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REPRODUCTION OF ANGLERFISH (*LOPHIUS BUDEGASSA* SPINOLA, 1807 AND *LOPHIUS PISCATORIUS* LINNAEUS, 1758) IN THE SARDINIAN SEAS

RIPRODUZIONE DELLE RANE PESCATRICI (*LOPHIUS BUDEGASSA* SPINOLA, 1807 E *LOPHIUS PISCATORIUS* LINNAEUS, 1758) NEI MARI DI SARDEGNA

Abstract - The study focuses on the reproduction and biology of the blackbellied anglerfish (*Lophius budegassa*) and anglerfish (*Lophius piscatorius*) in the Sardinian seas, based on data collected between 2015 and 2024 at depths from 44 to 669 meters. A total of 236 blackbellied anglerfish (14-82 cm TL) and 189 anglerfish (16-106 cm TL) were sampled. Microscopic analysis of gonads, sex ratio, spawning period, and size at maturity were examined. The sex ratio of *L. piscatorius* was close to 1:1, while *L. budegassa* had more males than females. Females of *L. budegassa* spawned in summer and autumn, while males spawned year-round, except in winter. These new findings enhance the understanding of the reproductive cycles of the two species and provide valuable information for their sustainable management and assessment.

Keywords: *Lophius budegassa*, *Lophius piscatorius*, spawning period, histology, Mediterranean Sea.

Introduction - The genus *Lophius* Linnaeus, 1758 includes seven species widely distributed in marine waters globally (Massaro *et al.*, 2024). Two species are present in the Mediterranean: the anglerfish (*Lophius piscatorius*) and the black-bellied anglerfish (*L. budegassa*) (Barcala *et al.*, 2019). Both species are demersal, with *L. piscatorius* found at depths up to 1000m and *L. budegassa* between 70m and 800m (Barcala *et al.*, 2019). These species are important for European fisheries in both the Atlantic and Mediterranean (Barcala *et al.*, 2019). A recent study (Barcala *et al.*, 2019) revealed that their distribution is closely linked to environmental factors like depth, temperature, and salinity. Although *L. budegassa* is more abundant, *L. piscatorius* has a higher biomass, indicating the presence of larger individuals (Barcala *et al.*, 2019). This difference is likely due to the deeper habitat preference of *L. piscatorius*, which results in lower exploitation rates compared to *L. budegassa* (Barcala *et al.*, 2019).

Despite their ecological and economic importance, biological knowledge of these species in the Mediterranean is limited, with most studies mainly focusing on distribution, age, growth, trophic ecology (López *et al.*, 2016), morphometry, and parasites (Colmenero *et al.*, 2013). Reproductive biology is crucial for understanding population dynamics and assessing the impact of fishing. Reproduction plays a key role in maintaining sustainable populations, and understanding reproductive parameters is vital for managing fish stocks.

This paper investigates the reproductive cycle of these species, focusing on gonadal development through macroscopic and microscopic (histological) analysis, aiming to identify sex-ratio, maturity size, and spawning period. The findings contribute to sustainable exploitation strategies and more effective fisheries management, particularly in Sardinia.

Materials and methods - The specimens of *L. budegassa* and *L. piscatorius* were collected in the Sardinia waters during experimental trawl fishing surveys (MEDITS, Mediterranean International Trawl Survey, Spedicato *et al.*, 2019) and through commercial landings within the Data Collection Framework at depths from 44m to 669m, between June 2015 and July 2024. For each specimen, the total length (TL, cm) and total weight (TW, g) were recorded. The sex and sexual maturity stage of each individual were determined according to Follesa and Carbonara (2019). An extended histological analysis of the gonads was carried out to describe the gonad morphology and oogenesis and spermatogenesis, validating the macroscopic observations.

The population sex-ratio (females:males) was calculated and the significance of its deviation from the 1:1 condition was tested as a null hypothesis through the χ^2 test. The reproductive period was estimated through an analysis of the seasonal distribution of the percentage of maturity stages of females and males. First maturity was considered to be the size (TL) of the smallest mature specimen examined for each sex. L_{50} (size at maturity = length at which 50% of the individuals are mature) were estimated by fitting maturity ogives to the proportion of mature individuals (stages from 2b to 4b) in each 1 cm TL size class for both sexes separately and using a binomial generalised linear model (GLM) with a logistic link.

Results - A total of 189 *L. piscatorius* specimens were captured, consisting of 92 females (22-106 cm LT), and 97 males (16-92 cm TL), resulting in a sex ratio of 0.95 ($X^2 = 0.21$, p-value = 0.65) (Fig. 1a,b). A total of 236 specimens of *L. budegassa* were analysed, consisting of 94 females (14-80 cm TL) and 142 males (16-62 cm TL), with a sex ratio of 0.66 ($X^2 = 5.20$, p = 0.0226) (Fig. 1c,d).

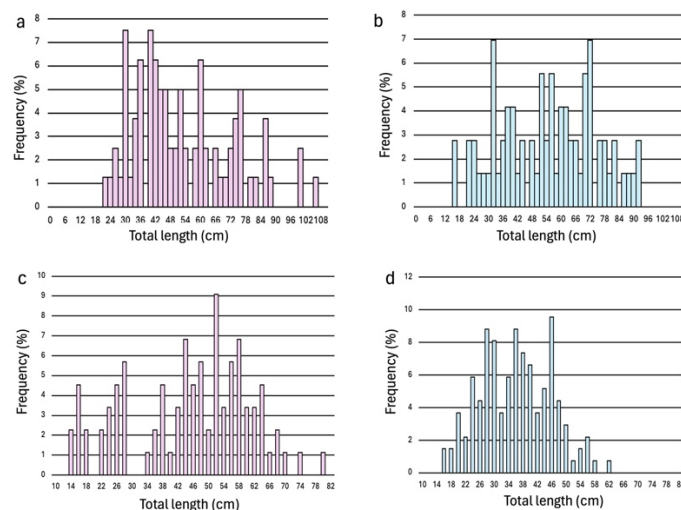


Fig. 1 - (a) *L. piscatorius*: size-frequency distribution of females; (b) *L. piscatorius*: size-frequency distribution of males; (c) *L. budegassa*: size-frequency distribution of females; (d) *L. budegassa*: size-frequency distribution of males.

(a) *L. piscatorius*: *distribuzione taglia-frequenza delle femmine*; (b) *L. piscatorius*: *distribuzione taglia-frequenza dei maschi*; (c) *L. budegassa*: *distribuzione taglia-frequenza delle femmine*; (d) *L. budegassa*: *distribuzione taglia-frequenza dei maschi*.

In both species, the ovarian structure consists of a flattened band with two distinct lobes that are folded and connected at the posterior end (Fig. 2a), in which in mature

condition, the oocytes are embedded in a gelatinous matrix (Fig. 2b). The ovary is characterized by an ovigerous membrane (OM) containing oocytes organized in clusters and connective tissue, and a non-ovigerous membrane made up of epithelial cells (Fig. 2c).



Fig. 2 – (a) Ovary (OV) in *L. piscatorius*; (b) Mature ovary with eggs visible (E); (c) Histological section of an ovary with cluster (CO) of oocytes (O), ovigerous (OM) and non-ovigerous membrane (NOM) and connective tissue (CT).

(a) Ovario (OV) di *L. piscatorius*; (b) Ovario maturo con uova (E) visibili; (c) sezione istologica di ovario con cluster (CO) di oociti (O), membrana ovigera (OM) e non ovigera (NOM) e tessuto connettivo (CT).

In *L. piscatorius* females (Fig. 3a), a low frequency of immature specimens (stage 1) was observed throughout the year, except in spring. A clear predominance of recovering (stage 2b) females was recorded in autumn. Maturing (stage 2c) and mature (stage 3) females, although less frequent, were found in summer and autumn. As for males (Fig. 3b), a low frequency of immature specimens (stage 1) was observed in all seasons except winter, while recovering males (stage 2b) were consistently present throughout the year, with a higher percentage in winter. Maturing (stage 2c) males were found only in spring and autumn, while mature (stage 3) males were present throughout the year, except in winter.

In *L. budegassa* (Fig. 3c, d), a predominance of immature (stage 1) females during winter was observed, and to a lesser extent, also in autumn. Females with maturing (stage 2c) ovaries were found throughout the year, except in autumn, with a higher percentage in winter. Unfortunately, mature (stage 3) females were not recorded. Immature males showed lower percentages in spring. The recovering (stage 2b) males were found in good proportions in all seasons, with a slight decrease in autumn. Maturing (stage 2c) males were recorded at low percentages year-round, while mature males (stage 3) had the higher percentages, with a slight decrease in winter.

The smallest mature female of *L. piscatorius* had 99.5 cm TL, while for *L. budegassa*, the smallest mature female measured 42.4 cm TL. As for the males, the smallest mature individual of *L. budegassa* had a TL of 26.1 cm, while the L_{50} was estimated at 41.4 cm TL. In contrast, mature male individuals of *L. piscatorius* showed a minimum size of 55 cm TL, with an L_{50} of 61.7 cm TL.

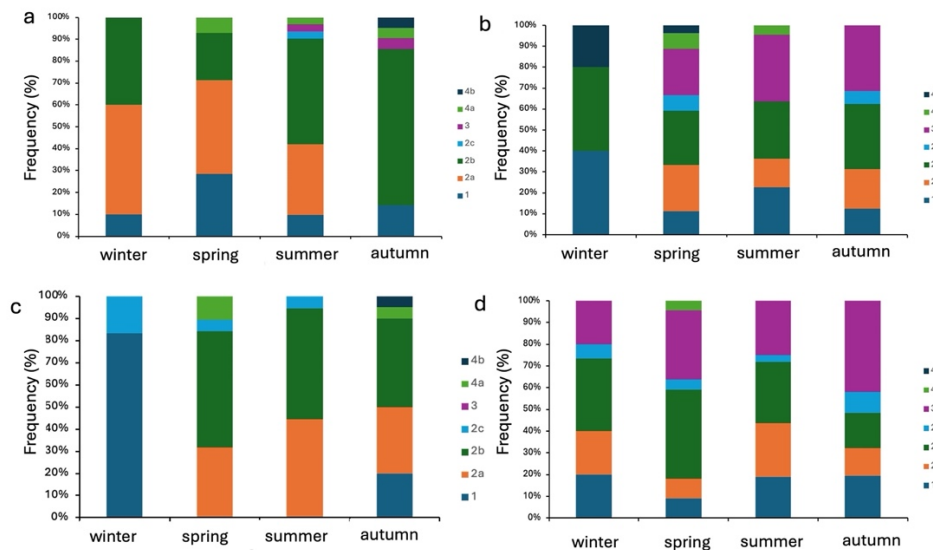


Fig. 3 - Seasonal distribution at each maturity stage of (a) *L. piscatorius* females; (b) *L. piscatorius* males; (c) *L. budegassa* females; (d) *L. budegassa* males.

Distribuzione stagionale degli stadi maturativi di (a) femmine di L. piscatorius; (b) maschi di L. piscatorius; (c) femmine di L. budegassa; (d) maschi di L. budegassa.

Conclusions - Both species exhibited a peculiar ovarian structure and dynamics, characteristic of the genus *Lophius* (Johnson *et al.*, 2008). The determination of the reproductive period for both species was mainly based on the observation of females in pre-spawning phase, due to the low number (in *L. piscatorius*) or absence (in *L. budegassa*) of spawning females. This suggests that mature females likely migrate to areas or depths not covered by the sampling. These results, considered preliminary, seem to indicate a reproductive period ranging from winter to summer for *L. budegassa*, and from summer to autumn for *L. piscatorius*. These findings are essential for the proper assessment and management of exploited stocks in the central-western Mediterranean Sea.

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