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The Reproductive Biology of *Pampus candidus* Fish in Iraqi Marine Water Located in the North-Western Region of the Persian Gulf

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ABSTRACT

The silver pomfret fish *Pampus candidus* (Previously known as *Pampus argenteus* Euphrasen) was collected from Iraqi marine waters in the northwest Persian Gulf between April and December 2021, using gillnet and demersal trawling. The lengths and weights of fish were recorded, along with data on the initial maturity length, sex ratio, gonadosomatic index (GSI), Dobriyal index, gonad maturation, development cycle, and absolute fecundity rate. The forked length of female individuals varied from 248 to 281mm, whereas that of male individuals ranged from 124 to 194mm. In July, young fish began to appear. Male individuals had a somehow shorter period of sexual maturity compared to female counterparts. Furthermore, it is noted that males tend to be generally less in size compared to females. The length at first maturity female and male was recorded as 203 and 115mm, respectively. The sex ratio tends to increase for males, and there were two peaks in the rise of the gonadosomatic index and Dobriyal's index, which indicate two periods of spawning activity during June and September. Six stages of fish maturity have been identified, with differences in the size of the eggs. They had a long and continuous breeding season that lasted from May to November, and they spawned by releasing eggs in batches. Notably, they have two distinct reproductive periods: The first during May and June and the second during October and November. The relationship of fecundity with weight was found to be more representative than with length. The document mentions that the silver pomfret spawning and nursery areas are adjacent to the Shatt al-Arab discharge area.

INTRODUCTION

The silver pomfret fish, *Pampus candidus* (Previously called *Pampus argenteus* Euphrasen), belongs to the family Stromateidae and is known locally in Iraq as Zobaidy. It tops the list of important species in Iraqi marine fisheries and is considered the most valuable fish in terms of price value and economic return in the region and the world **(Wei *et al*., 2021)**. Therefore, attention was paid to studying it from all aspects of biology and dynamics. The silver pomfret fish are distributed throughout the Persian Gulf and Oman Sea, extending East to India and Bangladesh in the northern Indian Ocean **(Pati , 1982; Kagwade, 1988; Rhman, 2004; Radhakrishnan *et al*., 2019)**. It has also been

recorded in the Mediterranean Sea in Tunisian waters **(Sami *et al*., 2014)**. Moreover, the silver pomfret fisheries have declined significantly in recent years due to overfishing, which has caused a decrease in silver pomfret stocks **(Wen *et al*., 2006; Lone *et al*., 2008a; Mohamed & Qasim, 2014)**. Overall, according to **Buchanan *et al*. (2019)**, the International Union for Conservation of Nature (IUCN) Red List has eight distinct degrees of extinction risks. Among these levels, the silver pomfret fish is classified as vulnerable due to its declining population. In addition, the Persian Gulf has numerous challenges to its fish stocks, particularly in fisheries that suffer from inadequate management. The Khor Al-Amaya and Khor Abdullah regions in Iraqi marine waters hold a significant importance as a fishing zone for silver pomfret fish in the northwestern Persian Gulf area. The geographical location of Khor Abdullah functions as a supplementary linkage between the Mesopotamian basin and the Arabian Gulf. The region of Khor is located inside an intertidal flat that undergoes continuous processes of deposition and erosion. Khor Abdullah is a geographical feature that extends across a distance of 60km and possesses a width of around 14km. It functions as a geographical barrier, separating the mudflats located in southern Iraq from the Warbah and Bubiyan Kuwait Islands **(Qasim & Ali, 2022)**. It uses drift gillnets and trawl nets to catch *P. candidus*. During the 1980s, the Regional Commission for Fisheries **(FAO, 2011)** recorded that the main species in the region's fisheries include the sabour (*Tenualosa ilisha*), the lizard (Liza spp.), and the silver pomfret (*Pampus argenteus*).

In recent years, interest in basic biology information, especially reproductive biology, has increased due to the declining natural resources of many species and the growing reliance on aquaculture activities to fill this decline **(Lone *et al*., 2008a)**. There has been significant interest in farming the highly valuable silver pomfret fish in China, Southeast Asia, the Indian Peninsula, and the Persian Gulf region **(Cruz *et al*., 2002)**. Many studies have been conducted on the reproductive biology of this species in various countries worldwide **(Kuthalingam, 1963; Mito & Senta, 1967; Gopalan, 1969; Pati, 1982; Kim & Han, 1989; Lee & Jin, 1989; Qixiang *et al*., 1989; Lone *et al*., 2008a, 2008b; Zhao *et al*., 2010)**. Additionally, in the Persian/Arabian Gulf region, **Abu-Hakima (1984)** and **Dadzie *et al*. (2000)** studied the reproductive biology of the silver pomfret in Kuwaiti waters, while **Almatar *et al*. (2004)** studied the number of spawning, fecundity, egg weight, and reproductive. In Iranian marine waters, the reproductive biology of *P. argenteus* in the area opposite the port of Bandar Abbas was studied by **Moumeni and Ehsan (2006)**. **Safikhani (1998)** also evaluated the reproductive biology in the Mahshahr estuary in the northeastern Persian/Arabian Gulf opposite the fisheries of Iraq and Kuwait, while **Narges *et al*. (2007)** addressed reproductive biology separately and its relationship with fisheries management. Moreover, **Shahram and Naming (2010)** investigated the reproduction and spawning of the fish under study. However, there were no studies on the reproductive of the silver pomfret fish in Iraqi marine waters, except for the study of **Mohamed and Ali (1993)** during 1990. Therefore, this research paper aimed

to evaluate the changes in the most important biological parameters of *P. candidus* fish that is reproductive in Iraqi marine waters as a result of changing environmental conditions of the region caused by the decrease in the levels of fresh water coming from the Shatt al-Arab. The study included the assessments of length frequency by month, the differences in the proportion of mature fish based on length, monthly changes in maturity, gonads morphology, proportions of different stages of maturity, the sex ratio, and the frequency of spawning.

MATERIALS AND METHODS

The total number of *P. candidus* fish studied was 344, including 224 males, 84 females, and 36 immature fish. The fish specimens were collected from the marine waters of Khawr Abdullah and Khor Al-Amaya in Iraq between April and December 2021. Gillnets and trawl nets were employed for this purpose, in addition to collecting samples from the landing site in Al-Faw City (Fig. 1). The measurements of the froked length (F.L.) were taken with an accuracy of 0.1mm, while the total weight of the fish was measured with an accuracy of 0.1gm. The gonads were removed from the fish after dissection in order to ascertain their sex, and their weight was recorded to the nearest 0.001gm. Four indicators were used to estimate the breeding season: monthly changes of the gonadosomatic and Dobriyal indexes. According to their gonadosomatic index (GSI), which expresses the maturity function as a monthly average based on the equation:

$$GSI\ (\%) = \frac{\textbf{Gonad weight (gm)}}{\textbf{Body weight (gm)}} \times \mathbf{100} \qquad \textbf{(Nikolski, 1963)}$$

To clarify the seasonal regression of gonads, the stages of gonad maturation were studied by macroscopic examination using the characteristics of physical and sensory examination, represented by the degree of opacity, consistency, the presence of blood vessels, the vision of eggs and sperm, and the form of gonad coloration **(Kesteven, 1960; White *et al*., 1998)**.

According to the monthly Dobriyal index (DI), as defined by **Dobriyal *et al*. (1999)**, it is the average cube root of gonad weight in grams (gm). The Chi-square test with a significance level of 0.05 was employed to assess whether the observed ratio deviates from the expected 1:1 ratio **(Sokal & Rohlf, 1995)**. The length of maturity (Lm_{50}) was calculated based on the most petite length at which 50% of the individuals were in a state of maturity **(Bagenal, 1978)**. The absolute fecundity was measured by counting the total number of mature eggs in the ovary at the stage of complete maturity. The eggs were preserved in modified Gilson fluid, which hardens the eggs and frees them from the ovarian membranes, as described by the Simpson method **(Poudel *et al*., 2023)**. Gravimetric sampling was used to calculate fecundity, as the weight of the total washed eggs is calculated, followed by counting and weighing a random sample of 500 eggs, after which the total number of eggs is calculated in the ovary, based on the equation:

$$F = n\ G/g$$

Where, F is the fecundity; (n) is the number of eggs in the secondary sample; (G) is the ovary weight, and (g) represents the weight of the sample in the same unit **(Holden & Raitt, 1974)**. Relative fecundity was calculated based on the absolute fecundity value divided by the total body weight.

Statistical analysis

Excel was used for drawing shapes, mathematical calculations, and statistical analysis. The Chi-square test with a significance level of 0.05 was employed to assess whether the observed ratio deviates from the expected 1:1 ratio.

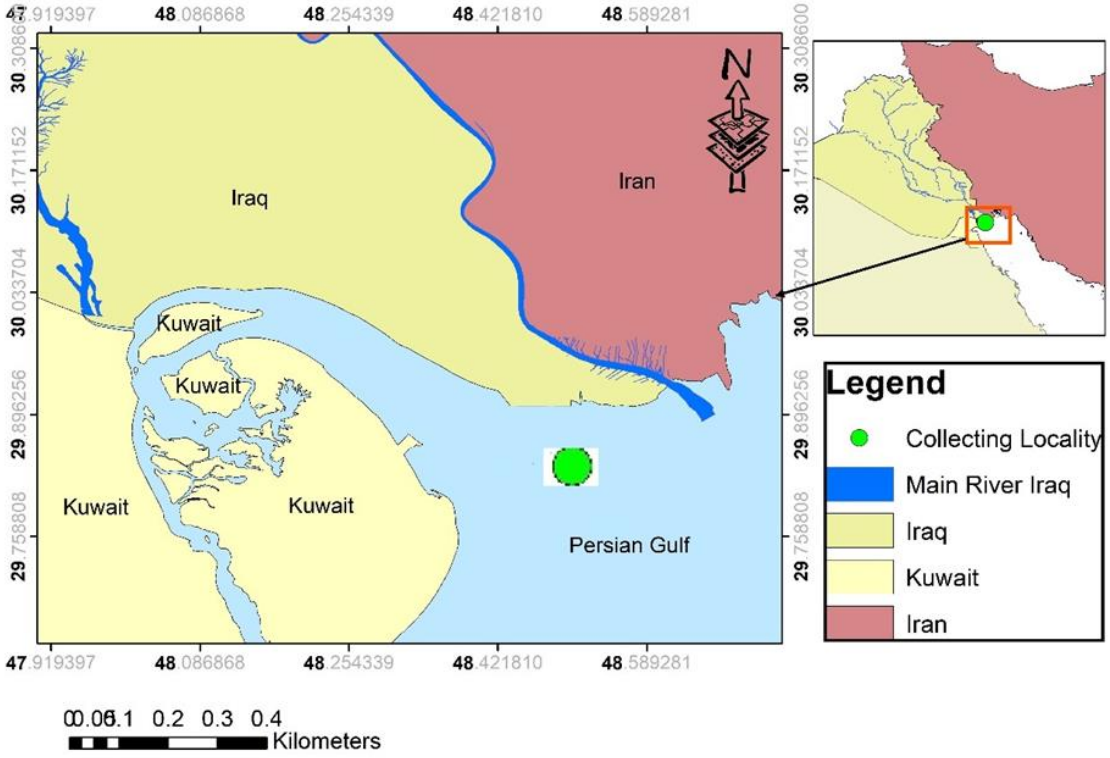

Fig. 1. Geographical representation of the designated research region

RESULTS

1. Size structure

In general, it can be said that there is a decrease in the lengths and weights of females toward the end of the season extending from May to November, while an irregular fluctuation was detected in males (Table 1). Two peaks were determined in the average weight and length of males; the first at the beginning of the season during April to May, and the second at its end during October and December (Fig. 2). While females showed a noticeable increase in weight during June and July despite the relative stability in length

(Fig. 2), immature fish appeared in July and August. Their average length in July was 45.7mm, with a range of 30- 56mm, and an average weight of 3.0gm, with a range of 1.5-4.7gm, while during August, it recorded an average length of 99.4mm, 82- 120mm, and an average weight of 27.7gm, with a range of 14.7- 45.5gm. The study revealed that males tended to have lesser length and weight compared to females. The smallest male had a forked length of 65mm and weighed 28gm, whilst the smallest female had a froked length of 215mm and weighed 288gm.

Table 1. Average, range, and standard deviation (SD) of lengths and weights of *P. candidus* studied during the months (April- December)

Month	Females						Males					
	No.	Froked length (mm)			Body weight (g)			Froked length (mm)			Body weight (g)		
		Range	Average	±SD	Range	average	±SD	Range	average	±SD	Range	average	±SD
Apr.	25	-249 285	264	13.5	889-562	682.1	30.6	238-130	194.3	20.3	433-72	263.9	60.6
May	64	203-292	254.2	13.9	982-288	627.5	40.2	270-92	188.2	25.6	676-28	238.7	55.7
Jun.	20	300-270	281.6	12.7	1309-623	941.6	45.8	230-164	191.8	19.7	382-159	254,1	20.1
Jul.	64	320-225	273.7	40.9	1190-427	821.3	60.1	223-70	130.6	27.5	403-21	161.8	65.2
Aug.	46	320-215	258.5	19.1	1370-331	702.7	47.5	215-115	173.6	19.7	347-48	190.6	32.6
Sep.	54	290-220	255	13.6	1003-440	665.8	39.7	228-65	124.1	35.6	394-7.1	91.7	45.7
Oct.	29	294-215	248.2	14.4	887-356	585.2	20.1	230-115	180.8	30	408-44	206.2	34.1
Nov.	29	295-215	249.3	15.2	888-345	585.8	19.5	231-113	180.8	25.5	406-43	206.1	45.8
Dec.	13	0	0	0	0	0	0	230-135	182.7	24.7	418-86.6	216.1	50.1

2. Length at first maturity

The smallest mature female fish, with a length of 203mm and a weight of 288.1gm, was recorded in the developing stage with a gonadosomatic index (GSI) of 0.7. It was caught in May, while the smallest mature male fish was recorded during August, with a length of 115mm, a weight of 48.5gm in the partial reproductive stage, and a gonadosomatic index (GSI) of 0.16. The length of sexual maturity (L_m50) was 210mm and 120mm for females and males, respectively. The findings indicate that males attain sexual maturity at a comparatively shorter duration than females.

3. Sex ratio

The sex ratio of males to females was skewed towards males side at 1:3.75, which is a ratio that is significantly different (Chi square, $P< 0.05$) from the expected ratio of 1:1 using the Chi-squared test. Males were more significantly numerous than females during April and May, that is, at the beginning of the breeding season. The males continued to outnumber females throughout the following months, with females disappearing in the

last month of the *P. candidus* reproductive migration months. Interestingly, there were two periods of increase in the percentage of females: the first period was in June and July, and the second period was in October (Table 2).

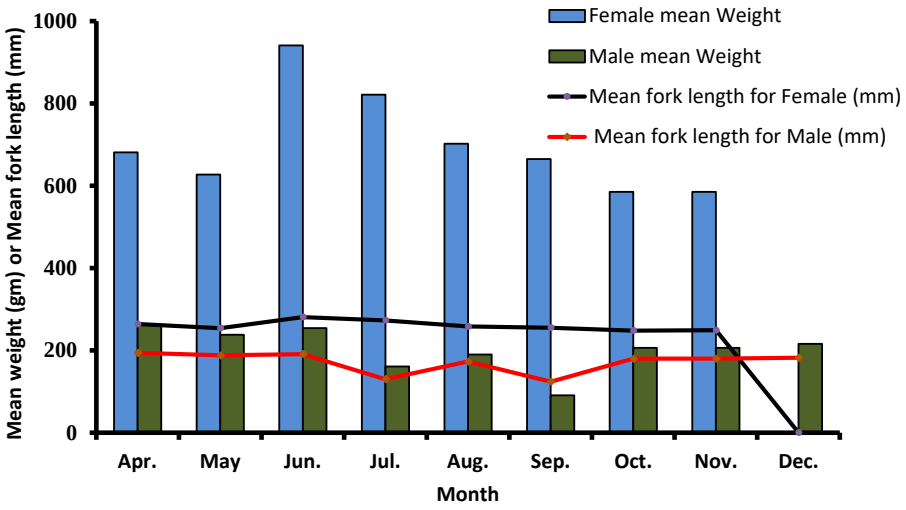

Fig. 2. Mean weight and mean froked length (mm) for female and male *P. candidus* during the period from April to December

4. Gonadosomatic index (GSI) and Dobriyal index

The GSI for females ranged from 2.58 to 9.4, with the lowest values observed in May and the highest values seen in June and September. The GSI of males ranged from 4 to 3.3, with the lowest values recorded in August and September, and the peak value occurred in April (Table 2). The monthly fluctuations in GSI and the Dobriyal index indicate the breeding season, which runs from June to November. It is also important to note that there are two distinct peaks in the increase of the GSI and the Dobriyal index, signifying two spawning periods occurring in June and September.

5. Microscopic description of the gonads

The gonads of *P. candidus* has six distinct phases of development, ranging from immature to the resting (Recovery) stage (Table 3). Partial spent stage also appeared, characterized by the ovaries being semi-flabby, reddish-brown in color, bloody, asymmetrical, and containing some opaque yellow eggs. For males, this stage was characterized by the testicles being flabby, semi-swollen, of heterogeneous tissue, and sperm still flowing under pressure (Table 3). The pattern of maturity or temporal occurrence in the maturity stages, as displayed in Fig. (3)shows that all fish heading to participate at the beginning of the breeding season during April were in the developed reproductive stage, followed by the first appearance of partially spent fish during May,

which continued in all months, almost except for July and December. The spent stage appeared during the month of May and continued throughout the months, except for December, reaching its peak in July. The developed stage continued to appear in all months, except December. December was characterized only by the presence of fish that completed the spawning, represented by fish in the recovery stage.

Table 2. The monthly values of the gonadosomatic index (GSI), Dobriyal index, and sex ratio of the silver pomfret fish in the northwest Persian Gulf

Month		Forked length (mm)	Weight (g)	Gonad function Females	Suitable function Males	Dobrial function Females	Dobrial function Males	Sex ratio M:F
Apr.	Mean (± SD)	211.1 (±39.4)	364.3 (±22.6)	3.05 (±0.9)	0.83 (± 0.1)	2.69 (±0.2)	1.28 (±0.2)	1:0.32
	Range	130-285	889-72.8	1.7-4.42	0.5-1.25	2.1-3.02	1.0-1.75	
May	Mean (± SD)	199.6 (±37.8)	305.2 (±19.8)	2.58 (±2.4)	0.49 (±0.2)	2.75 (±0.7)	1.08 (±0.2)	1:0.21
	Range	92-292	28.2-982	0.7-9.19	0.2-0.88	1.8-4.32	0.5-2.09	
Jun.	Mean (± SD)	218.7 (±44.5)	460.3 (±34)	9.4 (±2.5)	0.51 (±0.2)	4.39 (±0.5)	1.02 (±0.2)	1:0.43
	Range	164-300	160-1309	5.5-12.1	0.01-1.0	3.4-5.21	0.36-1.25	
Jul.	Mean (± SD)	125.5 (±81.1)	219.0 (±98.2)	8.96 (±4.5)	0.56 (±0.2)	4 (±0.8)	1.1 (±0.1)	1:0.63
	Range	30-320	1.5-1190	2.7-15.9	0.3-0.81	2.9-5.01	0.7-1.28	
Aug.	Mean (± SD)	177.5 (±57.5)	270.0 (±28.4)	8.2 (± 3.6)	0.4 (± 0.2)	3.6 (± 0.8)	0.9 (± 0.3)	1:0.28
	Range	82-320	15-1370	1.5-13.1	0.1-0.79	2.3-4.95	0.4-1.33	
Sep.	Mean (± SD)	143.5 (±65.7)	176.7 (±36.1)	9.4 (±4.4)	0.4 (±0.2)	3.7 (±0.07)	1.1 (±0.1)	1:0.17
	Range	65-290	7.1-1003	0.8-14.0	0.03-0.6	1.7-4.8	1.1-1.1	
Oct.	Mean (± SD)	199.4 (±43.4)	310.8 (±22.1)	6.6 (±2.3)	0.48 (±0.5)	3.3 (±0.4)	0.9 (±0.3)	1:0.38
	Range	115-294	44.2-887	3.6-11	0.05-2.76	2.5-3.97	0.4-2.24	
Nov.	Mean (± SD)	199.7 (±44.1)	310.8 (±22.6)	6.6 (±2.3)	0.48 (±0.4)	0.4 (±0.1)	0.9 (±0.2)	1:0.38
	Range	113-295	43.3-888	3.4-10.9	2.5-3.94	0.05-2.9	0.4-2.3	
Dec.	Mean (± SD)	182.6 (±27.8)	216.1 (±97.7)	0	0.8 (±0.2)	0	1.2 (±0.1)	1:0
	Range	135-230	86.6-418	0	0.5-1.34	0	0.9-1.31	

6. Ova size

The variation in egg size with the development of maturity stages is depicted in Fig. (4). This phenomenon allows for the establishment of a spawning rhythm, which determines the number of spawning batches. It is possible to observe the growth in egg sizes from the virgin to the mature stage and the decline in the percentage of large eggs from the spent to the partially spent stage. The virgin stage was characterized by the presence of only small eggs in the first six groups, with the predominance of the first group, whose diameters did not exceed 0.1mm, and the largest egg in it reached 0.6mm. The number of groups increased in the ovaries of mature-stage fish and reached ten stages. The maximum diameter of the eggs reached 1.1mm, with the possibility of

observing three distinct peaks within the groups: 0.2- 0.3, 0.6- 0.7, and 0.0- 1.0mm. The spent stage is similar to the mature group, with an apparent increase in the percentage of larger eggs in the 0.8- 1.1mm range.

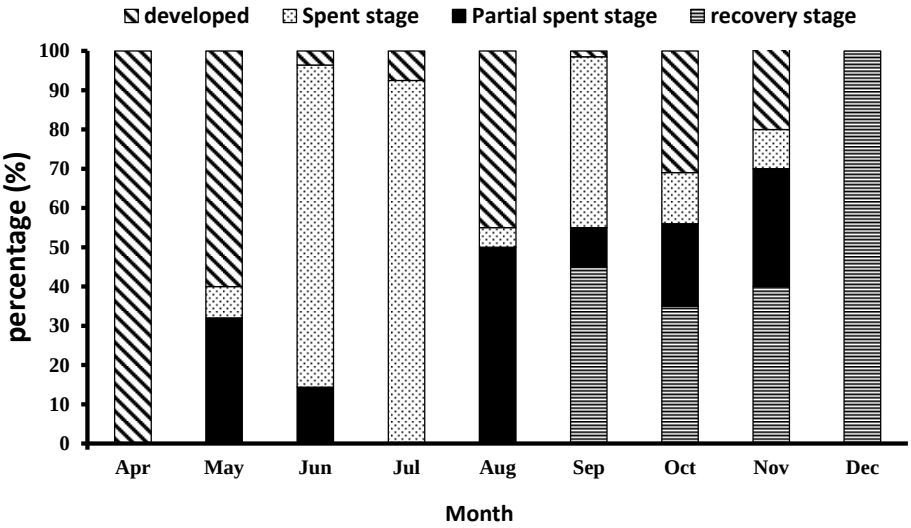

Fig. 3. Temporal occurrence of sexual maturity stages of *P. candidus*

Table 3. Distinguishing characters of the gonad maturity stages of females and male *P. candidus* in Iraqi marine waters

1. Immature stage

It is not easy to distinguish between the sexes with the naked eye. The thread is filamentous to rod-shaped, waxy white to semi-transparent yellow, and is at the top of the body cavity. It appears with a fork length range of 92- 119mm. GSI in this stage ranges between 0.15 and 0.20 with an average of 0.18 and is present from September to November.

2. Developing stage

Females: The ovary is pale yellow, its length is more than three-quarters of the coelom, the eggs are visible, its color is yellow, semi-transparent to translucent, granular in appearance, rod-shaped, and the abdomen is swollen. It appears with a bifurcated length range of 215- 242mm. GSI at this stage ranges from 4.6- 11.0 with an average of 6.2, and it is present from February to November.

Males: Testicles are dull reddish-white, vast, and opaque. The veins are visible about half to three-quarters of the cavity length. It appears with a diatom length range of 130- 238mm. GSI in this stage ranges from 0.2 to 2.7 with a rate of 0.75, and is present from February to November.

3. Running (Ripe) stage

Females: The ovary is yellow to orange, large, occupying the entire cavity, swollen, granular, lobed. yellow transparent eggs can be seen. The membrane is thin. The eggs come out with little pressure and may be seen outside the urogenital opening. The abdomen is very bloated. It appears with a crotch length range of 215- 320mm. GSI

in this stage ranges between 2.7 & 14, with an average of 8.8 and is present from May to November.

Males: The testicles are swollen cream-colored, and the tissue is homogeneous, not granular, more than three-quarters of the cavity. Sperm oozes under a slight pressure. It appears with a bifurcation length range of 162- 228mm. GSI at this stage ranges between 0.3 & 3.1, with a rate of 0.94. It is found from May to November.

4. **Partial spent stage**

Females: The ovaries are semi-flabby, the color is reddish-brown and bloody asymmetrical, the eggs are smaller in size than in the previous stage, and there are some opaque yellow eggs, they appear at the forked length range of 248- 295mm. GSI at this stage ranged between 1.0 and 3.5, with an average of 2.1, and is present from May to September.

Males: The testicles are flabby, almost swollen, the texture is not homogeneous, sperm still flow when pressed, the color is asymmetrical with some bloody areas. It appears with a crotch length range of 92- 119mm. GSI at this stage ranged between 0.1 & 0.79, with a rate of 0.41, and was present from May to September.

During the months.

5. **Spent stage:**

Females: The ovary appears empty, with a blood-red sac containing many opaque yellow eggs. It appears with a crotch length range of 200- 294mm. GSI at this stage ranged between 0.85- 3.4, with an average of 1.4, and was detected from October to November.

Males: The testicles are flabby, bloody white, dull in color, and elongated. It appears with a crotch length range of 175- 231mm. GSI at this stage ranged between 0.1 - 0.8, with an average of 0.4, and was present from October to November.

6. **Resting (Recovery) stage:**

Females: The ovaries are flesh-colored, semi-transparent, rod-shaped, and not solid in texture. It appears with a diatom length range of 260- 295mm. GSI at this stage ranges between 0.8- 3.4, with an average of 2.1. It is found from September to November.

Males: The testicle is greyish white, about a third of the length of the cavity, semi-flaccid, and the color is the same. It appears with a crotch length range of 135-230mm. GIS in this stage ranges between 0.3 and 1.3, with a rate of 0.8, and is present from September to November.

Three prominent peaks were distinguished in the frequency distribution of oocyte diameters in the mature and spent stages in which oocyte development was completed. Small-sized eggs and medium-sized eggs could be distinguished, followed by large eggs. It is also possible to determine the appearance of large eggs from the virgin to the mature stage and the spent of large eggs (0.8- 1.1mm) during the partial release stage after they were present in the spent stage.

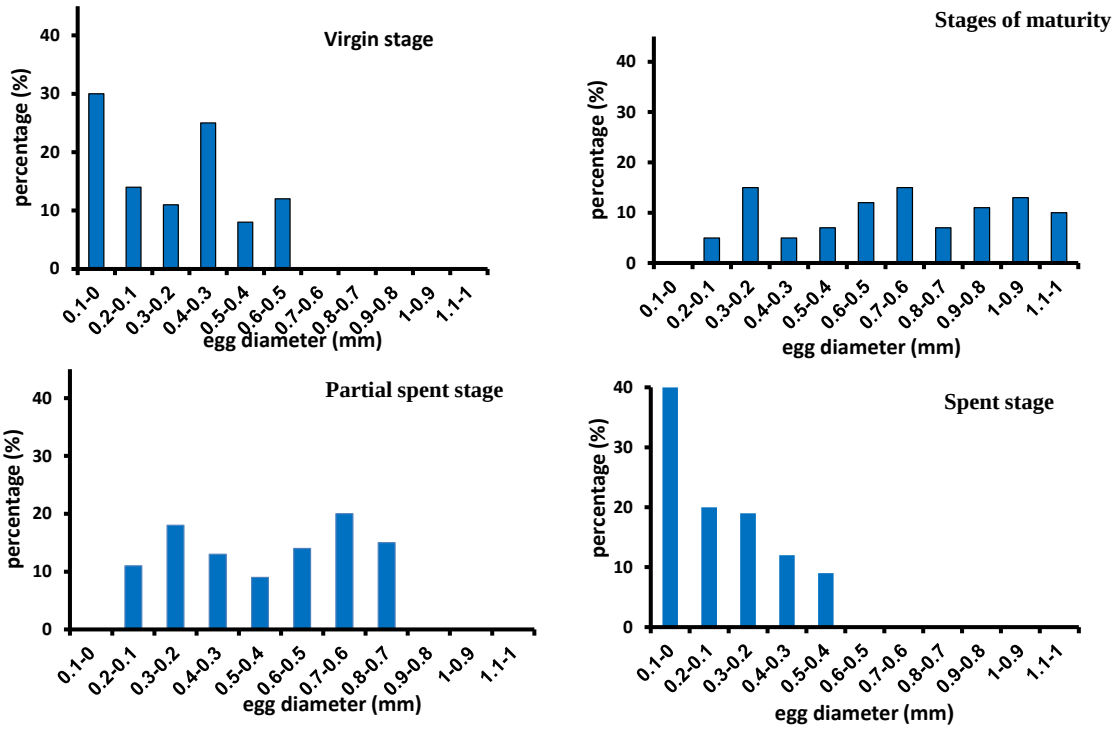

Fig. 4. Egg size with the development of maturity stages of *P. candidus*

7. Fecundity

The absolute fecundity rate was determined to be 525,180, with a range of 204,000-1,478,000 eggs observed in females with a forked length ranging from 215 to 310mm. The relative fecundity rate and range for the identical length were 727.5 and 495.9-1078.8 egg g^{-1}, respectively. The exponential connection was determined to be the most optimal correlation between absolute fecundity and length and weight. Based on the 95% confidence limits presented in Fig. (5), it can be observed that the link between weight and length had a more robust association. The correlation with weight was:

$$F = 133564\, e^{0.0018\, W}$$

$$R^2 = 0.9017$$

And with length:

$$F = 8.8195\, e^{0.0153 FL}$$

$$R^2 = 0.8173$$

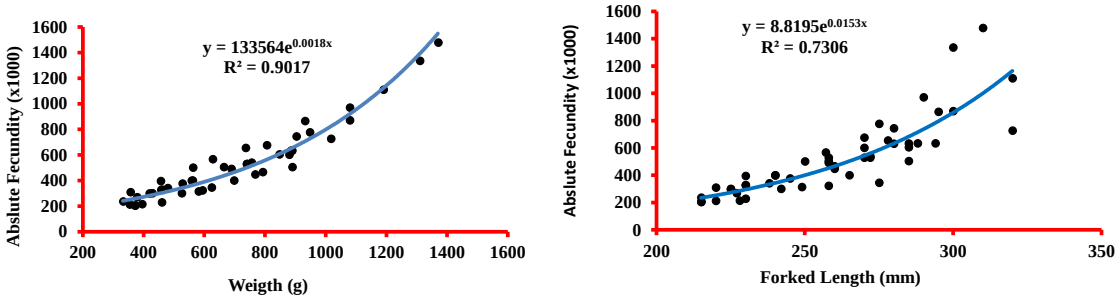

Fig. 5. The relationship of absolute fecundity with length and weight of *P. candidus*

DISCUSSION

Understanding the reproductive biology of a species provides valuable information on how to manage populations and comprehend future changes to the stock. Therefore, this study showed the most important features of reproductive *P. candidus*. They are oceanodromous benthopelagic fish that migrate in groups annually toward Iraqi marine waters to spawn in the Khor Abdullah area. The *P. candidus* is unisexual and does not display the secondary characteristics that distinguish the sexes. However, it is possible to differentiate between males and females during the reproductive season based on the external appearance of mature fish by the abdomen bulge. The phenomenon of males being smaller in length and weight than females is one of the features of *P. candidus* populations in the northern Gulf region, as most females are large. This is consistent with the findings of **Muhammad and Ali (1993)** and **Almatar *et al*. (2004)**. This difference in size may be due to the variation in growth rate between the sexes **(Vicentini & Araujo, 2003)**. In addition, a strategy to increase egg production in larger sizes is possible.

The results of the study showed that male *P. candidus* fish mature before females, and this is consistent with studies in the region, with differences in the maturity length of both sexes, as **Mohamed and Ali (1993)** recorded the maturity length (L_m) for males and females as 102 and 155mm, respectively, as well as **Narges *et al*. (2007)** recorded in Iranian marine waters; males were 180 and females were 222mm. While, **Nekuru *at el*. (2021)** recorded the length at sexual maturity at 181 and 208mm for males and females in the northwestern Persian Gulf and Oman Sea, respectively. **Dadzie *at el*. (2000)** found that males mature earlier than females at a minimum length of 125- 144mm, while female mature at a length of 205- 225mm in Kuwaiti waters, and mature females are present throughout the year with an increase from June to November, the length of the first maturity for females was 275 mm. **Ghosh *et al*. (2009)** recorded the maturity length in Korean waters as 180mm. On the other hand, **Kim and Han (1989)** recorded the maturity length as 185mm**. Liming and Yongsoung (2005)** found that at the mouth of the Pearl Estuary in China, the *Pampus argenteus* reaches maturity at a length of 150mm. **Lee and Jin (1989)** found that the *Pampus* sp. in eastern China matures before females and is

167mm in length, while females reach maturity at 186mm. **Pati (1982)** in his study revealed that the maturity length in Indian waters amounted for 150mm for males and 170mm for females. Differences may be geographical differences due to environmental differences.

Another phenomenon that distinguished *P. candidus* communities in Iraqi marine waters is the presence of males more than females. The sex ratio recorded in the current study is consistent with the result of **Narges *et al*. (2007)** in the Iranian waters. The study of **Muhammad and Ali (1993)** in the Iraqi waters, and the study of **Al-Abdul-Elah *et al*. (2002)** in the Kuwaiti waters, the sex ratio was recorded (females to males)at 2.1:1, which is in favor of males. The study did not agree with **Ghosh *et al*. (2009)**, who reached 1:1.75 in favor of females. **Shi *et al*. (2009)** found that the sex ratio was 1:1 for *Pampus argenteus* during the spawning season in the Chinese waters. Differences in factors such as growth rate, longevity, and mortality may lead to differences in the sex ratio, in addition to fishing methods that target larger, mostly female fish. The study of the microscopic examination of the gonads and the gonadosomatic index showed that the *P. candidus* breeding season in the Iraqi marine waters is a long period, and continuously extends from May to November and that there are two distinct periods of spawning season, the first during May and June while the second during October. **Mohamed and Ali (1993)** found that the breeding period in the Iraqi marine waters extends from May to September, with the peak of spawning from June to July. **Dadzie *et al*. (2000)** stated that the breeding season in Kuwaiti waters is long, extending from May to August with two peaks of spawning, the first is during May, and the second is during August. Whereas, **Almatar *et al*. (2004)** recorded the release from mid-May which continues until the beginning of October. During this time, the water temperature ranges from 26 to 32.8ºC. Larger females spawn earlier than smaller fish during the season. **Lone *at el*. (2008a)** also recorded, in the same waters, the lowest (GSI) for females was in January at 0.69± 0.11 when the temperature was 13.9, and the highest (GSI) was in June at 7.9± 0.04 when the temperature was 30.6. Therefore, the peak of spawning is in June and continues through September. It was also indicated that the females may spawn multiple times during the season and that the GSI is more closely related to temperature than photoperiod **(Lone *et al*., 2008b)**. **Safikhani (1998)** found that the breeding time of the silver pomfret in Iranian marine waters, the Mahshahr region, extends from March to September, with two peaks in June and September. **Narges *et al*. (2007)** also recorded the length of the breeding season with two peaks in their study. **Pati (1982)** found in the Bay of Bengal that the silver pomfret breeding season in the Indian waters was from February to August. On the other hand, **Lee and Jin (1989)** found a single peak in the Korean marine waters east of China from June to July. In this study, the breeding season extended with two peaks. The change in the breeding time of the silver pomfret in the regions may be due to asymmetry in populations, temperatures, and currents **(Lone *et al*., 2008b)** in addition to the different species of the silver pomfret.

Six stages of maturation of the *P. candidus* fish were identified in the current study, ranging from the immature to the resting (recovery) stage. **Kuthalinam (1963)** divided the stages of maturation of the gonads in the Bay of Bengal into five stages and determined its breeding season from January to February. **Gopaln (1969)** also described the silver pomfret reproduction in the Arabian Sea and divided the stages of maturity into seven. He concluded that each female spawn eggs twice a season, the reproductive period extends from February to August and reaches its peak in April-June, and that large fish mature sexually before small ones. **Hussain and Abdullah (1977)** mentioned that the silver pomfret breeding season in the northern Gulf extends from April until September and that there are two peaks for laying. The main one is during April-May, and the second is during September.

The study by **Abu-Hakima (1984)** compared some biological aspects of *Pampus* spp. reproduction with two types of the Gulf fish through a histological analysis of the gonads. It showed that the breeding season extends from March to August. **Moumeni and Ehsan (2006)** found a long reproductive period in Bandar Abbas, extending from March to September, and that this area is not a reproductive area due to the lack of advanced maturity stages. **Qixiang *et al.* (1989)** found that the spawning season in the East China Sea is from May to June. The gonads mature during March but do not go beyond the fourth stage after remaining in the second stage during winter. The silver pomfret can be classified as a short type and is offered in batches based on the behavior of offering shorts.

The results of the current study and studies in the region show that *P. candidus* reproduces in the northern Arabian Gulf region, characterized by the vast area between the tides and low tide, as reproduction occurs in the deep areas in two periods. The first is a major breeding period in April-June, and the second is in September-October. The species has a prolonged spawning period. **Parsamanesh (1998)** recorded the presence of small fish less than 100mm throughout the year. This is what **Pati (1982)** found in the Bay of Bengal: that the silver pomfret breed in areas far from the coast, offshore regions, and that early juveniles are abundant in all areas facing the coast, which are characterized by a wide extension in the intertidal zone. The survey conducted by **Dames and Moore (1983)** in the northwestern part of the Kuwaiti waters showed that silver pomfret eggs and larvae are present throughout the year in Kuwait Bay. The highest larval abundance was in Khor Subiya and the northern flat of Failaka Island during the summer months between May and August. The top reproductive of the silver pomfret throughout the late spring and summer can be inferred from the observed concentration of larvae in the vicinity of Khor Subiya. Certain eggs and larvae can be observed in alternative months and locations.

The variation in egg size across different stages of sexual maturity observed in this study reflects the reproductive pattern, showing that eggs are produced in large batches

during the breeding season, with sizes ranging between 0.2 and 1.1mm. The range of egg diameters for mature fish in the study area during the 1989 season ranged between 0.37- 1.18mm, and for the 1990 season, it ranged between 0.56- 1.1mm **(Mohamed & Ali, 1993)**. **Mito and Senta (1967)** found that egg diameters in the Sea of Japan during the breeding season ranged between 1.21- 1.35mm. **Mizuta *et al*. (1977)** explained that there are three stages of eggs with average diameters of 0.53, 0.93, and 1.31mm, and that there are several batches during the breeding season. **Almatar *et al*. (2004)** in their study of the maturation cycle and the frequency distribution of egg size, also concluded that the silver pomfret is a multiple batch spawner with an indeterminate fecundity. **Shi *et al*. (2009)** recorded the diameter of eggs in the fifth stage as 700- 850 microns. Several batches are released during the breeding season, with an average fork length of 225 and 140- 170mm for males. Moreover, the spawning season spans from the beginning of May until the beginning of June.

The absolute fecundity rate calculated in the current study is higher than that of other studies, with a high correlation with weight. This is due to the changes that occur in the weight of the gonads. **Muhammad and Ali (1993)** reported that the fecundity rate of the silver pomfret varies with fish size, ranging from 51,316 eggs for fish measuring 176mm in length and weighing 281g, to 245,356 eggs for fish measuring 254mm in length and weighing 960.2g. This fecundity is more closely related to weight than length. Similarly, **Pati (1981)** observed fecundity rates in the Bay of Bengal ranging from 40,610 to 90,460 eggs for fish between 191 and 238mm in length. **Dadzie *et al.* (2000)** documented fecundity in Kuwaiti waters ranging from 28,965 to 455,661 eggs, with positive correlations to standard length, ovarian weight, and body weight, but an inverse relationship with egg size. **Qinman *et al.* (2009)** found that absolute fecundity averaged 90,071.1 eggs, with a relative fecundity rate of 349.34 eggs per gram, showing a direct relationship with forked length, body depth, and height, as well as body weight. **Qixiang *et al.* (1989)** indicated that both absolute and relative fecundity are linearly related to weight and exponentially related to height. In addition, **Al-Matar *et al.* (2006)** confirmed that the number of eggs is directly proportional to fish weight or length.

Based on these findings, fishing nets should be sized to avoid capturing fish below the minimum length at which they can reproduce. Many fishermen have resorted to using illegal nets with smaller openings to catch fish below 130mm, leading to a decline in mature fish populations **(Jafar, 2011)**. To address this issue, management measures should include size-limit regulations to prevent catching immature fish, time-limit regulations to avoid fishing during peak reproductive periods, and limitations on the number of operating boats. Specifically, the minimum fishing length should be at least 260mm, with fishing prohibited in May and June. Additionally, carcass nets should be banned in breeding and nursery areas, and the use of gillnets larger than 76mm should be encouraged **(Forghani, 2011)**. Ensuring catches are above 270mm and prohibiting

fishing during June and August will help protect the estuary environment from overexploitation.

CONCLUSION

The current study reveals that *P. candidus* reproduces in the northern Persian Gulf region with spawning occurring in deep areas during two main periods: the primary breeding season from April to June and a secondary period from September to November. This reproductive period is relatively extended, with males maturing before females. The study identified six stages of maturation for *P. candidus*, ranging from immature to the resting (recovery) stage. The fish exhibit multiple-batch spawning behavior, with uncertain fecundity levels based on gonadal cycles, oocyte size frequency distribution, and overall fecundity analysis. Notably, Khor Abdullah has been confirmed as the key spawning and nursery area for *P. candidus* in the region.

REFERENCES

Abu-Hakima, R. (1984). Comparison of aspects of the reproductive biology of Pomadasys, Otoliths, and Pampus spp. in Kuwaiti waters. Fish. Res. 2: 177–200. https://doi.org/10.1016/0165-7836(84)90002-X

Al-Abdul-Elah, K. M.; Almatar, S.; Abu-Rezq, T.; James, C.M. and El-Dakour. S. (2002). Development of hatchery techniques for the silver pomfret. Asian Fish. Soc. 15: 107–121. https://doi.org/10.33997/j.afs.2002.15.2.002

Almatar, S. M.; Lone, K. P.; Abu-Rezq, T. S. and Yousef, A. A. (2004). Spawning frequency, fecundity, egg weight and spawning type of silver pomfret, *Pampus argenteus* (Euphrasen) (Stromateidae), in Kuwait waters. Journal of Applied Ichthyology, 20: 176–188. https://doi.org/10.1111/j.1439-0426.2004.00546.x

Bagenal, T. B. (1978). Aspect of fish fecundity. In: 75–101 Gerking, S. D. (Eds.) "Ecology of freshwater fish production". Blackwell Scientific Publications, London.

Buchanan, J.R.; Ralph, G.M.; Krupp, F.; Harwell, H.; Abdallah M.; Abdulqader, E.; Al-Husaini, M.; Bishop, J.M.; Burt, J.A.; Choat, J.H.; 486 Collette, B.B.; Feary, D.A.; Hartmann, S.A.; Iwatsuki, Y.; Kaymaram, F.; Larson, H.K.; Matsuura, K.; Motomura, H.; Munroe, T.; Russell, B.; Smith-Vaniz, W.; Williams, J. and Carpenter, K.E. (2019). Regional extinction risks for marine 488 bony fishes occurring in the Persian/Arabian Gulf. Biological Conservation 230:10-19. https://doi.org/10.1016/j.biocon.2018.11.027

Cruz, E. M.; Almatar, S. and Abdul Elah, K. (2002). Determination of the Minimum Lethal Temperature for Year 0 and Year 1 silver Pomfret (*Pampus argenteus* Euphrasen). Asian Fis. Sci., 15: 91-97.
https://doi.org/10.33997/j.afs.2002.15.1.010

Dadzie, S.; Abou-Seedo, F. and Al-Shallal, T. (2000). Reproductive biology of the silver pomfret, *Pampus argenteus* (Euphrasen), in Kuwait waters. J. of Applied Ichthyology, 16(6): 247-253.
http://dx.doi.org/10.1046/j.1439-0426.2000.00237.x

Dames and Moore. (1983). Aquatic biology investigation studies for the Subiya area, Kuwait Bay, and development of electrical networks. Ministry of Electricity and Water contract No. MEW/Cp/PGP-1113-80/81, Kuwait.

Dobriyal, A. K.; Rautela, K. K. and Rautela, A. S. (1999). Invention of a new index for the determination of sexual maturity in fishes. Uttar Pradesh Journal of Zoology, 19(3): 207-209.
https://doi.org/10.1111/j.1471-8286.2006.01438.x

FAO. (2011). FAO/Regional Commission for Fisheries. Report of the FAO/RECOFI Workshop on the Fishery Stock Indicators and Stock Status. Tehran, the Islamic Republic of Iran, 26-29 July 2009. FAO Fisheries and Aquaculture Report. No. 970. Rome, 46 pp.
https://www.fao.org/3/i2170e/i2170e.pdf

Forghani, S. (2011). The Management of Silver Pomfret (*Pampus argenteus*) Fishing in the Persian Gulf. World Journal of Fish and Marine Sciences, 3(6): 529–532.

Ghosh, S.; Mohanraj, G.; Asokan, P.K.; Dhokia, H.; Zala, M.S. and Bhint, H.M. (2009). Fishery and stock estimates of the silver pomfret, *Pampus argenteus* (Euphrasen), landed by gill netters at Veraval. Indian J. of Fisheries, 56(3): 177-182.

Gopalan, U.K. (1969). Studies on the maturity and spawning of silver pomfret, *Pampus argenteus* (Euphrasen), in the Arabian Sea. Bull. natl. Inst. Sci. (India), 38, 785-796.

Holden, M.J. and Raitt, D.F.S. (1974). Manual of fisheries science. Part 2-Methods of resource investigation and their application. F.A.O.
https://www.fao.org/fishery/en/publication/22750

Hussain, N.A. and Abdullah, M.A.S. (1977). The length-weight relationship, spawning season, and food habits of six commercial fishes in Kuwait. Indian Journal of Fisheries, 24: 181–194.

Jafar, E. (2011). Challenges of fishing industry in Iran's Khoozestsn province, Abadan chamber of Commerce. Industries and Magazine, 2: 10-14.

Kagwade, P.V. (1988). Pomfret resources along the north-west coast of India, In Living Resources of the Indian Seas. Bombay Research Centre, Central Marine Fisheries Research Institute, Bombay, India, 219- 224pp.

Kesteven, G.L. (1960). Manual of field methods in fisheries biology. *FAO* Manuals Fisheries Sciences, 1: 152 pp.

Kim, Y.U. and Han, K.H. (1989). Studies on the fishery biology of Pomfret, Pampus sp. In: "Korean water. 10 Morphology of the two species of the Genus Parnpus". Bulletin of Korean Fisheries Society. 22 (5): 241–265.

Kuthalingam, M.D. K. (1963). Observations on the fishery and biology of the silver pomfret, *Pampus argenteus* (Euphrasen) from the Bay of Bengal. Indian Journal Fish., 10 ,(1): 59–74.

Lee, T.Y. and Jin, J.J. (1989). Studies on the biology of pomfret, *Pampus* sp. In: The Korean waters. 2. Gonadal maturation and spawning. Bull. Fish. Soc., 22: 266–280.

L**one, K. P.; Al-Ablani, S. and Almatar, S.** (2008) Oogenesis, Histological Gonadal Cycle, Seasonal Variation and spawning Season of Female Silver Pomfret (Pampus argenteus, Euphrasen)From the Spawning Ground of Kuwait. Pakistan J. of Zool., 40 (6): 397–407.

Lone, K. P.; Al-Ablani, S. and Almatar, S. (2008) Spermatogenesis, Maturation, Seasonal Variation and Spawning Season of Silver Pomfret (*Pampus argenteus*, Euphrasen) Collected From the Natural Spawning Ground off Kuwait. Pakistan J. of Zool., 40(4): 263–273.

Liming, S., and Yongsong, Q. (2005). Estimation of growth and mortality parameters for *Pampus argenteus* in Pearl River Estuary and adjacent waters. Shuichan Xuebao, 29 (2):193-197.

Mito, S. and Senta, T. (1967). On the egg development and larval stages of silver pomfret concerning its spawning in the Seto Inland Sea. Bull. Japan. Soc. Sci. Fish., 33, 948–951.

Mizuta, Y.; Ito, T. and Ono, H. (1977). [*Basic information concerning the raising of the aperental pomfret*]. (Preliminary report). Res. Cultivat. Techn. 6(2): 33-38pp. (In Japanese)

Mohamed, A.R.M. and Qasim, A.M.H. (2014). Trend of the artisanal fishery in Iraqi Marine Waters, Arabian Gulf (1965-2011). Asian J. Appl. Sci., 2(2): 209–17.

Mohamed, A.R.M. and Ali, T.S. (1993). Reproductive biology of silver pomfret, *Pampas* argenteus (Euphrasen), in the Northwest Arabian Gulf. APA J. of Agri. Res., 3(2): 190–201. (In Arabic)

Moumeni, M. and Ehsan, K. (2006). Reproductive biology of silver pomfret Pampus argenteus in Bandar Abbas fishing ground. J. of Mari. Sci. and Technology, 5(3-4):53-64. (in Persian).

Muhammad, A. R. M., and Ali, T. S. (1993). Growth and mortality of Zubaidi fish in the northwestern Arabian Gulf. APA Journal of Agricultural Research, 3(1): 18–33.

Narges, A. N.; Preetha, K.; Maremmazi, J.; Eskandary, G-R., and Vahid,Y. (2007). Spawning Season of Argenteus (Euphrasen, 1788) in the North-west of the Persian Gulf and its Implications for Management. Pakistan J. of Bio. Sci.,10(24):4551-4554. https://doi.org/10.3923/PJBS.2007.4551.4554

Nekuru, A.; Kamrani, E.; Safaie, M.; Raeisi, H. and Momeni, M. (2021). Study of biological characterizes of reproductive of Silver Pomfret, *Pampus argenteus* (Euphrasen, 1788) in northern waters of Persian Gulf and Oman Sea (Hormozgan Province). Journal of Animal Environment, 13, (1): 371-380.

Nikolsky, G. V. (1963). The Ecology of Fishes. Academy Press, London and New York. 352 pp.

Parsamanesh, A.; Shalbaf, M. and Najafpour, N. (1998). On the status of *Pampus argenteus* fisheries in Khoozestan waters (North-West Persian GULF), I. R. Iran. Indian J. of Ani. Sci., 68: 407-409.

Pati, S. (1982). Studies on the maturation spawning and migration of Silver Pomfret, *Pampus argenteus* (Euphrasen) from Bay of Bengal. Matsya, 10, 12–24.

Pati, S. (1981). Fecundity of Silver Pomfret, *pampus argentus* from Bay of Bengal. Indian J. Mar. Sci., 10: 103–104.

Poudel, J.; Shrestha, J. N.; Rajbanshi, D., and Limbu, J. H. (2023). Fecundity of Glyptothorax telchitta (Hamilton, 1822) from Tamor River, Nepal. Our Nature, 21(1): 60–66.

Qasim, A. M. and Ali, T. S. (2022). Spatiotemporal Analysis on Shipwrecks in Shatt Al-Arab River and Iraqi Marine Waters Northwest Arabian Gulf. Basrah Journal of Agricultural Sciences, 35(1): 212–228. https://doi.org/10.37077/25200860.2022.35.1.16

Qinman, C.; Chunying, Y. and Xiaoshuang, L. (2009). The study on fecundity of silver *pomfret Pampus* argenteus in Bohai Bay. Marine Science Bulletin, 28 (6): 66-69.

Qixiang, G., Haier, N., Lunping, L., and Chunjing, Z. (1989). On the change of the ovary in annul cycle of silver Pomfret stromateoides argenteus from the East China Sea. J. of Fisheries of China 13(4): 316-325.

Radhakrishnan, D. P., Kumar, R. G., Mohitha, C., Shanis C P, R., Kinattumkara, B. K., Saidumohammad, B. V., & Gopalakrishnan, A. (2019). Resurrection and Re-description of Pampus candidus (Cuvier), Silver Pomfret from the Northern Indian Ocean. Zoological studies, 58, e7. https://doi.org/10.6620/ZS.2019.58-07

Rhman, M.; Safur, M.; Rahman, R. and Kamal, D. (2004). Length-Weight relationship, Condition Factor and Harvesting Records of Silver Pomfret (*Pampus argenteus*) In the Southwestern Region of Bangladesh, Pakistan J. of Bio. Sci. 7, (4): 452-456.

Safikhani, H. (1998). Studies on the biology of silver pomfret, Pampus argenteus (Euphrasen) from Mahshahr estuaries of Iran. M.S. Thesis, Azad University of Tehran. (in Persian)

Sami, M.; Rym, E.; Othman, J. and Missaoui, H. (2014). First Record of *Pampus argenteus* (Euphrasen, 1788) (Osteichthyes: Stromateidae) in the Tunisian Coast (Mediterranean Sea). Journal of Marine Biology and Oceanography, 3 (1).

Shi, Z.H.; Zhao, F.; Wang, J.; Peng, S. and Wang, H. (2009). Artificial insemination and incubation of silver pomfret (Pampus argenteus) from Zhoushan fishing ground. Fishery Modernization, 36(1): 18-21. (In Chinese)

Shahram, F. and Naming, M. (2010). Reproduction and Spawning of the silver pomfret (*Pampus argenteus*) in Persian Gulf. Proceeding of the Azerbaijan Society Zoologists, 2, 644-649.

Sokal, R.R. and Rohlf, F.J. (1995) Biometry: The Principles and Practice of Statistics in Biological Research. 3rd Edition, W.H. Freeman and Co., New York.

Vicentini, R. N. and Araujo, F. G. (2003). Sex Ratio and size structure of Micropogonias furnieri (Desmarest, 1823) (Perciformes, Sciaenidae) in Sepetiba Bay, Rio de Janeiro, Brazilian J. of Bio., 63(4): 559-566.

Wei, J.; Wu, R.; Xiao Y.; Zhang, H.; Jawad, L.A.; Wang, Y.; Liu, J. and Al-Mukhtar, M.A. (2021). Validity of *Pampus liuorum* Liu and Li, 2013, Revealed by the DNA Barcoding of Pampus Fishes (Perciformes, Stromateidae). Diversity,13(12): 618. https://doi.org/10.3390/d13120618

Wen, T.Y.; Jian, L. and Gen, H.Y. (2006). Multiplex genotyping of novel microsatellites from silver pomfret (*Pampus argenteus*) and cross-amplification in other pomfret species. Molecular Ecology Notes, 6(4): 1073-1075.

White, D.B.; Wyanski, D.M. and Sedberry, G.R. (1998). Age, growth and reproductive biology of the black belly rosefish from the Carolinas, USA. *Journal of Fish Biology*, *53*(6): 1274-1291. https://doi.org/10.1111/j.1095-8649.1998.tb00248.x

Zhao, F.; Shi, Z. H. and Zhuang, P. (2010). Advance in reproductive biology and artificial breeding technology of silver pomfret, *Pampus argenteus*. Mari. Sci. 34: 90–96.