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RESEARCH ARTICLE **BIOLOGY**

Comparative Study on the Reproductive Biology of *Mullus surmuletus* (Linnaeus, 1758) and *Mullus barbatus* (Linnaeus, 1758) along the Benghazi Coast, Eastern Libya (Mediterranean Sea)

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ABSTRACT

The purpose of this study was to examine the reproductive biology differences between *Mullus barbatus* and *Mullus surmuletus* along the coast of Benghazi, Eastern Libya (Mediterranean Sea). Sex ratio, gonadosomatic index (GSI), length at first sexual maturity and fecundity were among the important factors analyzed, along with comparisons to earlier research. From January to December 2022, samples were taken monthly from commercial trawl catches. The overall sex ratio was male-biased in both species (1:1.39 in *M. surmuletus* and 1:1.23 in *M. barbatus*). Males and females of *M. surmuletus* and *M. barbatus* were 12.9 cm and 13.2 cm, respectively, at 50% maturity. According to GSI values, *M. barbatus* spawned from late winter to early summer, while *M. surmuletus* spawned primarily in the spring. Despite interspecific variations, fecundity estimates in both species had a positive correlation with fish size. These results shed light on the reproductive tactics of two demersal species that are significant to the region's economy and show how environmental factors, such as climate change, may affect these species' ability to reproduce.

دراسة الاختلافات في بيولوجية التكاثر لسمكة التريليا الرملية وسمكة التريليا الصخرية في ساحل بنغازى – البحر المتوسط – شرق ليبيا

عزالنصر عاشور فرج أبزيو[*1]

الكلمات المفتاحية
بيولوجيا التكاثر
سمكة التريليا الرملية
سمكة التريليا الصخرية
الساحل الشرقي لليبيا على البحر المتوسط

الملخص

الهدف من هذه الدراسة هو تحديد الاختلافات في بيولوجيا التكاثر بين التريليا الرملية *Mullus barbatus* و التريليا الصخرية *Mullus surmuletus* على طول ساحل بنغازي، شرق ليبيا (البحر الأبيض المتوسط). كان الشق الجنسي، ومعامل الدليل المنسلي (GSI)، والطول عند بلوغ النضج الجنسي الأول، والخصوبة من بين العوامل المهمة التي تم تحليلها، إلى جانب مقارنتها بالبحوث السابقة. تم أخذ عينات شهريًا من يناير إلى ديسمبر 2022، بواسطة شباك الجر ، كان اجمالي الشق الجنسي يميل إلى الذكور في كلا النوعين (1:1.38 في التريليا الصخرية و 1:1.22 في التريليا الرملية). بلغ طول الذكور والإناث من التريليا الصخرية حوالي 12.9 سم والتريليا الرملية بحوالي 13.2 سم على التوالي عند بلوغ 50٪ من النضج. وفقًا لقيم معامل الدليل المنسلي (GSI) تتكاثر التريليا الرملية من أواخر الشتاء إلى أوائل الصيف، بينما تكاثرت التريليا الصخرية بشكل أساسي في الربيع. على الرغم من الاختلافات بين الأنواع، كانت تقديرات الخصوبة في كلا النوعين مرتبطة ارتباطًا إيجابيًا بحجم الأسماك. تسلط هذه النتائج الضوء على المقارنة التكاثرية لنوعين من الأسماك القاعية التي تعتبر مهمة بالاقتصاد في الساحل الليبي، وتوضح كيف يمكن أن تؤثر العوامل البيئية، مثل تغير المناخ، على قدرة هذه الأنواع على التكاثر.

Introduction

The study of reproduction of fishes is an important item in fish biology; so far, it has its practical importance in solving some fishery management questions such as the determination of spawning stock. The availability data based on reproductive parameters and environmental variation lead to a better understanding of observed fluctuation in reproductive output and enhances our ability to estimate recruitment [1,2]. Family: Mullidae (Goatfish) is one of the most valuable and highly priced fish families in Libya that are mainly exploited by trawl fishery since it shares with about 13% of the total trawl landings in the Libyan Mediterranean water [3,4]. Of the six genera belonging to the family Mullidae, four are recorded in the Mediterranean Sea: Mullus, Upeneus, Pseudupeneus, and, more recently, Parupeneus [5]. Among them, the two dominant species, Mullus surmuletus and Mullus barbatus, represent key targets of the Libyan Mediterranean demersal fisheries [3].Of the six genera belonging to the family Mullidae, four are recorded in the Mediterranean Sea: Mullus, Upeneus, Pseudupeneus, and, more recently, Parupeneus [5]. Among them, the two dominant species, *Mullus surmuletus* and *Mullus barbatus*, represent key targets of the Libyan Mediterranean demersal fisheries [3].The striped red mullet *Mullus surmuletus* (Linnaeus ,1758) is a commercially important species of goatfish found in the Mediterranean Sea, eastern North

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Atlantic Ocean, and the Black Sea. They can be found on sand bottom and in water as shallow as 5 meters (16 ft) or as deep as 409 meters (1, is 342 ft). This species can reach a length of 40 centimeters (16 in) SL though most are only around 25 centimeters (9.8 in) [6]. The greatest recorded total length 33.6 cm n 398.3 g in total was captured with trammel nets along the coast of Benghazi, Libya (Southern Mediterranean) on November 14, 2022 [7]. The target species feed on benthic organisms such as shrimps and amphipods, polychaetes, mollusks, and benthic fishes. Spawning occurs from May to July, eggs and larvae are pelagic [8,9]. Red mullet *Mullus barbatus* (Linnaeus, 1758) is a species of goatfish found in the Mediterranean Sea, Sea of Marmara, the Black Sea and the eastern North Atlantic Ocean, where its range extends from Scandinavia to Senegal [6]. They are fished, mostly by trawling, with the flesh being well regarded. It is a demersal fish and occurs at depths ranging from 10 to 328 m (30 to 1,080 ft) over muddy, sandy or rocky and gravel bottoms. The red mullet is carnivorous, the diet consisting mainly of polychaete worms, bivalve mollusks and crustaceans [10]. The barbells are sensory organs and are used to help locate prey. Spawning occurs from in April and May [11]. The stomach contents of *Mullus surmuletus* and *Mullus barbatus* in Libyan waters indicated a constant occurrence of shrimp and decapods in both species. However**,** *M. surmuletus* exhibited a broader prey spectrum, also consistently containing amphipods and polychaetes [4]. There were some studies on its sexual cycle and reproduction [12-17]. InTurkish waters, there were few studies on Mullus spp. that referred to some aspects of its biology [18-22]. In the Egyptian Mediterranean waters, the only previous study concerning the biology of *M. surmuletus* and *M. barbatus* was that of [23-25].who studied growth, mortality and spawning stock biomass of Mullus spp. in the Egyptian Mediterranean waters. However, these two species did not have the same interest in the Libyan Mediterranean, since we couldn't find any article dealing with the reproductive biology of *M. surmuletus* or *M. barbatus* from the Libyan Mediterranean water [4,9]. In order to assess the commercial potential of *M. surmuletus* and M. barbatus stocks in the Benghazi coast, Mediterranean Sea, Eastern Libya, the current study intends to assess the spawning period, length at first sexual maturity, and fecundity—all of which are significant biological parameters..

Materials and Methods

Samples were collected on board fishing trawlers from Benghazi coast eastern Libyan, Mediterranean Sea throughout the period of January to December 2022 (Fig. 1). A total of 450 specimens of *M. surmuletus* and 411 *M. barbatus* were examined.

Total length (TL) was recorded to the nearest cm, and total weight to the nearest g.

Sex ratio

Sex ratio was determined as the monthly percentage of males to females (M: F). Chi-Square test at (0.05) significance level was used to find if the sex ratio is significantly different from 1:1.

Gonado- somatic index (GSI)

Gonado-somatic index (GSI) was determined described by a formula by [26] as follow:

GSI = 100 × G/W

Where, (G) is the gonad weight and (W) is the body weight.

Length at first sexual maturity(L50)

The length at which 50% of Mullus surmuletus and M. barbatus reach their sexual maturity was estimated by fitting the percentage maturity against mid lengths [27].

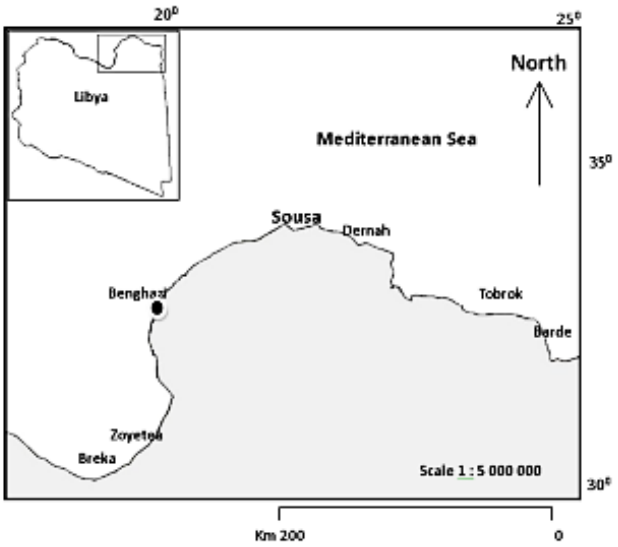

Figure 1: Map showing the collection site, Benghazi coast in the eastern Libyan Mediterranean coast

Fecundity

About 51 specimens of *M. surmuletus* and 41 of *M. barbatus* were carefully removed during the breeding season. Ovaries were washed , weighed to the nearest 0.01 gm. and then preserved in 4 % formalin. Three sub-samples from each ovary were taken and weighed to the nearest 0.01g. Each sub-sample was placed in a Petri-dish containing a drop of distilled water and eggs were counted under a binocular microscope (X16). The absolute fecundity were calculated according [28] as follow:

Absolute Fecundity = No. of eggs in sub sample × Gonad weight/ Weight of sub sample.

Results and Discussion

Sex ratio

Of the 450 sexed *M. surmuletus* specimens, the number of males was 189 representing 42.0% of the total number, while the number of females was 261 representing 58.0% of the total number, with sex ratio of (1males: 1.38 females. Monthly variations of sex ratio of *M. surmuletus* collected from Benghazi coast during the period from January to December 2022 showed that females were higher in numbers than males throughout the whole period of study showed the overall sex ratio 1:1.38 (Table 1). This result agreed well with [10].who mentioned that the female of *M. surmuletus* predominated the samples. In the present study, the highest percentage of females (60.0%) was observed in February, (68.2%) in April, (61.8%) in May, (64.1%) in June and (60.7%) in August. Therefore in the present study females were dominant in all length intervals and in all months. These results good agreed with findings of [27] in Algeria and [4] in Egypt. The value of Chi-Square showed highly significant difference between both sexes. ($F = 33.050$; $P < 0.05$).

This result agreed well with [29]. who mentioned that the female of *M. barbatus* predominated the samples. The dominance of red mullet males was reported in some studies [30] ,[31]. but females were generally dominant in the most studies. Because the sex ratio varies from place to place and occasionally within the same area due to a variety of factors like reproduction, food availability, and environmental conditions, this is acceptable [32,33].

Table 1: Monthly variations in sex ratio of M. *surmuletus* Benghazi coast, eastern Libya during the period from January till December 2022

		Males		Females		
Months	**No. of fish**	**No.**	**%**	**No.**	**%**	**Sex ratio**
January (2022)	**39**	17	43.6	22	56.4	**1 : 1.29**
February	**40**	16	40.0	24	60.0	**1 : 1.50**
March	**34**	17	50.0	17	50.0	**1 :1.00**
April	**44**	14	31.8	30	68.2	**1 : 2.14**
May	**34**	13	38.2	21	61.8	**1 : 1.62**
June	**39**	14	35.9	25	64.1	**1 : 1.79**
July	**48**	22	45.8	26	54.2	**1 : 1.18**
August	**28**	11	39.3	17	60.7	**1 : 1.55**
September	**33**	14	42.4	19	57.6	**1 : 1.36**
October	**53**	23	43.4	30	56.6	**1 : 1.30**
November	**25**	12	48.0	13	52.0	**1 : 1.08**
December	**33**	15	45.5	18	54.5	**1 : 1.20**
Total	**450**	**188**	41.8	**262**	58.2	**1 : 1.39**

Significance (F = 33.05 – P<0.05)

Table 2: Monthly variations in sex ratio of *M. barbatus* Benghazi coast, eastern Libya during the period from January till December 2022

		Males		Females		
Months	**No. of fish**	**No.**	**%**	**No.**	**%**	**Sex ratio**
January (2022)	**41**	18	43.9	23	56.1	**1 : 1.28**
February	**35**	16	45.7	19	54.3	**1 : 1.19**
March	**32**	14	43.8	18	56.2	**1 :1.28**
April	**38**	16	42.1	22	57.9	**1 : 1.38**
May	**33**	16	48.5	17	51.5	**1 : 1.06**
June	**32**	15	46.9	17	53.1	**1 : 1.13**
July	**32**	14	43.8	18	56.3	**1 : 1.29**
August	**22**	10	45.5	12	54.5	**1 : 1.20**
September	**35**	16	45.7	19	54.3	**1 : 1.19**
October	**53**	25	47.2	28	52.8	**1 : 1.12**
November	**25**	12	48.0	13	52.0	**1 : 1.08**
December	**33**	13	39.4	20	60.6	**1 : 1.54**
Total	**411**	**185**	45.0	**226**	55.0	**1 : 1.23**

Significance (F = 34.05 – P<0.05)

Length at first sexual maturity (L50)

The length at first sexual maturity L50 is very an important parameter in fisheries research to determine the optimum mesh size and minimum legal size that may be needed to maintain the suitable spawning stock and to ensure at least one spawning for the mature individuals. As shown in (Figure 2&3), both males and females of *M. surmuletus* attained their first sexual maturity at length group (12.5 – 13.4 cm) by 50.9% and 44.9% for both males and females respectively. The length at 50% mature was estimated to be 12.9 cm for males, 13.2 cm for females *M. surmuletus*. The estimation of length at first sexual maturity showed some variation from the other studies, but the age at first maturity attained at first year for both sexes. These results are similar with the previous studies [13-15, 21, 23, 34] reported that the L50 of males and females was 13 cm and 15 cm, respectively in the Egyptian Mediterranean water, corresponding to the first and second year of life. He mentioned that the smallest ripe male was of length 11-12 cm TL, while the smallest female was 13-14 cm TL. [13] found that the length at first maturity for *M. surmuletus* was 13.8 cm for females and 12.6 cm length for males in Tunis coast, while [8] reported the mean length at first maturity in males (TL=18 cm) and females (TL=16cm) in France [38] found that the mean length of females and males at first maturity was 15.0 cm TL in Mallorca. However, [39] estimated length for first sexual maturity for *M. surmuletus* as 13.5 cm.

As shown in (Figure 4&5), both males and females of M. barbatus attained their first sexual maturity at length group (12.5 – 13.4 cm) by 50.8% and 47.8% both males and females respectively. The length at 50% mature was estimated to be 11.9 cm for males, 12.5 cm for females *M. barbatus*. These results are similar with the previous studies [10,36,37]. they indicated that the length at first maturity is between 10.3 cm to 13.5 cm.

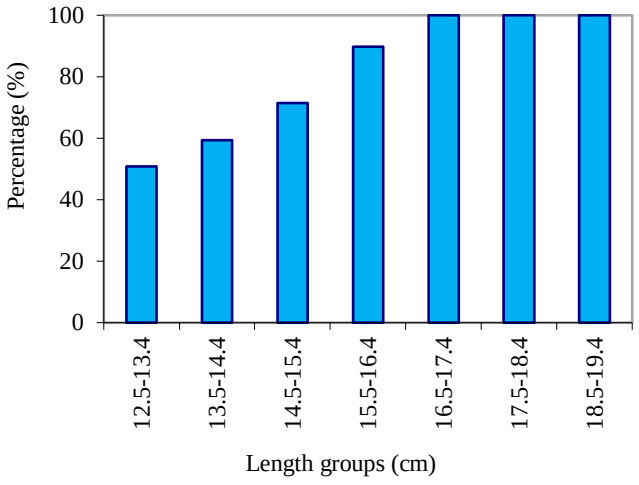

Figure 2: Length at first sexual maturity of males M. surmulatus from Benghazi coast, eastern Libya during the period from January till December 2022

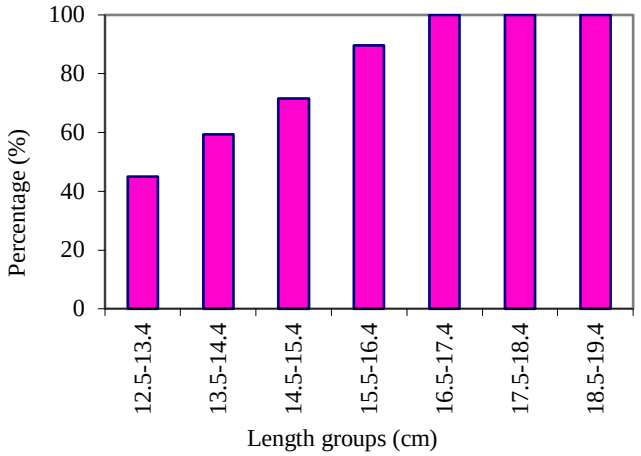

Figure 3: Length at first sexual maturity of females M. surmulatus from Benghazi coast, eastern Libya during the period from January till December 2022

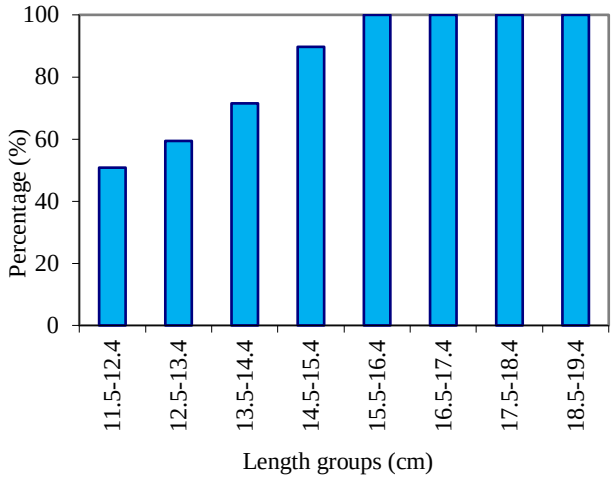

Figure 4: Length at first sexual maturity of males M. barbatus from Benghazi coast, eastern Libya during the period from January till December 2022

Gonado-somatic index (GSI)

In M. surmulatus, The GSI reached its peak value in March (5.98 and 7.89), in April (6.12 and 8.12) and May (6.10 and 8.13) for male and female respectively thus, the spawning season occurred in spring. Afterward the GSI decreased reaching its minimum value in November for males (1.00) and (2.00) for females (Fig. 6). [38]. distinguished four phases in *M. surmuletus*, which are successive and definite in sexual cycle; these are; phase one which is slow maturation, phase two, repaid maturation, phase three, spawning and phase four, the rest stage. The variations in GSI can clarify these different phases. The phase of slow growth usually lies in autumn and early winter. Rapid growth is in January to March, while spawning time starts by the end of March to the end of May, finally, the rest phase, starts after spawning.

In *M. barbatus*, the GSI recorded the value in March (3.08 and 5.88) for males and females respectively, then increased to the highest values in June (5.08 and 7.09) for males and females thus, the spawning season occurred in spring and the beginning summer. Afterward the GSI decreased reaching its minimum value in December for males (0.87) and (1.47) for females (Fig. 7). These results are similar with the previous studies [29,37] .Who decided this species breeds once a year from March to July for males and from February to June for females.

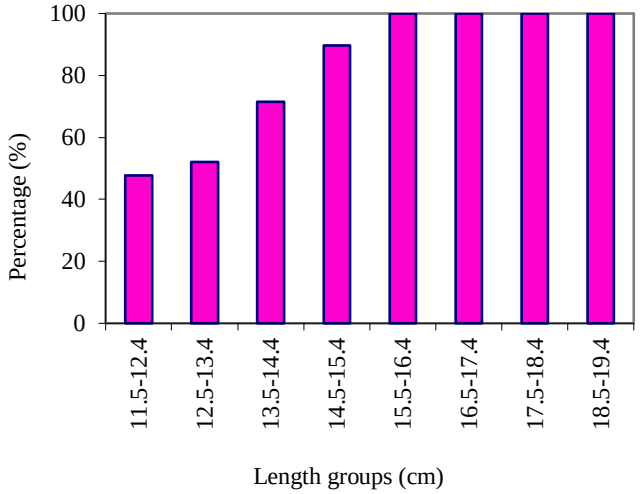

Figure 5: Length at first sexual maturity of females *M. barbatus* from Benghazi coast, eastern Libya during the period from January till December 2022

Fecundity

The knowledge of the fecundity of fishes is very important in fisheries, population dynamic and food availability items. In the present study, fecundity estimation and counting of the more advanced groups of eggs was based on the ripe eggs. Specimens were taken for fecundity estimation during the spawning season.

For estimation of the absolute fecundity of *M. surmuletus*, 68 ripe females with total length ranged between 12.9-19.4 cm. were examined. The ripe females were grouped into size classes according to their total range with 0.9 cm, interval. Fecundity increased as the fish grow in length (Table 3). The mean absolute fecundity ranged between 19476 to 98760 egg/fish for fish length range of 12.5-19.4 cm. with average 47211±6117. This result is almost identical to that of [23]. Who reported that the average absolute fecundity was 49980±11209, and [25]. Who estimated that the absolute fecundity for fish ranging in length from 13-20.9 cm was 18640 to 83448.

The absolute fecundity of *M. barbatus*, 59 ripe females with total length ranged between 12.9-19.4 cm, were examined. The ripe females were grouped into size classes according to their total range with 0.9 cm, interval. Fecundity increased as the fish grow in length (Table 4). The mean absolute fecundity ranged between 18476 to 78764 egg/fish for fish length range of 12.5-19.4 cm. with average 41117±7689. This result nearly similar well with [29,37].

CONCLUSION

This study is the first attempt to present comprehensive data on the reproductive biology of *Mullus barbatus* and *Mullus surmuletus* along the Eastern Libyan coast of Benghazi (Mediterranean Sea). Important metrics that provide crucial baseline information for reproduction and stock evaluation were analyzed, including fecundity, length at first sexual maturity, gonadosomatic index, and sex ratio. Fecundity information is especially helpful for predicting recruitment trends and times. Despite differences in sex ratio, size at first maturity, and absolute fecundity, the results show no significant differences in the two species' overall reproductive biology. However, it was discovered that both

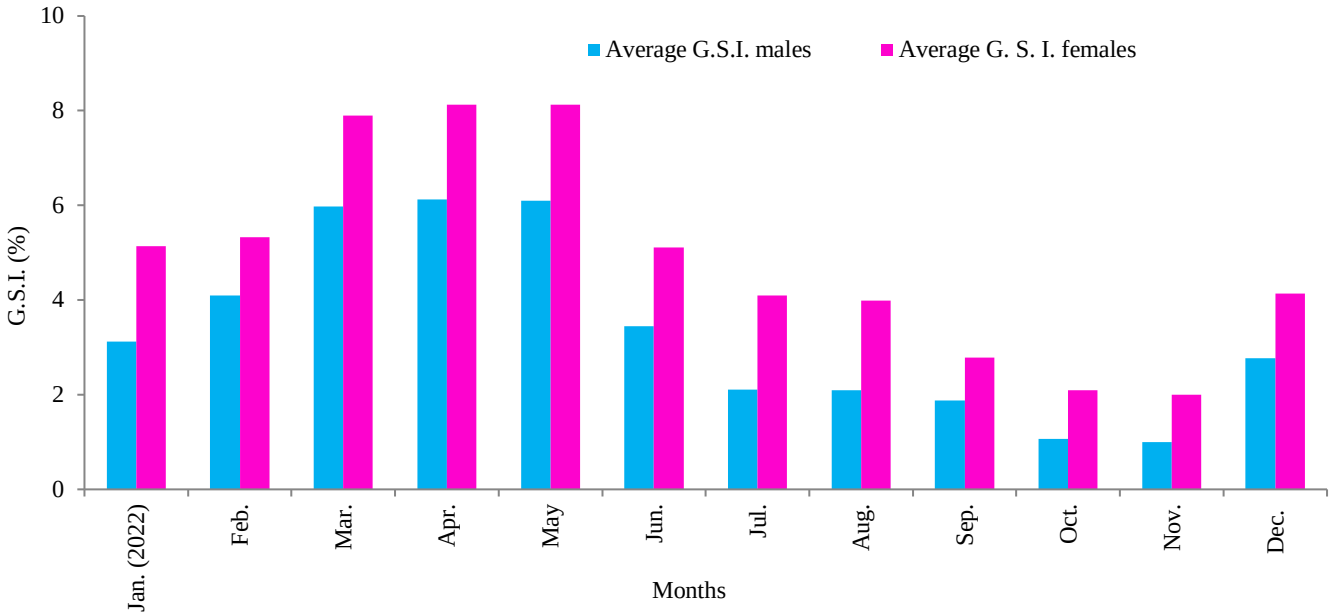

Figure 6: Monthly variation of gonado-somatic index of males and females M. surmulatus from Benghazi coast, eastern Libya during the period from January till December 2022

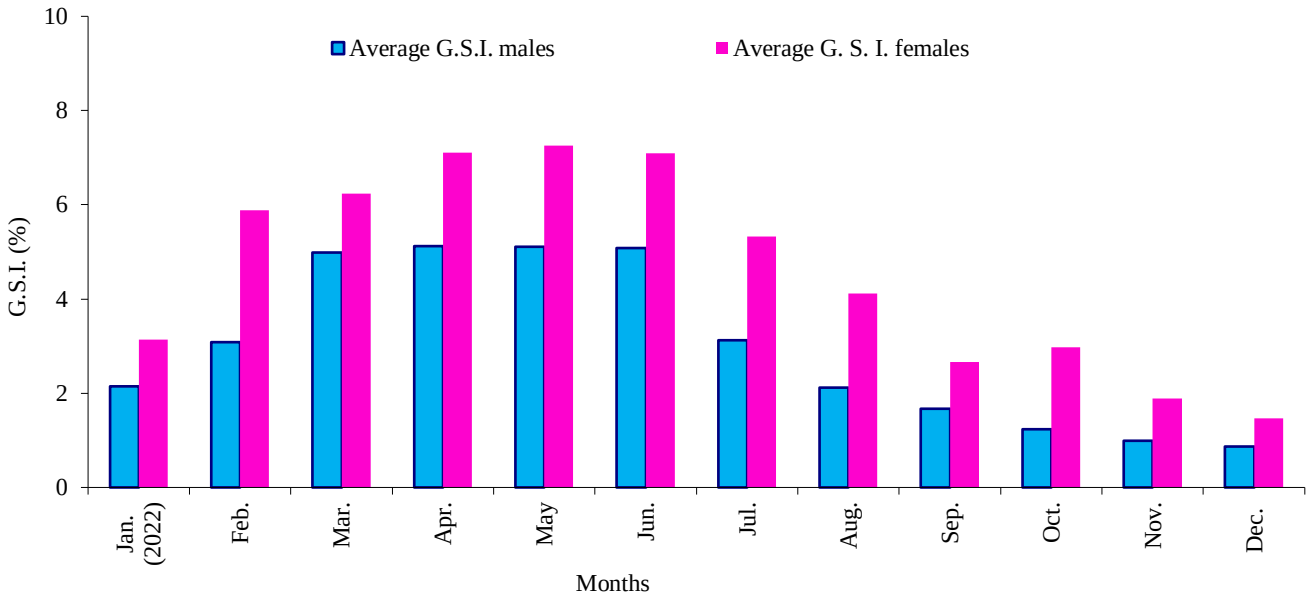

Figure 7: Monthly variation of gonado-somatic index of males and females M. barabatus from Benghazi coast, eastern Libya during the period from January till December 2022

Table 3: Relation between fecundity and total body length (cm) of females M. surmulatus from Benghazi coast, eastern Libya during the period from January till December 2022

Total length (cm)			**Absolute Fecundity**		
Range	**Average**	**No.**	**Minimum**	**Maximum**	**Average**
12.5-13.4	13.2	7	19476	22657	21067 ± 2232
13.5-14.4	13.9	11	20333	23412	21873 ±2135
14.5-15.4	15.1	10	22.98	34254	17139 ±4365
15.5-16.4	15.8	14	47897	55378	51638 ±5434
16.5-17.4	16.9	9	54689	65478	60084 ±6432
17.5-18.4	17.9	8	62342	77564	69953 ±10987
18.5-19.4	19.1	9	78690	98760	88725 ±11234
		68			**47211±6117**

Table 4: Relation between fecundity and total body length (cm) of females *M. barbatus* from Benghazi coast, eastern Libya during the period from January till December 2022

Total length (cm)			Absolute Fecundity		
Range	**Average**	**No.**	**Minimum**	**Maximum**	**Average**
12.5-13.4	12.7	9	18476	20657	21567±3267
13.5-14.4	13.9	9	19333	21412	20373±4378
14.5-15.4	14.9	6	20098	35255	27677±6117
15.5-16.4	15.9	12	37898	56373	47136±6589
16.5-17.4	16.8	8	44679	66578	55629±8790
17.5-18.4	17.9	7	52343	69564	60954±10987
18.5-19.4	19.1	8	68697	78764	73731±11119
		59			**41117±7689**

species' spawning seasons, which mostly take place in the spring and early summer, closely overlapped.

To guarantee that individuals reproduce at least once prior to capture, a minimum landing size that matches the length at first sexual maturity should be established.

Implementing **seasonal closures** during the peak spawning period (spring–early summer) to protect breeding stocks.

Monitoring **catch composition** regularly to detect shifts in sex ratio and maturity patterns that may indicate overfishing or environmental stress.

Encouraging **long-term reproductive studies** to track potential impacts of climate change and environmental variability on these demersal stocks.

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