GSC Advanced Research and Reviews
eISSN: 2582-4597 CODEN (USA): GARRC2
Cross Ref DOI: 10.30574/gscarr
Journal homepage: https://gsconlinepress.com/journals/gscarr/

(RESEARCH ARTICLE)

Check for updates

Some biological aspects of *Penaeus semisulcatus* (Decapoda, Penaeidae) in the Iraqi marine waters

Abdul-Razak Mahmood Mohamed [1, *], Khelud Abd Ali Hassan [2] and Jassim Muhsan Abed [1]

[1] *Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah, Iraq.*
[2] *Department of Marine Vertebrates, Marine Science Centre, University of Basrah, Iraq.*

GSC Advanced Research and Reviews, 2025, 22(03), 103-115

Publication history: Received on 12 January 2025; revised on 01 March 2025; accepted on 03 March 2025

Article DOI: https://doi.org/10.30574/gscarr.2025.22.3.0059

Abstract

The study explored the fishery, growth, and reproductive biology of the green tiger shrimp, *Penaeus semisulcatus*, in Iraqi marine waters of the northwest Arabian Gulf from November 2022 to October 2023. Monthly shrimp landings varied significantly, ranging from a low of 57 tons in December 2022 to a high of 407 tons in September 2023, totaling 3,515 tons over the entire year. During this period, 2,394 specimens of *P. semisulcatus* were sampled, measuring between 10.0 and 25.0 cm in length. The length-weight relationship revealed that male *P. semisulcatus* exhibited isometric growth, while females showed positive allometric growth. The average condition factor for males was 1.01 ± 0.061, while females had an average of 1.03 ± 0.090, indicating good health for both sexes. The species' growth model was represented by the formula L_t= 28.7 (1-exp(-0.45(t+0.326))). The overall sex ratio was found to be 1:1.06 (male to female). The length at which 50% of the population reaches maturity (L_{m50}) was determined to be 8.4 cm. The gonado-somatic index (GSI) values for females varied from 2.11% in October to 8.95% in March. These results can contribute to providing information for species management in the study region.

Keywords: *Penaeus semisulcatus*; Shrimps fishery; Growth and reproductive biology; Iraq; Arabian Gulf

1. Introduction

Penaeid shrimps are commercially important and widely distributed worldwide in sub-tropical and tropical regions. They make up the majority of the catch in shrimp fisheries, with total catches in 2020 reaching 3.2 million tons from a total of 5.6 million tons of crustaceans [1]. Despite shrimp diversity, *Metapenaeus affinis*, *Penaeus semisulcatus* and *Parapenaopsis stylifers* were the major contributors to shrimp catches from Iraqi waters [2]. These species have been important for the artisanal marine fisheries in Iraq for many years. Their landings increased from 123.4 tons (1.85% of the total catch) in 2008-2009 to 7,288 tons (14.4% of the total catch) in 2020-2022 [3].

The green tiger shrimp, *P. semisulcatus* De Haan 1844 inhabits the continental shelf from shallow coastal waters to a depth of 130 m, but mostly in waters less than 60 m, on mud, sandy mud, or sandy grit. The species can form small shoals and is predominantly nocturnal, burying in the substrate in the daytime; mostly fished at night when the highest catches are obtained, but in some areas also by day [4]. Mohammed *et al.* [5] stated that the life cycle of *P. semisulcatus* involves a coastal, shallow-water juvenile phase and an offshore, deeper-water adult phase in Kuwait waters. *P. semisulcatus* is widespread in Iraqi marine waters and is characterized by its large size compared to *M. affinis*. The total catches of *P. semisulcatus* in Iraqi marine waters in 1996 varied from 121.0 to 193.9 tons [2].

Previous studies on the fishery and biology of *P. semisulcatus* in Iraqi waters are limited. Ali [2], Ali *et al*. [6], and Ali and Ahmed [7] studied the fisheries of *P. semisulcatus* in Iraqi marine waters. Abbas and Ghazi [8] focused on the landings of *P. semisulcatus* in the main markets of Basrah Province, and Ghazi [9] studied the reproductive biology of *P.*

* Corresponding author: Abdul-Razak M Mohamed

semisulcatus in the marine waters of Iraq. Lastly, Hassan *et al.* [10] studied the stock assessment of *P. semisulcatus* in Iraqi marine waters.

Consequently, the present study presents information about fishery, growth and reproductive biology of *P. semisulcatus* in Iraqi marine waters, northwest Arabian Gulf from November 2022 to October 2023.

2. Material and methods

The study was carried out in the Iraqi marine waters, northwest Arabian Gulf from November 2022 to October 2023. Iraq has a coastline of 105 km with a continental shelf of 1034 km^2 and a territorial sea of 716 km^2 [11]. The area features a large river delta formed by the Euphrates, Tigris, and Karun rivers, which converge in the Shatt Al-Arab and flow into the Arabian Gulf [12]. The waters have a long history of artisanal fishing, targeting a variety of fish and shrimp species. These include river shad (*Tenualosa ilisha*), silver pomfret (*Pampus argenteus*), mullets (*Planliza subviridis* and *P. klunzingeri*), Emperor (*Lethrinus nebulosus*), Seabream (*Acanthopagrus arabicus* and *A. berda*), croakers (*Otolithes ruber* and *Johnieops belangerii*), and shrimp species such *as P. semisulcatus* and *M. affinis* [3]. Fishing activities are primarily concentrated in the Shatt Al-Arab estuary, Khor Abdulla, and Khor Al-Amaya regions. Different gear such as drift gillnets, trawl nets, traps (gargoor), and stake nets (hadra) are utilized [13].

Shrimp samples were collected randomly from the main landing and auction site for marine resources at Al-Fao town (Fig. 1). Specimens were stored in the iceboxes and transported to the Department of Fisheries and Marine Resources laboratory for further examination. The monthly raw data on the total fish and shrimp landings from November 2022 to October 2023 were collected from the main landing and auction site as documented by the Basrah Agriculture Directorate. A trend line (technical analysis) was used to show the general direction and designate patterns of fish species' landings by the TREND function.

The specimens were identified according to Fischer and Bianchi [4] and sexed macroscopically by visual examination of the gonads. Each specimen was measured for total length (TL) - from the tip of the rostrum to the end of the telson, and carapace length (CL) - from the posterior margin of the orbit to the posterior margin of the carapace using a biometric ruler to the nearest 0.1 cm. The weights of the shrimp and gonad were measured using a digital balance to the nearest 0.1 g. The lengths were grouped into 1.0 cm length groups for males and females.

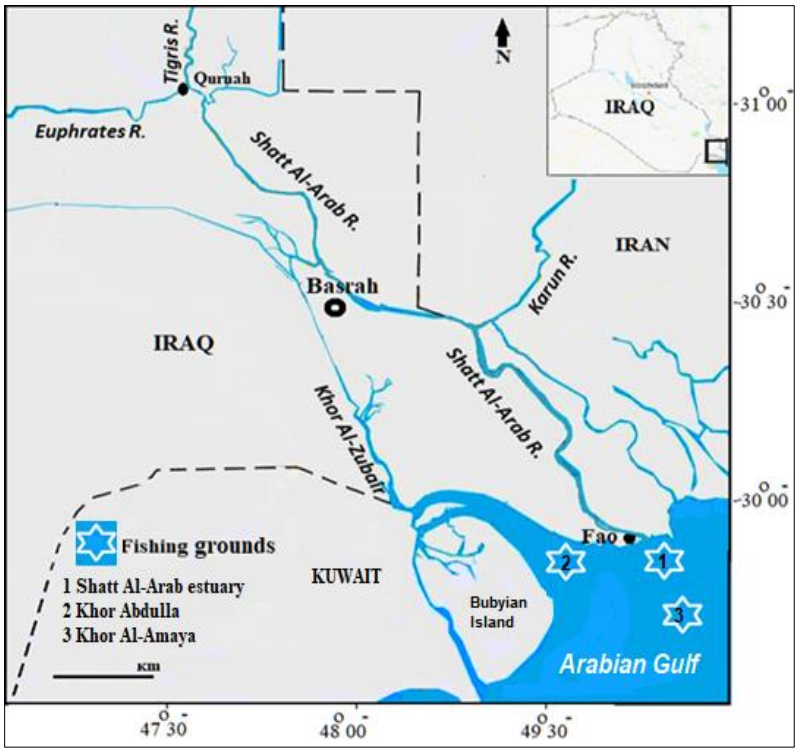

Figure 1 Fishing grounds of *P. semisulcatus* in Iraqi marine waters

The relationship between carapace length (CL) and total length (TL) for each species was estimated using the linear regression formula: CL= a + bTL, where a and b are constants. The length-weight relationship for males and females was determined using the power function $W= aL^b$ [14], where W is the weight of shrimp in grams, L is the total length in cm, a is a coefficient related to the body form, and b is an exponent indicating growth. To identify growth types (isometric or allometric), significant deviations from the b values were observed using a t-test [15]. A t-test was performed to check the similarity of the regression line between males and females.

The relative condition factor (K_n) of the shrimp was calculated separately for males and females as $K_n= W/W'$, where W is the observed weight and W' is the calculated weight of shrimp, determined by inputting 'a' and 'b' values from the length-weight relationship [14].

Growth in length was described using the von Bertalanffy growth function (VBGF):

$$L_t= L\infty\ (1 – \exp\ (-K(t - t_0)))$$

Where $L\infty$ is the asymptotic length, K is the growth rate, L_t is the expected length at age t years and t_0 is the theoretical age at length zero. The growth parameters ($L\infty$ and K) were estimated from the length-frequency data using the ELEFAN I incorporated in the FiSAT II software [16], with the initial seed value for $L\infty$ as the largest individual (L_{max}) seen in the samples, thus: $L\infty= L_{max}/0.95$ [17]. The theoretical age at length zero (t_o) was estimated independently, using the following equation [18]:

$$\log_{10}\ (-t_0) = -0.3922 – 0.275\ \log_{10}L\infty – 1.0381\ \log_{10}K$$

The ratio of the number of males to females was determined monthly for only those shrimp whose gonads were identifiable as male and female. The sex ratio was tested by the chi-square (χ^2) test. The estimation of the size at first sexual maturity (L_{m50}) was done only with female shrimps using the proportion of mature fish in each length class and via the following equation [19]:

$$\text{Log}\ (L_{m50})= -0.1189 + 0.9157*\ \text{Log}\ (L_{max})$$

where L_{max} is the largest individual observed in the samples. The gonadosomatic index (GSI) of the shrimp was calculated monthly by the following equation [20]:

$$\text{GSI= Weight of gonad/ Total body weight} * 100.$$

The obtained data were analyzed using Microsoft Office Excel, ver., 2010.

3. Results

3.1. Shrimp fishing

The monthly shrimp and total fish landings of the Iraqi artisanal marine fisheries from November 2022 to October 2023 are illustrated in Figure 2. The monthly shrimp landings alternated from 57 tons in December 2022 to 407 tons in September 2023, with an overall value of 3,515 tons. Total fish landings ranged from 1,487 tons in December 2022 to 2,948 tons in September 2023, with an overall value of 26,522 tons. Both shrimp and total fish catches showed a positive trend during this period (b= 22.41 and 94.83, respectively). The overall contribution of shrimp to the total landing was about 13.25%.

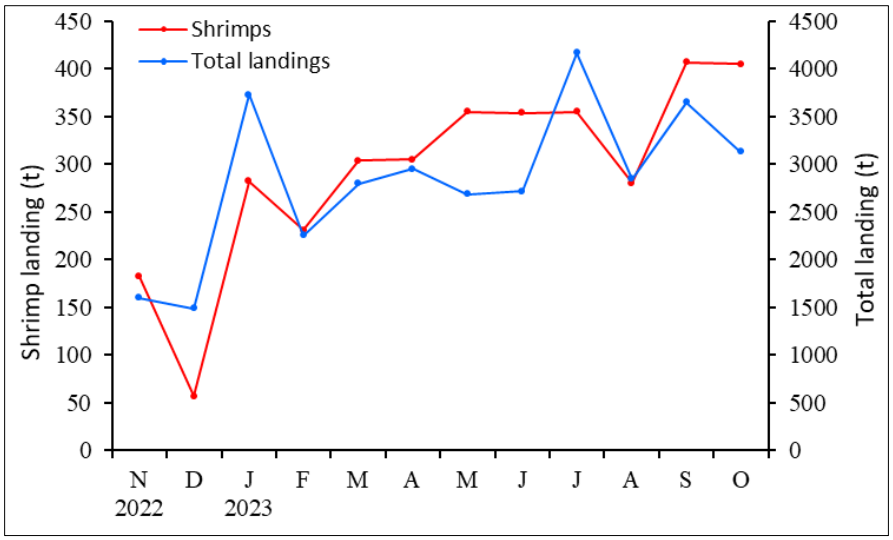

Figure 2 Monthly shrimps and total landings by Iraqi marine fisheries during 2022-2023

3.2. Length-frequency distributions

The seasonal length-frequency distributions of 2,394 *P. semisulcatus* with a total length range of 10.1 to 25.1 cm are shown in Figure 3. 843 specimens of the species were collected in winter, the smallest shrimp was 11.0 cm and the largest was 22.0 cm. The 15.0 cm size group was numerically dominant (19.2%) and the lengths from 14.0 to 18.0 represented 72.2 % during this season. The number of individuals collected in spring was 453 individuals ranging in length from 11.0 to 25.0 cm, and the highest frequency of catch belonged to the length group 17.0 cm constituting 16.1%, while the length groups from 14.0 to 18.0 cm formed 69.5%. The sample of *P. semisulcatus* was composed of 702 specimens in summer ranging from 10.0 to 25.0 cm and the most dominant length was 12 cm, accounting for 19.6%, while the length groups 11.0 to 16.0 cm formed 80.9%. Lengths of 716 individuals of the species collected in autumn varied from 10.0 to 22.0 cm, and the most dominant length group recorded was 13.0 cm, representing 27.4%, while the length groups 12.0 to 16.0 cm constituted 87.7%.

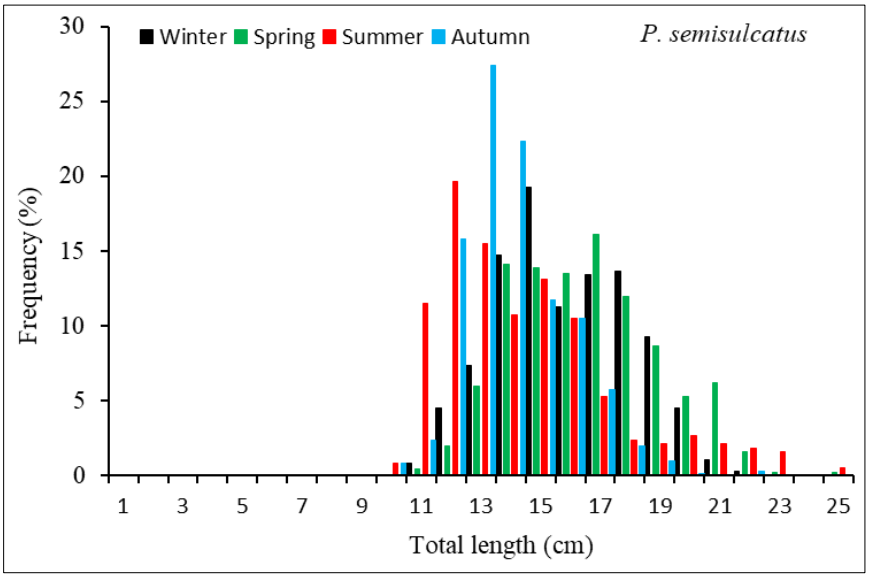

Figure 3 The seasonal length-frequency distributions of *P. semisulcatu*

3.3. The length-weight relationships

The length-weight relationship for both sexes was analyzed using 1,876 specimens of *P. semisulcatus*, consisting of 854 males and 1,022 females (Fig. 4). The total lengths of males varied from 10.1-20.1 cm and 5.2-74.4 g and females from 10.2-25.1 cm and 8.7-146.7 g. The length-weight relationships were:

$W = 0.0068*TL^{3.035}$, $r^2 = 0.915$ for males

$W = 0.0056TL^{3.136}$, $r^2 = 0.952$ for females

The male specimens exhibited an isometric growth pattern (t= 1.093, p<0.05), while the female showed a positive allometric growth pattern (t= 6.137, p<0.05). The study also found a significant difference in the lengths and weights between the male and female specimens (t= 8.598, p<0.05).

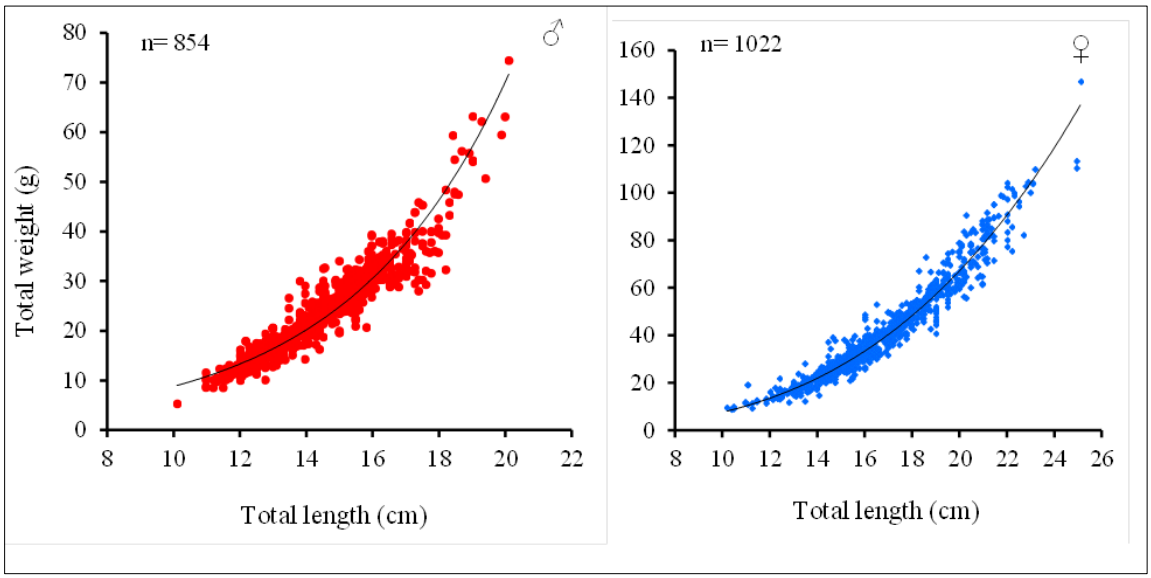

Figure 4 The length-weight relationship of males and females of *P. semisulcatus*

The estimated relationship of total length (TL) to its carapace length (CL) for 483 specimens of *P. semisulcatus* was CL= 0.3857*TL - 0.4054, $r^2 = 0.910$.

3.4. Relative condition factor (K_n)

The relative condition factor (K_n) of *P. semisulcatus* showed monthly fluctuations in both sexes (Fig. 5), and there was no significant difference in K_n values between them (t= 0.52, p>0.05). K_n values for males fluctuated from 0.86 in July to 1.09 in May, while for females from 0.91 in March to 1.18 in January. The mean values of K_n for males and females were 1.01± 0.061 and 1.03± 0.090, respectively.

3.5. Growth model

Monthly total length-frequency data for combined sexes of *P. semisulcatus* was evaluated using the ELEFAN-I incorporated in the FiSAT II software. The initial seed value for $L\infty$ used in the ELEFAN-I was 25.1 cm. The optimized growth curve was superimposed on the restructured length-frequency histograms of *P. semisulcatus* shown in

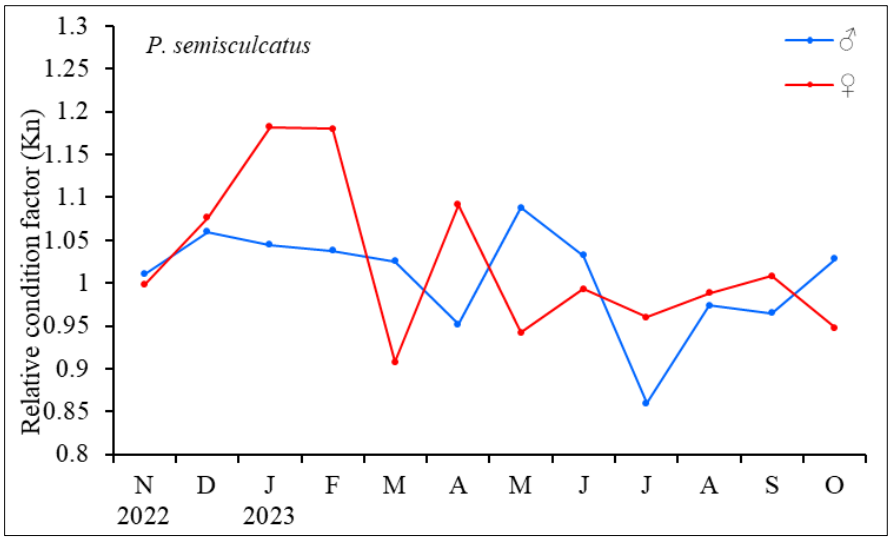

Figure 5 Monthly variations in relative condition factor of male and female *P. semisulcatus*

Figure 6. The best growth constants (L∞ and K) values were estimated as 28.7 cm and 0.45, respectively, so the theoretical age at zero (t_o) was -0.326. The growth model for *P. semisulcatus* was:

$$L_t = 28.7\ (1- \exp\ (-\ 0.45\ (t + 0.326)))$$

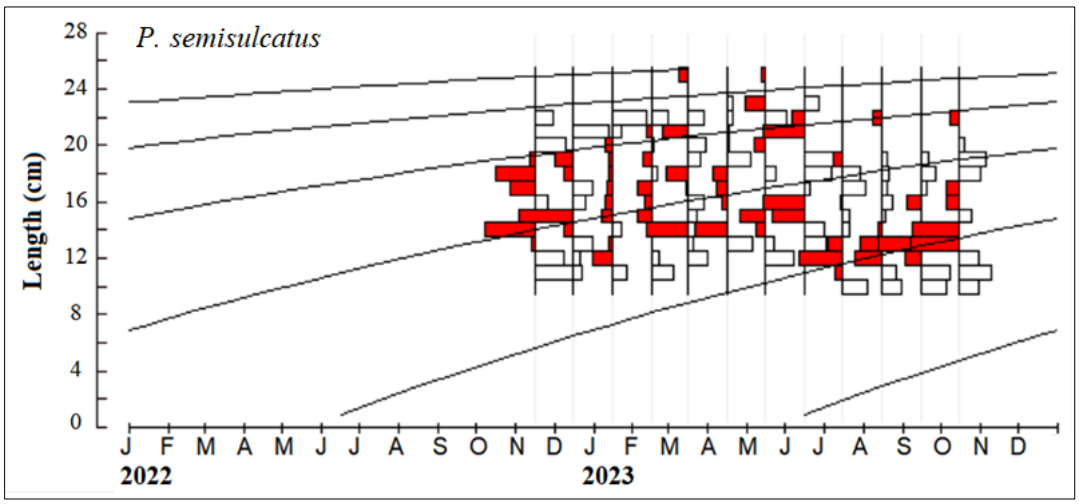

Figure 6 Restructured length-frequency distribution with growth curves for P. semisulcatus.

3.6. Reproduction

3.6.1. Sex ratio

Out of a total of 1868 *P. semisulcatus* specimens examined from Iraqi marine waters, 908 (48.6%) were males and 960 (51.4%) were females (Table 1). It was observed that females outnumbered males in all months except for December, January, June, July, and September. The overall sex ratio (male: female) was 1:1.06 which was not significantly different from the hypothetical 1:1 sex ratio ($\chi 2 = 1.40$; $P < 0.05$).

Table 1 Monthly sex ratio of *P. semisulcatus* in Iraqi marine waters

	Total number	No. of specimens		Sex ratio (M: F)	χ^2
		Males	Females		
N 2022	337	131	206	1:1.57	16.7
D	243	156	87	1:0.56	19.6
J 2023	129	66	63	1:0.95	0.1
F	232	107	125	1:1.17	1.4
M	88	41	47	1:1.15	0.4
A	110	50	60	1:1.20	0.9
M	84	42	42	1:1.00	0
J	70	42	28	1:0.67	2.8
J	223	113	110	1:0.97	0
A	146	66	80	1:1.21	1.3
S	80	48	32	1:0.67	3.2
O	126	46	80	1:1.74	9.2
All	1868	908	960	1:1.06	1.4

3.6.2. Maturity

This study observed 657 of *P. semisulcatus* to determine their lengths at first sexual maturity (L_{m50}). Maturity curves were generated by plotting the percentage of mature females against their length groups (Fig. 7). The length at first maturity (L_{m50}) was 14.2 cm. This finding was confirmed using the equation of Binohlan and Froese (2009), yielding 14.5 cm for *P. semisulcatus* based on the largest length for each species in the samples.

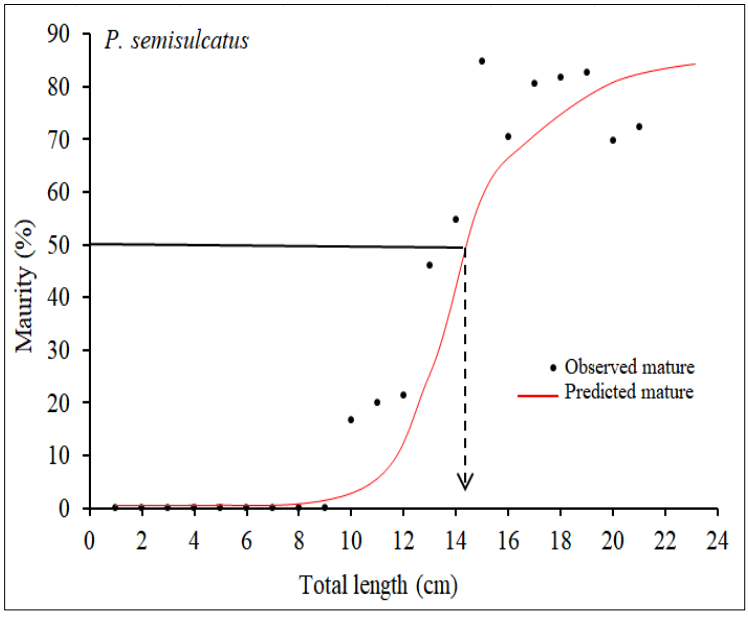

Figure 7 The length at first sexual maturity (L_{m50}) of *P. semisulcatus.*

3.6.3. Gonado-somatic index

The monthly difference of the gonado-somatic index (GSI) of female *P. semisulcatus* is presented in Figure 8. The highest value of GSI (8.95%) occurred in March and then gradually dropped with some fluctuation to the lowest value (2.11%) in October.

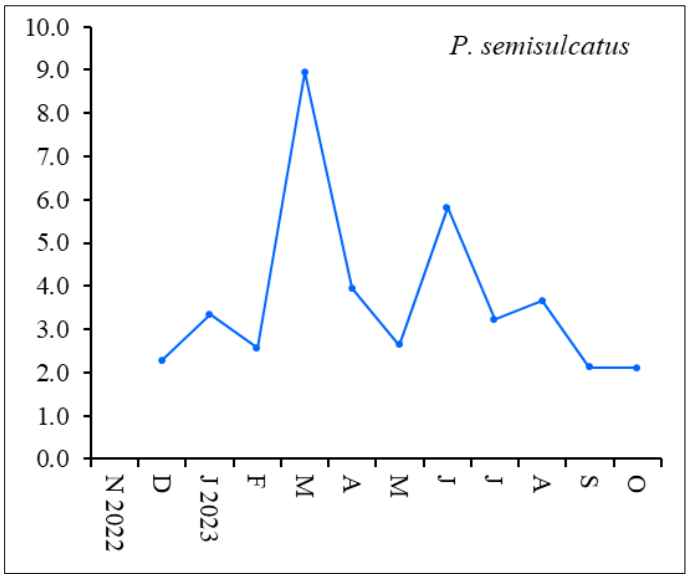

Figure 8 Monthly variations in the gonado-somatic index (GSI) of females *P. semisulcatus*

4. Discussion

The study shows that Iraqi artisanal marine fisheries had annual shrimp and total fish landings of 3,515 and 26,522 tons, respectively. Mohammed *et al.* [5] stated that the total shrimp caught in the 1995/1996 seasons was 1,657 tons in Kuwaiti waters. Ali [2] reported that the total catch of *P. semisulcatus* in 1996 ranged between 121.2 and 193.9 tons, and the catch of *M. affinis* in marine waters during the 1998-1999 season was between 174.6 and 279.36 tons. Niamaimandi *et al*. [21] stated that the landing of penaeid shrimp from the northern part of the Arabian Gulf fluctuated between 480 tons and 2,700 tons per year from 1998 to 2004, and *P. semisulcatus* formed more than 80%. The landings of penaeid shrimps exhibited significant fluctuations over the last decade as the landings in 2008 were 43,695 tons and gradually decreased to 37,642 tons in 2019, so its contribution to the total marine landings of Maharashtra, India declined from 13.1% to 10.8% [22]. According to Mohamed and Abood [23], the total fish landing was 19,877 tons in 2020 and 1,364 tons in 2021, while shrimp landings were 3,107 and 2,221 tons, respectively. Furthermore, the total fish landings was 16,971 tons in 2022, with shrimp landings at 1,961 tons [3]. Both total fish and shrimp landings experienced significant increases in the current study. This improvement in the landings of the species from Iraqi marine waters may be attributed to the development of infrastructure, the upgrading of navigation technology and the increasing mechanized power of fishing boats [23].

The study found that male *P. semisulcatus* are generally smaller than females. This result aligns closely with findings from other researchers studying this species. The size ranges observed in this study (10.1-20.1 cm, 3.5-7.4 cm CL for males and 10.2-25.1 cm, 3.5-9.3 cm CL for females) were similar to those observed in the Gulf of Suez, Egypt, 8.0-20.2 cm for males and 8.8-24.4 cm for females [24], and somewhat comparable to the Pilar and Capiz Bays, Philippines, 6.5-21.5 cm for males and 7.5-21.5 cm for females [25]. They were better than those stated by other authors [26-33], which the lengths ranging from 1.4-4.1 cm (CL) for males and 1.2-5.4 cm (CL) for females in Hormozgan coastal waters of Iran [32] to 2.0-6.6 cm (CL) in the Bombana and Adjacent Waters, Indonesia [33]. Conversely, Niamaimandi *et al.* [34] recorded the smallest values of lengths (2.2-4.4 cm CL) for this species in the Bushehr coastal waters of the Arabian Gulf. These differences in size ranges may be due to various factors, such as water temperature, food availability, population density, fishing pressure, and possibly the use of different fishing gears [35-37].

The growth coefficients (b) of the length-weight relationship of males and females *P. semisulcatus* showed an isometric growth pattern in males and a positive allometric growth pattern in females. The isometric growth pattern indicates that the speed of weight and total length gains in a balanced state, whereas a positive allometric growth pattern referees that the shrimp shows a faster growth in weight as it increases in length [38]. Mehanna [24] noted that the growth of *P.*

semisulcatus exhibited isometric growth for all sexes in the Gulf of Suez, Egypt, and Alrashada *et al*. [31] found the same growth for the whole sample of species in the Saudi coast, Arabian Gulf. Niamaimandi *et al*. [34] discovered that both male and female *P. semisulcatus* in the Bushehr coastal waters of the Arabian Gulf displayed a positive allometric growth pattern. Similarly, Hosny [26] reported positive allometric growth for females and a whole sample of the species on the Saudi coast of the Arabian Gulf. However, other researchers showed negative allometric growth [27, 29-30, 32-33]. The value of growth coefficient (b) in the length-weight relationship may differ due to various factors such as habitat, season, stage of maturity, sex, food availability, health, stress, sampling methodology and the difference in the sizes of individuals [39, 15, 40, 37].

The relative condition factor is considered an index of general well-being and suitability of shrimp to grow in a particular water body, and the value expresses the degree of well-being, relative robustness, plumpness and fatness in numerical terms [35, 41]. There was no variation in the relative condition factor between the sexes of *P. semisulcatus* and had overall K_n values above 1.0, indicating healthy populations. Le Cren [14] stated that K_n values greater than 1.0 indicate good well-being, while values less than 1.0 imply the opposite. The condition factors of many species fluctuate due to their reproductive cycle, feeding rhythms, and other environmental and physiological factors [42-44].

The asymptotic length ($L\infty$) of *P. semisulcattus* was 28.7 cm TL (10.7 cm CL), slightly exceeding the values reported by Mehanna [24] in the Gulf of Suez, Egypt ($L\infty$= 26.6 cm TL), Villarta *et al.* [25] in the Pilar and Capiz Bays, Philippines (26.3 and 27.1 cm TL for males and females, respectively) and El-Ganainy and Yassien [27] in the Gulf of Suez, Red Sea, Egypt (10.4 cm CL). It also surpassed the measurements from other studies [45, 26-30, 46, 31-33]. However, Niamaimandi *et al.* [24] recorded the lowest values of $L\infty$ for *P. semisulcattus* in the Bushehr coastal waters of the Arabian Gulf (3.8 cm CL for males and 5.0 cm CL for females). The estimated growth coefficient (K) for *P. semisulcattus* in this study was lower than that reported by other studies [5, 24, 21, 27-28, 46, 33]. Generally, the value of K ranged from 0.7 for males in the Jizan Area, Red Sea Coast, Saudi Arabia [47] to 2.2 for females in the Bushehr coastal waters of the Arabian Gulf [34]. According to Pauly and Munro [48], the K value for penaeid shrimps ranges from 0.39 to 1.6. The differential in the growth parameters of the same species in various regions could be influenced by many factors, like environmental conditions, nutrient abundance, metabolic and reproductive activities, genetic makeup of the individual, fishing pressure, and sampling method [35, 49, 42, 50-51].

The frequency of female *P. semisulcatus* was higher than that of males, although the ratio of males to females (1:1.06) was not significantly different from the theoretical 1:1 sex ratio. Other studies have reported similar results on the species in the same region. Mohammed *et al*. [5] stated that female *P semisulcatus* dominance occurred in the summer and autumn, while male dominance occurred in winter and spring, the period coinciding with maximum spawning activity in the Kuwait water, Arabian Gulf. Niamaimandi *et al.* [52] stated that the overall average male-to-female ratio was 0.84 in the Bushehr waters, Arabian Gulf, Mehanna *et al*. [28] in their study in the Oman coast, Arabian Sea, stated that the overall ratio of males to females was 1:1.18 and was not significantly different from 1:1. Alrashada *et al.* [31] reported that the overall sex ratio of the species in the Saudi coast, Arabian Gulf was 1:0.85. The sex ratio shows significant variation for the same species in different water bodies, and the predominance of sex may differ due to sexual segregation during the spawning period, the life stage, behavioral characteristics between the sexes, mortality, migration, vulnerability to fishing gear and fishing site [35, 53-54].

The study revealed that the length at first maturity (L_{m50}) of *P. semisulcatus* was 14.5 cm (5.2 cm CL) which was similar to the value of 14.9 cm for the species in the northwestern Arabian Gulf recorded by Khorshidian [55]. According to King [20], the L_{m50} for female *P. semisulcatus* was 15.7 cm, while Niamaimandi *et al*. [52] stated that females in the Bushehr coastal waters of the Arabian Gulf reach sexual maturity at 4.0 cm CL. Rabaoui *et al.* [46] found that the L_{m50} for female species in the Saudi coasts of the Arabian Gulf was 2.3 cm CL. In the coastal waters of Hormozgan in Iran, sexual maturity (L_{m50}) is achieved at 3.79 cm CL [32], and 3.87 cm CL in the Bombana and adjacent waters in Indonesia [33]. The size of the first maturation varies between regions, influenced by factors such as habitat conditions, food availability, and trophic parameters specific to each province [56-59].

Gonad maturity results showed that the highest value of the gonadosomatic index (GSI) for females *P. semisulcatus* in this study was observed in March. The spawning of *P. semisulcatus* was reported to take place during winter and spring in the western Arabian Gulf [60]. Mohammed *et al*. [5] found that the data they collected did not support the spring and autumn recruitment pattern of *P. semisulcatus* in the Kuwait waters, Arabian Gulf. Instead, they revealed that there was consistently a single major recruitment in the summer months of June and (or) July, depending on the year, this recruitment pattern may be supplemented by a second late-summer recruitment in August or early September. However, the species was found to spawn in autumn (November and January), and in spring with peak activity occurring during April in the northwestern Gulf [55]. Niamaimandi *et al*. [52] concluded that the peak of spawning activity of *P. semisulcatus* in the Bushehr waters, Arabian Gulf was in December, decreased slightly from January to February, peaked

again in March, and was then followed by a decrease in the proportion of mature females. Moreover, Ghazi [9] stated that the reproductive periods of *P. semisulcatus* in Iraqi marine waters of the Arabian Gulf were in May and December based on the color and size of the ovary and the histological examination. The details of the penaeid shrimp biology study are still lacking, and there is insufficient information and data about their reproduction, spawning seasons, and maturation [61].

5. Conclusion

In conclusion, the contribution of shrimp from Iraqi marine landings was important attaining 13.25% of the total fishery landings. The size range of *P. semisulcatus* was comparable to that documented by several authors in various geographic localities. The species exhibited isometric growth for males and positive allometric growth for females. The mean values of the relative condition factor indicated a healthy status for the species The asymptotic length ($L\infty$) of *P. semisulcatus* was consistent with findings from other studies on this species. Although the frequency of female *P. semisulcatus* was higher than that of males, the overall sex ratio did not significantly differ from the theoretical ratio. The length at first maturity (L_{m50}) for the species was comparable to results from other studies. The highest gonado-somatic index (GSI) for females *P. semisulcatus* was recorded during March. These findings can inform fisheries management and contribute to the conservation of the species in the region. The asymptotic length ($L\infty$) of *P. semisulcatus* was consistent with findings from other studies on this species.

Compliance with ethical standards

Acknowledgments

The authors thank the Department of Fisheries and Marine Resources, College of Agriculture, University of Basrah for providing the essential research facilities required for this study.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] FAO. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO. 2022. https://doi.org/10.4060/cc0461en

[2] Ali MH. The fisheries of commercial shrimps in Iraq. Marina Mesopotamica. 2001; 16(2): 405-417.

[3] Mohamed ARM, Abood AN. The current status and recent trends of Iraqi marine fisheries in the northwest Arabian Gulf. Indiana Journal of Agriculture and Life Sciences,.; 2024; 4(1): 9-20. DOI-https://doi.org/10.5281/zenodo.10722694

[4] Fischer W, Blanchi G. FAO species identification sheets for fishery purposes. Western Indian Ocean (Fishing Area 51), Rome, FAO. 1984; Vol. 1, 253pp.

[5] Mohammed HM, Bishop JM, Xu X. Population characteristics of green tiger prawns, *Penaeus semisulcatus*, in Kuwait waters prior to the Gulf War. Hydrobiologia. 1996; 337: 37-47.

[6] Ali MH, Abdullah DS, Ahmed HK. The fishery assessment and the annual population structure of the catches of the commercial shrimp *Metapenaeus affinis* in Iraqi marine waters. Marina Mesopotamica. 2001; 16(1): 209-219.

[7] Ali MH, Ahmed HK. Socioeconomic study for the wealth of marine shrimp in the territorial sea of Iraq. Iraqi Journal of Aquaculture. 2015; 12(2): 59-70.

[8] Abbas AT, Ghazi AH. Commercial shrimp landings of two penaeid shrimps in the main markets of Basrah Province, Iraq. Mesopotamian Journal of Marine Sciences. 2021; 36(1): 73-78. DOI: 10.58629/mjms.v36i1.18.

[9] Ghazi AHH. Study of some reproductive aspects of *Penaeus semisulcatus* shrimp in marine Iraqi water, North West Arabian Gulf. Iraqi Journal of Aquaculture. 2015; 12(2): 77-87.

[10] Hassan KA, Mohamed ARM, Abed JM. Stock assessment of the green tiger shrimp *Penaeus semisulcatus* De Haan, 1844 from Northwest Arabian Gulf, Iraq. Global Journal of Fisheries Science. 2024; 6(4): 86-96.

[11] Earth Trends. Coastal and Marine Ecosystems-Iraq. 2003. https:// earthtrends.wri.org.

[12] Pohl T, Al-Muqdadi SW, Ali MA, Al-Mudaffar NF, Ehrlich H, Merkel B. Discovery of a living coral reef in the coastal waters of Iraq. Scientific Reports. 2014; 4: 4250. DOI:10.1038/srep04250.

[13] Mohamed ARM, Jawad LA. Marine artisanal fisheries of Iraq. In: L.A. Jawad (ed.). The Arabian Seas: Biodiversity, Environmental Challenges and Conservation Measures. Springer, Cham; 2021. https://doi.org/10.1007/978-3-030-51506-5_41.

[14] Le Cren ED. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). Journal of Animal Ecology. 1951; 20: 201-219.

[15] Froese R. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. Journal of Applied Ichthyology. 2006; 22 (4): 241-253.

[16] Gayanilo FCJr, Sparre P, Pauly D. FAO-ICLARM Stock Assessment Tools II (FiSAT II). Revised version. User's guide. FAO Comp. Info. Ser. (Fisheries). 2005; 8: 1-168.

[17] Taylor CC. Cod growth and temperature. ICES Journal of Marine Science. 1958; 23(3): 366-370.

[18] Pauly D. Some simple methods for assessment of tropical fish stocks. FAO Fishery Technical Paper. 1983; 234: 52.

[19] Binohlan C, Froese R. Empirical equations for estimating maximum length from length at first maturity. Journal of Applied Ichthyology. 2009; 25(5): 611-613. DOI: 10.1111/j.1439-0426.2009.01317.x

[20] King MM. Fisheries Biology, Assessment and Management. 2nd ed. Wiley-Blackwell Publishing Ltd. 2007. DOI:10.1002/9781118688038

[21] Niamaimandi N, Arshad AB, Daud SK, Saed RC, Kiabi B. Population dynamic of green tiger prawn, *Penaeus semisulcatus* (De Haan) in Bushehr coastal waters, Persian Gulf. Fisheries Research. 2007; 86: 105-112. https://doi.org/10.1016/j.fishres. 2007.05.007

[22] Dongre SJ, Metar SY, Nirmale VH, Chogale ND, Naik SD, Gangan SS. Preliminary observation on the stock of Jinga shrimp, *Metapenaeus affinis* (H. Milne Edwards, 1837) along the Ratnagiri coast of Maharashtra, India. Journal of the Marine Biological Association of India. 2023; 65(2): 95-99. Doi:10.6024/jmbai.2023.65.2.2372-14

[23] Mohamed ARM, Abood AN. Characterization of Iraqi artisanal marine fisheries, northwest of the Arabian Gulf. Asian Journal of Fisheries and Aquatic Research. 2023; 21(2): 22-33. DOI: 10.9734/AJFAR/2023/v21i4546

[24] Mehanna SF. Population Dynamics of *Penaeus semisulcatus* in the Gulf of Suez, Egypt. Asian Fisheries Science. 2000; 13: 127-137

[25] Villarta KA, Annabelle del Norte-Campos GC, Campos WL. Some aspects of the population biology of the green tiger shrimp *Penaeus semisulcatus* De Haan, 1844 from Pilar and Capiz Bays, Northern Panay, West Central Philippines. Sci. Diliman. 2006; 18(1): 1-10.

[26] Hosny CF. Population dynamics of *Penaeus semisulcatus* De Haan, exploited by the industrial fleet of Manifa, Saudi Arabia, Arabian Gulf. King Abdul Aziz University Journal, Oceanography. 2007; 18: 3-24.

[27] El-Ganainy AA, Yassien MH. The population biology of penaeid prawns in the Gulf of Suez, Red Sea, Egypt, Marine Biology Research. 2012; 8(4): 405-411. DOI: 10.1080/ 17451000.2011.637564

[28] Mehanna SF, Khvorov S, Al-Kharusi L, Al-Mamery J. Fisheries and population dynamics of the green tiger shrimp, *Penaeus semisulcatus*, from the Arabian Sea, Oman. International Journal of Environmental Science and Engineering. 2012; 3: 33-41.

[29] Mohamed S., El-Aiatt A. Population dynamics and fisheries management of *Penaeus semisulcatus* Exploited by shrimp trawl of Bardawil Lagoon, North Sinai, Egypt. Egyptian Journal of Animal Production. 2012; 49: 185-191.

[30] Abdul-Wahab MM. Population dynamics of the shrimp *Penaeus semisulcatus* in the Yemeni Red Sea waters. Iranian Journal of Fisheries Sciences. 2014; 13(3): 585-596.

[31] Alrashada YN, Tharwat A, Boqursain A. Population dynamics of the green tiger prawn, *Penaeus semisulcatus* de Haan, 1844 in the Saudi coast of the Arabian Gulf. Indian Journal of Animal Research. 2019; 53: 1-6.

[32] Alizadeh E, Safaie M, Momeni M, Kamrani E. Population dynamics of two morphotypes of green tiger shrimp *Penaeus semisulcatus* de Haan, 1844 in the northern coast of Iran. Indian Journal of Fisheries. 2022; 69(2): 7-18. DOI: 10.21077/ijf.2022.69. 2.102674-02

[33] Suman A, Hasanah A, Fitriani A, BintoroG. Stock Status of Green Tiger Prawn (*Penaeus semisulcatus* De haan, 1844) in Bombana and Adjacent Waters, Southeast Celebes, Indonesia. International Journal of Zoology and Animal Biology. 2023; 6(1): 000447. DOI: 10.23880/izab-16000447

[34] Niamaimandi N, Arshad AB, Daud SK, Saed RC, Kiabi B. Growth parameters and maximum age of prawn, *Penaeus semisulcatus* (De Haan) in Bushehr waters, Persian Gulf. Iranian Journal of Fisheries Sciences. 2008; 7(2): 187-204.

[35] Nikolsky GV. The ecology of fishes. Academic Press, London and New York; 1963.

[36] Weatherley AH, Gill HS. The biology of fish growth. Academic Press, London, UK; 1987.

[37] Cuadrado JT, Lim DS, Alcontin RMS, Calang JL, Jumawan JC. Species composition and length-weight relationship of twelve fish species in the two lakes of Esperanza, Agusan del Sur, Philippines. FishTaxa. 2019; 4(1): 1-8.

[38] Riedel R, Caskey LM, Hurlbert SH. Length-weight relations and growth rates of dominant fishes of the Salton Sea: implications for predation by fish-eating birds. Lake and Reservoir Management. 2007; 23: 528-535.

[39] Ricker WE. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Canada. 1975; 191: 1-382.

[40] Mili S, Ennouri R, Chhibi M, Laouar H, Romdhane N, Missaoui H. Length-weight relationships (LWRs) of endemic and introduced freshwater fish species in 13 Tunisian reservoirs. Journal of New Sciences, Agriculture and Biotechnology. 2017; 41(8): 2253-2259.

[41] Bagenal TB, Tesch FW. Age and growth. In: Bagenal T, ed. Methods for assessment of fish production in freshwater. 3rd ed. IBP Handbook No. (3). Blackwell Sci. Publ. Oxford, UK; 1978. p. 101-130.

[42] Wootton RJ. 2011. Growth: environmental effects. In: Farrell AP, ed. Encyclopedia of fish physiology: from genome to environment. Elsevier Science Publishing Co. Inc, United States; 2011. p. 1629-1635.

[43] Datta SN, Kaur VI, Dhawan A, Jassal G. Estimation of length-weight relationship and condition factor of spotted snakehead *Channa punctata* (Bloch) under different feeding regimes. SpringerPlus. 2013; 2(1): 436.

[44] De Giosa M, Czerniejewski P, Rybczyk A. Seasonal changes in condition factor and weight-length relationship of invasive *Carassius gibelio* (Bloch, 1782) from Leszczynskie Lakeland, Poland. Advances in Zoology. 2014: 1-7. DOI: 10.1155/2014/678763

[45] Rabaoui L, Lin YJ, Maneja R, Qurban M, Abdulrahman P, Premlal P, Al-Abdulkader K, Roa-Ureta R. Nursery habitats and life history traits of the green tiger shrimp *Penaeus semisulcatus* (De Haan, 1844) in the Saudi waters of the Arabian Gulf. Fisheries Research. 2017; 195: 1-11. https://doi.org/10.1016/ j.fishres.2017.06.013

[46] Sabry E, Abdallah M, Al-Solami L. Growth, Mortality and Sustainable Exploitation of the Shrimp (*Penaeus semisulcatus*) Fishery in the Jizan Area (Red Sea Coast, Saudi Arabia). JKAU: Mar. Sci. 2006; 17: 3-11.

[47] Pauly D, Munro JL. Once more on the comparison of growth in fish and invertebrates. ICLARM Fishbyte. 1984; 2(1): 21.

[48] Sparre P, Venema SC. Introduction to tropical fish stock assessment. Part 1. Manual. FAO fisheries technical paper. No. 306. 1, Rev. 2. FAO, Rome, Italy. 1998.

[49] Panda D, Mohanty SK, Pattnaik AK, Das S, Karna SK. Growth, mortality and stock status of mullets (Mugilidae) in Chilika Lake, India. Lakes & Reservoirs. 2018: 1-13.

[50] Çiloğlu E, Ateş C. Population dynamics of deep-water pink shrimp (*Parapenaeus longirostris* Lucas, 1846) (Decapoda, Paenaeidae) in the coastal waters of Tuzla (Eastern part of the Sea of Marmara). Aquatic Research. 2022; 5(3): 196-208. https://doi.org/ 10.3153/AR22019

[51] Niamaimandi N, Aziz A, Siti Khalijah D, Che Roos S, Kiabi B. Reproductive biology of the green tiger prawn (*Penaeus semisulcatus*) in coastal waters of Bushehr, Persian Gulf. ICES Journal of Marine Science. 2008; 65: 1593-1599.

[52] Mouine N, Ktari MH, Chakroun-Marzouk N. Reproductive characteristics of *Spondyliosoma cantharus* (Linnaeus, 1758) in the Gulf of Tunis. Journal of Applied Ichthyology. 2011; 27: 827-831.

[53] Gerami MH, Ghorbani R, Paighmabari SY, Momeni M. Reproductive season, maturation size (L_{m50}) and sex ratio of *Metapenaeus affinis* (Decapoda: Penaeidae) in Hormozgan shrimp fishing grounds, south of Iran. International Journal of Aquatic Biology. 2013; 1(2): 48-54. https://www.researchgate.net/publication/236623234

[54] Khorshidian K. Biological characteristics of commercially exploited Penaeidae shrimp (*Penaeus semisulcatus*) in the north-western part of the Persian Gulf. Final Project 2002. The United Nations University, Iceland. 2002; 41 p.

[55] Sinovcic G, Zorica B. Reproductive cycle and minimum length at sexual maturity of *Engraulis encrasicolus* (L.) in the Zarmanja River estuary (Adriatic Sea, Croatia). Estuary and Coastal Shelf Sciences. 2006 69: 439-448. http://dx.doi.org/10.1016/j.ecss.2006. 04.003

[56] Arendt JD. Size-fecundity relationships, growth trajectories, and the temperature-size rule for ectotherms. Evolution. 2011; 65: 43-51.

[57] Resende AGA, de França EJ, de Oliveira CD, Santana FM. Maturity, growth and natural mortality rate of the introduced fish *Parachromis managuensis* (Perciformes: Cichlidae) in the semiarid region of Brazil. Acta Limnologica Brasiliensia. 2020; 32: e29. https://doi.org/ 10.1590/S2179-975X2820

[58] Ugrin N, Paladin A, Krstulovi´c Šifner S. Fecundity, length at first sexual maturity and gonadal development of *Lepidorhombus boscii* in the Eastern Adriatic Sea. Biology. 2023; 12: 1-15. https://doi.org/10.3390/ biology12010131

[59] Price ARG, Jones DA. Commercial and biological aspects of the Saudi Arabian Gulf shrimp fishery. Bull. Mar. Res. Centre Saudi Arabia. 1975; 6: 1-24.

[60] Henry CB, Mulanda CA, Njiru J. Ovarian development of the penaeid shrimp *Penaeus indicus* (Decapoda): A case for the Indian Ocean coastal waters of Kilifi Creek, Kenya. Fisheries and Aquaculture Journal. 2019; 10(1): 1-8. doi: 10.35248/2150-3508.19.10.262