# Corso di Dottorato di Ricerca in Scienze della Vita e dell'Ambiente
## Ciclo XXXVI

# Comparative investigation of the biology and ecology of Egyptian and common sole in the Adriatic Sea


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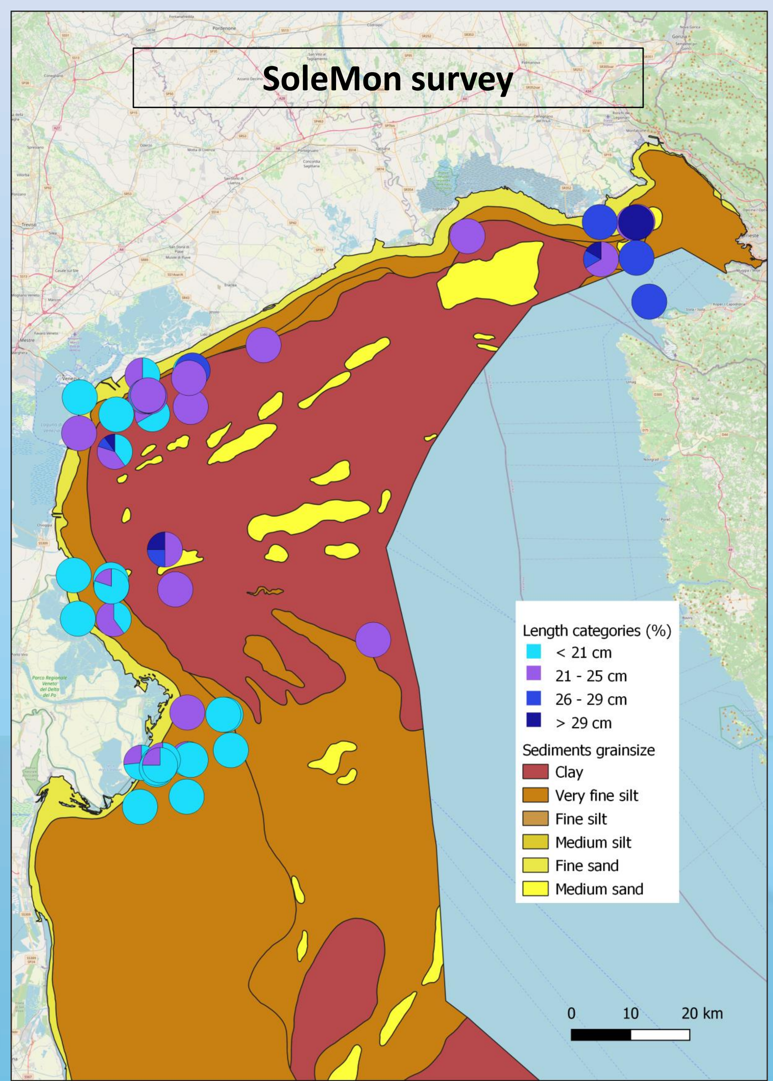
Two cryptic species of sole live in sympatry in the Adriatic Sea, where they share the same habitats (sandy-muddy bottoms in marine and brackish waters). They are morphologically very similar, but some external traits allow them to be distinguished (Sabatini *at al.*, 2018). They are genetically separated and reproductively isolated (Borsa and Quignard, 2001; Boukouvala *et al.*, 2012). Both are valuable fishery resources in the Mediterranean Sea, the common sole in the entire basin, the Egyptian sole mainly in the eastern area (Mehanna, 2007). The Egyptian sole does not appear in the Mediterranean fisheries statistics because it is landed together with the common sole, except for Egypt.

The project work aims to shed light on the main life-history traits and ecological role of common and Egyptian sole in the Adriatic Sea. The results concerning the spatial distribution of Egyptian sole in the Adriatic and the comparison of the growth and reproductive biology of the two species are presented below.

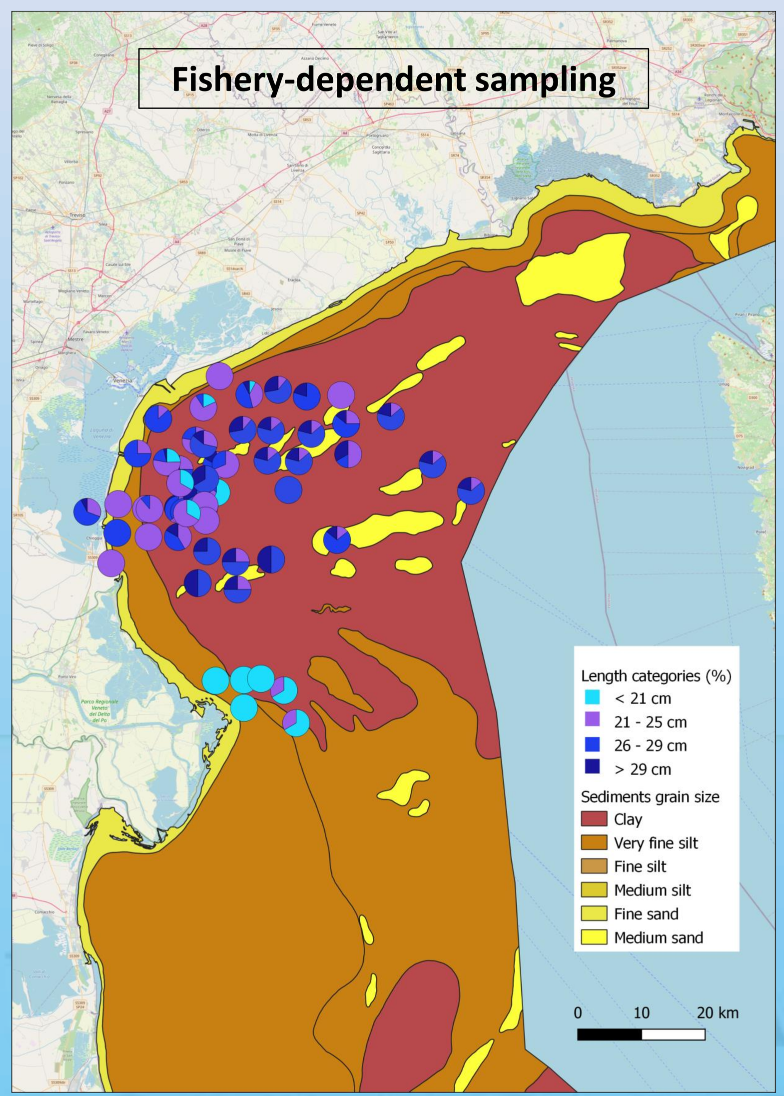
## Egyptian sole distribution in the Adriatic Sea




Egyptian sole catches from SoleMon surveys (2011 – 2022)

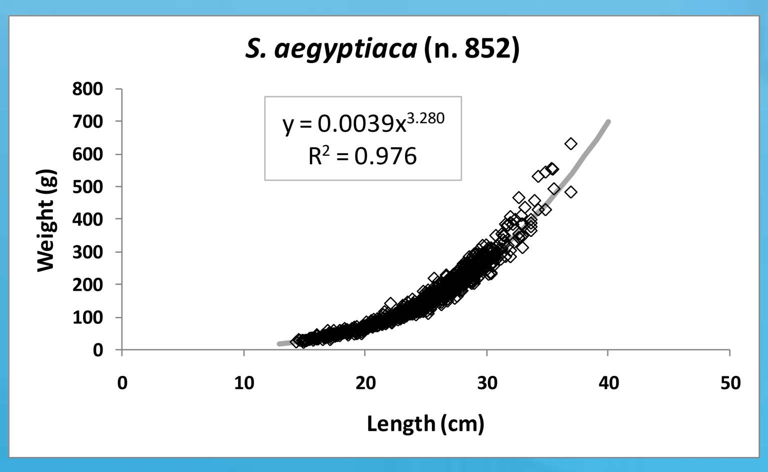
The SoleMon surveys caught mainly the smaller and medium Egyptian soles in the coastal area (length categories 1 and 2, see map on the left), confirming the importance of the Po River mouth and coastal waters as elective habitats for juveniles of different marine species (Colloca *et al., 2015*), Egyptian sole included.

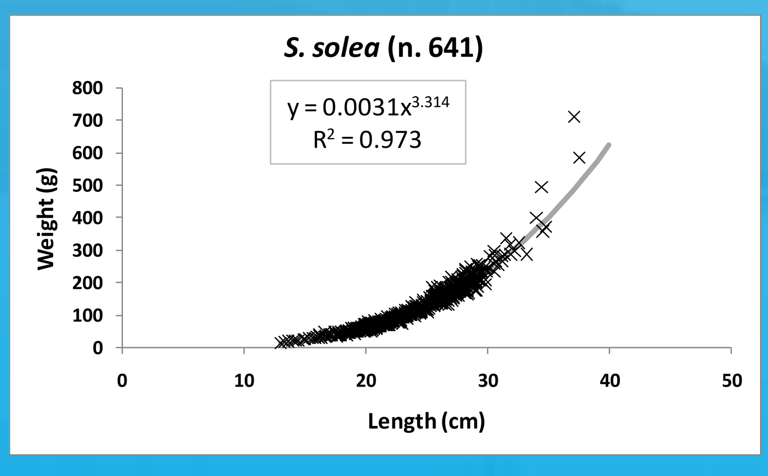
Catches of the largest individuals (length categories 3 and 4, see map on the right) were frequent from fishery activities. Furthermore, fishing provided additional information on the spatial distribution of this species. The presence of the largest individuals was mainly observed in the central area of the Gulf of Venice. Fishermen report the presence of the largest soles in correspondence with the medium sand sediments (see the map), called by some of them "scano".




Egyptian sole catches from fishery-dependent sampling (2011-2016 and 2021)

## Age and growth



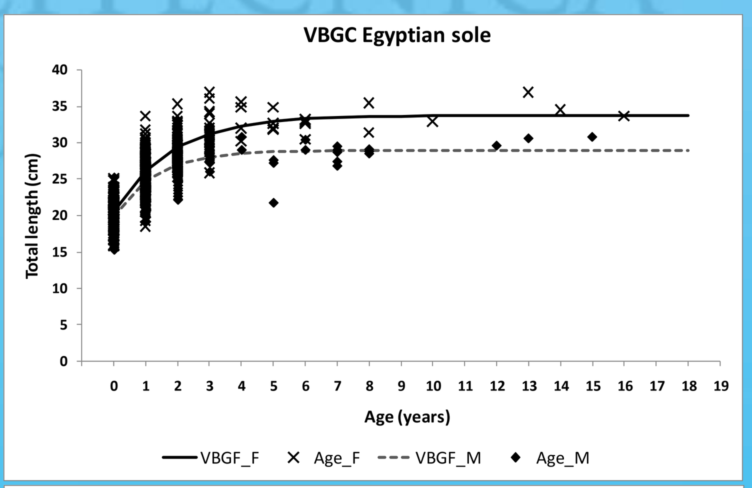



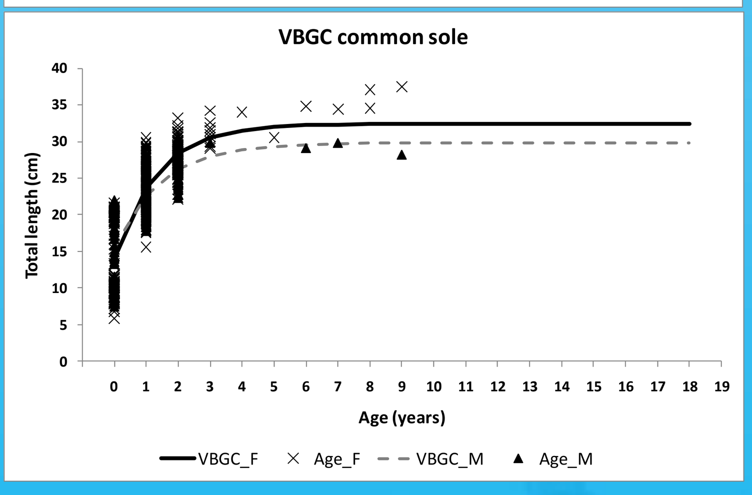

Both species showed positive allometric growth ($p < 0.0005$), with b value equal to 3.280 for the whole sample of Egyptian sole (t test = 15.86 $p < 0.0005$) and 3.314 for common sole (t test = 14.49 $p < 0.0005$).
The comparison of the W-L relationship showed a significant difference between sexes in both species (SA: F test= 29.47 $p<0.0001$; SS: F test= 10.30 $p=0.001$). The results are summarized in the table below.

| SA | a | b | $R^2$ | N | TL (cm) | Weight (g) |
|---|---|---|---|---|---|---|
| Total sample | 0.0039 | 3.280 | 0.976 | 852 | 14.3-37.0 | 24-632 |
| Females | 0.0032 | 3.347 | 0.978 | 417 | 15.1-37.0 | 28-632 |
| Males | 0.0057 | 3.156 | 0.973 | 428 | 14.3-33.7 | 25-389 |
| SS | | | | | | |
| Total sample | 0.0031 | 3.314 | 0.973 | 641 | 13.0-37.5 | 15-712 |
| Females | 0.0029 | 3.339 | 0.974 | 366 | 13.0-37.5 | 15-712 |
| Males | 0.0044 | 3.193 | 0.968 | 274 | 13.3-29.8 | 18-230 |

The von Bertalanffy curves showed a similar trend for both species, with fast growth in the first two years of life and the asymptotic length achieved starting from the third year (see VBGC graphs on the right). The trend was similar between the sexes, but females tended to be bigger and reached a higher asymptotic length than males (VBGC parameters and the values of the growth performance index are summarized in the table below).

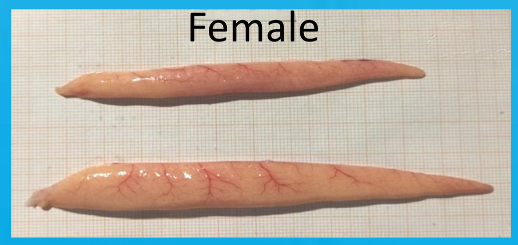
| | Linf | k | t0 | ø´ |
|---|---|---|---|---|
| SA females | 33.6 | 0.56 | -1.6 | 2.80 |
| SA males | 28.8 | 0.78 | -1.5 | 2.81 |
| SS females | 32.4 | 0.76 | -0.74 | 2.90 |
| SS males | 29.7 | 0.68 | -1 | 2.78 |

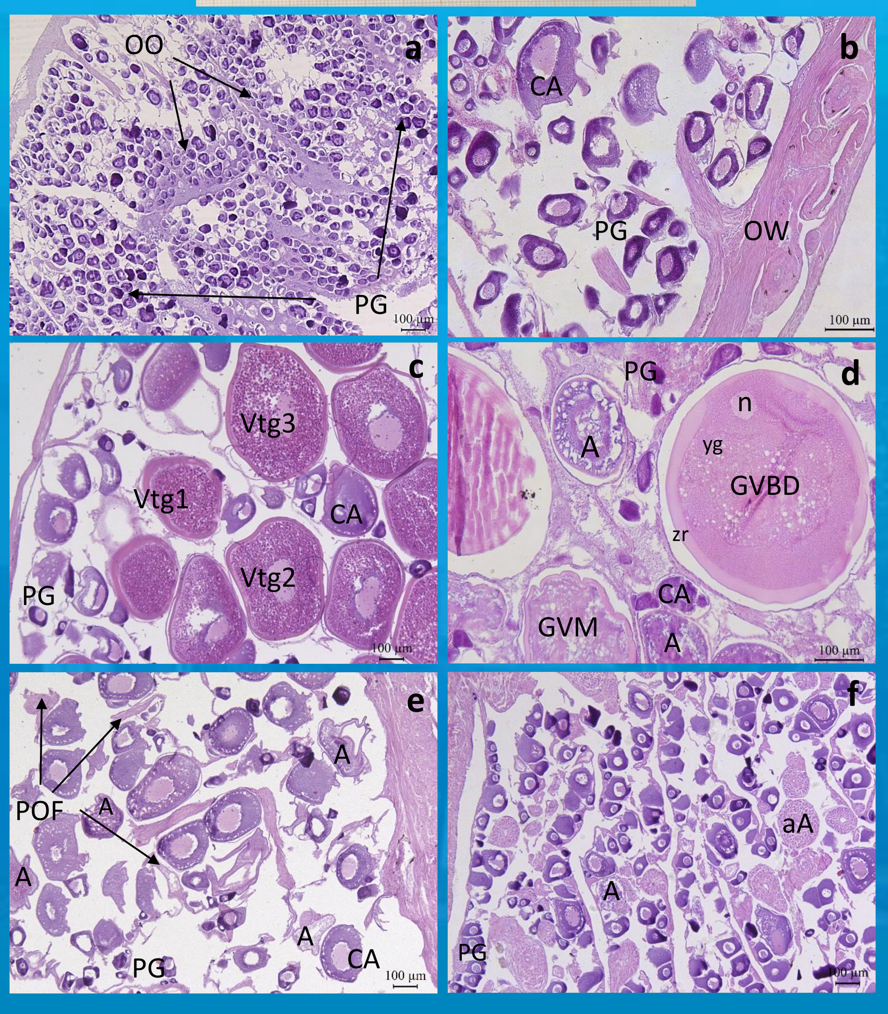



More than 90% of the individuals analyzed were between 0+-3+ years old, but both species can reach more than ten years. Older common sole are not shown here because samples came from the coastal fishery sampling, whereas older specimens are more frequent offshore (Scarcella *et al.*, 2014).

## Reproductive biology

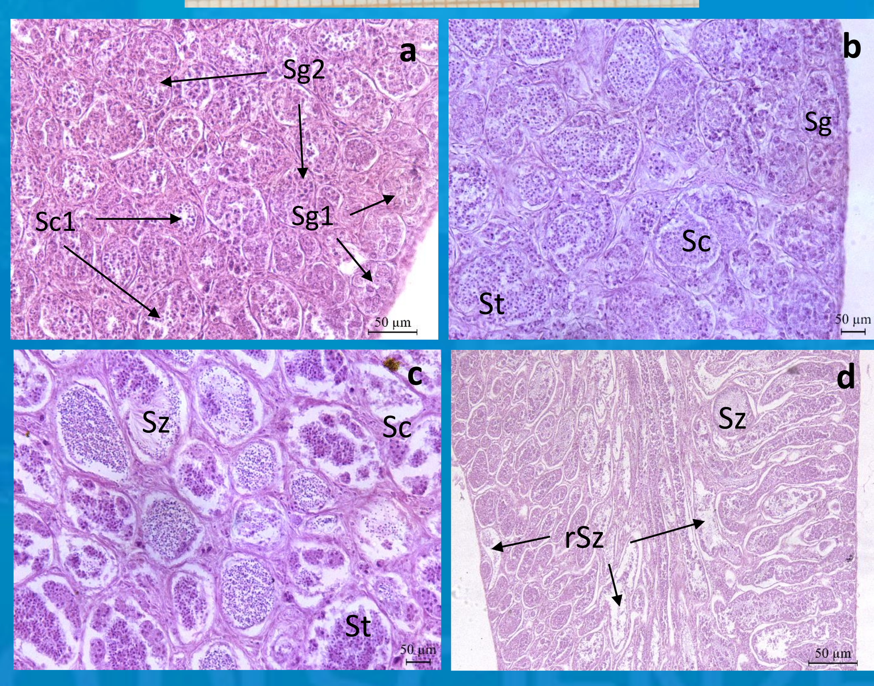



Photomicrographs of ovarian histology of Egyptian sole, illustrating the reproductive phases:
a: immature-virgin; b: early developing; c: developing; d: spawning capable; e: regressing; f: regenereting.

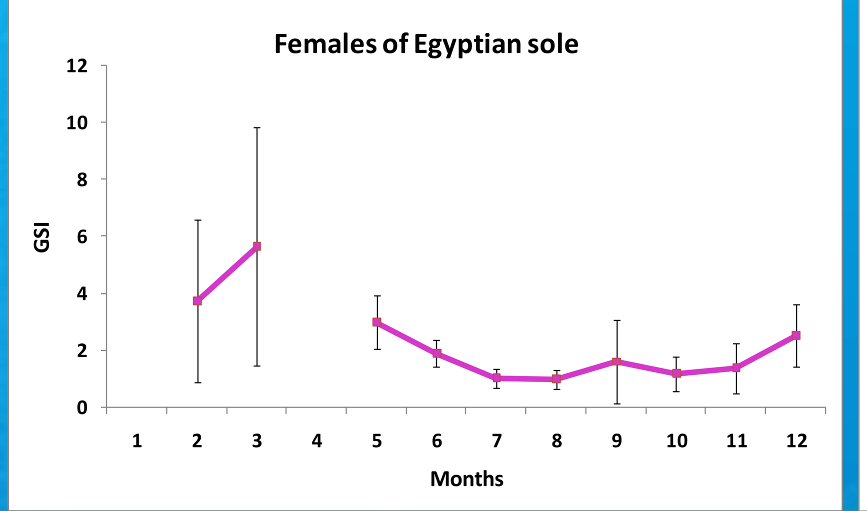
Oo=oogonia, PG=primary growth oocytes, CA=cortical alveolar oocytes, Vtg1=primary vitellogenic oocytes, Vtg2=secondary vitellogenic oocytes, Vtg3=tertiary vitellogenic oocyte, GVM=germinal vescicle migration, GVBD=germinal vescicle breakdown or hydration, POF=postovulatory follicles, OW=ovarian wall, aA=advanced atresia, A=atresia, n=nucleus, yg=yolk granules, zr=zona radiata.

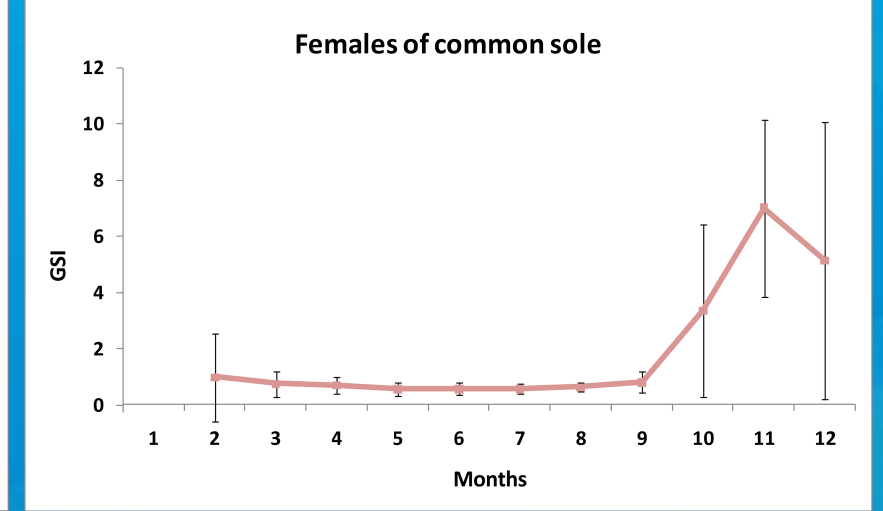
Histological analyses were performed on 47 Egyptian soles (28 females and 19 males) and 68 common soles (42 females and 26 males). The development phases of the ovary and testis of the Egyptian sole are shown here .


Photomicrographs of testicular histology of Egyptian sole, illustrating the reproductive phases:
**a**: early developing; **b**: developing; **c**: mid-germinal developing; **d**: regressing.

Sg1=primary spermatogonia, Sg2=secondary spermatogonia, Sc= spermatocyte, St=spermatid, Sz= spermatozoa, rSz=residual spematozoa.




The monthly trend of Egyptian sole's GSI did not seem very clear due to the low number of samples available in some months. However, spawning-capable specimens were mainly observed in February and March, and regressing gonads appeared in May. This species is considered a winter spawner in several areas of the Mediterranean, with GSI peaks in December or January (El-Husseiny, 2001, Ahmed *et al.*, 2010, Khalifa *et al.*, 2018).

The common sole's GSI showed the highest values between October and December, with a peak in November. The reproductive activity seemed to last until February when some spawning-capable gonads were still present. Moreover, the highest percentage of the regressing stage was recorded in March. These results confirmed that the species is a winter spawner in the Adriatic Sea, as reported by other authors (Piccinetti and Giovanardi, 1984; Vallisneri *et al.*, 2000).

The GSI trend of males was similar to that of females in both species, but with a much lower scale of values (from 0.04 to 0.14).