Reproduction of black anglerfish (*Lophius budegassa*) in northern Spanish waters

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AIM

Black anglerfish (*Lophius budegassa*) is an **important** species in European bottom **fisheries**. The aim of the study is to improve the knowledge on **sex ratio** and on **maturity ogive** of the Iberian stock of this species (northern Spanish Atlantic waters), based on 5 years sampling period. These results are of interest to the **stock assessment** of black anglerfish.

MATERIAL & METHODS

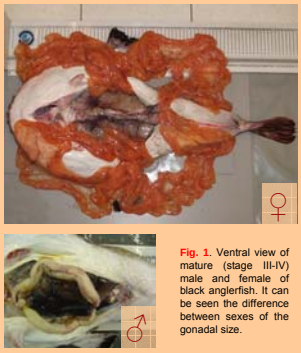


Fig. 1. Ventral view of mature (stage III-IV) male and female of black anglerfish. It can be seen the difference between sexes of the gonadal size.

• **Samples** were collected from periodical samplings of landings of commercial vessels and from IEO research surveys in ICES Div. VIIIc-IXa, from 2006 to 2010. A total of **904 specimens** (length range **5-99 cm**) were sexed (**Fig. 1**) and their gonads were macroscopically staged using a five-stage ICES **standardized international maturity scale** (5): **I (immature), II (developing / resting), III (pre-spawning), IV (spawning), V (post-spawning).**

• **Spawning period** was determined by analyzing the seasonal changes of the maturity stage over the annual period. Only potentially mature individuals were used, i.e. individuals with length > L25. The L25 values chosen for males and females were 39 cm and 53 cm, respectively, determined in the histological study of (1), due to the correct identification of some maturity stages is only possible by means of histology.

• **Maturity ogives** by length were constructed using only data collected during the period when a high percentage of mature fish was observed. For a more accurate determination of this period, in addition to the results on the spawning season here estimated, additional information reported from other studies was also considered (2, 3, 1). Data from October to July were used in this analysis.

Maturity percentages were calculated by pooling the maturity stages relative to the total. Initially it might be possible to set as mature specimens only those in maturity stages III, IV and V, as it has been considered in previous studies (4, 3, 1). However, according to the ICES maturity scale (5), established after those studies and that is the used in the present work, there are mature individuals in the stage II. Mature resting stage was aggregated along with stage II in that ICES maturity scale due to difficulties with the macroscopic discrimination. To distinguish between immature virgin and resting non-virgin fish in stage II was not a feasible option (6). The correct identification of these stages is only possible by means of histology, but samples in the spawning season should minimize this inaccuracy, when the proportion of resting females should be minimal (5). On the other hand, the stage II is the most abundant in females throughout the year, because it is more difficult to find females in stage III and especially in stages IV and V, mainly due to migration to areas less accessible to fishing (3). Thus, in order to attempt a better discrimination of which individuals in stage II are mature, it was considered that those males and females in stage II and with a length > L75 would be potentially mature and therefore included in the analysis. The L75 value chosen was that estimated by (1) using histology: 42.97 cm and 64.03 cm for males and females respectively.

Therefore **3 scenarios** with different kinds of restrictions were taken into account when choosing of individuals to be considered mature: **A) Stages II, III, IV, V; B) Stages II (only specimens with length>L75), III, IV, V; C) Stages III, IV, V**.

The maturity percentages were fitted to the **logistic model**: yi = 1/(1+exp(-a-bxi)), where yi is the proportion of mature fish at length or age xi (0<yi<1; 0<xi<+∞), while a and b are the function parameters.

• The INBIO (v 1.2) R-package (7) was used for estimating the **sex ratio** and the **L50 values** and their uncertainties by simulation techniques.

RESULTS & DISCUSSION

Sex ratio

Table 1. Sex ratio of black anglerfish obtained in the present and previous studies in North Atlantic waters.

Stock	Area	ICES Divisions	Author	Females (%)	Proportion Males	Females
Northern shelf stock	Shetland Islands	IVa	Laurenson *et al*. (2008b)	54.88	1 :	1.22
	West of Scotland	VIa	Laurenson *et al*. (2008b)	50.25	1 :	0.97
Northern stock	Northern Bay of Biscay	VIIIabd	Quincoces (2002)	51.20	1 :	1.05
	ICES Subarea VII	VIIb-k	Landa *et al*. (2012)	54.90	1 :	1.22
Southern stock	Atlantic Iberian waters	VIIIc, IXa	Duarte *et al*. (2001)	49.40	1 :	0.98
	North of Spain	VIIIc, IXa	**Present study**	**50.30**	**1 :**	**1.01**
	Portuguesse waters	IXa	Azevedo (1996)	42.55	1 :	0.74

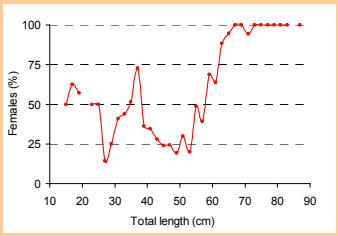


Fig. 2. Female percentage of black anglerfish by length class (2 cm).

The sex ratio was **1:1.01** (50.30% of females). This value is **within the range** given in **previous studies**, showing lower overall values in Iberian waters than in northern waters (**Table 1**).

Sex ratio **varies with length** (**Fig. 2**). Males were slightly more numerous in the length range 40-57 cm. After ~57 cm, females outnumbered males, and above ~70 cm all fish were females. The variation of the sex ratio by length **agree** with the presented in **other studies** (3, 1, 8). Seasonal and bathymetric variations in sex ratio by length found in white anglerfish (3, 1, 9) can also occur in black anglerfish. Therefore, interannual variations in the fleet behaviour (regarding to depths or season where they mainly fish) or in the sampling will influence the overall sex ratio value obtained in each study.

Spawning period

High percentages of **mature males** (stages III, IV, V) occurred during the **whole year** (**Fig. 3**). However, **few females** were found **in those stages**. Most pre-spawning females occurred between November and July, spawning females between February and July, and post-spawning females between May and October. Although the overall spawning period was not easy to define, the results for both sexes suggest that might be between **November and July**.

These results **agree with** previous data obtained in **North Atlantic** waters, where the spawning period was from October to July (2, 3, 1). However, it must be taken into account the different methodologies and sample size used in each study, and the possible geographic variability. The spawning peak seems to be between May and July in northern Bay of Biscay (1). In Iberian Atlantic waters, spawning takes place from October-November to February-March (2, 3).

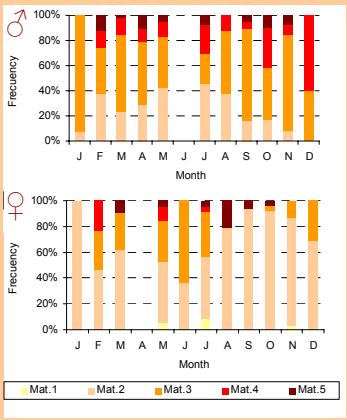


Fig. 3. Monthly percentage of each maturity stage by sex of black anglerfish.

Maturity ogive

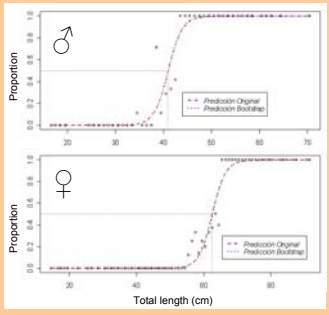


Fig. 4. Maturity ogive by sex of black anglerfish.

The maturity ogives were estimated from samples collected during the **spawning period** (**Fig. 4**). The L50 values obtained in the 3 scenarios showed differences, especially for females (~ 52, 62 and 81 cm, in scenario A, B and C respectively). It is explained by the scarcity of females captured by the fleet on stages III, IV and V, and the greater abundance on those in stage II, since the difference between the 3 scenarios is due to the inclusion, or not, of that stage II as mature.

The option of choosing as **mature** those specimens on stage III, IV, V plus those on stage II with length>L75 (scenario B) was considered the most appropriate. Because the stage II is the most abundant in females, it was necessary an alternative that allow to include as mature fish those non-virgin resting specimens from the assigned macroscopically stage II. The scenario B allowed the inclusion in the analyses of at least a important part of that information.

Table 2. Lengths at first maturity (L50), maturity parameters and number of black anglerfish, obtained in the selected scenario B.

Parameter	males value	males CV boot	females value	females CV boot	combined sexes value	combined sexes CV boot
a	-28.44	0.20	-31.60	0.19	-5.72	0.07
b	0.69	0.19	0.51	0.18	0.12	0.08
L50 (cm)	**40.97**	0.01	**62.44**	0.01	**46.95**	0.02
n	323		313		636	

The L50 values obtained using the scenario B (**Tab. 2**) are **similar** to those obtained in the only published histological study of this species in Atlantic waters (1), which showed values of 41, 59 and 52 cm for males, females and both sexes combined, respectively.

The obtained maturity parameters are of interest for the **stock assessment** of black anglerfish, especially for estimating its spawning stock biomass (5).

Further investigation is needed to obtain better estimations of the **female** maturity ogive.

More **histology** work should be done for black anglerfish since the correct identification of the maturity stages (e.g. the mature specimens on stage II) is only possible by means of histology (5).

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