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Research Article

Reproductive Pattern and Length at First Sexual Maturity of The Whiting (*Merlangius merlangus*, Nordmann, 1840) in The Black Sea

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Abstract: Samples of whiting (*M. merlangus*) (n = 1545) were collected using bottom trawl in the southern Black Sea during 2017–2018 and were subjected to reproductive biology assessments. These assessments included the gonadosomatic index, macroscopic and microscopic gonad phases, oocyte diameter distributions, batch fecundity, microscopic analysis of oocytes, and histology. The assessment results revealed a significant difference in sex ratio the samples (female: 877, male: 668). Analyses of the gonadosomatic index (GSI), along with macroscopic and microscopic phase evaluations, indicated that the most intense reproductive periods occurred in May and November, with two peaks observed during the studied year. Examination of oocyte structures and diameter distributions in histological sections taken from the ovaries each month showed that the whiting in the southern Black Sea exhibited multi-spawning behavior and had determinate fecundity. Additionally, the monthly batch fecundity (FB) and relative batch fecundity (FBR) of spawning whiting were calculated throughout the year. The average FB was 17823 ± 21,353 hydrated oocytes, while the FBR was 243 ± 143 hydrated eggs per gram. The length at first maturity for males and females were 12.80 cm and 13.72 cm, respectively. In light of the study's results, it is recommended to develop a new fisheries management strategy aimed at contributing to the sustainability of whiting stocks in the Black sea. This strategy should consider the most efficient spawning periods identified in this study, as well as other reproductive strategies, and focus on preserving larger individuals that can enhance egg production within the stocks.

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1. Introduction

Recent reports on the sustainability of global fisheries are concerning. As global fisheries production continues at maximum levels, the recovery of aquatic resources may soon become nearly impossible, with stocks at risk of collapse due to current fishing activity. International organizations emphasize the need to maintain fish stocks at optimal sustainable levels and ensure that depleted stocks are restored to exploitable levels. To achieve these global targets, the institutions and organizations responsible for fisheries management must establish and implement effective strategies and policies based on the current status of fish stocks (Mora et al., 2009; FAO, 2021).

Reproduction is a physiological process essential for the continuation of species across all organisms. As fecundity and reproductive strategy are two key topics in fish population dynamics and biological studies, understanding the reproductive strategy of a stock is crucial for effective fisheries management (Murua and Saborido-Rey, 2003).

Sustainable management of fish resources is directly linked to the reproductive potential of fish stocks. This potential is a critical factor for commercial demersal and semi-demersal species (Ferreri et al., 2009). Recent advancements in the understanding of reproductive biology and growth have led to a more precise definition of fecundity. Given the subjectivity and variability in the available information, it is essential to examine the developments occurring in the gonads of fish to evaluate fishery resources accurately. Microscopic studies are necessary to determine reproductive timing, maturation periods, spawning stock biomass, and the reproductive potential of stocks in various geographical and environmental contexts. In particular, the microscopic examination of partially spawning fish allows for accurate identification of spawning maturity stages (Ferreri et al., 2009).

The fishing activities and anthropogenic pollutants have adversely impacted the ecosystem of the Black Sea over time (Prodanov et al., 1997; Daskalov, 2002; Akoğlu et al., 2014). This unfavorable situation has reduced biodiversity of this ecosystem and is gradually reducing the productivity of commercial species from this region. This situation has also threatened the sustainability of whiting stocks, one of the most important commercial species obtained from the Black Sea. Since 2000, the annual whiting production of the countries bordering the Black Sea has been fluctuating (FAO, 2019; TÜİK, 2021). In this regard, it becomes important to elucidate the reproductive biology of this species and relate it to fisheries to ensure the sustainability of whiting stocks in the Black sea.

In this context, the aim of the study is to determine the spawning peaks of whiting in the Black Sea, examine the changes in oocyte structures within the gonads, analyze monthly variations in oocyte diameters, assess fecundity parameters, and investigate seasonal changes in spawning frequency and the lengths at first sexual maturity.

2. Materials and Methods

The study was conducted in the southern Black Sea from March 2017 to February 2018 (Figure 1). A total of 1545 specimens of *Merlangius merlangus* were collected during monthly sampling operations with the Karadeniz Araştırma research vessel. Samples were taken from depths of 5–65 m using a bottom trawl net with a mesh size of 12 mm.

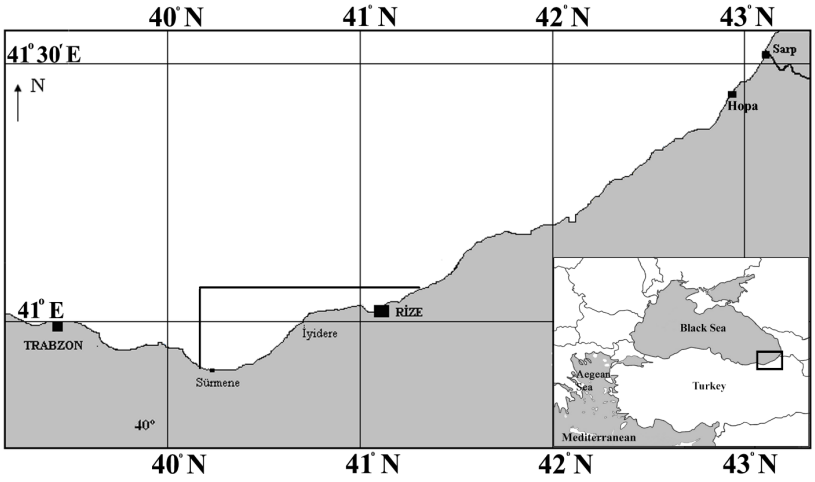

Figure 1. Study area.

The total length (TL) of each fish specimen was measured to the nearest millimeter (1 mm). Gonads were removed through dissection, and sex determination was performed. Each specimen's body and gonads were weighed with an accuracy of 0.01 g. The reproductive period throughout the year was assessed by calculating the gonadosomatic index (GSI), which was computed using the following formula (Craig et al., 2000; Nunes et al., 2011; Flores et al., 2015).

$$GSI = \left(\frac{GW}{TW - GW}\right) * 100 \quad (1)$$

Where GW represents the weight of the gonads and TW represents the total body weight of the fish specimen.

Gonads were examined both macroscopically and microscopically to detect changes in gonadal and oocyte structures in the ovaries during the reproductive period. These examinations were categorized into five phases: immature (I), developing (II), spawning (III), regressing (IV), and regenerating (V), as described by Brown-Peterson et al. (2011).

A total of 877 female ovarian specimens were examined macroscopically, while 307 of these were subjected to microscopic examination. For the microscopic analysis, ovarian samples intended for both histological examination and oocyte frequency distribution analysis were placed in 10% neutral buffered formalin for one day, followed by preservation in 70% alcohol. The histological samples were then washed under running water overnight and passed through an alcohol concentration gradient. After cleaning with xylene, the samples were embedded in paraffin blocks at 65 °C overnight. Using a microtome, the paraffin-embedded ovarian samples were sectioned into thin slices of 5–10 µm and stained with hematoxylin-eosin. (Hunter and Goldberg, 1980; Hunter et al., 1992; Murua and Motos, 2006). The stained samples were examined under a microscope to stage the oocyte structures.

Batch fecundity is defined as the number of hydrated oocytes in each ovary sample, estimated using the gravimetric method (Hunter et al., 1985; Hunter et al., 1992). Only ovaries containing hydrated oocytes were used to calculate partial fecundity, while those with post-ovulate follicles were excluded. A total of 61 ovaries were included in the determination of partial fecundity. Hydrated oocytes from the anterior, middle, and posterior regions of the gonad samples (0.1 g each) were counted under a binocular microscope. Batch fecundity (FB) was calculated using the following equation (Hunter et al., 1985; Murua et al., 2003; Macchi et al., 2005).

$$F_B = \sum_{i=1}^{m} \left(\frac{ni * Gi}{gi}\right) * \left(\frac{1}{m}\right) \quad (2)$$

Where Gi denotes the weight of the gonad sample from the ith female, gi denotes the subsample weight of the ith female, ni denotes the number of the hydrated oocytes in the subsample from the ith female, and m denotes the total number of samples used to estimating batch fecundity.

The relative batch fecundity (FBR) was calculated by dividing the number of hydrated oocytes in the batch fecundity by the body weight.

Annual fecundity (FA) was defined as the number of hydrated eggs released by a female in a year (Hunter et. al., 1992; Murua et. al., 2003; Murua and Saborido-Rey, 2003). The relationships of body weight with FB and length with FB were determined through regression analysis. The diameters of oocytes in mature gonads during the spawning season were measured using a binocular microscope and used to calculate oocyte frequency distributions. The length at first sexual maturity was calculated as the ratio of mature individuals to total individuals based on macroscopic examination of gonad samples collected at the peak of the reproduction period. The length at first maturity (Lm_{50}) was calculated using the logistic function provided below (Saborido-Rey and Junquera, 1998; Flores et al., 2015).

$$P = 1/(1 + \exp(a + b * L)) \quad (3)$$

$$Lm_{50} = -(a/b) \quad (4)$$

Where P denotes the proportion of mature individuals in the length class, and L denotes total length; a: intercept, b: slope.

Statistical significance levels of the data (GSI, FB, FBR) were determined using ANOVA, Kruskal-Wallis test followed by Dunn test for non-parametric data, chi-square test and independent t-test using SigmaPlot 12.0 software.

3. Results

A total of 1545 whiting (*M. merlangus*) specimens were collected over a duration of 12 months. The length distribution of all specimens ranged from 7.5 to 25 cm; for females, the range was 7.5 to 25 cm, while for males, it was 7.5 to 19 cm. The sample set comprised 57% females (n = 877) and 43% males (n = 668). The chi-squared test performed to compare the sex ratios in the length classes (7.5 to 19) revealed a significant difference in the sex ratios in the length groups ($\chi^2_{(df:12)} = 169{,}127$; $p < 0.001$). The proportion of males (43%) and females (57%) in the sample set also demonstrated a significant deviation from the standard 1:1 ratio ($\chi^2_{(df:1)} = 28{,}272$; $p < 0.001$).

The monthly GSI values calculated for the whiting specimens, categorized by sex, revealed two peaks occurring in May and November during the year (Figure 2).

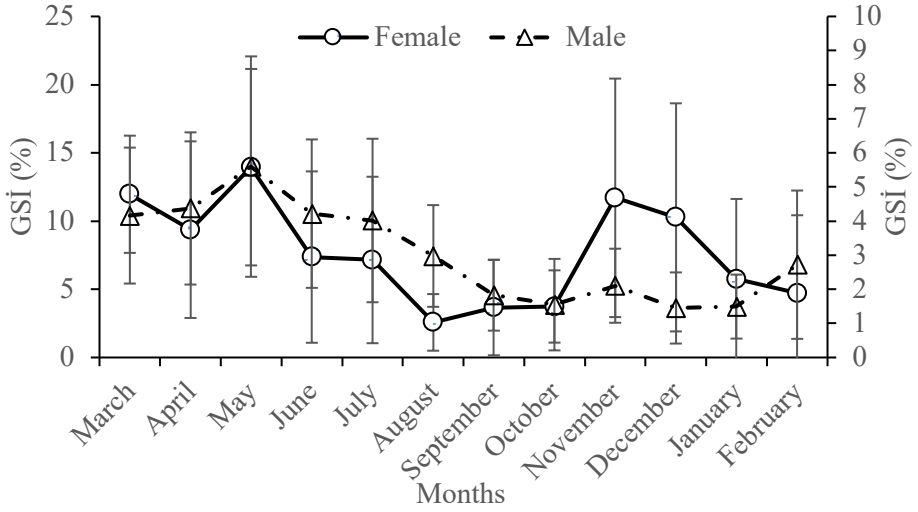

Figure 2. Monthly gonadosomatic indices for female and male *M. merlangus* specimens.

The highest GSI values were recorded in May, with females exhibiting a value of 13.94 ± 7.200 and males showing 5.59 ± 3.231. Statistical analysis of the monthly GSI values for females revealed significant differences in peak months ($F_{(df:11)} = 29.93$; $p < 0.001$), and similar results were obtained for males ($F_{(df:11)} = 20.36$; $p < 0.001$). In order to determine the maturity phase of the ovaries, ovary samples from females were examined macroscopically every month to reveal the five phases (Figure 3). The examinations revealed the presence of all five phases in all months except for March.

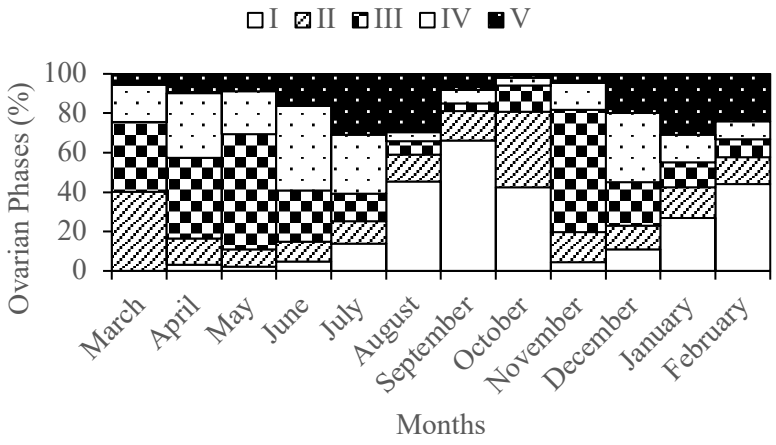

Figure 3. Monthly macroscopically determined gonad maturation phases in *M. merlangus*.

Histological sections were received from the ovaries taken every month to determine the maturity phases of the ovary. The sections were categorized as having one of five phases according to the changes that occurred in the oocyte structures within the ovary (Figure 4).

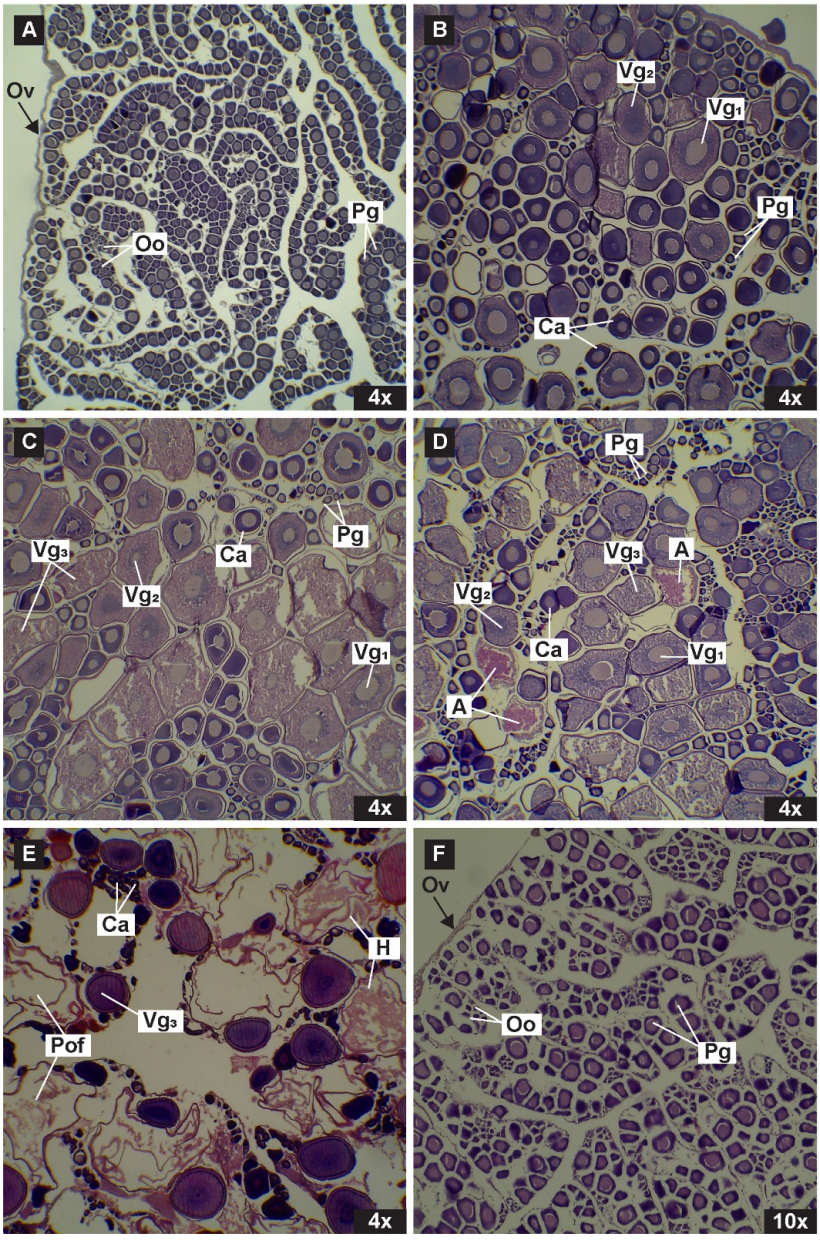

Figure 4. Histological sections showing developmental phases in ovary and oocyte structures: A, immature I; B, developing II; C-D, spawning III; E, regressing IV; F, regenerating V (Ov: ovarian wall; Oo: oogonia; Pg: primary growth oocyte; Ca: cortical alveolar oocyte, Vg1: primary vitellogenic oocyte; Vg2: secondary vitellogenic oocyte; Vg3: tertiary vitellogenic oocyte; h: hydrated oocyte; Pof: postovulatory follicle; A: atresia oocyte).

Phase I: This phase was characterized by a high presence of oogonia (Oo) and primary growth (Pg) oocytes. The oocyte nuclei were considerably large and occupy a significant portion of the oocyte cytoplasm. No atretic oocytes (A) are observed (Figure 4A).

Phase II: This phase was characterized by the presence of Pg, cortical alveolar (Ca), primary vitellogenic (Vg1), and secondary vitellogenic (Vg2) oocytes structures. In addition, the diameters of a few oocytes were enlarged while the nucleus diameters were decreased. The atresia structures were not observed in this phase (Figure 4B).

Phase III: The atresia and tertiary vitellogenic (Vg3) oocytes were the first ones to be identified in this phase. While Pg, Ca, Vg1, Vg2, and Vg3 were observed heterogeneously within the ovary, the Vg1, Vg2, and Vg3 oocytes were further intense (Figure 4C and 4D).

Phase IV: This phase was characterized mainly by hydrated oocytes (H) and postovulatory follicles (Pof) with a few Ca and atresia oocytes (A) (Figure 4E).

Phase V: In this phase, the reconstruction of the ovary had begun, the ovary walls had thickened, and the oogonia and Pg oocytes had been remodeled (Figure 4F). The monthly evaluation of the histological sections revealed the presence of all five phases in the ovaries of the fish specimens during all months.

The fecundity of 61 female specimens was estimated by evaluating a minimum of three samples each month (Phase III). Only hydrated oocytes were used to calculate batch fecundity. Average batch fecundity values (FB) and relative batch fecundity values (FBR) were calculated for all months (Table 1).

Table 1. Monthly mean batch fecundity (FB) and mean relative batch fecundity (FBR) along with the corresponding standard deviations

Months	N	Average (F_B)	Average F_{BR}
March	3	2217±874	67±3
April	5	9520±4660	328±162
May	3	33142±49792	311±152
June	3	2335±2134	80±58
July	7	9539±6021	222±124
August	3	3070±504	110±160
September	4	8751±5343	267±160
October	3	7090±3724	107±36
November	11	25859±17652	334±118
December	6	25412±22424	247±140
January	8	18293±8364	221±98
February	5	35726±39734	325±181
Total/Average	61	17823±21353	243±143

The Kruskal-Wallis test revealed a significant difference among the monthly mean batch fecundity values ($H_{(df:11)} = 27.979$, $p < 0.05$). Similarly, the difference among the monthly mean relative batch fecundity values was also significant ($H_{(df:11)} = 25.098$, $p < 0.05$). Among the evaluated samples, the smallest spawned individual measured 13.7 cm (24.11 g) and had a batch fecundity of 4542 hydrated oocytes, while the largest individual measured 32.6 cm (279.58 g) and had a batch fecundity of 108353 hydrated oocytes. The average batch fecundity was estimated at 17823 ± 21353 hydrated oocytes, while the relative batch fecundity ranged from 40 to 589 hydrated oocytes g^{-1}, with an average of 243 ± 143 hydrated oocytes g^{-1} (Table 1). Furthermore, regression analysis revealed that the batch fecundity of whiting was significantly and positively correlated with female body weight and length ($p<0.05$) (Figure 5A and 5B).

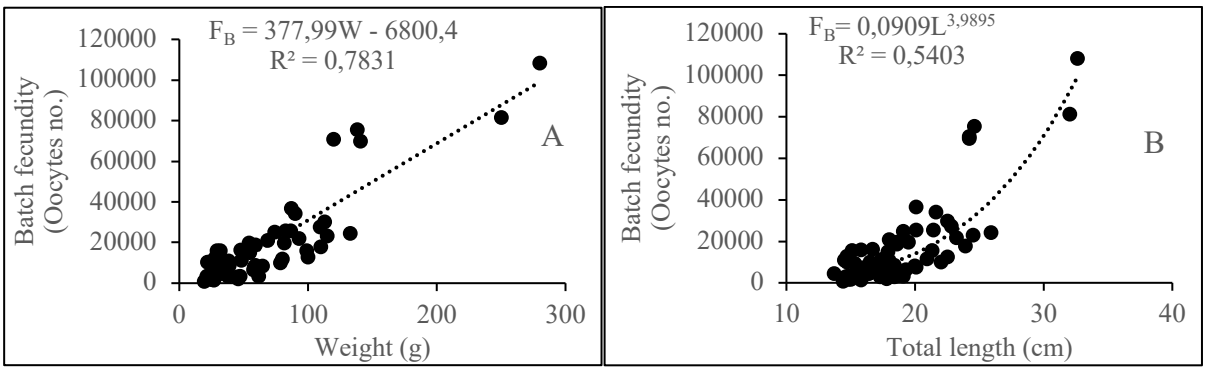

Figure 5. The relationship between the total weight and batch fecundity (A) and the total length and batch fecundity (B).

To determine the egg diameter of whiting fish, samples were collected monthly from mature gonads. Oocytes with diameters greater than 0.1 mm were measured. The oocyte diameters measured each month are presented in Table 2 and Figure 6.

Table 2. Monthly-measured average diameters of hydrated oocytes and total oocytes along with standard deviations

Months	N	Hydrated oocyte diameter (mm)	N	Total (mm)
March	630	1.01±0.195	1419	0.65±0.330
April	362	1.18±0.224	1277	0.68±0.349
May	432	1.27±0.131	1232	0.77±0.395
June	261	0.87±0.084	684	0.62±0.221
July	196	1.03±0.151	508	0.71±0.280
August	486	1.08±0.234	1113	0.78±0.322
September	165	1.12±0.126	994	0.57±0.269
October	115	1.39±0.099	237	0.91±0.479
November	798	1.34±0.217	2486	0.75±0.433
December	725	1.29±0.284	2637	0.72±0.401
January	690	1.49±0.167	2119	0.83±0.483
February	687	1.49±0.213	2178	0.84±0.473
Total/Average	5547	1.21±0.177	16874	0.74±0.098

The average diameter of the oocytes measured throughout the year was 0.74 ± 0.098 mm, while the average diameter of the hydrated oocytes was 1.21 ± 0.177 mm. The Kruskal-Wallis test revealed a significant difference among the monthly measured average diameters of the oocytes ($H_{(df:11)}$= 545.68, $p < 0.001$). Similarly, the difference among the monthly measured diameters of the hydrated oocytes was also significant $H_{(df:11)}$= 2575.57, $p < 0.001$). The monthly measured diameters of the hydrated oocytes ranged from 0.7 mm to 1.9 mm.

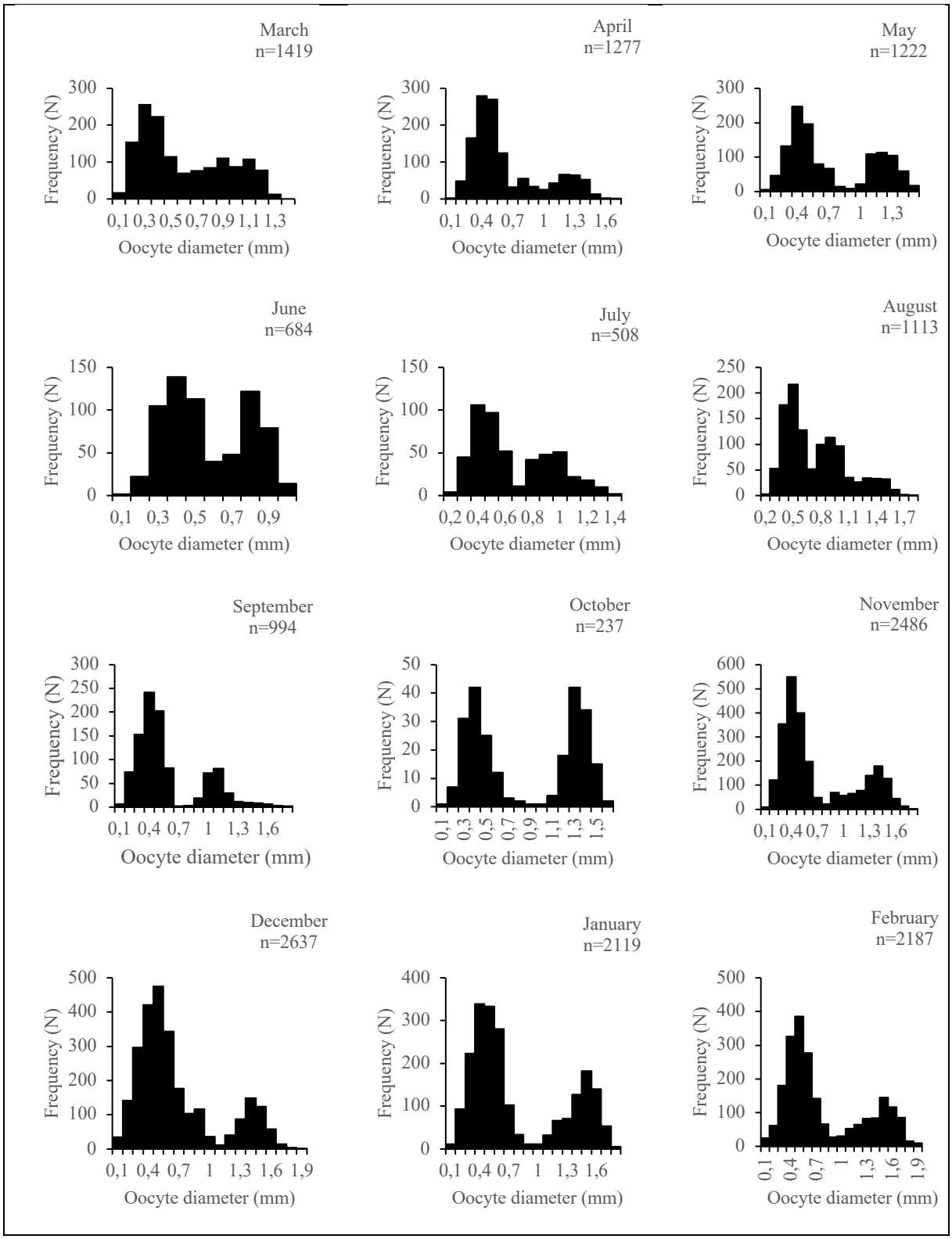

Figure 6. Monthly oocyte frequency distributions.

The length at first sexual maturity (Lm_{50}) was determined for both mature males and females (Figure 7), observed to be 12.80 cm and 13.72 cm, respectively.

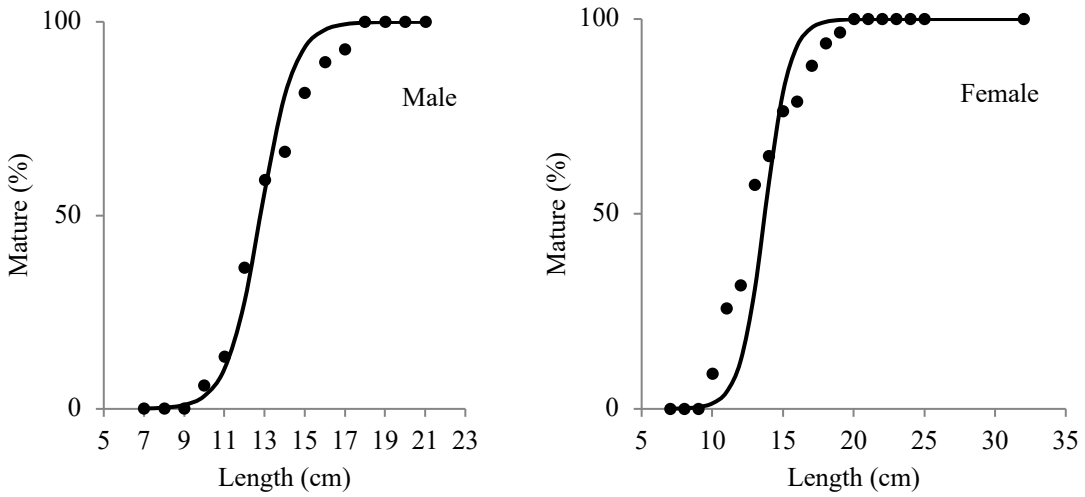

Figure 7. The length at first sexual maturity in *M. merlangus*.

4. Discussion

Considering the biometric data obtained in this study, female whiting stocks from the Black Sea were found to be larger than their male counterparts and dominated the length classes and sex ratio significantly differed from the expected 1:1 ratio. Similar findings have been documented in previous studies on whiting stocks in the Black Sea (Çiloğlu et al., 2001; Bilgin et al., 2012; Sağlam and Sağlam, 2012; Mazlum and Bilgin, 2014; Yıldız and Karakulak, 2019).

The reproductive period and fecundity are two critical factors for fishery management. Additionally, the gonadosomatic index (GSI), allows for a quick and cost-effective determination of the reproductive period (De Vlaming et al., 1982; Somarakis et al., 2004; Stahl and Kruse, 2008; Nunes et al., 2011; Flores et al., 2015). The monthly GSI values for males and females throughout the year, as determined in the current study, peaked twice—first in May and then in November (Figure 2). Based on the GSI values obtained for females, it can be inferred that whiting spawned heavily during the months of May to August and November to February. Male gonads were predicted to be emptied during the months of May to September and November to January. In previous studies on the whiting population in the Southern Black Sea, reproductive periods were identified as occurring from spring to autumn (Genç et al., 1998) and extending into late summer, mid-autumn, and early winter (Bilgin et al., 2012). Other studies conducted in the Black Sea indicated that whiting fish reproduce at temperatures of 7–15 °C and spawn throughout the year (Genç et al., 1998; Çiloğlu et al., 2001; Samsun, 2005).

Reproductive timing in fish is crucial for successful spawning and recruitment (Tomkiewicz et al., 2003; Lowerre-Barbieri et al., 2011). Marine fish exhibit various reproductive timing characteristics, including annual, seasonal, and diel patterns (Lowerre-Barbieri et al., 2009). One of the approaches for determining the reproductive period and reproductive strategy in fish is the histological approach, which is further categorized into macroscopic and microscopic examinations. The macroscopic examination is a rapid and cost-effective way to assess the reproductive status of fish (Tomkiewicz et al., 2003). However, this method can be subject to margins of error in the visual staging of fish gonads. In contrast, microscopic analysis, while more expensive and time-consuming, offers valuable insights into the reproductive period. This method examines the oocyte structures within fish gonads and provides greater reliability in determining reproductive phases (Saborido-Rey and Junquera, 1998; Tomkiewicz et al., 2003; Vitale et al., 2006; Stahl and Kruse, 2008).

The present study attempted to determine the reproductive period by establishing the maturity phases of the whiting ovaries sampled using macroscopic and microscopic examinations. Macroscopic phasing was established based on the developments in the external appearance of the gonads considering the criteria specified in the method. In regard to phase III based on the macroscopic examination, which is the beginning of the egg-laying stage, it was observed that the reproductive periods occurred almost

during the periods determined based on the GSI, i.e., during May–August and November–February (Figure 2–3). In separate studies, Samsun (2005) and Bilgin et al. (2012) had observed the presence of almost all phases throughout the year in the macroscopic staging of the whiting ovaries in the southern Black Sea. In the present study as well, all phases were observed throughout the year, except for phase (I) based on macroscopic phasing, which occurred in March.

Since determining the reproductive strategies of fish is crucial for fisheries management, it becomes important to accurately evaluate ovarian development to determine the ovary maturation process, reproduction period, and oocyte recruitment (Murua and Saborido-Rey, 2003; Lowerre-Barbieri et al., 2011; Alonso-Fernandez et al., 2013). Subsequently, the results of GSI, macroscopic and microscopic methods were by being compared to evaluated. All maturity phases were observed in the ovarian sections sampled from March, the first month of sampling, through February, the last month. This indicates that whiting in the Southern Black Sea reproduce year-round. Additionally, based on the microscopic phasing results, it can be inferred that whiting in this region exhibit a multiple spawning pattern. Atretic oocytes were detected at lower rates throughout the year in the monthly ovarian sections. Histological examination revealed that the peak spawning periods for whiting coincided with those identified by the gonadosomatic index (GSI) and macroscopic methods, specifically in spring and autumn. Furthermore, regressing (phase IV) and regenerating (phase V) phases were rarely observed in microscopically examined ovarian samples from March to May. In contrast, these regressing and regenerating phases were observed at significantly higher rates during visual examinations of specimens from the same months (Figure 3). It was difficult to determine the gonad structures of the ovaries in the regenerating phase (V) and those in the immature phase (I) using the visual examination due to considerable similarity; in addition, there was a change in the ratio of the number of individuals in these phases. Stahl and Kruse (2008) and Brown-Peterson et al. (2011) also reported difficulties and confusion in visually staging the regeneration and immature phases of gonads. Additionally, inaccurate visual phasing of individuals that have reached sexual maturity but skipped the breeding period without spawning (Rideout et al., 2005; Rideout and Tokievicz, 2011) complicates the assessment of the actual number of productive females in the stock, negatively impacting the determination of spawning stock biomass. In this context, it can be said that microscopic staging is a more accurate method for determining spawning stock biomass.

The estimation of spawning biomass in multiple-spawning fish depends on the number of batches spawned and the number of eggs in each batch (Hunter and Goldberg, 1980). Determining fecundity is crucial for predicting spawning biomass (Hunter et al., 1985; Murua et al., 2003; Rogers et al., 2019). In this context, estimating fecundity, which is influenced by environmental and other biological factors, helps us understand not only the basic mechanisms that regulate annual variability in fecundity but also variability in recruitment (Murua and Saborido-Rey, 2003). In the present study, the fecundity status of whiting specimens was evaluated. It was found that the values of relative batch fecundity (FBR) and batch fecundity (FB) determined from the monthly samples exhibited variability, peaking during the intensive spawning periods in May and February (Table 1).

Statistical analysis revealed that the differences between the monthly values of both FB and FBR were not significant ($p > 0.05$). However, the months with the most intense whiting spawning were identified as May and February. The consistent detection of FB throughout the year further indicates that whiting spawn year-round in the Black Sea. In studies on the egg fecundity of whiting in the Black Sea, annual fecundity has been determined by counting all oocytes without considering batch fecundity. İşmen (1995) reported annual fecundity values of 313 000, 314 000, and 263 000 eggs for whiting in the Black Sea in the years 1991, 1992, and 1993, respectively. Ak (2009) reported an annual fecundity of 179 672 eggs in the southern Black Sea, while Samsun (2005) found it to be 140 838 eggs in the western Black Sea. When the fecundity value was statistically compared with those from previous studies in the Black Sea, the difference was found to be insignificant ($p > 0.05$). In developing a management plan for multiple spawning stocks, it is crucial to consider partial fecundity as a unit of measurement to more accurately assess egg productivity, spawning stock, and individual recruitment. The most effective measure for determining egg productivity in multiple spawning fish is batch fecundity (Hunter et al., 1985; Lowerre-Barbieri et al., 1996).

In the present study, a positive relationship was observed between batch fecundity and somatic weight and also between batch fecundity and total length (Figure 5A-5B). As the somatic weight of whiting in the Southern Black Sea increases, batch fecundity also increases linearly. In contrast, as total

length increases, batch fecundity rises exponentially. Thus, it can be concluded that batch fecundity is a function of both total length and somatic weight. Similar findings have been reported for whiting in the Black Sea (İşmen, 1995; Samsun, 2005). Hislop (1974) found in his study of *Merlangius merlangus* in the North Sea, the Minch, and Iceland that fecundity increases with both length and age, with a curvilinear relationship between fecundity and length. Additionally, studies on *Merluccius merluccius* by Kjesbu et al. (1998), Macchi et al. (2005), and El Habouz et al. (2011) demonstrated that batch fecundity positively correlates with both somatic weight and total length, reinforcing the notion that batch fecundity is influenced by these factors.

The observation of a certain increase in the diameter of hydrated oocytes (Table 2) measured monthly throughout the year in the present study is an indicator of fecundity determinability. Murua and Saborido-Rey (2003) also reported that the increase in oocyte diameters during the reproductive period was indicative of fecundity determinability. The frequency distribution of oocytes within the ovaries of multiple spawning fish is crucial for determining whether the species exhibits determinate or indeterminate fecundity (Hunter and Macewicz, 1985; Hunter et al., 1985; Murua and Saborido-Rey, 2003). The presence of a hiatus between vitellogenic oocytes and hydrated oocytes in the oocyte frequency distribution indicates that batch fecundity is determinate (Hunter and Macewicz, 1985; Lowerre-Barbieri et al., 1996; Macchi et al., 2005; Murua and Motos, 2006). The monthly distribution of oocyte diameters observed in the present study (Figure 6) reveals such a hiatus, indicating that the batch fecundity of whiting in the Southern Black Sea is determinate. A Previous report indicate that whiting is iteroparous, group-synchronous, fecundity determinate, and a batch spawner (Murua and Saborido-Rey, 2003). These criteria should be considered when determining the spawning stock biomass of whiting.

The length at first sexual maturity (Lm_{50}) is another crucial parameter that plays a key role in the sustainability of fish stocks (Tsikliras and Stergiou, 2013). Compared to previous studies reporting the length at first sexual maturity of whiting in the Black Sea, the corresponding values obtained in the present study were found to be lower (Table 3).

Table 3. The values of the length at first sexual maturity (Lm50) reported in the previous studies conducted in the Black Sea

Researchers	First sexual maturity length (L_{m50})	Research area
İşmen (1995)	Female:14.7 cm. Male:12.5 cm	Black Sea
Samsun (2005)	Female:13.8 cm. Male:12.9 cm	Black Sea
Bilgin (2012)	Female:14.6 cm. Male:13.9 cm	Black Sea

The t-test analysis comparing the length at first sexual maturity values obtained in the present study with those from previous studies (İşmen, 1995; Samsun, 2005; Bilgin et al., 2012) revealed a significant difference among females ($p < 0.05$), while no significant difference was found among males ($p > 0.05$). Despite a long-standing ban on bottom trawling in the eastern Black Sea, comparisons of first sexual maturity parameters suggest that there has been no recovery in whiting fish stocks. Previous studies on the length at first sexual maturity (Tsikliras and Stergiou, 2013; Hunter et al., 2015; Lappalainen et al., 2016) indicated that environmental fluctuations (such as temperature and nutrition) and high levels of fishing exploitation could negatively affect these parameters. To conserve stock biomass and ensure the sustainability of fisheries, it is recommended that fish be allowed to spawn at least once during their lifetime (Beverton and Holt, 1957). The fundamental parameter for maintaining a population is the spawning stock. Sustainable fishery management should be established by determining the spawning stocks of the whiting fish population in the Black Sea and considering the criteria determined in this study and other studies.

Conclusion

It is expected that banning all types of fishing activities on the whiting population during periods of intensive reproduction will contribute to the sustainability of the whiting stocks and fisheries. It is believed that banning all fishing activities during the peak spawning periods of whiting populations would contribute to the sustainability of whiting stocks and fisheries. Therefore, banning all fishing

during at least one of the peak spawning periods (particularly May and August, as they overlap with the spawning periods of other fish) should be considered by fisheries management agencies.

For a more accurate assessment of recruitment, the fecundity of whiting should be estimated based on hydrated oocytes. The biomass of the spawning stocks of the whiting population in the southern Black Sea is currently unknown. Batch fecundity should be taken into account when determining the spawning stock biomass of whiting with multiple spawning and determinate fecundity.

The fisheries management to be implemented on the whiting population should be planned according to the determined spawning stocks. The length values at first sexual maturity obtained in this study showed a decrease compared to the values of previous studies. The presence of individuals with smaller sexual maturity length in the spawning stock may mean a decrease in egg production, decrease in quality and decrease in recruitment. In order to ensure a healthier recruitment, The whiting fishery should be adjusted to a minimum size of 14 cm so that individuals larger than the minimum landing size can remain in the spawning stock.

Ethical Statement

Ethical approval is not required for this study.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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Author Contributions

YC: Conceptualization, Methodology, Formal Analysis, Visualization, Writing—Original Draft Preparation. The author developed the research idea, designed the methodology, and performed the data analysis and initial manuscript writing. CŞ: Supervision, Investigation, Writing—Review & Editing. The author supervised the research process, contributed to data collection, and revised the manuscript. EÖ: Data Curation, Validation. The author contributed to organizing and validating the data and preparing materials for the study.

References

Ak, O. (2009). Fish egg and larvae distribution with egg production and distribution of economic demersal fishes whiting (*Merlangius merlangus euxinus* Nordmann, 1840) and red mullet (*Mullus barbatus ponticus*, Ess. 1927) (PhD thesis). Atatürk University, Erzurum, Türkiye.

Akoglu, E., Salihoglu, B., Libralato, S., Oguz, T., & Solidoro, C. (2014). An indicator-based evaluation of Black Sea food web dynamics during 1960–2000. *Journal of Marine Systems, 134*, 113–125. doi:https://doi.org/10.1016/j.jmarsys.2014.02.010

Alonso-Fernandez, A., Villegas-Rios, D., Valdes-Lopez, M., Olveira-Dominguez, B., & Saborido-Rey, F. (2013). Reproductive biology of pollack (*Pollachius pollachius*) from the Galician shelf (north-west Spain). *Journal of the Marine Biological Association of the United Kingdom, 93*, 1–13. doi:https://doi.org/10.1017/S0025315413000283

Beverton, R. J. H., & Holt, S. J. (1957) On the dynamics of exploited fish populations. *Fisheries Investigations, 19*, 1-533.

Bilgin, S., Bal, H., & Taşçı, B. (2012). Length based growth estimates and reproduction biology of whiting, *Merlangius merlangus euxinus* (Nordman, 1840) in the Southeast Black Sea. *Turkish Journal of Fisheries and Aquatic Sciences*, *12*, 871–881.

Brown-Peterson, N. J., Wyanski, D. M., Saborido-Rey, F., Macewicz, B. J., & Lowerre-Barbieri, S. K. (2011). A standardized terminology for describing reproductive development in fishes. *Marine and Coastal Fisheries*, *3*(1), 52–70. doi:https://doi.org/10.1080/19425120.2011.555724

Craig, S., MacKenzie, D. S., Jones, G., & Gatlin, D. M. (2000). Seasonal changes in the reproductive condition and body composition of free-ranging red drum, *Sciaenops ocellatus*. Aquaculture, 190, 89–102. doi:https://doi.org/ 10.1016/s0044-8486(00)00386-0

Çiloğlu, E., Şahin, C., Zengin, M., & Genç, Y. (2001). Determination of some population parameters and reproduction period of whiting (*Merlangius merlangus euxinus* Nordmann, 1840) on the Trabzon-Yomra coast in the eastern Black Sea. *Turkish Journal of Zoology*, *25*, 831–837.

Daskalov, G. M. (2002). Overfishing drives a trophic cascade in the Black Sea. *Marine Ecology Progress Series*, *225*, 53–63. doi:https://doi.org/10.3354/meps225053

De Vlaming, V., Grossman, G., & Chapman, F. (1982). On the use of the gonosomatic index. Comparative Biochemistry and Physiology, *73*, 31–39.

El Habouz, H., Recasens, L., Kifani, S., Moukrim, A., Bouhaimi, A., & El Ayoubi, S. (2011). Maturity and batch fecundity of the European hake (*Merluccius merluccius*, Linnaeus, 1758) in the Eastern Central Atlantic. *Scientia Marina, 75*, 447–454. doi:https://doi.org/10.3989/scimar.2011.75n3447

FAO. (2019). Fisheries and Aquaculture FishStatJ - Software for Fishery and Aquaculture Statistical Time Series [online]. Retrieved from https://www.fao.org/fishery/en/topic/166235 [Accessed 10 December 2021].

FAO. (2021). The State of World Fisheries and Aquaculture 2020: Sustainability in action. Rome: Food and Agriculture Organization of the United Nations.

Ferreri, R., Basilone, G., D'Elia, M., Traina, A., Saborido-Rey, F., & Mazzola, S. (2009). Validation of macroscopic maturity stages according to microscopic histological examination for European anchovy. *Marine Ecology, 30*, 181–187. doi:https://doi.org/10.1111/j.1439-0485.2009.00312.x

Flores, A., Wiff, R., & Diaz, E. (2015). Using the gonadosomatic index to estimate the maturity ogive: application to Chilean hake (*Merluccius gayi gayi*). *ICES Journal of Marine Science, 72*, 508–514. doi:https://doi.org/10.1093/icesjms/fsu155

Genç, Y., Zengin, M., Başar, S., Tabak, İ., Ceylan, B., Çiftçi, Y., Üstündağ, C., Akbulut, B., & Şahin, T. (1998). Ekonomik deniz ürünleri araştırma projesi (Project No: TAGEM/IY/96/17/3/001). Trabzon: Su Ürünleri Merkez Araştırma Enstitüsü. (in Turkish)

Hislop, J. R. G., & Hall, W. B. (1974). The fecundity of whiting, *Merlangius merlangus* (L.) in the North Sea, The Minch and at Iceland. *ICES Journal of Marine Science*, *36*, 42–49. doi:https://doi.org/10.1093/icesjms/36.1.42

Hunter, J. R. (1985). Preservation of northern anchovy in formaldehyde solution. An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy *Engraulis mordax*. *NOAA Technical Report, 36*, 13 pp.

Hunter, J. R., Lo, N. C. H., Leong, R., & Macewicz, B. (1985). Batch fecundity in multiple spawning fishes. An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy *Engraulis mordax*. *NOAA Technical Report, 36*, 12 pp.

Hunter, J. R., & Goldberg, S. R. (1980). Spawning incidence and batch fecundity in northern anchovy, *Engraulis mordax*. *Fishery Bulletin, 77*, 641–652.

Hunter, J. R., & Macewicz, B. J. (1985). Measurement of spawning frequency in multiple spawning fishes. An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy *Engraulis mordax*. *NOAA Technical Report,* 36, 16 pp.

Hunter J. R, Goldberg S R, (1980). Spawning ıncidence and batch fecundity in northern anchovy, *Engraulis mordax*. *Fishery Bulletin, 77*, 641-652.

Hunter, J. R., Macewicz, B. J., Lo, N. C. H., & Kimbrell, C. A. (1992). Fecundity, spawning, and maturity of female Dover sole, *Microstomus pacificus*, with an evaluation of assumptions and precision. *Fishery Bulletin*, *90*, 101–128.

Hunter, A., Speirs, D. C., & Heath, M. R. (2015). Fishery-induced changes to age and length dependent maturation schedules of three demersal fish species in the Firth of Clyde. *Fisheries Research, 170*, 14–23. doi:https://doi.org/10.1016/j.fishres.2015.05.004

İşmen, A. (1995). The biology and population parameters of the whiting *(Merlangius merlangus euxinus*, Nordmann) in the Turkish coast of the Black Sea (PhD thesis). Middle East Technical University, Ankara, Türkiye. doi:https://doi.org/10.1016/0165-7836(94)00327-S

Kjesbu, O. S., Witthames, P. R., Solemdal, P., & Walker, M. G. (1998). Temporal variations in the fecundity of arcto-Norwegian cod (*Gadus morhua*) in response to natural changes in food and

temperature. *Journal of Sea Research, 40*, 303–321. doi:https://doi.org/10.1016/S1385-1101(98)00029-X

Lappalainen, A., Saks, L., Sustar, M., Heikinheimo, O., & Jürgens, K. (2016). Length at maturity as a potential indicator of fishing pressure effects on coastal pikeperch (*Sander lucioperca*) stocks in the northern Baltic Sea. *Fisheries Research, 174*, 47–57. doi:https://doi.org/10.1016/j.fishres.2015.08.013

Lowerre-Barbieri, S. K., Ganias, K., Saborido-Rey, F., Murua, H., & Hunter, J. R. (2011). Reproductive timing in marine fishes: Variability, temporal scales, and methods. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, 3*,* 71–91. doi:https://doi.org/10.1080/19425120.2011.556932

Lowerre-Barbieri, S. K., Henderson, N. L., Walters, S. J., Bickford, J., & Muller, R. (2009). Defining a spawning population (spotted seatrout *Cynoscion nebulosus*) over temporal, spatial, and demographic scales. *Marine Ecology Progress Series*, *394*, 231–245. doi:https://doi.org/10.3354/meps08262

Lowerre-Barbieri, S. K., Chittenden, M. E. Jr., & Barbieri, L. R. (1996). The multiple spawning pattern of weakfish in the Chesapeake Bay and Middle Atlantic Bight. *Journal of Fish Biology*, *48*, 1139–1163. doi:https://doi.org/10.1111/j.1095-8649.1996.tb01811.x

Macchi, G. J., Pajaro, M., Wöhler, O. C., Acevedo, M. J., Centuriòn, R. L., & Urteaga, D. G. (2005). Batch fecundity and spawning frequency of southern blue whiting (*Micromesistius australis*) in the southwest Atlantic Ocean. *New Zealand Journal of Marine and Freshwater Research*, *39*, 993–1000. doi:https://doi.org/10.1080/00288330.2005.9517370

Mazlum, R. E., & Bilgin, S. (2014). Age, growth, reproduction and diet of the whiting, *Merlangius merlangus euxinus* (Nordmann, 1840), in the Southeastern Black Sea. *Cahiers de Biologie Marine*, *55*, 463–474. doi:https://doi.org/10.21411/CBM.A.4583868B

Mora, C., Myers, R. A., Coll, M., Libralato, S., Pitcher, T. J., et al. (2009). Management effectiveness of the world's marine fisheries. *PLoS Biology*, *7*(6). doi:https://doi.org/10.1371/journal.pbio.1000131

Murua, H., Kraus, G., Saborido-Rey, F., Witthames, P. R., & Thorsen, A. et al. (2003). Procedures to estimate fecundity of marine fish species in relation to their reproductive strategy. Journal of *Northwest Atlantic Fishery Science*, *33*, 33–54. doi:https://doi.org/10.2960/J.v33.a3.

Murua, H., & Motos, L. (2006). Reproductive strategy and spawning activity of the European hake *Merluccius merluccius* (L.) in the Bay of Biscay. *Journal of Fish Biology*, *69*, 1288–1303. doi:https://doi.org/10.1111/j.1095-8649.2006.01169.x

Murua, H., & Saborido-Rey, F. (2003). Female reproductive strategies of marine fish species of the North Atlantic. *Journal of Northwest Atlantic Fishery Science*, *33*, 23–31. doi:https://doi.org/10.2960/J.v33.a2

Myers, R. A., Hutchings, J. A., & Barrowman, N. J. (1997). Why do fish stocks collapse? The example of cod in Atlantic Canada. *Ecological Applications*, *7*, 91–106. doi:https://doi.org/10.1890/1051-0761(1997)007[0091:WDFSCT]2.0.CO;2

Nunes, C., Silva, A., Soares, E., & Ganias, K. (2011). The use of hepatic and somatic indices and histological information to characterize the reproductive dynamics of Atlantic sardine *Sardina pilchardus* from the Portuguese coast. *Marine and Coastal Fisheries*, *3*, 127–144. doi:https://doi.org/10.1080/19425120.2011.556911

Prodanov, K., Mikhaylov, K., Daskalov, G., Maxim, K., Chashchin, A., et al. (1997). Environmental management of fish resources in the Black Sea and their rational exploitation. *General Fisheries Council for the Mediterranean: Studies and Review*, *68*, 1–100. doi:https://doi.org/10.1007/978-94-011-5758-2_14

Rideout, R. M., Rose, G. A., & Burton, M. P. M. (2005). Skipped spawning in female iteroparous fishes. *Fish and Fisheries, 6*, 50–72. https://doi.org/10.1111/j.1467-2979.2005.00174.x

Rideout, R. M., & Tomkiewicz, J. (2011). Skipped spawning in fishes: More common than you might think. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*, *3*, 176–189. doi:https://doi.org/10.1080/19425120.2011.556943

Rogers, R., Rowe, S., Rideout, R. M., & Morgan, M. J. (2019). Fecundity of haddock (*Melanogrammus aeglefinus*) off southern Newfoundland. *Fisheries Research*, *220*, 1–6. doi:https://doi.org/10.1016/j.fishres.2019.105339

Saborido-Rey, F., & Junquera, S. (1998). Histological assessment of variations in sexual maturity of cod (*Gadus morhua* L.) at the Flemish Cap (north-west Atlantic). *ICES Journal of Marine Science*, *55*, 515–521. doi:https://doi.org/10.1006/jmsc.1997.0344

Sağlam, N. E., & Sağlam, C. (2012). Population parameters of whiting *(Merlangius merlangus euxinus* L., 1758) in the South-Eastern Black Sea. *Turkish Journal of Fisheries and Aquatic Sciences*, *12*, 831–839. doi:https://doi.org/10.4194/1303-2712-v12_4_11

Samsun, S. (2005). The research on some reproduction and feeding characteristics of the whiting (*Gadus merlangus euxinus*, Nordmann, 1840) (PhD thesis). Ondokuz Mayıs University, Samsun, Turkey. (in Turkish)

Somarakis, S., Ganias, K., Tserpes, G., & Koutsikopoulos, C. (2004). Ovarian allometry and the use of the gonosomatic index: A case study in the Mediterranean sardine, *Sardina pilchardus*. *Marine Biology, 146*, 181–189. doi:https://doi.org/10.1007/s00227-004-1419-2

Stahl, J. P., & Kruse, G. H. (2008). Classification of ovarian stages of walleye pollock (Theragra chalcogramma). *Resiliency of Gadid Stocks to Fishing and Climate Change; Alaska Sea Grant College Program AK-SG-08-01*, 1-20. doi:https://doi.org/10.4027/rgsfcc.2008.01

Tomkiewicz, J., Tybjerg, L., & Jespersen, A. (2003). Micro- and macroscopic characteristics to stage gonadal maturation of female Baltic cod. *Journal of Fish Biology*, *62*, 253–275. doi:https://doi.org/10.1046/j.1095-8649.2003.00001.x

Tsikliras, A. C., & Stergiou, K. I. (2013). Size at maturity of Mediterranean marine fishes. *Reviews in Fish Biology and Fisheries*, 24, 219–268. https://doi.org/10.1007/s11160-013-9330-x

TÜİK (2021). Turkish Statistical Institute, Data Portal for Statistics, Fishery Statistics [online]. Retrieved from https://biruni.tuik.gov.tr/medas/?kn=97&locale=tr [Accessed 10 December 2023].

Vitale, F., Svedang, H., & Cardinale, M. (2006). Histological analysis invalidates macroscopically determined maturity ogives of the Kattegat cod (*Gadus morhua*) and suggests new proxies for estimating maturity status of individual fish. *ICES Journal of Marine Science*, *63*, 485–492. doi:https://doi.org/10.1016/j.icesjms.2005.09.001

Yıldız, T., & Karakulak, F. S. (2019). Age, growth and mortality of whiting (*Merlangius merlangus* Linnaeus, 1758) from the Western Black Sea, Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, *19*, 793–804. doi:https://doi.org/10.4194/1303-2712-v19_9_08