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# REPRODUCTIVE TRAITS AND MACROSCOPIC ASSESSMENT OF OVARIAN DEVELOPMENT IN *SOLEA SOLEA (SOLEIDAE)*: PRELIMINARY RESULTS FROM THE CENTRAL ADRIATIC SEA

## *ASPETTI RIPRODUTTIVI E VALUTAZIONE MACROSCOPICA DELLO SVILUPPO OVARICO IN* SOLEA SOLEA *(SOLEIDAE): RISULTATI PRELIMINARI DAL MARE ADRIATICO CENTRALE*

**Abstract** – *This study aimed to investigate key aspects of the reproductive biology of common sole (*Solea solea*) and assess the gonadal development in females through the macroscopic examination of the ovary. Monthly sampling was carried out during the entire year of 2019, in the context of the Data Collection Framework (DCF, EU Regulation 2017/1004). A total of 438 samples (N=311 female and N=127 males) of* S. solea *were collected from commercial landings by the fishing fleet of Ancona (Central Adriatic Sea). Ovaries were classified macroscopically following a four stages maturity scale derived from the Brown-Peterson's (2011) and suitably modified. The obtained results evidenced that the spawning period was from September to January. The monthly sex ratio was consistently in favour of females, which outnumbered males especially in the largest length classes (total length > 25 cm). The length at first maturity for females was estimated at 22.98 cm.*

**Keywords**: *Common sole, reproductive cycle, $L_{50}$, sex ratio, Adriatic Sea*

**Introduction** – The Common sole (*Solea solea*, Linnaeus, 1758) is a demersal and sedentary flatfish lives on sandy and muddy bottoms of the continental shelf and in shallow lagoons (Sardi *et al*., 2023; FAO, 2025). This is a gonochoric, dioecious species exhibiting a single marked spawning peak during the reproductive season (Ganias, 2013). Generally, each female can release between 8 and 12 batches per spawning season, at a rate of one batch per week (Le Bec, 1983).
Common sole has high ecological and commercial value in the Mediterranean, particularly in the Adriatic Sea (GSA 17), where it represents one of the most valuable flatfish species, subjected to a constant demand from industries and markets (Cerim *et al*., 2019). In the last decade, the Italian production of common sole has averaged approximately 2000 tons/year, accounting for 23% of the landings of Mediterranean and Black Sea (FAO-GFCM Area 37). Understanding its reproductive biology is crucial for effective management and conservation. While Sabatini *et al.* (2025) recently described the reproductive cycles of *Solea solea* and *S. aegyptiaca* Chabanaud, 1927 referred to entire GSA 17 using histological validation, this study addresses a complementary objective by assessing reproductive traits of *S. solea* through macroscopic ovarian staging at a local scale within fishery-dependent sampling.

**Materials and methods** – A total of 438 specimens were collected monthly off the coast of Ancona (Adriatic Sea) in 2019, from commercial landings of a professional fishing vessel using beam trawls, commonly known in the Adriatic area as "rapido" gear. Biometric data, such as total length (to the nearest cm below) and body weight, for both females and males, were measured, and the sex was identified.
Ovary maturity was assessed using a four-stage maturity scale (*1-immature, 2-developing/regenerating, 3-spawning capable, 4-regressing*), derived from Brown-Peterson *et al.* (2011) and suitably modified (*regenerating* and *developing* stages were grouped into a single stage due to their indistinguishable macroscopic morphology).

The reproductive cycle was determined by analysing the monthly distribution of ovarian developmental stages. The sex ratio was assessed across sampling months and size classes by using the following formula:

$$SR = F / (F + M)$$

All females subjected to macroscopic ovary stage assessment were used to estimate the size at first maturity ($L_{50}$), which is the length at which 50% of individuals reach sexual maturity. For this purpose, females were classified as *mature* (specimens in 2-*developing/regenerating, 3-spawning capable, 4-regressing* stages) or *immature*, according to the macroscopic approach. $L_{50}$ was calculated by the following logistic function (Prager *et al*., 1989):

$$p = [1 + e - r (x - x 50)]-1$$

**Results** - Ovary maturation stages were classified as: *immature*, *developing/regenerating*, *spawning capable* and *regressing* (Fig. 1).

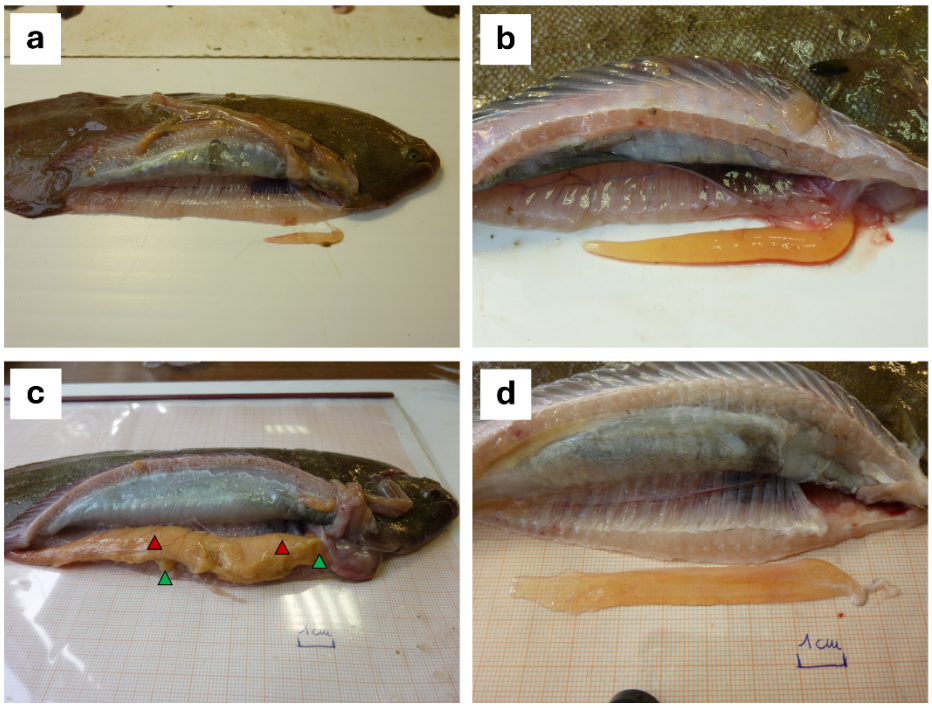


Fig. 1 - Sex identification of common sole specimens and macroscopic evaluation of ovaries at different maturity stages. (a) Immature; (b) Developing/Regenerating; (c) Spawning capable; (d) Regressing stages. Green arrow = individual oocyte; red arrow = blood vessel prominent. (Photos by Sabrina Colella).
*Identificazione del sesso degli esemplari di sogliola e valutazione macroscopica degli ovari in diversi stadi di maturità. (a) Immaturo; (b) Developing/Regenerating; (c) Spawning capable; (d) Regressing. Freccia verde: singolo oocita Freccia Rossa: Vaso sanguineo prominente. (Foto di Sabrina Colella).*

The monthly trend indicated that the sex ratio was unbalanced in favour of females throughout the entire year (Fig. 2a). Differently, the sex ratio per length class indicated that males prevailed in the smallest length classes while females prevailed in the largest length classes (TL>25 cm) (Fig. 2b). Males were observed in all length classes between 19 to 29 cm, while females constituted the entire population from the 30 cm class to the maximum length found during the annual sampling (35 cm).

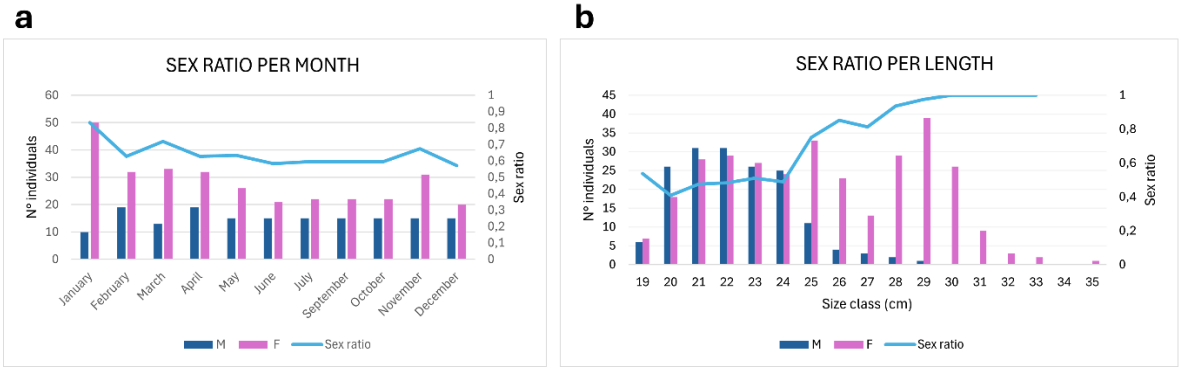


Fig. 2 - (a) Sex ratio per month, (b) sex ratio per length class (cm).
*(a) Rapporto sessi per mese, (b) rapporto sessi per classe di lunghezza (cm).*

Fig. 3 shows the distribution of macroscopic gonadal development stages across the sampling months. Immature females were identified in all months except September and December. Females at the developing stage were present throughout the year, while spawning females were recorded only from September to January.

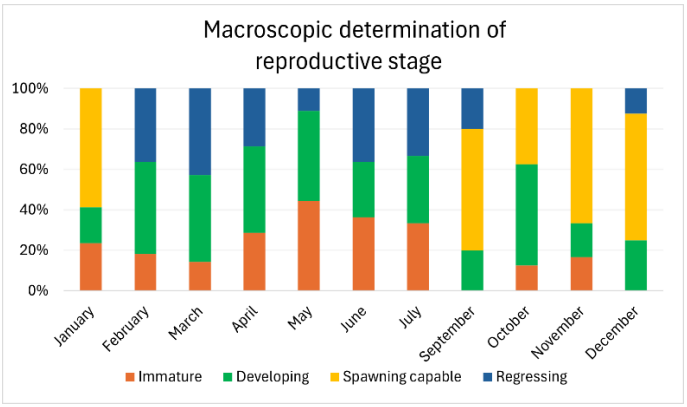


Fig. 3 - Monthly frequency distribution of different macroscopic maturity stages of *Solea solea* female specimens.
*Distribuzione di frequenza mensile dei differenti stadi di maturità macroscopici di campioni di femmine di* Solea solea.

$L_{50}$ was calculated on a total number of 311 (Total Length from 19 to 35 cm) individuals, and it was identified at 22.98 cm TL (Fig. 4).

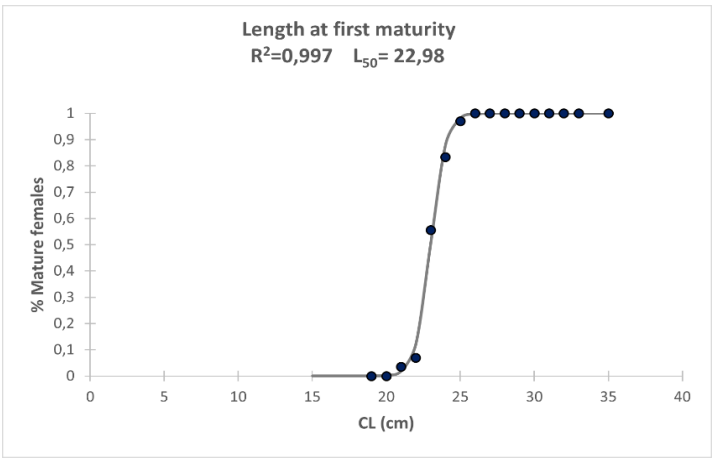


Fig. 4 - Length at first maturity calculated based on gonadal macroscopic analysis.
*Taglia di prima maturità calcolata sulla analisi macroscopica delle gonadi.*

**Conclusions** – Macroscopic evaluation of ovaries posed challenges, particularly in differentiating between the *developing* and *regenerating* stages, highlighting that histological validation is essential*,* especially in pre- and post-spawning periods*.*
Reproductive studies on the common sole in the central Adriatic Sea are scarce and often outdated, except for a recent paper, Sabatini et al. (2025), which took into account samples from the entire GSA 17 at different depths. Although length at first maturity evaluation can be affected by statistical methodology as reported by Cerim et al., 2019, the value estimated in this study was comparable with the value reported by Sabatini et al. (2025) (Total Length=25 cm), in the entire GSA 17. Concerning the reproductive period, the frequency distribution of maturity stages identified the spawning period of *S. solea* from September to January, similar to the results reported from Sabatini et al. (2025), although in the latter work no data was available for January. The trend of sex ratio highlighted the dominance of females not only during the entire year, but also from 25 cm of total length. Reproductive parameters may be influenced by different factors such as food availability, fishing pressure, and climate change, potentially suggesting an adaptive reproductive strategy. These findings imply the need for more detailed investigation into the reproductive biology of common sole in order to implement adequate management and sustainable exploitation of this important fishery resource over time.

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