7.77 \times 10^{-6} (FL)^{3.0669}$	0.92	Kohler <i>et al.</i> (1996)	390	79-243	5-166	North-western Atlantic (North America)

**Table 3.** Variables of Length-Weight equation: Weight (round or carcass) = a Length (total or fork)<sup>b</sup>, length type, weight type for six species of sharks from sampling data collected by scientific observers on Spanish longliners in waters of South Western Indian Ocean. Length and weight means and ranges for males, females and sex combined are presented, and size of sample is included (N)

										Weight =	a (Lengt)	$(h)^b$
IOTC		Туре	Туре			Mean	Length	Mean	Weight			2
Code	Species	of	of	Sex	Ν	length	range	weight	range	а	b	$\mathbf{r}^2$
		Length	Weight	·		(cm)	(cm)	(Kg)	(Kg)			
BSH	Blue shark	RND	TL	combined	2311	225	98 - 350	52,3	3,5 - 180	1,3307 x 10-6	3,2043	0,9416
	(Prionace glauca)			males	1994	226	98 - 339	52,6	3,5 - 162			
		DIVE	-		209	- 100	103 - 330	52,1	4,7 - 180	2 20 40 40 4	2 1 60 7	
		RND	FL	combined	2279	189	81 - 298	52,3	3,5 - 180	2,7968 x 10-6	3,1697	0,9556
				famalas	19/0	189	81 - 284	52,6	3,5 - 162			
		DUIT	-		239	185	80 - 298	52,2	4,7 - 180	1 (075 10 5	0.11.60	
		DWT	TL	combined	2137	241	116 - 394	26,1	1,0 - 125	1,68// x 10-/	3,4163	0,9399
				fomolos	1/10	240	110 - 394	25,8	1,4 - 125			
		DU	-		- 22	- 202	129 - 375	27,0	2,0 - 85	4.0100 10.7	2.2620	0.0540
		DWI	FL	combined	2129	203	82 - 352	26,1	1,0 - 125	4,0189x 10-7	3,3620	0,9542
				famalas	274	202	62 - 552 105 - 205	25,0	1,4 - 125			
TAT	0:11 1 1	DND			3/4	209	105 - 305	27,5	2,0 - 85	6 50 60 10 6	2.007.6	0.0072
FAL	Silky shark	RND	TL	combined	390	126	70 - 296	15,6	2,5 - 183	6,5069 x 10-6	2,9876	0,9073
	(Carcharninus			fomolos	1/4	127	70 - 282	16,0	2,5 - 150			
	jaicijormis)	DND	171	1 i i	109	120	70 - 290	10,0	3 - 163	1 7 2 5 5 10 6	0.1771	0.0644
		RND	FL	combined	369	105	66 - 244	16,0	2,5 - 183	4,7255 x 10-6	3,17/1	0,9644
				formalas	100	105	60 - 255 68 - 244	16,0	2,5 - 150			
		DU	T		162	105	112 210	10,0	3,1 - 183	5 ((2)) 10 (	2 0007	0.0401
		DWI	TL	combined	95 52	163	113 - 318	1/,0	4 - 104	5,6621 x 10-6	2,8897	0,9481
				females	55 40	160	113 - 262 121 - 318	20.0	4,5 - 02			
		DIVT	FI	iciliaics		105	07 260	17.0	<u> </u>	1 2077 10 5	2 9 2 2 2	0.0250
		DWI	FL	combined	94 52	135	97 - 269	17,0	4,5 - 104	1,2977 x 10-5	2,8323	0,9259
				famalas	55 40	132	97 - 233	20.0	4,5 - 02			
0.00	3371.14.41.4.1.4.1	DND	T	Ternales	40	140	102 - 209	20,0	3 - 104	4.0111 10.0	2 0727	0.0000
ocs	Whitetip shark	KND	IL	combined	93	1/3	68 - 259	45,8	2,0 - 142	4,9111 x 10-6	3,0737	0,9666
	(Carcharninus)			females	02 20	162	08 - 234	38.3	2,0 - 140			
	iongimanus)	DND	EI	nome in a d	23	144	57 210	46.2	0,3 - 142	1 9429 - 10 5	2.0245	0.0729
		KND	FL	malas	92	144	57 219	40,2	2,0 - 142	1,8428 x 10-5	2,9245	0,9738
				females	29	133	76 - 210	38.3	2,0 - 140			
		DWT	TI	some in a d	121	104	115 075	21.2	6.0 40	2 4026 - 10 5	2 5 9 6 1	0.0127
		DWI	IL	males	131	194	115 - 275	21,5	63-49	2,4036 x 10-5	2,3801	0,9127
				females	09 41	188	123 - 273	19.9	60-49			
		DWT	FI	combined	121	160	04 243	21.2	6.0 40	8 0/21 x 10 5	2 1 1 7 8	0.0035
		DWI	I.F.	malac	131	162	102 243	21,5	6 2 49	8,0451 x 10-5	2,4478	0,9035
				famalas	09 41	105	102 - 243	22,1	6.0 40			
DCIZ	Crocodile shark	DND	TI	acmhinad	- 41	133	94 - 230	19,9	0,0 - 49	0.0942 - 10.2	1 2 4 5 5	0 2767
LOV	(Pseudocarcharias	KND	IL	males	330	98	78 - 118	4,4	2,3 - 0,5	9,0845 x 10-5	1,5455	0,2707
	(1 seudocurenarias kamoharai)			females	25	100	79 - 117	4.6	2.3 - 6.4			
		RND	FI	combined	310		69 - 102	4.4	23-65	3 3532 x 10-4	2 1156	0.4302
		KND	1.L	males	291	88	70 - 102	4,4	2,3 - 6,5	5,5552 x 10-4	2,1150	0,4302
				females	22	90	69 - 102	4.6	2.3 - 6.4			
SMA	Shortfin mako	RND	TL	combined	503	170	65 - 281	48,6	2,1 - 149	1,0497 x 10-5	2,9593	0,9776
	(Isurus oxyrinchus)			males	208	165	67 - 281	44,5	2,1 - 148			
				females	286	174	65 - 257	51,8	2,1 - 149			
		RND	FL	combined	495	154	58 - 261	48,9	2,1 - 160	1,1160x 10-5	3,0029	0,9824
				males	204	151	60 - 261	44,9	2,1 - 148			
				females	282	157	58 - 237	52,0	2,1 - 160			
		DWT	TL	combined	327	184	90 - 270	39,5	4,8 - 110	5,2018 x 10-6	3,0200	0,9666
				males	127	179	90 - 257	36,0	4,8 - 98			
				females	184	188	99 - 270	42,3	5,0 - 110	-	-	-
		DWT	FL	combined	327	168	75 - 243	39,6	4,8 - 110	6,7236 x 10-6	3,0239	0,9691
				males	127	163	75 - 236	35,9	4,8 - 98			
				females	184	171	91 - 243	42,3	5,0 - 110			
SPL	Scalloped	RND	TL	combined	15	183	141 - 271	38,8	13,0 - 102	3,2510 x 10-6	3,0957	0,9591
	hammerhead			males	7	191	150 - 271	46,9	13,0 - 102			
	(Sphyrna lewini)			females	7	177	153 - 238	32,7	17,5 - 70	-	-	-
		RND	FL	combined	15	145	115 - 220	38,8	13,0 - 102	9,1646 x 10-6	3,0300	0,9789
				males	7	154	115 - 220	46,9	13,0 - 102			
				females	7	139	116 - 188	32,7	16,0 - 70			

**Table 4.** Fork Length (FL) – Total Length (TL) conversion factors determined for the major target and bycatch species of sharks by different authors in various areas of the Atlantic Ocean. The regression coefficient  $(r^2)$ , the sample sizes (N) and the length and weight ranges are indicated

Species	Equation	$\mathbf{r}^2$	Reference	Ν	FL range (cm)	TL range (cm)	Area
BSH (Blue shark)	FL=11.27+0.78TL	?	Stevens (1975)	?	?	?	North Atlantic
(Prionace glauca)	FL=1.39+0.83TL	0.99	Kohler <i>et al.</i> (1996)	572	52-282	64-337	North-western Atlantic (North America)
	FL=-1.2+0.84TL	0.99	Campana <i>et al.</i> (2005)	792	?	?	North-western Atlantic (Canada)
FAL (Silky shark) (Carcharhinus falciformis)	FL=-2.65+0.84TL	0.99	Kohler <i>et al.</i> (1996)	15	73-212	90-258	North-western Atlantic (North America)
SMA (Shortfin mako) (Isurus oxyrinchus)	FL=-1.71+0.93TL	0.99	Kohler <i>et al.</i> (1996)	199	65-338	70-368	North-western Atlantic (North America)
SPL (Scalloped hammerhead) (Sphyrna lewini)	FL=-0.31+0.78TL	0.99	Kohler <i>et al.</i> (1996)	111	64-216	82-278	North-western Atlantic (North America)

**Table 5.** Conversion factors and variables of relationship (*Length* x = (a)*Length* y + b) between lengths (total length, *TL*; fork length, *FL*) for seven species of sharks, sex combined, from sampling data collected by scientific observers on Spanish longliners in waters of south-western Indian Ocean. Length and weight means and ranges for males, females and sex combined are presented, and size of sample is included (*N*)

						_	]	FL = (a)TL + b	)	TL = (a)	FL + b	
			Mean		Mean	-						
Code	Species		TL	TL range	FL	FL range						
		Ν	(cm)	(cm)	(cm)	(cm)	а	b	$\mathbf{r}^2$	а	b	FACTOR
BSH	Blue shark	6485	236	93 - 394	197	68 - 352	0,8561	-4,5542	0,9791	1,1436	10,1367	1,20
	(Prionace glauca)											
FAL	Silky shark	520	128	77 - 304	105	66 - 247	0,8113	1,0883	0,9732	1,2060	1,5174	1,22
	(Carcharhinus falciformis)											
ocs	Whitetip shark	193	185	68 - 275	151	57 - 243	0,8602	-7,2885	0,9753	1,1339	12,8071	1,22
	(Carcharhinus longimanus)											
PSK	Crocodile shark	407	99	68 - 118	88	62 - 103	0,8083	7,1478	0,8498	1,0518	7,3824	1,14
	(Pseudocarcharias kamoharai)											
SMA	Shortfin mako	1144	181	55 - 335	164	50 - 300	0,9047	0,5963	0,9887	1,0929	1,3866	1,10
	(Isurus oxyrhinchus)											
SPL	Scalloped hammerhead	20	189	140 - 287	150	115 - 230	0,7994	-1,0546	0,9913	1,2406	2,8667	1,26
	(Sphyrna lewini)											
SPZ	Smooth hammerhead	71	219	135 - 328	172	114 - 262	0,8039	-4,3490	0,9826	1,2225	9,0821	1,28
	(Sphyrna zygaena)											

**Table 6.** Round weight (RND) – Dressed or carcass weight (DWT) conversion factors determined for the major target and bycatch species of sharks by different authors in various areas of the Atlantic Ocean. The regression coefficient  $(r^2)$ , the sample sizes (N) and the length and weight ranges are indicated

Species	Equation	r <sup>2</sup>	Reference	Ν	DWT range (cm)	RND range (cm)	Area
BSH (Blue shark)	RND=0.4+1.22DWT	0.99	Campana <i>et al.</i> (2005)	17	?	?	North-western Atlantic (Canada)
	RND=2.4074DWT	?	Mejuto et al. (2002)	?	?	?	Atlantic Ocean
SMA (Shortfn mako)	RND=1.4541DWT	?	Mejuto et al. (2002)	?	?	?	Atlantic Ocean

**Table 7.** Conversion factors and variables of relationship (*Weight* x = (a)*Weight* y + b) between weights (round weight, *RND*; dressed weight, *DWT*) for four species of sharks, sex combined, from sampling data collected by scientific observers on Spanish longliners in waters of south-western Indian Ocean. Length and weight means and ranges for males, females and sex combined are presented, and size of sample is included (*N*)

							FL = (a)T	L+b / RND =	= (a)DWT+b	TL = (a)FL + b /	DWT= (a)RND+b	_
			Mean RND	RND	Mean DWT	DWT range						_
Code	Species	Ν	(Kg)	range (Kg)	(Kg)	(Kg)	a	b	$\mathbf{r}^2$	а	b	FACTOR
BSH	Blue shark	1404	58,9	5,5 - 162	24,4	1,4 - 72	2,3106	2,5515	0,9826	0,4252	-0,6600	2,45
	(Prionace glauca)											
FAL	Silky shark	87	37,4	9 - 296	17,4	4,5 - 104	2,5630	-7,3147	0,9717	0,3792	3,2625	2,03
	(Carcharhinus falciformis)											
OCS	Whitetip shark	72	54,5	12 - 142	20,5	6,0 - 47	3,0592	-8,1552	0,9749	0,3188	3,1065	2,57
	(Carcharhinus longimanus)											
PSK	Crocodile shark	249	53,1	8,0 - 149	36,1	5,0 - 105	1,4070	2,3473	0,9922	0,7052	-1,3759	1,49
	(Pseudocarcharias kamoharai)											

Table 8. Sex of specimens per size interval of 5 cm TL, to the lowest centimetre, obtained by observers on board during the AP 08/2004, percentage of females per size interval and totals for Blue shark (BSH)

Prionace glauca: BSH
Indian Ocean
RAI-AP-08/2004

Sex ratio				
TL (cm)	Number of males	Number of females	Total	% FEMALES
80-84	-	1	1	100%
00.04	-	-	-	-
90-94	2	1	3	33%0
95-99	4	2	0	33%
100-104	4	6	10	60% 229/
105-109	8	4	12	33%
110-114	9	2	11	18%
115-119	18	l	19	5%
120-124	23	6	29	21%
125-129	19	1	20	5%
130-134	24	3	27	11%
135-139	46	5	51	10%
140-144	31	2	33	<b>6%</b>
145-149	22	5	60	8%
150-154	64	2	66	3%
155-159	74	2	/6	3% 100/
160-164	/5	8	83	10%
165-169	91	5	96	5%
1/0-1/4	96	4	100	4%
1/5-1/9	11/	2	119	2%
180-184	125	5	150	4%
185-189	152	9	101	0%
190-194	150	17	147	12%
195-199	111	14	123	1170
200-204	175	27	202	13%
203-209	130	44	200	2270
210-214	137	61	198	24 /0
220-224	178	63	2/1	26%
220-224	133	42	175	2070
220-234	149	+2 57	206	2470
230-234	143	36	179	2070
240-244	151	27	178	15%
245-249	150	38	188	20%
250-254	176	29	205	14%
255-259	187	45	232	19%
260-264	171	37	208	18%
265-269	193	41	234	18%
270-274	194	36	230	16%
275-279	166	35	201	17%
280-284	174	29	203	14%
285-289	156	29	185	16%
290-294	145	28	173	16%
295-299	118	21	139	15%
300-304	122	27	149	18%
305-309	84	29	113	26%
310-314	74	29	103	28%
315-319	47	15	62	24%
320-324	40	9	49	18%
325-329	24	13	37	35%
330-334	27	7	34	21%
335-339	8	5	13	38%
340-344	9	3	12	25%
345-349	4	4	8	50%
350-354	-	5	5	100%
355-359	-	5	5	100%
360-364	1	I	2	50%
365-369	-	-	-	-
3/0-3/4	1	-	1	-
313-319	-	-	-	-
200-284 285 290	1	-	1	-
300-304	- 1	-	-	-
570-374	1	-	1	-
Total	4950	1040	5990	17%

**Table 9.** Sex of specimens per size interval of 5 cm *TL*, obtained by observers on board during the AP 08-2004,percentage of females per size interval and totals for Short-fin mako (SMA)

Isurus oxyrinchus:	SMA
Indian Ocean	
RAI-AP-08/2004	

TL (cm)	Number of males	Number of females	Total	% FEMALES
55-59	1	-	1	-
60-64	2	1	3	33%
65-69	3	2	5	40%
70-74	10	19	29	66%
75-79	6	6	12	50%
80-84	-	4	4	100%
85-89	3	4	7	57%
90-94	7	3	10	30%
95-99	11	9	20	45%
100-104	4	5	9	56%
105-109	7	3	10	30%
110 114	5	5 7	10	58%
115 110	5	1	12	100%
113-119	-	4	4	100%
120-124	5	2	5	40%
125-129	4	8	12	67%
130-134	4	6	10	60%
135-139	5	5	10	50%
140-144	9	6	15	40%
145-149	4	17	21	81%
150-154	9	18	27	67%
155-159	19	16	35	46%
160-164	16	8	24	33%
165-169	15	18	33	55%
170-174	25	25	50	50%
175-179	32	42	74	57%
180-184	31	36	67	54%
185-189	22	41	63	65%
190-194	31	21	52	40%
195-199	21	44	65	68%
200-204	26	27	53	51%
205-209	17	49	66	74%
210-214	10	28	38	74%
215-219	12	20	32	63%
220-224	10	23	33	70%
225-229	5	21	26	81%
220-234	3	16	19	8/0/
230-234	9	10	21	57%
233-239	5	12	17	5770 710/
240-244	2	12	17	/1/0
243-249	3	15	10	8170 500/
250-254	3	5	0	50 76
255-259	4	0	10	60 % 500/
200-204	2	2	4	50%
265-269	3	4	/	57%
270-274	1	3	4	75%
275-279	-	4	4	100%
280-284	1	2	3	67%
285-289	-	3	3	100%
290-294	-	1	1	100%
295-299	-	1	1	100%
300-304	-	3	3	100%
305-309	-	-	-	-
310-314	-	1	1	100%
315-319	-	-	-	-
320-324	-	-	-	-
325-329	-	-	-	-
330-334	-	-	-	-
335-339		1	1	100%



Figure 1. Area covered by the AP-08/2004 in international waters of the South Western Indian Ocean and sets made during this AP. Points show shooting longline position



A1: 18J conventional metallic hook; A2: 18J conventional blue hook; A3: 18O circular metallic hook; A4: 18O circular blue hook

Figure 2. Configuration of the longline. The number, type and situation of the hooks are indicated.



Figure 3. Lengths obtained for sharks caught by Spanish longliners in South-western Indian Ocean





**Figure 4.** Total Length (*TL*)-Round weight (*RND*) relationship (sex combined) for six species of sharks in the south-western Indian Ocean, based on data collected by Spanish longliners during experimental cruise in 2005. For shortfin mako, the present study has been compared with the data of Stevens (1983)



Figure 5. Fork Length (*FL*)-Round weight (*RND*) relationship (sex combined) for six species of sharks in the south-western Indian Ocean, based on data collected by Spanish longliners during experimental cruise in 2005, and comparison with the equations proposed by different authors (Anon. 1999, Campana *et al.* 2005, García-Cortés&Mejuto 2002, Kohler *et al.* 1996 and Present Study) depending on each species.





**Figure 6.** Total Length (*TL*)-Dressed Weight (*DWT*) relationship (sex combined) for four species of sharks in the south-western Indian Ocean, based on data collected by Spanish longliners during experimental cruise in 2005 and comparison with the equation proposed by Amorim *et al.* (1997) for the BSH





**Figure 7.** Fork Length (*FL*)-Dressed Weight (*DWT*) relationship (sex combined) for four species of sharks in the south-western Indian Ocean, based on data collected by Spanish longliners during experimental cruise in 2005 and comparison with the equation proposed by Campana *et al.* (2005) for the BSH, and the data from García-Cortés&Mejuto (2002) for BSH, FAL and OCS



**Figure 8.** Fork Length (*FL*)-Total Length (*TL*) conversion factors (sex combined) for seven species of sharks in the South-western Indian Ocean, based on data collected by Spanish longliners during experimental cruise in 2005 and compared with another studies (Campana *et al.* 2005, Kohler *et al.* 1996 and Stevens 1975) for four of them

TL (cm)



**Figure 9.** Fork Length (*FL*)-Total Length (*TL*) linear regressions (sex combined) for seven species of sharks in the South-western Indian Ocean, based on data collected by Spanish longliners during experimental cruise in 2005 and compared with another studies (Campana *et al.* 2005, Kohler *et al.* 1996 and Stevens 1975) for four of them





**Figure 10.** Round Weight (*RND*)-Dressed weight (*DWT*) conversion factors (sex combined) for four species of sharks in the South-western Indian Ocean, based on data collected by Spanish longliners during experimental cruise in 2005 and compared with another studies (Campana *et al.* 2005 and Mejuto *et al.* 2002)





**Figure 11.** Sex ratio by length class, in number of individuals (N), for *Prionace glauca* (BSH) and *Isurus oxyrinchus* (SMA) from longline fishery in the South Western Indian Ocean. The total number of specimens caught (*nt*) is included



Figure 12. Percentage of females, by length class, for *Prionace glauca* (BSH) and *Isurus oxyrinchus* (SMA) from long-line fishing in the South Western Indian Ocean



Figure 13. Percentage of females by quarters of year 2005 for *Prionace glauca* (BSH) from long-line fishing in the South Western Indian Ocean



**Figure 14.** Percentage of females by quarters of year 2005 for *Isurus oxyrinchus* (SMA) from long-line fishing in the South Western Indian Ocean