PRELIMINARY RESULTS ON SEX RATIO AND MATURITY OF THE SWORDFISH (*XIPHIAS GLADIUS*) IN THE STRAIT OF GIBRALTAR; IMPLICATIONS FOR THE STOCKS STRUCTURE

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SUMMARY

During the main fishing season of swordfish (April- June) by the artisanal Moroccan longline fishery in the strait of Gibraltar and the adjacent Atlantic waters, 383 swordfish were sampled for estimating the sex-ratio patterns by size and the size at first maturity (L_{50}). The preliminary results showed that the sex ratio is slightly in favor of males for sizes less than 130 cm LJFL (Lower jaw-Fork length), whereas females are largely predominating in sizes larger than 140cm LJFL. Fifty per cent (50%) of females were estimated to be mature at 166 cm LJFL. The sex ratio by size pattern and maturity ogive analyses showed that a high mixing rate between the Mediterranean and the North Atlantic stocks occurs west of the 05°W boundary separating the two stocks.

RÉSUMÉ

Pendant la principale saison de pêche d'espadon (avril-juin) des palangriers artisanaux marocains dans le détroit de Gibraltar et les eaux de l'Atlantique adjacentes, 383 espadons ont été échantillonnés pour estimer les schémas de sex-ratio par taille et la taille à la première maturité (L50). Les résultats préliminaires ont montré que le sex-ratio est légèrement en faveur des mâles pour les tailles inférieures à 130 cm LJFL (longueur maxillaire inférieur - fourche), alors que les femelles prédominent largement dans les tailles supérieures à 140 cm LJFL. Il a été estimé que cinquante pour cent (50 %) des femelles étaient matures à 166 cm LJFL. Le sex-ratio obtenu par les analyses du mode de taille et d'ogive de maturité a montré qu'un taux élevé de mélange entre la Méditerranée et l'Atlantique Nord se produit à l'Ouest de la délimitation de 05ºW qui sépare les deux stocks.

RESUMEN

Durante la principal temporada de pesca de pez espada (abril-junio) de la pesquería de palangre artesanal marroquí en el estrecho de Gibraltar y las aguas atlánticas adyacentes, se muestrearon 383 peces espada para estimar los patrones de ratio de sexos por talla y la talla de primera madurez (L50). Los resultados preliminares demostraron que la ratio de sexos es ligeramente favorable a los machos para las tallas inferiores a 130 cm LJFL (longitud mandíbula inferior a la horquilla), mientras que las hembras predominan bastante en tallas superiores a 140 cm LJFL. Se estimó que el cincuenta por ciento (50%) de las hembras están maduras a los 166 cm LJFL. Los análisis de la ratio de sexos por patrón de tallas y los análisis de la ojiva de madurez demostraron que existe una elevada tasa de mezcla entre los stocks del Mediterráneo y el Atlántico norte al oeste del límite de los 0,5ºW que separa los dos stocks.

KEYWORDS

Xiphias gladius, *Strait of Gibraltar, sex ratio by size, size at first maturity, GLM, mixing*

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1. Introduction

Swordfish (*Xiphias gladius*) is one of the most commercially important species caught by the Moroccan longline fleet in the strait of Gibraltar during its reproductive migration from the Atlantic to the Mediterranean Sea during the period from April to October of each year (Idrissi & Abid, 2006). The average annual catches of this species during the decade 2004-2013 was around to 900 tones but since 2012 show a clear decline due to the total ban of the driftnet fisheries implemented by the Moroccan fishery department. In the latest years annual catches from the Gibraltar area do not exceed 250 tones. Despite this remarkable decline in the catches, Morocco is still the second biggest swordfish producer in the Mediterranean Sea after Italy (Anon., 2015).

The Strait of Gibraltar is known to be a mixing area between the Mediterranean and the North Atlantic swordfish stocks. The International Commission for the Conservation of Atlantic Tunas (ICCAT) has repeatedly recommended the realization of biological and genetic studies on the swordfish caught west of the 05°W boundary separating the two stocks with the goal to assess the mixing rate in this area (Anon., 2015).

Little is known about the sex-ratio patterns and the sexual maturity of swordfish exploited in the strait of Gibraltar (El Hannach, 1987; De la Serna, 1992a; De la Serna, 1992b Abid, 1998; Srour *et al*., 2003). El Hannach (1987) estimated the size at first maturity based on the gonado-somatic index analysis. The maturity by size or age data is one of the key inputs for age-based models used for to assess the stock spawning biomass (SSB) of this species (Anon., 2015).

In this perspective, this study aims to update the sex-ratio patterns and estimate the size at first maturity for swordfish caught in this mixing area, based on the biological sampling conducted in the port of Tangier located in the strait of Gibraltar during the period from April to June 2014.

2. Materials and methods

During the main fishing season of swordfish in the strait of Gibraltar (April- June 2014, 383 swordfish (*Xiphias gladius*) were sampled from the Moroccan longline (**Figure 1**).

For each sampled fish, the following data were collected: Lower Jaw- fork length (LJFL), the eviscerated weight of fish (GW), the sex, and the maturity stage of the fish (visual determination) (Poisson and Fauvel, 2009) as well as the female gonads weight. The length of fish was measured at the nearest centimeter using a measuring tape. All data were aggregated by a 10 cm size class for the consecutive analysis.

In this study, sex ratio was defined as the proportion of females in the total catches (Arocha & Lee, 1996; Mejuto & García-Cortes, 2003):

$$\text{Sex-ratio (\%)} = \text{Number females}/ (\text{Number females} + \text{Number males})$$

The predicted proportion of female by size class was computed by means of a Generalized Linear Modeling (GLM) approach, assuming a binomial error structure model (McCullagh and Nelder, 1989)

According to previous studies on swordfish, maturity (Kume and Joseph, 1969; Arocha& Lee, 1996; Mejuto & Garcias-Cortes., 2003) a female swordfish is considered in an active stage of reproduction when it has a gonadal index (GI) equal or greater than 2.09.

Kume and Joseph (1969) defined the gonadal index by the following formula:

$$GI= (W_{gonad}/LJFL^3)*10^4$$

W_{gonad}: weight of gonads in grams
LJFL: Lower jaw- Fork length

The size at first maturity of swordfish (L_{50}) is defined as the size at which 50% of females are mature. L_{50} was calculated using the linear form of a logistic curve describing the relationship between the proportion of mature fish and fish length:

$$\text{Ln } (P/1\text{-}P) = a + b*LJFL$$

P: the observed proportion of mature female
a and b are linear regression parameters of the model
LJ-FL: mid value of each size class

L50 is the size of fish corresponding to P = 0.5, which means that L_{50}= -a/b

The predicted proportion of mature fish was estimated using a logistic model:

$$\% \text{ predicted mature females} = 1/ (1+\exp (-b*(LJFL-L_{50})))$$

LJFL: Lower jaw fork length
L50: size at first maturity
b= slope of the linear regression form of the model

3. Results

3.1 Size distribution

The sizes of sampled fish ranged from 94 to 245 cm LJFL. Females had a wider range (104- 245 cm LJFL) and a larger mean size (162 cm ±27 LJFL) than males (94-181 cm LJFL) (125 cm ± LJFL) (**Figure 2 and Table 1**).

3.2 Sex-ratio

The overall sex ratio is slightly in favor of females, which represent 60% of catches. Males outgrow females in sizes less than 130 cm LJFL, whereas females are predominating in catches for sizes larger than 140 cm. The proportions of females and males tend to be equal for sizes between 130 and 140 cm LJFL (**Figure 3**).

3.3 Size at first maturity (L50)

Fifty per cent (50%) of female swordfish are estimated to be mature at 166 cm LJFL (**Figure 4 and Table 2**). The smallest mature female in our sample is 126 cm LJFL, with a gonadal index (GI) of about 2.14.

The average gonadal index increases with the fish size to reach a maximum of 2.94 for sizes between 200 cm and 209 cm LJFL**.** It is noticeable that females of sizes 140- 149 cm with relatively high gonadal index (GI = 5.5) were observed in our sample (**Figure 5**).

4. Discussion

The overall sex ratio obtained in this study is slightly in favor of females, which represent 60% of the total catches. This percentage is similar to that (56%) estimated by De la Serna (1992a), Abid (1998) and Srour *et al*. (2003) for swordfish caught in the study area. The estimated proportion of females in catches is also comparable to that (50%) obtained by other authors for the same species in various Mediterranean areas (De Metrio, 1995 & Orsi Relini *et al*. 1999). For the swordfish caught in the North West Atlantic, the results can be different according to the spatio- temporal strata. Suzuki & Miyabi (1991) and Arocha & Lee (1996) found that proportions of males and females are in general equal. On the other hand, the results of a most recent study showed that males are predominating in the catches with proportion reaching up to 82% (Mejuto *et al*, 2003).

In our sample, females are more numerous in sizes larger than 140 cm; they represent nearly 100% at 190 cm LJFL. A similar pattern was observed for the Mediterranean swordfish (De Metrio, 1995; De la Serna *et al*. 1996 and OrsiRelini *et al*. 1999). In contrast, in the North West Atlantic, Arocha & Lee (1996) found that females outnumber males in sizes larger than 175 cm and constitute almost 100% of catches at 225 cm.

It should be noted that the higher proportion of males in catches during the study period (April-June) in smaller sizes (100 -130 cm LJFL) coincides with a higher proportion of mature females larger than 140 cm LJFL with higher gonadal index values. A similar pattern was previously observed in the same area by De la Serna (1992), which could be related to the sexual maturity before spawning as mature males as small as 90cm LJFL were observed in the Mediterranean (OrsiRelini *et al*., 1999). The concentration of mature males (125-175cm LJFL) in spawning areas where there is a higher proportion of mature females (larger than 175cmLJFL) was also observed in the subtropical Atlantic area (Mejuto *et al*., 1995; Arocha & Lee, 1996; Mejuto & Cortes, 2003).

The size at first maturity estimated in this study (166 cm LJFL) is higher than that of the Mediterranean swordfish (142 cm LJFL) (De la Serna *et al*., 1996); at the same time, this size is lower than the size at first maturity of the North Atlantic swordfish (180 cm LJFL) (Taylor & Murphy, 1992; Arocha & Lee, 1996 and Arocha, 2007). These differences could be explained by the fact that our sample is a mixture of fish of Mediterranean and Atlantic origin.

The smallest mature female observed is 126 cm LJFL. Nearly 30% of females caught in the strait of Gibraltar are expected to be mature at 140-149 cm, LJFL, whereas, no mature female less than 150 cm LJFL was observed in the North Atlantic (Arocha & Lee, 1996; Mejuto & Garcias -Cortes, 2003). Thus, those mature females are more likely to belong to the Mediterranean population. They were about entering the Mediterranean for spawning. This hypothesis is also supported by the fact that no spawning areas for swordfish were reported in the Northeast Atlantic between 35° and 45°N and 10° and 40°W (Garcias-Cortes & Mejuto, 1988; Mejuto & Garcias-Cortes, 2003).

The findings from this study are consistent with those from a recent growth study of swordfish caught in the study area, showing that fish caught in the strait of Gibraltar has a similar growth pattern as the Mediterranean swordfish (Abid *et al*., 2013). This means that a high mixing rate between the Mediterranean and the North Atlantic stocks occurs west of the 5°W boundary established by ICCAT to separate the two stocks.

Further research on the reproductive biology of swordfish caught in the Strait of Gibraltar based on histological analysis of gonads is needed to confirm the obtained results.

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Table 1. Number of fish, size range, the average size and standard deviation of swordfish size sampled in the port of Tangier.

Sexe	*N*	*Size range (cm)*	*Average size (cm)*	*Standard deviation*
Female	231	104-245	162	27
Male	152	94-181	125	14
Total	**383**	**94-245**	**148**	**29**

Table 2. Number of female with GI<2.09 and =>2.09 and the proportion of mature females (Observed *vs* predicted).

LJ-FL (cm)	*Female with GI <2.09*	*Female with GI =>2.09*	*Total*	*% Observed Mature Female*	*% Predicted mature Female*
100	3		3	0.00	0.06
110	7		7	0.00	0.09
120	13	3	16	0.19	0.13
130	15	4	19	0.21	0.20
140	15	4	19	0.21	0.28
150	22	7	29	0.24	0.38
160	14	14	28	0.50	0.49
170	13	15	28	0.54	0.60
180	5	20	25	0.80	0.70
190	3	10	13	0.77	0.79
200	2	12	14	0.86	0.86
210	2	5	7	0.71	0.90
220		1	1	1.00	0.94
230		1	1	1.00	0.96
240		1	1	1.00	0.97
Total	**121**	**90**	**211**		

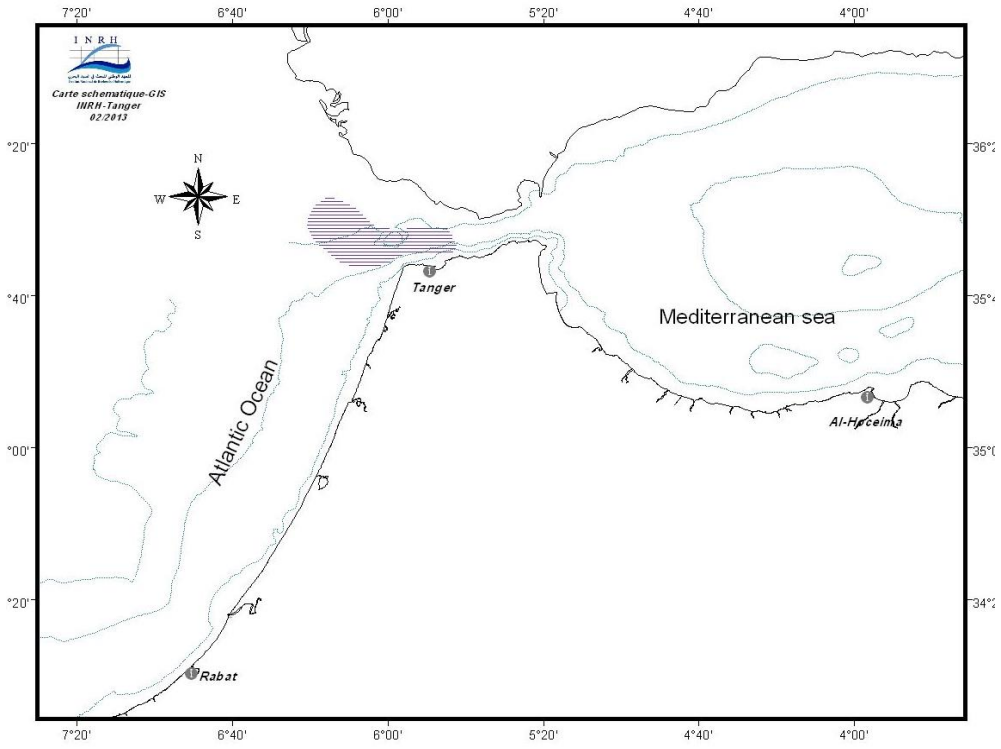

Figure 1. Fishing grounds (shaded area) of the Moroccan longline fleet targeting swordfish in the strait of Gibraltar and adjacent Atlantic areas.

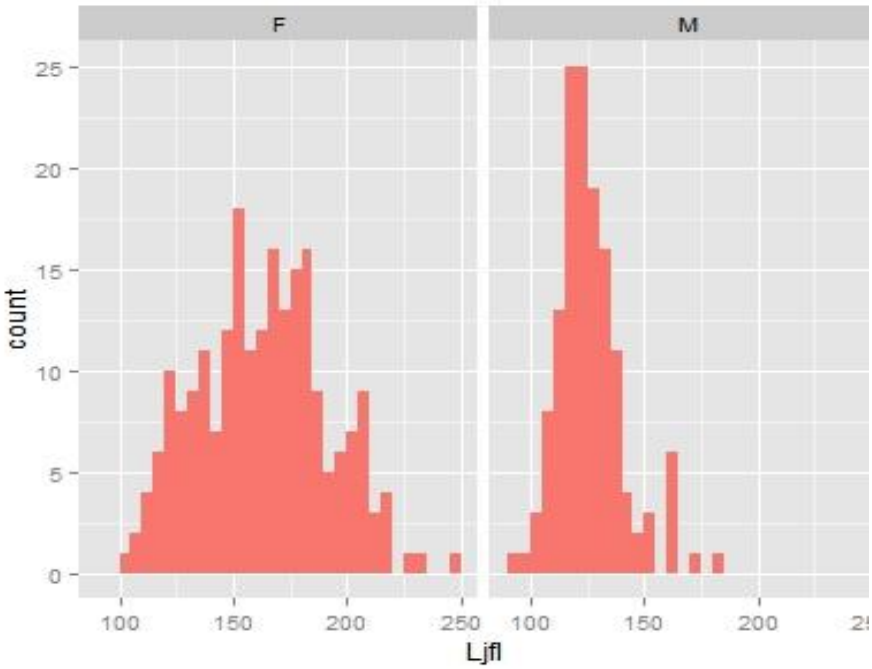

Figure 2. Size frequency distribution of swordfish by sexes (F=female, M=males).

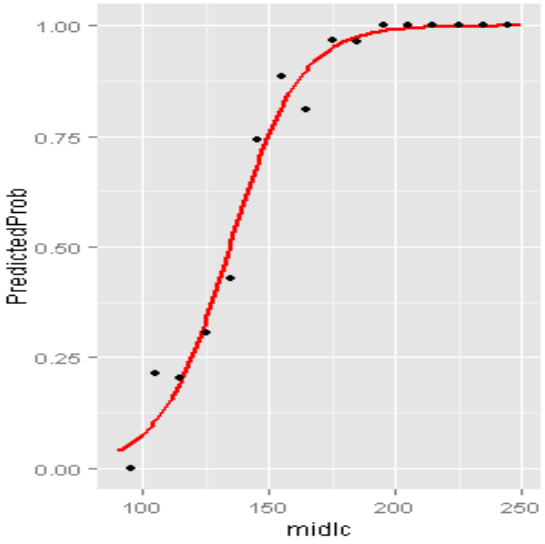

Figure 3. Predicted proportion of female swordfish by size (midlc: mid length class)

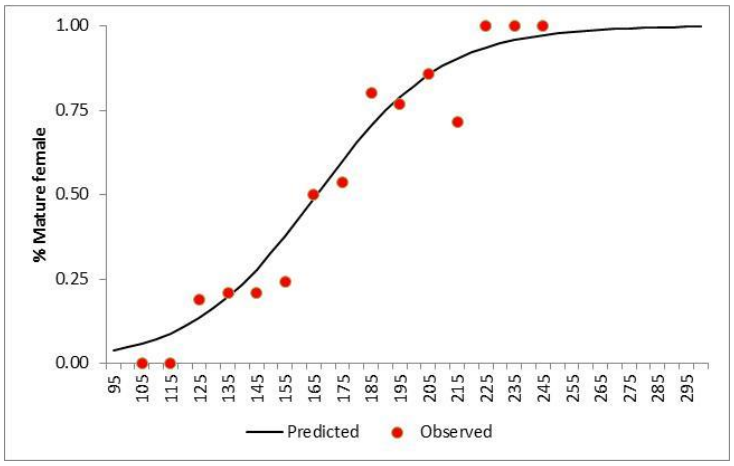

Figure 4. Maturity ogive of female swordfish caught in the Strait of Gibraltar.

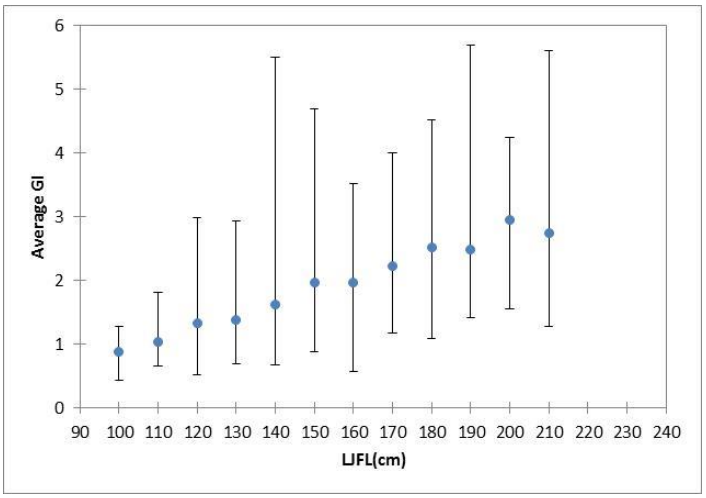

Figure 5. Average Gonadal index, minimum and maximum GI by length class (LJFL) for female swordfish caught in Strait of Gibraltar.