

Research Article

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Reproduction of *Sardinella maderensis* (lowe, 1838), in Syrian Marine Waters (Eastern Mediterranean)



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Abstract

From October 2021 to September 2022, we collected 600 *Sardinella maderensis* specimens along the Syrian coast in Latakia, ranging from 9.5 cm to 26.5 cm in length and weighing between 6.3 g and 180.4 g. The focus was on studying *S.maderensis* reproductive characteristics as part of an ongoing comprehensive biological investigation. Females achieved first sexual maturity at 17 cm, males at 19 cm. Peak sexual maturity occurred in May for males (5.51) and in April for females (4.49). The study revealed an average absolute fertility of 36,031.07 and a relative fertility of 437.63, providing key insights into *S.maderensis* reproductive dynamics in the studied coastal region.

Keywords: Clupeidae; *Sardinella maderensis*; Syrian marine waters; Reproduction; Sexual maturity; Fertility

Introduction

Food security is a significant concern, with approximately 821 million people worldwide suffering from famine, malnutrition, and undernutrition [1]. As fish meat constitutes a crucial human food source, rich in easily digestible proteins and essential nutrients such as Iodine, Phosphorus, and Omega-3 Fatty acids [2], studying fish comprehensively is imperative.

Focusing on the Clupeidae fish family, it ranks first in global economic fish catches, contributing over 20% to the world's total fishery yield. Annually, more than a thousand tons of this family are caught in the Mediterranean Sea [1] underscoring its paramount importance. Sardine fish are widespread throughout the Mediterranean and hold high economic value [3,4]. Those caught in our regional waters fall under the list of economically significant marine species. Hence, studying their reproduction is crucial for understanding spawning times, determining length at first sexual maturity, aiding in the establishment of laws restricting their capture during spawning, and setting fishing net dimensions to preserve marine biological resources.

Methods and Materials

The research was conducted within the Post-Graduate Studies Laboratory at Tishreen University during the period from October

2021 to September 2022. A total of 600 *S.maderensis* specimens (291 males, 308 females, 1 hermaphrodite) were collected from the Syrian coast of Latakia Province Figure 1. The sampling was performed using artisanal fishermen's boats, employing Purse seine and Gillnets (14*14mm).

Upon transportation of the samples to the laboratory, morphometric measurements were taken, including weight to the nearest gram and length to the nearest cm. Subsequently, the fish were dissected, and organs such as liver, gonad, and digestive tube were removed. The following measurements were recorded.

Fish weight after all evisceration to the nearest 0.01 g to obtain the empty weight. Gonad weight to the nearest 0.01 g and determine the stage of sexual maturity with the naked eye. Then gonads were preserved in 10% formalin for a day to stabilize it, then a series of routine procedures were performed to treat it with paraffin wax and to obtain a permanent slide containing the tissue sections according to the reference [5].

Gonado Somatic Index (G.S.I), was calculated using the formula:

$$G.S.I = (Gonad Weight / Total Body Weight) * 100$$

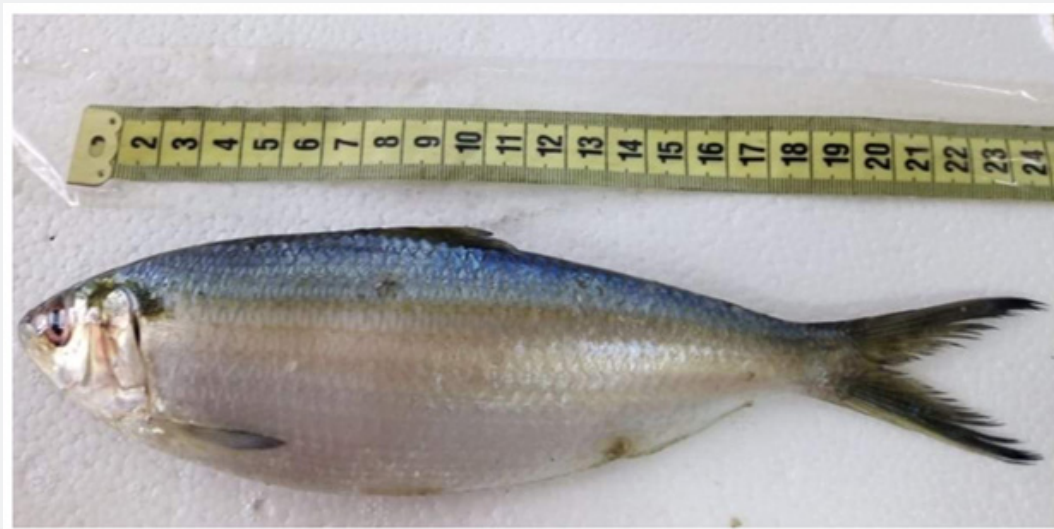


Figure 1: General view of *S. maderensis* caught on 10/19/2021, W:127.72 g and TL: 24 cm.

Oocyte count was conducted in the gonads of mature fish to calculate absolute and relative fecundity.

The following formulas were used for fecundity calculations, adapted from [6]:

$$Fa = Gw * D$$

Fa: Absolute fertility.

Gw: Ovary weight (g).

D: Number of eggs per gram of ovary weight.

$$Fr = Fa / W$$

Fr: Relative fertility per gram of body weight

Fa: Absolute fertility.

W: Total weight of the fish.

Results

Morphological and Histological development of the gonads in *Sardinella maderensis*

Over the course of a year, the study showed that the gonads went through five stages of maturity, and this was in accordance with the reference of [7], and the stages are the study conducted a thorough analysis of the gonadal development in *Sardinella maderensis* throughout an entire year, unveiling five discernible maturity stages. This categorization is consistent with the observations made by Balli et al. [7] and is outlined as follows:

Stage 1 (Immature):

a) Ovary and testicle approximately 1/3 of the body cavity length.

b) Transparent pinkish ovaries and white testicles.

c) Eggs not visible to the naked eye

d) The sex cells in the histological preparations of the ovary appear at the stage of egg-generating cells, characterized by a very small spherical shape, while the sex cells in the testis are represented by the sperm-generating cells, which appear in a spherical shape (Figure 2).

Stage 2 (Virginity and recovery):

a) Ovary and testis approximately 1/2 of the body cavity length.

b) Transparent pinkish ovaries and white testicles.

c) Eggs not visible to the naked eye.

d) In the ovaries, oocytes appear in the cytoplasmic stage of growth, which constitute most of the sex cells. These cells are large as a result of the increase in the size of the nucleus and cytoplasm.

e) The male reproductive cells in the testicle are represented by sperm generating cells that are in the process of division, and their division leads to an increase in their number and a decrease in their size (Figure 3).

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Stage 3 (maturation):

a) Ovary and testis approximately 2/3 of the body cavity length.

b) Ovaries appear yellow, pink with granular texture and testicles are plump and white.

c) Eggs are not visible to the naked eye.

d) Oocytes appear histologically in the trophic cytoplasmic stage of growth and begin to accumulate nutrients in the form of yolk granules and fat droplets. They enlarge in size and become

bright orange in color as a result of the presence of yolk.

e) In the testis, the seminiferous tubules are filled with cysts containing sperm cells (Figure 4).

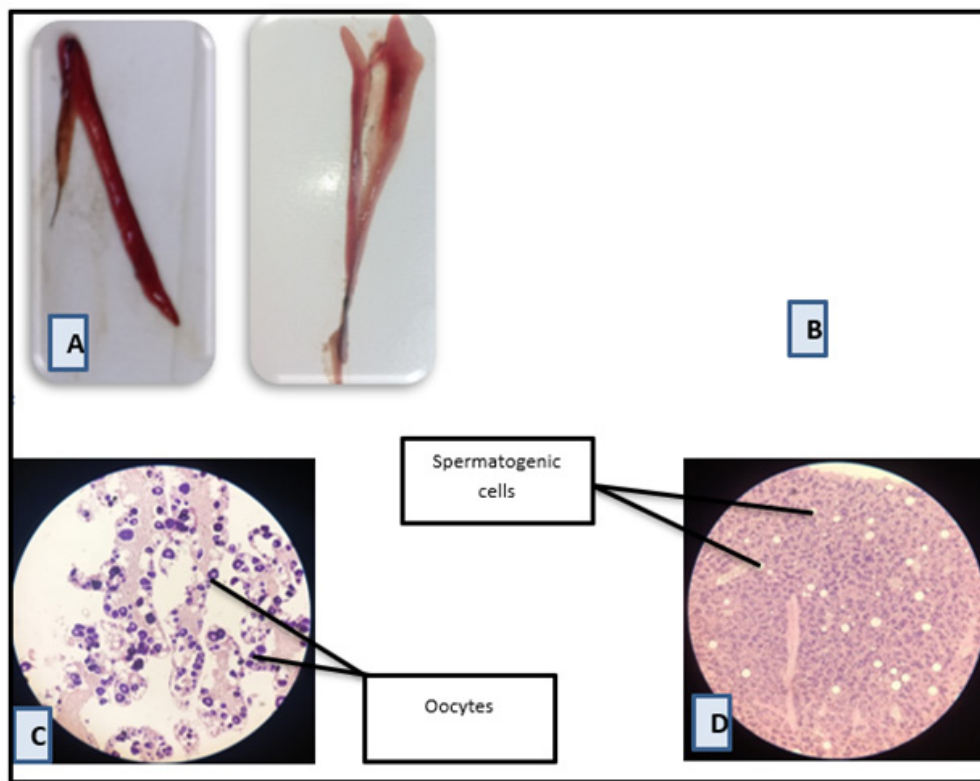


Figure 2: *S. maderensis* gonads in the first stage of maturity

A: *S. maderensis* ovary in the first maturity stage, weighing 70.09g and length 19.5cm, ovary weight 0.4g.

B: Testicle of the first stage of maturity, *S. maderensis*, weighing 61.27 g and length 18 cm. Testicle weight 0.3 g

C: Cross-section of an ovary at the first maturation stage showing oogenesis cells and primary oocytes, 10x magnification.

D: Cross-section of a testis at the first maturation stage showing spermatogenic cells at 10x magnification

Stage 4 (Spawning):

a) Ovary and testis approximately 2/3 of the body cavity length

b) Orange-pink ovaries with visible surface blood vessels and Creamy white, soft testicles.

c) It is noted in the ovaries that there are burst follicles from which the eggs were released, and which will subsequently be decomposed.

d) It is observed in the testicles that semen is formed, which carries sperm (Figure 5).

Stage 5 (Adulthood after Maturation and Ovulation):

a) Ovary and testis approximately 2/3 of the body cavity length

b) Orange-pink ovaries with visible surface blood vessels and Creamy white, soft testicles due to bleeding caused by the explosion of egg sacs.

c) Flaccid testes.

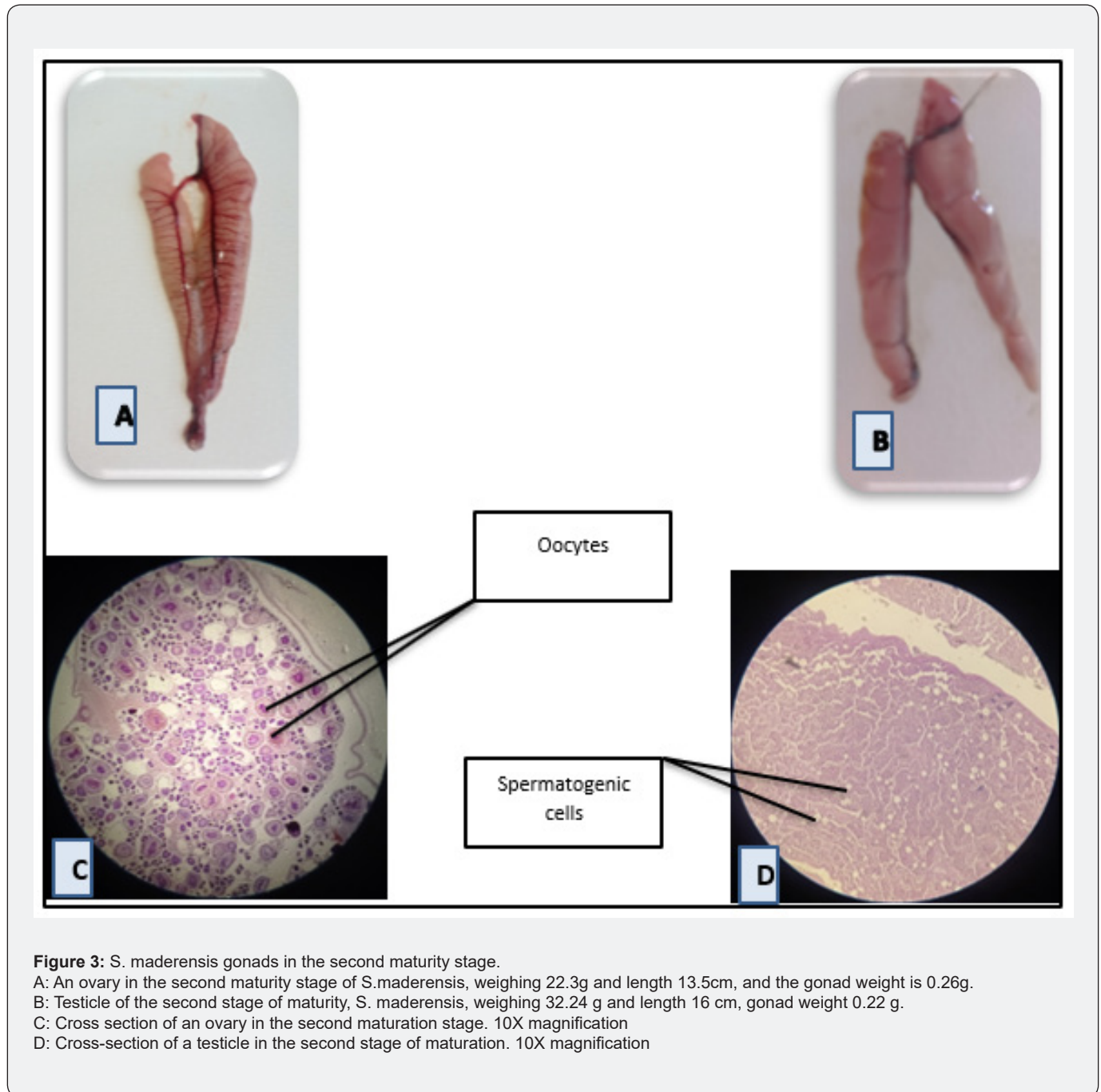
d) Histological sections show the presence of few eggs or simple remains of sperm, and the empty sacs and egg remains are subjected to a process of decomposition (Figure 6).

Fertility

This fecundity was determined for fish with weights ranging between 67.49 g and 93.57 g, with an average of (81.38±11.06) g, while the standard lengths ranging between (17 and 24.5) cm, with an average of (22.85±1.27) cm. The total Fertility of maturity females was calculated (40 individuals in the fourth stage) reaching 36,031.07 eggs (Table 1).

Table 1: Estimated fertility of *S. maderensis* females during the research period 2021-2022.

Absolute fertility	Relative fertility	Ovary weight/g	Maximum height	Standard length/cm	Total weight of female/g	Number of adult females	Months
44261.435	578.399661	5.26±3	4.05±0.77	21.4±3.03	85.61±45.18	14	April
45058.26	486.9029346	3.57±0.75	4.82±1.85	22.7±1.3	93.570±11.55	14	May
39676.84875	473.6085268	2.65±1.1	5.51±0.47	22.8±2.7	78.68±14.05	8	June
15127.7225	211.5979896	1.77±0.52	4.28±0.38	24.5±0.75	67.49±25.91	4	July
36031.06656	437.627278	3.313±1.5	4.67±0.65	22.85±1.27	81.38±11.06	-	Average



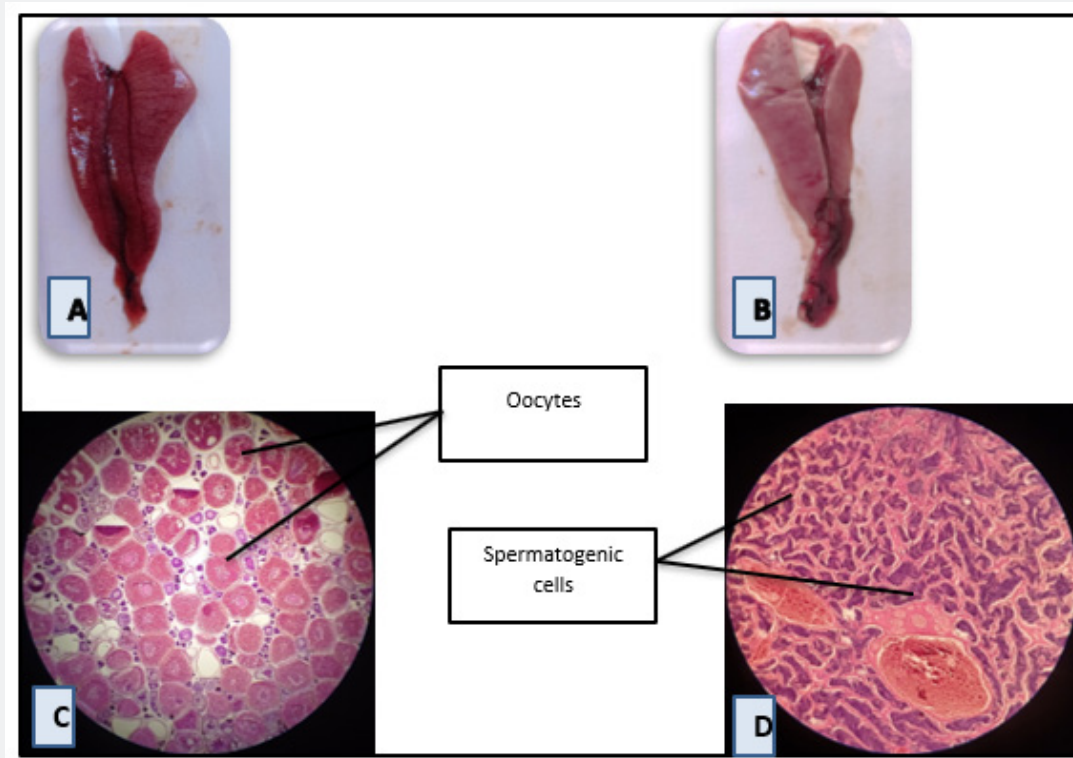


Figure 4: *S. maderensis* gonads in the third stage of maturity.

- A: An ovary in the third stage of maturity, *S. maderensis*, weighing 36.64 g and length 17 cm. The reproductive weight is 2.07 g.
 B: Testicle of the third stage of maturity, *S. maderensis*, weighing 78.05 g and length 20.5 cm, gonad weight 2.8 g.
 C: Cross-section of an ovary in the third maturation stage. 10X magnification

Monthly variations in Gonado Somatic Index (GSI%):

Through figure 7, it is observed that the GSI% curve for females showed a single peak that corresponding to ovarian growth, maturation, and subsequent egg release. The highest peak was recorded in May (2.1 ± 4.49), coinciding with the appearance of ovaries in the fourth stage of maturity. Conversely, the lowest point was observed in September (0.006 ± 0.04), indicating that the majority of ovaries were in the second maturation stage post-spawning, following the fifth stage.

Likewise, in males, figure 8 showed that the GSI% curve for males showed a single peak, corresponding to the growth and maturation of the testes, with the highest peak recorded in April (5.51 ± 2.93). This coincided with the appearance of testes in the fourth stage of maturity. The lowest record was observed in September (0.007 ± 0.05), indicating that the majority of testes were in the second maturation stage, following the fifth stage.

Discussion

Throughout the study, the sexual maturity index exhibited a single peak during the summer months, coinciding with the

spawning season. Males reach first sexual maturity in April (5.51), while females reach peak sexual maturity in May (4.49). Female *S. maderensis* attain first sexual maturity at a length of 17 cm, while males reach it at 19 cm, with an average absolute fertility of 36031.07 and relative fertility of 437.3.

In contrast, in Cameroon, females reach first sexual maturity at a length of 19.10 and males at 17.43. The peak values of GSI% observed in January, April, and May, which are the peak spawning months [8]. While GSI% values ranged from 0.11 to 2.6 in males and 0.19 to 3.4 in females. The spawning period spans from April to September, with lengths at first maturity being 15.5 cm for males and 16.7 cm for females [9]. In Morocco, the peak spawning occurs between November and December, with a second peak in July. Females reach first sexual maturity at a length of 20.75 cm and males at 21.76 cm [7].

Conclusion

Sardinella maderensis reproduce in the summer months from April to July. Females achieved first sexual maturity at 17 cm, males at 19 cm. Average maximum height (0.65 ± 4.67) Peak sexual maturity occurred in May for males (5.51) and in April for

females (4.49). The study revealed an average absolute fertility rate of 36,031.07 and a relative fertility rate of 437.63. It is not preferable to catch sardines during the summer months, and it is

also preferable to use fishing nets whose opening diameters are not less than 4 cm.

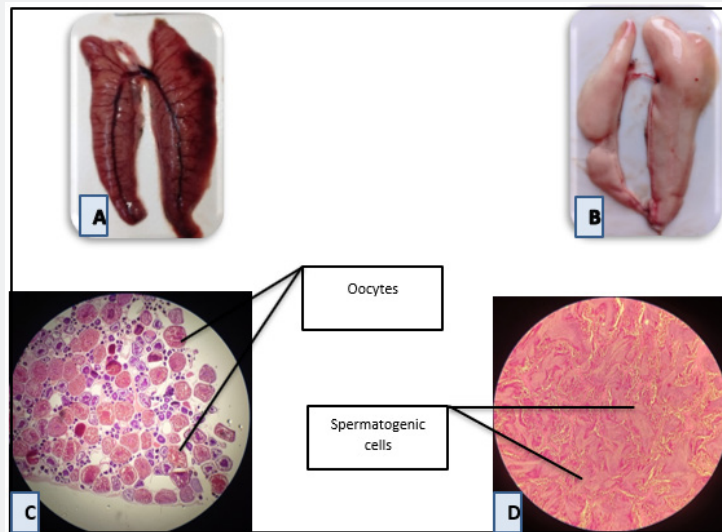


Figure 5: *S. maderensis* gonads in the fourth stage of maturity.

A: An ovary in the fourth maturity stage of *S. maderensis*, weighing 105.64 g and length 22.5 cm. The reproductive weight is 13.04 g.

B: Testicle of the fourth stage of maturity, *S. maderensis*, weighing 113.6 g and length 23.5 cm, gonad weight 5.3 g.

C: Cross section of an ovary at the fourth stage of maturity. 10X magnification.

D: Cross-section of a testicle at the fourth stage of maturity. 10X magnification.

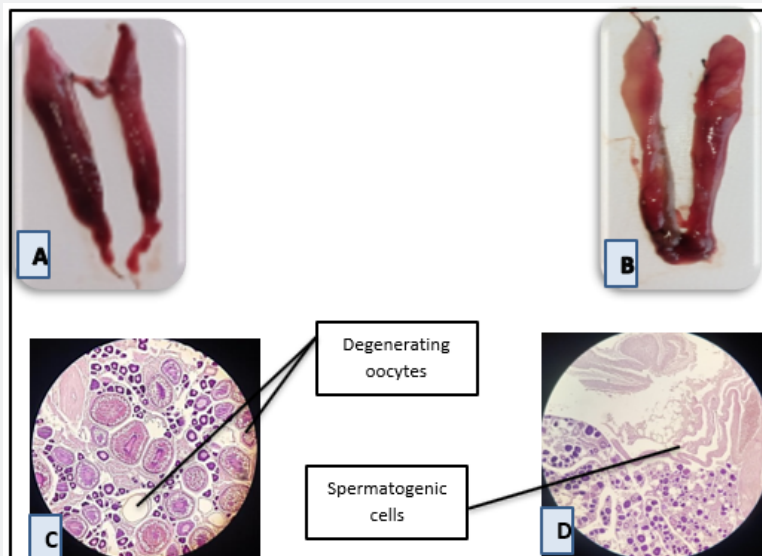


Figure 6: *S. maderensis* gonads in the fifth stage of maturity.

A: An ovary in the fifth stage of maturity, *S. maderensis*, weighing 65.64 g and length 24 cm, and the gonad weight is 1.9 g.

B: Testicle of the fifth stage of maturity, *S. maderensis*, weighing 70.6 and length 24.5 cm, gonad weight 1.8 g.

C: Cross-section of an ovary at the fifth stage of maturity. 10X magnification

D: Cross-section of a testis at the fifth stage of maturity. 10X magnification

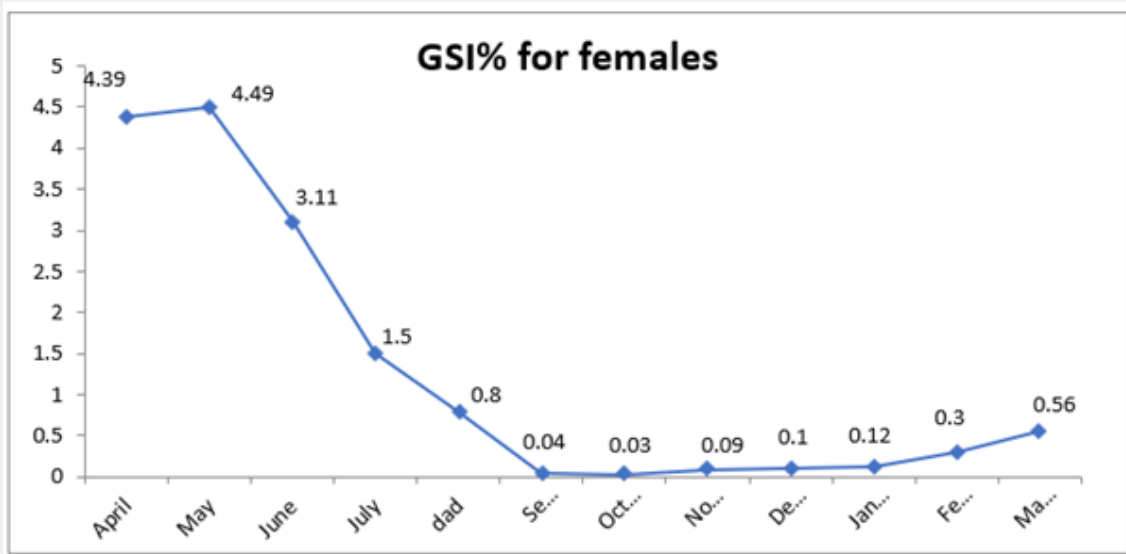


Figure 7: Monthly variations in GSI% values in S. maderensis females on the Syrian coast during the research period 2021-2022.

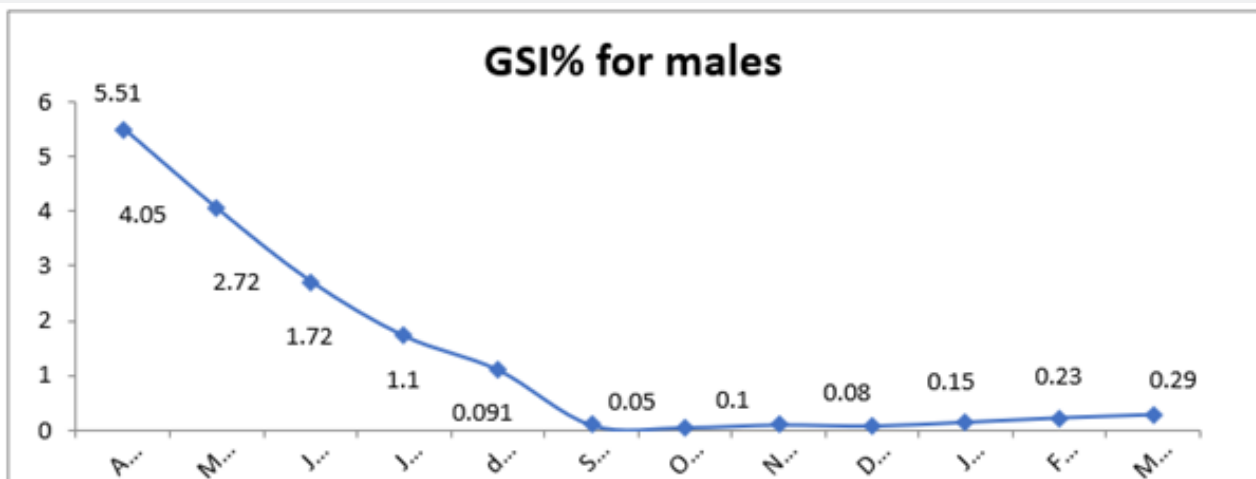


Figure 8: Monthly variations in GSI% values among males of S. maderensis on the Syrian coast during the research period 2021-2022.

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