

ORIGINAL ARTICLE

Reproductive parameters of the chub mackerel, *Scomber japonicus* (Houttuyn, 1782) from the East Mediterranean Sea, Egypt

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Abstract

This study aimed to explore the reproductive biology and histology of *Scomber japonicus* from the Mediterranean Sea, Egypt. For this purpose, a total of 511 specimens were collected monthly from Alexandria landing site from the catches of purse-seine nets during 2017-2018. Throughout the reproductive cycle, four maturity stages were determined for males and females (Immature (I); Maturing (II); Ripe and spawning (III), and Spent stage (IV)). Females were predominant the sex ratio (1 Male: 1.19 Female). The maturity stages with Gonado-somatic Index (GSI) and ova diameter, illustrating the fractional spawning mode of *S. japonicus* with an extended spawning (March-June) and a maximum GSI peak in April-May for both sexes. Likewise, Female Hepato-somatic index (HIS) exhibited significant rise during spawning time. The mean absolute fecundity was 28762.98 ± 15431.04 oocytes per ovary showing positive correlations with both total weight (0.974) and total length (0.95). The relative fecundity ranged from 420 to 2553 egg/cm for length (TL), and from 76 to 379 egg/g for total weight, showing significant correlation with total length (0.906), and insignificance with total weight (0.398). The length at maturity was 19.7cm and 19.5cm for males and females, respectively. The histological investigations confirmed the spawning time via yolky stages with a partial mode of asynchronous oocytes. These data are updated and provided insights about the reproductive strategy of *S. japonicus* and its future fishery management in the area.

Keywords: Reproductive biology, Gonadal histology, *Scomber japonicus*, Mediterranean Sea, Egypt.

INTRODUCTION

The *Scomber japonicus* (Houttuyn, 1782) known as the 'chub mackerel' is among the famous species of the Scombridae family. It lives between 0–300m (depth) (Collette & Naunen 1983), which makes it primarily a coastal pelagic species. However, it is usually abundant between 50-200m in subtropical waters of about 10-27°C (Castro & Santana 2000). *Scomber japonicus* is widely distributed over continental shelves. It is mainly found in the tropical and subtropical regions of the Pacific, Indian, and Atlantic oceans and adjacent Seas (Collette & Naunen 1983). This species is usually ranked one of the most important commercial species in its habitat (FAO 2010). In Egypt, it represents an important fishery resource in the Red and Mediterranean seas (Gafrd 2018). The chub mackerel forms one of the principal and commercial fish species of purse seine

fishing operations in the Red Sea (Mehanna 2004), and in the Mediterranean Sea of Egypt (Faltas 1983; Akel 2009; Farrag et al. 2014). Therefore, it is necessary to get detailed and continuous information for effective fish stock management. Among these data are the reproductive data, which include fecundity and spawning evaluation that are essential topics for studying the biology and population dynamics of fish species (Shalloof & Salama 2008; Costache et al. 2011; Farrag et al. 2019), and help to understand the variations in the output of reproduction with any environmental fluctuation and they would increase our ability to record any recruitment's differences (Kraus et al. 2002). The reproduction knowledge of *S. japonicus* has been studied extensively in the Pacific and Atlantic oceans by many authors (Watanabe & Yatsu 2004; Caramantin-Soriano et al. 2009;

Shiraishi et al. 2009). While many studies have been done in the Mediterranean (Kiparissis et al. 2000; Bayhan 2007; Özekinci et al. 2009; Cengiz 2012). Even though Egypt has long coasts over the Mediterranean, little works have been done by (Rizkalla 1998) on *S. japonicus* and (El-Aiatt & Shalloof 2020) on the Atlantic mackerel *S. scombrus*. Hence, the main objective of this study is to update the reproductive knowledge on the chub mackerel, *S. japonicus* in the Egyptian Mediterranean Sea with more detailed data regarding sex ratio, fecundity, first maturity, and spawning time combined with histological investigations to provide fishery management officers with the critical information needed to develop science-based management measures.

MATERIAL AND METHODS

Sampling: A total of 511 *S. japonicus* specimens were collected randomly on a monthly basis from the commercial catches of the landing site of Alexandria (Jan. 2017 to Dec. 2018). Fish samples were caught by the night purse-seine net. Specimens were sexed, measured as total length (TL) to the nearest millimeter (mm) using a measuring board and total weight (TW) with a precision of 0.01g using a digital balance. Moreover, the gutted weight was recorded. Sex was determined macroscopically by shape, appearance, and gonad structure for each specimen (Males = 200; Females = 239 and 72 unsexed specimens). The unsexed fishes were considered immature or in the resting phase; this is why macroscopic examination could not determine the sex. The maturity stages for both sexes were determined macroscopically according to the maturity scale described by several literatures (Núñez & Duponchelle 2009; Ismail et al. 2018) and modified according to Cikeš Keč & Zorica (2012), including four maturity stages (Immature (I); Maturing (II); Ripe and spawning (III) and Spent stage (IV)). Gonado-somatic Index (GSI) was calculated as $GSI = \text{gonad Weight} / \text{gutted Weight} \times 100$, while Hepato-somatic Index (HIS)

was calculated as $HIS = \text{liver Weight} / \text{gutted Weight} \times 100$ (Sokal & Rohlf 1969).

The size at first maturity (L_{50}) was determined for fully mature individuals, including the ripe, spawning, and spent stages during the spawning activity. It was calculated by fitting a logistic model to the proportion of mature specimens by length: $P = 1 / (1 + e^{-r(L - L_{m50})})$ (King 1995), the equation was transformed to: $L_n ((1-P)/P) = r_1 L_m - r_2 L$ Where P : is the proportion of sexually mature individuals, r_1 : is the slope of the curve, r_2 : is the intercept, L : is the total length of the fish in cm. By plotting $L_n [(1 - P)/P]$ against L , the L_{50} could be estimated as L_m (L_{50}) = the intercept divided by the slope.

Fecundity and egg diameter: In this study, two terms of fecundity were studied (absolute fecundity and relative fecundity). The fecundity of 84 fully ripe/well-developed ovaries that had the chance to be spawned in the long spawning season was estimated. Only yolky mature oocytes (Vitellogenic ones) were counted to calculate fecundity. Three sub-samples of eggs were taken from the right lobe of the ovary (0.01g for each subsample). Then, the average number of oocytes was calculated as the total number of oocytes (all stages of oocytes) in the fully ripe ovary during the spawning period following Bagenal (1978). The absolute fecundity was estimated according to Nikolsky (1963) as equation $Fa = GW/w \times X$ Where Fa is the absolute fecundity, GW is the total gonad weight (g), w is the mean weight of sub-samples and X is the counted number of eggs in the sub-sample. The relative fecundity corresponding to the length and weight (Number of eggs per unit gram body weight and cm of the body length) was calculated as suggested by Bagenal (1978). The oocyte diameters at different developmental stages were measured to the nearest μm by using a sensitive ocular micrometer (at 0.01mm sensitivity) fixed in the eyepiece of a light microscope.

Histological examination: Histology was conducted to cover and confirm spawning and the type of oocyte development (synchronous/ asynchronous);

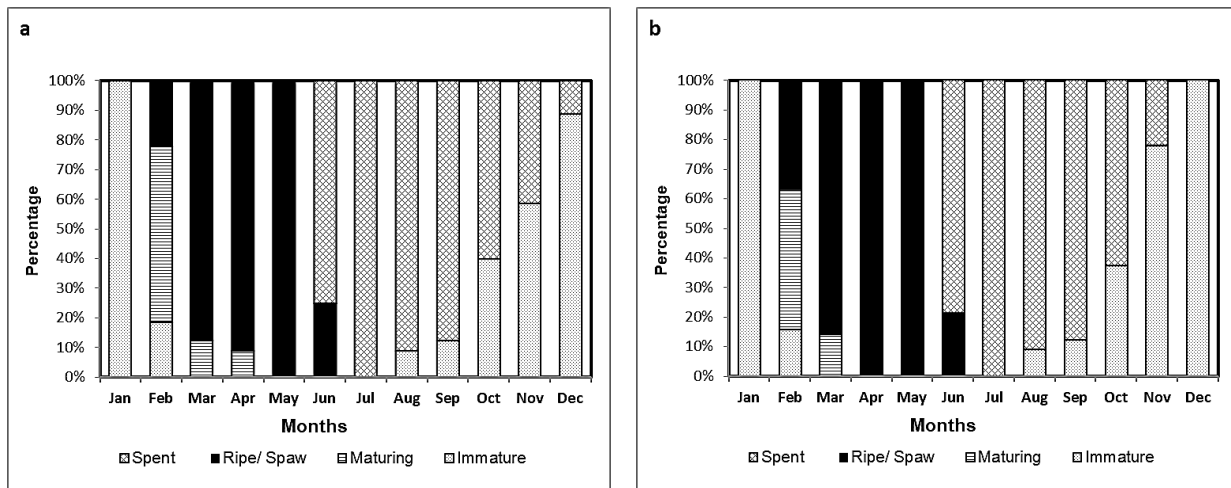


Fig.1. Monthly distribution of maturity stages in *S. japonicus* female (a) and male (b).

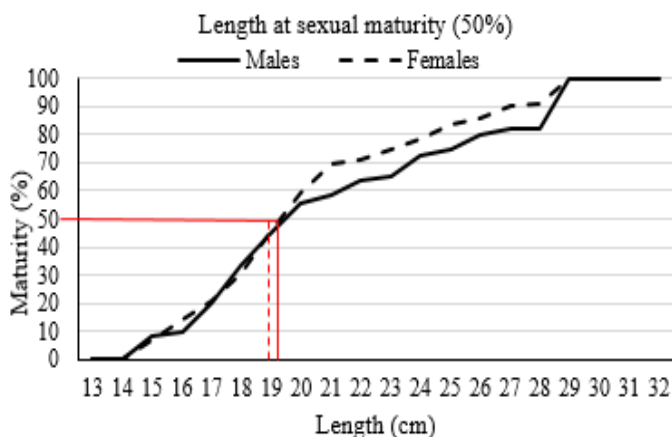


Fig.2. Length at first sexual maturity for males and females of *S. japonicus*.

the type of fecundity (determinate/ indeterminate). Small pieces of gonads were placed in 10% neutral buffered formalin for assessment and histological examinations. The procedures of histology were applied according to the general protocol of histological investigation; and stained with hematoxylin and eosin (H & E) (Humason 1979) with some modifications (Ismail et al. 2016). Oocyte stages were classified and described microscopically (Yamamoto & Yamazaki 1961), while spermatogenic cells were categorized according to Grier (1981). Then the slides were photographed using a light microscope.

Statistical analysis: Data of GSI and HIS are expressed as mean $\pm$ standard error; significant differences between months were tested using one-

way analysis of variance (ANOVA) followed by the Tukey test for multiple comparisons. The probability of a significant difference was set at $P < 0.05$. The analysis was carried out using the SPSS® version 22.0 package (SPSS 1998).

RESULTS

Population and sex ratio: The analysis of the specimens of *S. japonicus* illustrated the presence of 239 (40.93%) females, and 200 (34.19%) males, while the remaining specimens amounted to 72 (24.87%), and they could not be assigned to a definite sex due to being immature or in the resting phase of reproduction. The overall sex ratio between males and females was 1: 1.19.

Spawning season (Maturity stages & length at sexual maturity): Monthly variations in macroscopic maturity stages displayed that the immature stage reported from August till February, maturing stage in female *S. japonicus* was recognized in high percentage from February (59.2%) to April (9%). The ripe and spawning stage was prolonged from March until June, with the maximum peak at April-May (Fig. 1a). The spent stage was displayed from June to December. Males of *S. japonicas* showed a similar pattern of maturity stages distribution as females (Fig. 1b); the male immature stage was reported from August till February, while the maturing stage was detected in February and March. The male ripe and spawning

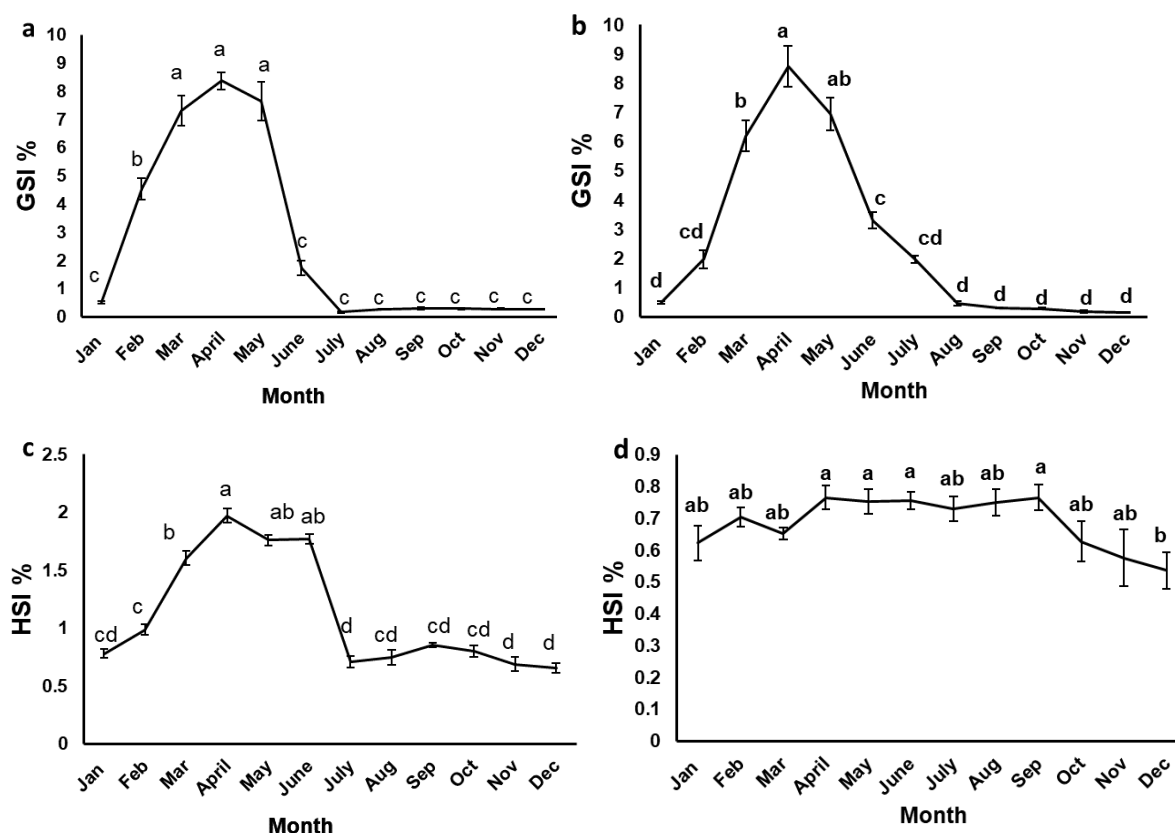


Fig.3. Monthly changes in gonado-somatic index (GSI) and hepato-somatic index (HIS) of *S. japonicus* in females (a and c) and males (b and d), data are represented as (Mean $\pm$ SE) different letters indicate significant differences between months ($P < 0.05$).

stage was detected from February to June. The male spent stage was detected from June till November (Fig. 1b). The length at maturity of *S. japonicus* was 19.7cm and 19.5cm for males and females, respectively (Fig. 2).

Gonado-somatic index (GSI): For males and females, the gonado-somatic index (GSI) exhibited a similar pattern with regard to the peak of maturity stages distribution. The significantly elevated GSI indices were observed between March and May, with the highest peak in April for both sexes (Fig. 3 a, b). GSI started to decline towards December when GSI values were extremely low, and a great number of gonads were in the spent and resting phase. The monthly variations of maturity stages were matched up with the GSI pattern of both sexes. *S. japonicus* spawned from late March to June, with a peak in April occurring simultaneously for both sexes. Hepato-somatic index data of females showed a significant increase starting from March and reached

its maximum from April to June (Fig. 3c), displaying a similar pattern of the GSI curve. While male HIS did not show a significant peak (Fig. 3d)

Fecundity and egg diameter: The estimated absolute fecundity for ripe and spawning females of *S. japonicus* varied between 8820 and 71492 per ovary with an average of 28762.98 ± 15431.04 for length varying between 21.8 and 34.4cm and an average of 26.68 ± 5.45 cm, respectively. The same values were recorded for the total weight ranging from 127.8 to 391.49g and average total weight of 188.04 ± 63.1 g, respectively. A significant positive relationship was recorded between fecundity, total length (0.950), and body weight (0.974). The relative fecundity ranged between 420 and 2553 egg/cm with an average of 1054.64 ± 510.64 egg/cm for fish length (TL) varying between 21.8 and 34.4cm, while ranged from 68 to 309 egg/g with an average of 155.91 ± 64.33 egg/g for the fish weight (TW) varying between 110.42 and 391.49g. A

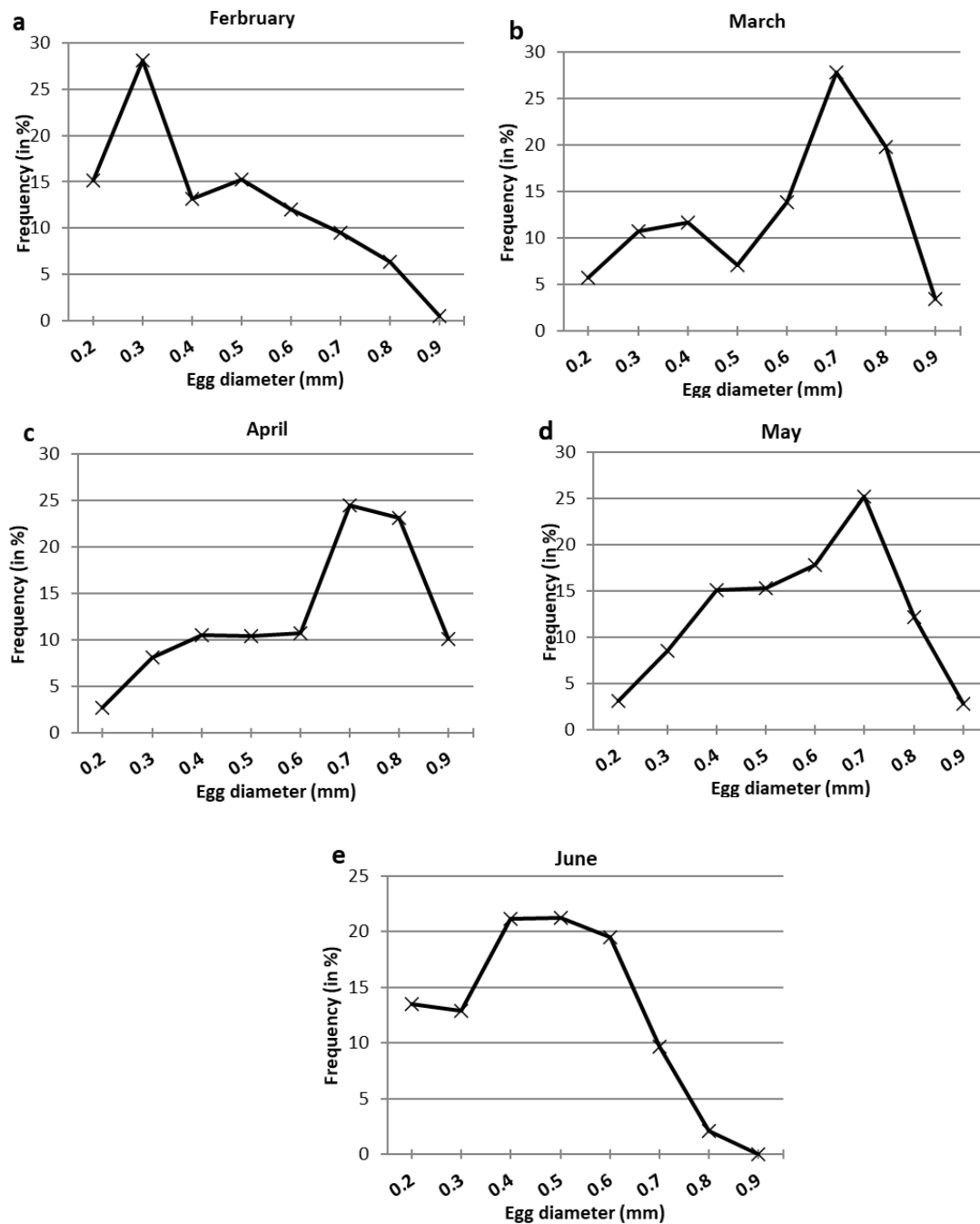


Fig.4. Frequency distribution profile of egg diameter for *S. japonicus* (February, March, April, May and June).

significant positive relationship was found between the relative fecundity and the fish's total length (0.950), while an insignificant relationship was recorded between the relative fecundity and the total weight of *S. japonicus* (0.35). The egg diameter during the spawning season ranged from 200 to 893 μ m. Based on the size, the oocytes were divided into two main groups: 1) previtellogenic (transparent) oocytes (200 to 521 μ m) and 2) yolky

and ripe oocytes (vitellogenic) with a range of 521 to 893 μ m. A large percentage of previtellogenic oocytes in the ovary (more than 70%) was observed in late February, with a smaller percentage of vitellogenic oocytes (28%) of the total counted eggs. By March and April, the vitellogenic oocytes percentage increased (Fig. 4a, b).

From April to May, the highest percentage of large vitellogenic oocytes (700-900 μ m) was

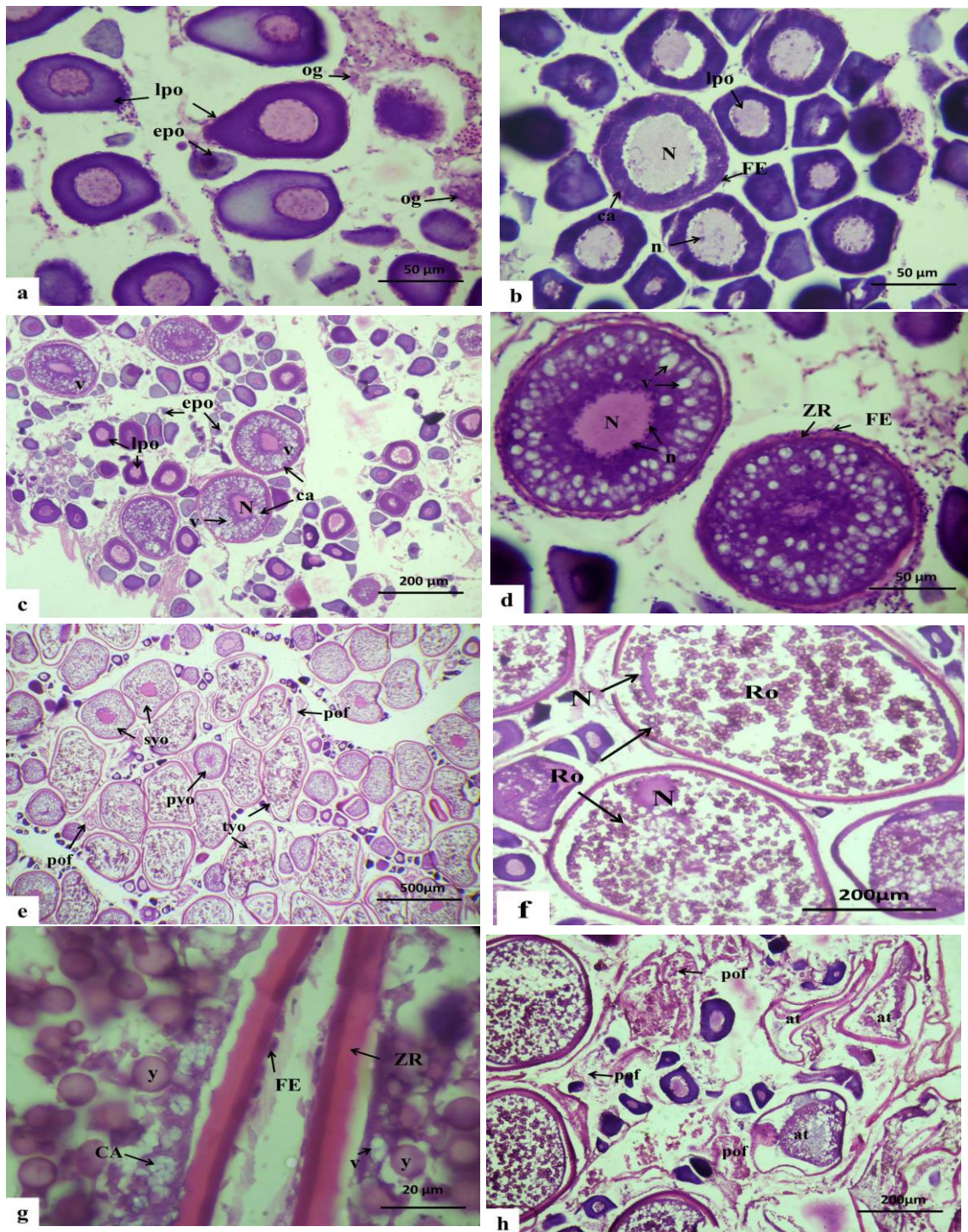


Fig.5. Photomicrographs of a cross section in ovary; **a.** Immature stage displaying nests of oogonia (og), early perinucleolar oocytes (epo) and late perinucleolar oocyte (lpo). **b.** Maturing stage displaying early cortical alveoli oocyte with follicular layer (FE). **c.** Maturing stage with more advanced cortical alveoli oocyte (ca) with more vesicles (v). **d.** Maturing stage with magnified cortical alveoli oocyte (ca) with large nucleus (N) and number of circulars arranged nucleolus (n) and enclosed by zona radiata (ZR) and clear follicular layer (FE). **e.** Ripe and spawning stage with primary yolk oocyte (pyo), secondary yolk oocyte (syo) and tertiary yolk oocyte (tyo) with some post-ovulatory follicles (pof). **f.** Magnified ripe oocyte (Ro) with migratory nucleus (N). **g.** Vitellogenic oocyte wall magnified displaying follicular layer (FE), zona radiata (ZR), cortical alveoli (CA), vacuoles (V) and yolk granules (y). **f.** Mature oocyte with migratory nucleus (N). **h.** Early Spent stage with many post-ovulatory follicles (pof) and different atretic oocytes stages (at). (H & E staining).

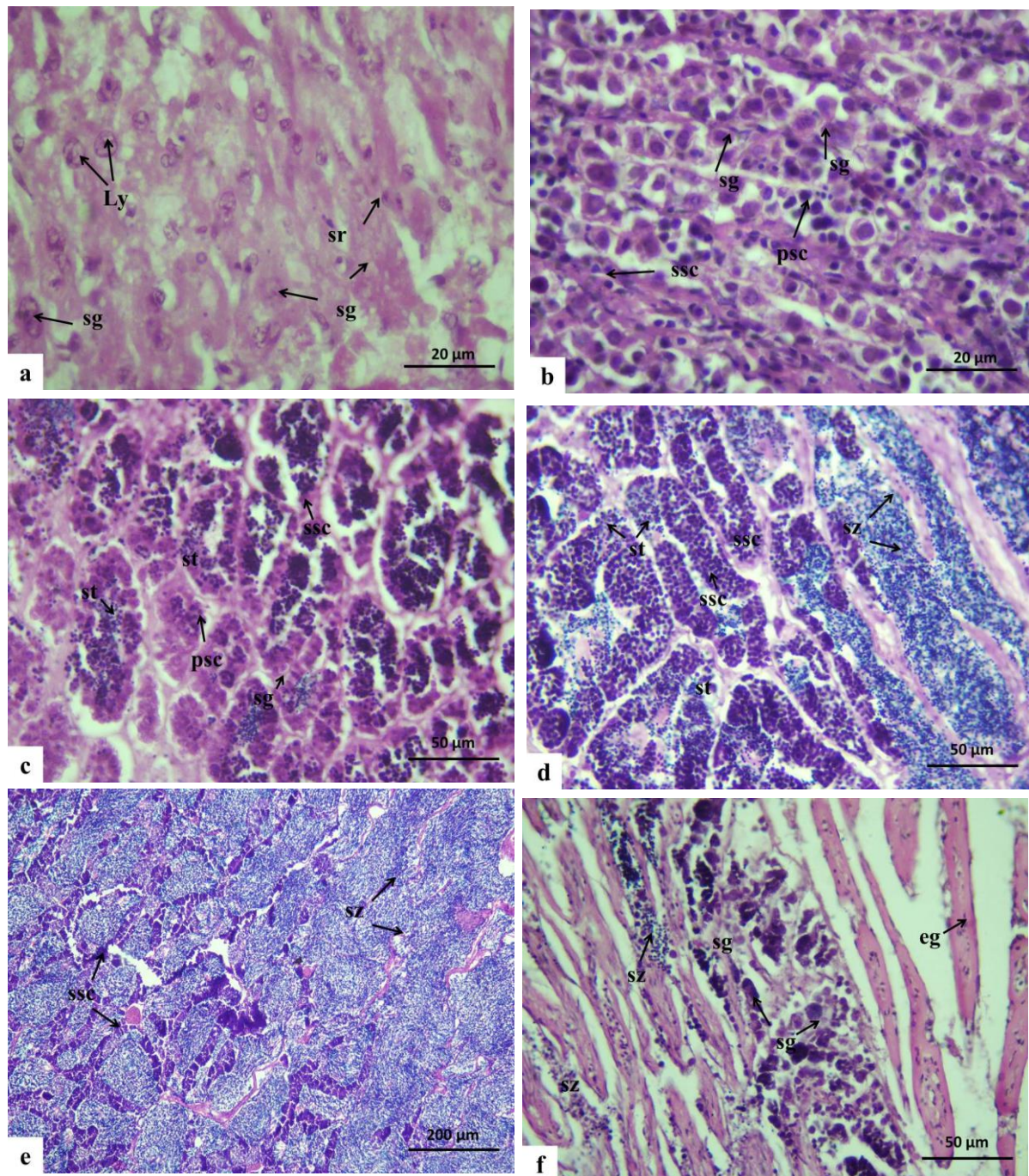


Fig.6. Cross sections in *S. japonicus* testes **a.** immature stage with spermatogonia, (sg), leydig cells (ly), and sertoli cells (sr). **b.** Maturing stage with nests of primary spermatocytes (psc), secondary spermatocytes (ssc), with nests of spermatogonia (Sg). **c.** More advanced maturing stage with primary spermatocytes (psc), secondary spermatocytes (ssc) and spermatids (st). **d.** and **e.** Ripe and spawning stage showing ruptured lobules and spermatozoa of maximum amount (sz), few spermatids (st) and secondary spermatocytes (ssc). **f.** Spent stage with trapped unreleased spermatozoa (sz), new generation of spermatogonia (sg) and eosinophilic granulocytes (eg) (H & E staining).

reported (Fig. 4c). While during June, the vitellogenic oocytes decreased, and the majority of counted eggs were less than 500µm in diameter, also the large oocyte represented only about 11.74% of the investigated samples (Fig. 4d). The presented

two oocyte groups of *S. japonicus* indicated that the fish released its ripe ova in batches during the extended spawning period.

Histological investigation

Ovarian histology: Four ovarian stages were

Table 1. Some studies concerned with the spawning and length at maturity of *S. japonicus* from different regions.

References	Locality	Months	Length at first maturity
Tuggac (1957)	Marmara Sea (Turkey)	Apr - Jul	-----
Atli (1962)	Black Sea (Turkey)	Jun - Aug	-----
Mužinić (1979)	Adriatic Sea	Apr - Sep	26.0 (-) cm
Westhaus-Ekau & Ekau (1982)	Azores	Apr - Jun	-----
Serra (1983)	Southern Brazil	Jan - May	30.0 (FL) cm
Martins (1996)	Portugal	Feb - Apr	-----
Seckendorff & Zavala-Camin (1985)	Northern Chile	Jul - Dec	18.0 (FL) cm
Lorenzo (1992)	Canary Islands	Dec - Mar	-----
Gluyas-Millán and Quiñonez Velázquez (1997)	Gulf of California	Nov - Apr	19.3 (SL) cm
Rizkalla (1998)	Alexandria, Medit. Sea, Egypt	May - Jul	-----
Carvalho et al. (2002)	Azores	Mar - Aug	27.7 (TL) cm
Hwang et al. (2008)	Korea	May	28.8 (FL) cm
Yukami et al. (2009)	East China Sea	Feb - Jun	-----
Cikeš Keč & Zorica (2012)	Eastern Adriatic Sea	May - Aug	18.3 (FL) cm
Present study	Alexandria, Medit. Sea, Egypt	Mar - Jun	19.7 TL cm (Males); 19.5 TL cm (Females)

classified histologically for *S. japonicus* as follows:

1. *Immature stage I*: At this stage, the cytoplasm gave a strong basophil reaction, and the oocyte diameter ranged from $153.64 \pm 12.64 \mu\text{m}$ (Fig. 5a). At this primary growth phase of oocytes, Oogonia appeared with a bulky nucleolus. Both early and late perinuclear oocytes had small nucleoli.

2. *Maturing stage II*: the oocytes were distinguished by cortical alveoli vesicles in the cytoplasm. The oocytes had a large nucleus with a granular appearance with numerous nucleoli with an average diameter of $233.3 \pm 7.4 \mu\text{m}$. The existence of the ovarian follicle (FE) is discernible in the maturing stage (Fig. 5b). In the more advanced maturing stage, the cortical alveoli oocyte increased in number and size ($365.74 \pm 72 \mu\text{m}$) to generate a number of rows in the cytoplasm. The zona radiata (ZR) appeared adjoining the oocyte amongst the cytoplasm and ovarian follicle (Fig. 6c).

2. Ripe and spawning stage III: The incidence of yolk granules was the principal aspect of the oocytes showing the buildup of acidophilic yolk globules in the yolk vesicles and the entire cytoplasm of the vitellogenic oocytes (with an average size of $624 \pm 63 \mu\text{m}$). The oocyte size had enlarged considerably with yolk accumulation (Fig. 5d), with a marginated nucleus in the cytoplasm (with oocyte diameter $784 \pm 109 \mu\text{m}$) (Figure 5f). The zona radiata enlarged to

maximum thickness ($13\text{--}15 \mu\text{m}$) at the wall of the ripe oocyte (Fig. 5e & g).

3. Spent stage IV: there was a clear decrease in the number of vitellogenic and ripe oocytes, while there was an increase in the atretic and post-ovulatory follicles as well as the perinuclear oocytes (Fig. 5h). Testicular cycle (spermatogenesis) also showed four stages with some differences as follows:

1. Immature stage I: This stage was distinguished by being predominated by spermatogonia in the lobular lamina. Spermatogonia were distinguished by the faintly stained cytoplasm with a spherical-shaped nucleus, hormones-producing cells (sertoli and leydig) and blood vessels (Fig. 6a).

2. Maturing stage II: Both primary and secondary spermatocytes were principal with limited nests of spermatids in addition to some spermatogonial nests (Fig. 6b, c).

3. Ripe and spawning stage III: Testes had the maximum size and were full of spermatozoa with few other developmental cell types. Lobule tissue was broken down and both seminiferous lobules and vas deferens were packed with spermatozoa (Fig. 6d & e).

4. Spent stage IV: the seminiferous lobules released almost all spermatozoa, and their structure was distorted with some residual trapped spermatozoa and new generation of spermatogonia. The lobular

lamina showed eosinophilic granulocytes (Fig. 6f).

DISCUSSION

The present results of *S. japonicus* showed that males were predominant in the larger fish length classes and females predominated in smaller fish as well as in the overall sex ratio (M:F = 1:1.19). Contradicting results were reported in the Turkish waters (Cengiz 2012) and in the eastern Adriatic Sea (Cikes Kec & Zorica 2012), where females predominated the larger size. In an earlier study, Rizkalla (1998) reported no significant difference between both sexes in the Egyptian Mediterranean waters. This disagreed with Techetach et al. (2010) and Allaya et al. (2013). These authors reported that females were predominant at the larger length groups in the North Moroccan Atlantic Coast and in the Tunisian waters' populations. While more males than females were recorded in the Greek waters (Kiparissis et al. 2000) for *S. japonicus* population. The differences in the fish growth parameters and the migratory behaviors in both males and females may explain the variations in the sex ratio among the different fish sizes (Moreno & Morales-Nin 2003).

In fisheries research, the length at first sexual maturity is a vital parameter to determine the legal size that ensures at least one spawning event for the matured fish (Osman et al. 2011; Ismail et al. 2018). During the present study, the length at maturity of *S. japonicus* was 19.7cm and 19.5cm for males and females, respectively. These values were nearly in agreement with the estimated value from the Canary Islands of 19.9cm TL (Lorenzo & Pajuelo 1993). While in the Northern Aegean Sea, Turkey, they were higher in Saros Bay (Cengiz 2012), where the length at first maturity for all samples was 18.0 cm. On the other hand, it was lower than the values of TL reported by (Carvalho et al. 2002) for *S. japonicus* from the Azores (27.78cm), and the estimated value of the Portuguese mainland coast that amounted to 31 cm (Martins et al., 1983). The different localities show differences in lengths at first maturity, which may be related to many factors

such as temperature and food availability (Nikolsky 1963; Hempel 1965), long-term fishing pressure and net selectivity (Helser & Almeida 1997; Jennings et al. 2001), genetic factors (Wootton 1998), and the use of different statistical methods (Froese & Binohlan 2000). More differences are found in Table 1, showing variations in locations and spawning time due to habitat variations and the previously mentioned factors.

In the present study, the gonado-somatic index (GSI) revealed that the spawning season extends from March until June, with the maximum peak in April-May. This extended spawning season was also reported for the Azores population (Westhaus-Ekau & Ekau 1982) and in the Eastern Adriatic Sea in from May to August (Cikes Kec & Zorica 2012). On the other hand, a different pattern of the GSI peak of *S. japonicus* was reported (Techetach et al. 2010; Allaya et al. 2013) in which the GSI for males and females displayed two peaks during the year: between December and February and between June and August, such as in the population of the Tunisian waters (Allaya et al. 2013) and the Moroccan North Atlantic Coast population (Techetach et al. 2010). The chub mackerel's spawning season varies between different regions. It usually extends three to five months (Cikes Kec & Zorica 2012). In the Northern Hemisphere, the spawning season appears to be limited to the first six months of the year, while in the Southern Hemisphere, it is limited to the last six months (Perrotta et al. 2001). However, near the equator, the spawning season may extend all year round (Castro & Santana 2000). The chub mackerel spawning usually occurs in water temperatures between 15° to 20°C, thus resulting in differences in the timing of the spawning seasons based on regions (Cikes Kec & Zorica 2012). Moreover, there is a relation between spawning and the length at maturity together with variations in habitats, as shown in Table 1, that it was noticed; the habitat and time may explain the differences in the time of spawning even in the same location, which has been shown between

the present investigation and that of (Rizkalla 1998). This difference may be due to the catchability of such species and its fisheries status (Cengiz 2012; Vasconcelos et al. 2012), which may have changed due to overexploitation.

In the present work, the absolute fecundity of *S. japonicus* varied between 8820 and 71492 with an average of 28762.98 ± 15431.04 per ovary and only the yolky eggs with a diameter ranging from 0.521 to 0.893mm were considered. Rizkalla (1998), estimated the absolute fecundity of *S. japonicus* from the Egyptian Mediterranean water ranging from 65000 to 174908. Moreover, much higher numbers for absolute fecundity were reported in other populations (Cikes Kec & Zorica 2012; Cengiz 2021). These differences for the same species could be attributed to the diverse methods of counting and the considered egg diameter for ripe ova. Witthames et al. (1995) reported that fecundity may differ according to the adaptations of the fish species to the different environmental habitats. Furthermore, fecundity is known to fluctuate on an annual basis and may be subjected to long-term changes, as reported by Rijnsdorp (1991). The size and number of the produced eggs and larvae by a single fish are determined by its survival potential and how this fish allocate its energy to growing, reproducing, behavior and maintenance (Roff 2000). Nevertheless, fecundity and size relations have been used primarily to estimate fish fecundity (Dulčić et al. 1998). The present fecundity regressions have high determination coefficients, indicating that the potential fecundity is predicted. The relationships amongst absolute fecundity and both total length and total weight suggested that the large-sized weighty *S. japonicus* individuals with heavy gonads have larger number of eggs. This relationship suggests that while growing, more energy is allocated by this species to reproduce similar to many other pelagic species (Tsikliras & Antonopoulou 2006; Zorica et al. 2011).

The present histological examination of *S. japonicus* gonad tissue showed that female fish

are batch spawners with an asynchronous group of oocytes development and an extended spawning season (March–June). Similar results were reported by Dickerson et al. (1992) from California and Cikes Kec & Zorica (2012) from the Eastern Adriatic Sea. In the present investigation, the yolky oocytes were observed with variable sizes and various maturity status, indicating multiple spawning modes. Many authors have described similar cases for different fish species (Al-Absawy 2004; Osman et al. 2011; Plaza et al. 2007).

In the present work, ovarian histology displayed that the ripe ovary had a considerable number of empty follicles and oocytes with different stages of yolk deposition at spawning and spent periods. Ripe ova were discharged during these stages, and a new generation for the following breeding season appeared as early stages of cytoplasmic growth were distinguished. These findings correlated with Plaza (2007) and Osman et al. (2011) for *Etrumeus teres*, a pelagic fish caught by the same fishing nets. Moreover, the presence of less developed and developed oocytes with varied sizes in the ripe and spawned ovary is evidence of the multiple spawning mode in *S. japonicus* with asynchronous ovarian groups to spawn several times during the breeding season, as reported by Dickerson et al. (1992).

A similar trend of different oocyte developmental stages in ovaries was also observed in testes through spermatogenic activity. All types of spermatogenic cells were observed in the maturing and ripe testes in accordance with Osman et al. (2011) and Al-Absawy (2004). During the ripe stage and through the spermiation process, the seminiferous tubules discharged the spermatozoa into the lobular lumen. At the periphery of many lobules, a new generation of spermatogonia appeared that may induce the multiplication for the next spawning event. Therefore, during the spawning season, the various sizes of both spermatocytes and oocytes at different stages of maturation development (mature, nearly ripe, and ripe) confirmed the spawning time for *S. japonicus*

as well as its mode of spawning as a multi-spawner and asynchronous species. These findings were similar to those obtained in other species by Assem (1995) in *Solea vulgaris* and *S. aegyptiaca*, (El-Boray, 1997) in *Rhabdosargus haffara*, (Assem, 1999) in *Caranx crysos*, (Al-Absawy 2004) in *Trachinotus ovatus*, and (Al-Absawy 2008) in *Merluccius merluccius*. This also was in accordance with indeterminate fecundity, which refers to batch fecundity, as supported by Dickerson et al. (1992). The presence of yolky oocytes during the ripening stage (March to June) illustrates a prolonged spawning time with an increase in the GSI, by the macroscopic observation of the ripening stage.

CONCLUSION

This study's results gave further insights into the reproductive history of *S. japonicus* and the current status of its wild stock in the Egyptian Mediterranean waters, to help the management and conservation measures of the species.

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مقاله کامل

پارامترهای تولیدمثلی ماهی قباد ژاپنی، *Scomber japonicus* (Houttuyn 1782) در دریای مدیترانه شرقی، مصر

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چکیده: این مطالعه با هدف بررسی زیست‌شناسی تولیدمثل و بافت‌شناسی ماهی قباد ژاپنی، *Scomber japonicus* در دریای مدیترانه، مصر انجام شد. بدین‌منظور در مجموع ۵۱۱ نمونه ماهیانه با استفاده از تورهای محاصره‌ای از بندر ماهی‌گیری اسکندریه طی سال‌های ۲۰۱۷-۲۰۱۸ جمع‌آوری شد. در طول چرخه تولید مثل، چهار مرحله برای نرها و ماده‌ها تعیین شد (نابالغ (I)؛ بلوغ (II)؛ رسیده و تخم‌ریزی (III) و مرحله گذر از تخم‌ریزی (IV)). بر اساس نسبت جنسی، جنس ماده غالب بودند (۱ نر: ۱/۱۹ ماده). مراحل بلوغ با شاخص گنادوسوماتیک (GSI) و قطر تخمک، نشان‌دهنده حالت تخم‌ریزی مرحله‌ای *S. japonicus* با تخم‌ریزی طولانی (مارس-ژوئن) و حداکثر شاخص گنادوسوماتیک در ماه آوریل-مه برای هر دو جنس بود. همچنین، شاخص وزنی کبد ماده (HIS) در طول زمان تخم‌ریزی افزایش معنی‌داری را نشان داد. میانگین باروری مطلق $28762/98 \pm 15431/04$ تخمک در هر تخمدان بود که همبستگی مثبتی با وزن کل (۰/۹۷۴) و طول کل (۰/۹۵) نشان داد. هم‌آوری نسبی از ۴۲۰ تا ۲۵۵۳ تخم در سانتی‌متر برای طول (TL) و از ۷۶ تا ۳۷۹ تخم در گرم برای وزن کل متغیر بود که با طول کل (۰/۹۰۶) و با وزن کل (۰/۳۹۸) همبستگی معنی‌داری نشان داد. طول در زمان بلوغ برای نرها و ماده‌ها به ترتیب ۱۹/۷ و ۱۹/۵ سانتی‌متر بود. بررسی‌های بافت‌شناسی زمان تخم‌ریزی را از طریق مراحل زرده‌ای با حالت جزئی تخمک‌های ناهم‌زمان تایید کرد. این داده‌ها، اطلاعات کلی به‌روز در مورد استراتژی تولید مثل *S. japonicus* و مدیریت شیلاتی در آینده این گونه را در منطقه ارائه می‌کنند.

کلمات کلیدی: زیست‌شناسی تولیدمثل، بافت‌شناسی غدد جنسی، *Scomber japonicus*، دریای مدیترانه، مصر.