Sex Ratio, Spawning Cycle, and Size at Maturity of Bluespotted Seabream (*Pagrus caeruleostictus*,Valenciennes 1830) from the Coast of Ghana

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ABSTRACT

The decline in commercially important fish stocks, particularly demersal species, is a growing concern in Ghana, where these fish contribute significantly to food security. Despite their critical role, a lack of comprehensive biological studies has hindered the development of effective sustainable management strategies. This study aimed to address this gap by investigating key reproductive aspects of *Pagrus caeruleostictus*, a commercially valuable demersal fish in Ghana. A total of 560 individuals were sampled from the coast of Greater Accra, and their sex ratio, spawning cycle, and length at first maturity were analyzed. The results revealed a skewed sex ratio of 1 male:0.67 female. The peak spawning period for females occurred in April, while males peaked in March. The major spawning seasons for females and males were identified as July-August and March-April, respectively. Notably, larger size classes were dominated by males, supporting the hypothesis of protogyny in *P. caeruleostictus*. The length at first maturity was 18.4 cm for females and 21.1 cm for males. These findings suggest that the current minimum legal harvesting length, as outlined in Ghana's Fisheries Regulation, should be revised to reflect the reproductive biology of this species and ensure its long-term sustainability in Ghanaian waters.

Keywords: Fisheries regulation, Gonadal stages, Life history, Population structure, Reproduction, Sparidae

INTRODUCTION

Effective management and conservation of fisheries resources rely heavily on understanding the reproductive potential of fish populations (Lowerre-Barbieri *et al*., 2011). The reproductive success of fish directly influences population dynamics, genetic diversity, ecosystem integrity, and food security, particularly for households in coastal regions that depend on these resources. Among the key species in Ghana are seabreams, belonging to the family Sparidae (Correia *et al*., 2012).

In Ghana, various fisheries sectors, including artisanal, semi-industrial, and industrial, employ different techniques such as hook-and-line fishing to target seabream species (Koranteng, 2001; Ayode, 2011; Nunoo *et al*., 2014). Important seabream species in Ghanaian waters include *Pagellus bellottii, Dentex* spp., and *Pagrus caeruleostictus* (Clottey *et al*., 2021). The Bluespotted Seabream (*Pagrus caeruleostictus*), a demersal species found in diverse substrates–such as rocky bottoms up to depths of 200 m–ranges from Portugal to Angola, including the Mediterranean basins (Hamida *et al*., 2010; Konoyima and Seisay, 2020). Its diet consists

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of crustaceans, mollusks, fish, polychaetes, ascidians, and echinoderms (Clottey *et al*., 2021). Numerous studies (e.g., Owusu-Boateng, 1994; Clottey *et al*., 2021; Amponsah *et al*., 2023; Clottey *et al*., 2024) highlight the species' significant role in food security and the economic welfare of coastal households in Ghana. However, only two studies (i.e. Owusu-Boateng, 1994; Clottey *et al*., 2024) have focused on the reproductive aspects of *P. caeruleostictus* from the coast of Ghana. A recent study by Clottey *et al*. (2024) on the sampled species from the coast of Ghana provided scientific information on some aspects of biology and stock assessment of the species. However, given the importance of the sampled species to food security and economic wellbeing in Ghana, it is essential to have more scientific information on its reproductive aspects for proper management. Therefore, the study sought to assess the reproductive aspects of the Bluespotted seabream in Ghana which would serve as additional information for effective management (Kuoame *et al*., 2018).

MATERIALS AND METHODS

Study area

The study focused on three offshore stations of Tema Harbour, located along the coast of Greater Accra, Ghana (Figure 1). Tema Harbour is one of the largest harbour in West Africa, that has influenced development within its catchments in Ghana (Botwe *et al*., 2018). The harbour, completed in 1952, has an 800–foot–wide entrance with a minimum depth of 35 feet, covering an expansive 410 acres of enclosed water and manages trades for industrial and commercial firms (Khadi, 2015).

Data collection

We carried out a survey using a semi-industrial trawler with a bottom trawl net. The dimension of the cod-end was 1 inch (diagonal stretch) mesh size. Sampling was done between January to December 2019 with 560 individuals of

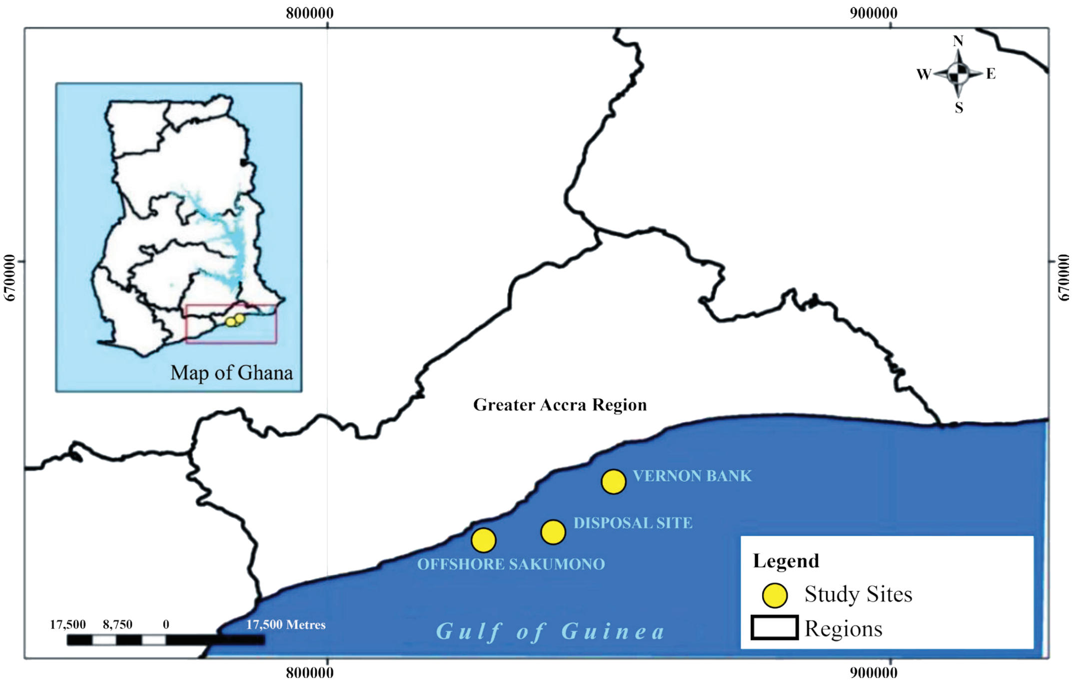

Figure 1. Sampling areas around Tema harbour, along the coast of Greater Accra, Ghana.

P. caeruleostictus obtained (Figure 2). The catches obtained were identified using Kwei and Ofori-Adu (2005) identification keys. Each specimen was measured for total length (TL) to the nearest 0.1 cm, body and gonad weight to the nearest 0.01 g. The sex and maturity stages of individuals were identified after dissecting the abdominal cavity.

Methods

The sex ratio of male and female individuals was determined monthly to assess potential variations over time. To evaluate whether there was a statistically significant difference between the sexes, the Chi-square test (χ^2) was applied at a 95% confidence interval, with significance defined by a p-value<0.05 (Heithaus, 2001).

Female gonad maturity stages were classified following the protocol by Holden and Raitt (1974), which is based on the morphology and color of the gonads. These stages are defined as follows: Stage I, immature; Stage II, maturing; Stage III, nearly ripe; Stage IV, ripe and running (spawning); and Stage V, spent. Table 1 provides a detailed description of the criteria used to identify the maturity stages of the species macroscopically.

Table 1. Maturity stages of the gonads of *Pagrus caeruleostictus*.

Stages	**Female**	**Male**
I. Immature	Ovaries were very thin semi-transparent tubes	Testes were thin transparent but wider than ovaries
II. Maturing	Ovaries are semi-transparent pale orange or yellowish wider tubes with no visible eggs	Testes appear as white thinner tubes
III. Nearly ripe	Ovaries are larger in size and orange in color with visible oocytes as small granules	Testes are larger, deeper with creamy-white colour
IV. Ripe and running	Ovaries reach the maximum diameter with larger oocytes, deep orange color with plentiful veins and arteries	Testes are very large and fragile when handled and sperm can extrude if the testis break
V. Spent	Ovaries size decrease, reddish in colour and flaccid	Testes are pinkish white in colour, shrunken in size

Source: Holden and Raitt (1974) protocol

Figure 2. A picture of *Pagrus caeruleostictus* (Valenciennes 1830).

For the spawning cycle, the percentage of Gonadosomatic Index (% GSI) was identified using the equation:

$$\% \text{ GSI} = \frac{\text{Gonad weight}}{\text{Body weight}} \times 100 \text{ (King,1995).}$$

The length at maturity for the sampled species was conducted using the log transformed equation of the logistic curve by Kings (1995):

$$\text{In } \frac{1\text{-P}}{\text{P}} = \text{a+bL}$$

where PL = proportion of mature individuals; L = total length (cm); a, b = constants.

From the log transformed equation using the constants (a,b), L_{c50} was estimated as:

$$L_{c50} = \frac{a}{b}$$

A one-way analysis of variance (ANOVA) was used to assess the significance of differences in the gonadosomatic index (GSI). The Mann-Whitney test was used to test for significance differences in GSI between male and female samples. A significance level of $p = 0.05$ was used. A chi-square test of independence was conducted to determine the association between the sex of the samples and the sampling periods.

RESULTS AND DISCUSSION

Sex ratio

The number of male individuals (351) was significantly higher than that of females (209), resulting in a sex ratio of 1:0.67, favoring males (Chi-square test of independence = 35.5, df = 11, $p \leq 0.001$). Males were dominant in all months except for July and November 2019, with the highest male proportion observed in May 2019. In contrast, the highest proportion of females was recorded in July 2019 (Figure 3).

Studies on the sex ratio of fish are essential for fisheries management because they ensure proportional fishing of two sexes and also, give the information needed in assessing the reproductive potential of fish stocks (Jega *et al.*, 2017). The number of female individuals of the species was significantly lower than the males with a ratio of

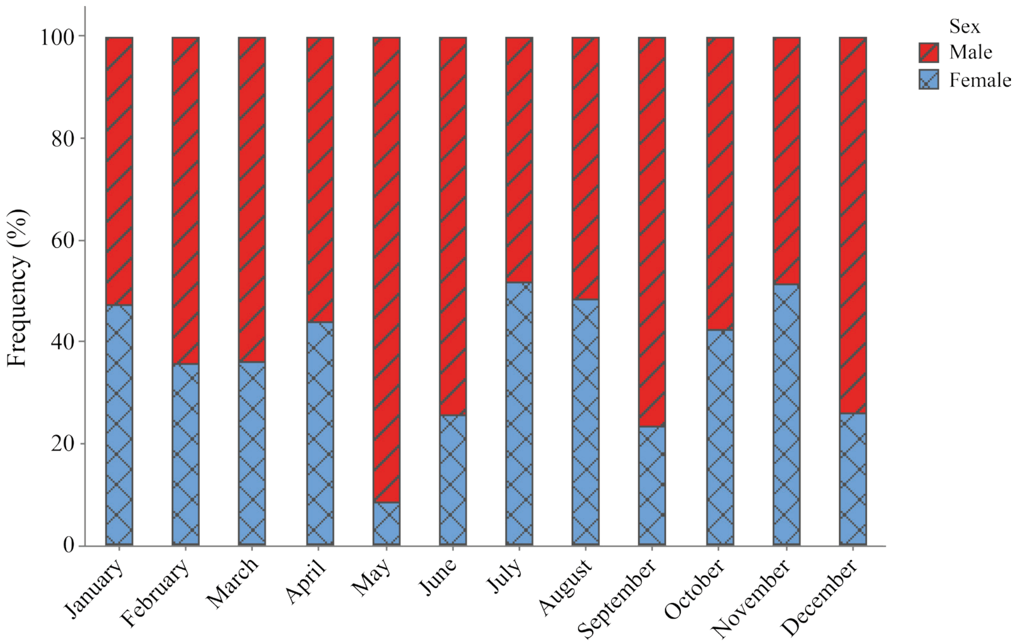

Figure 3. Changes in sex of *Pagrus caeruleostictus* on a monthly basis.

females to males to be 0.67:1. This shows a variation from the actual ratio of 1:1 for the sexes, which is largely expected in the natural environment. Studies by Gandega *et al*. (2022) from the Mauritian waters also documented more males than female individuals of *P. caeruleostictus*. In contrast, from the coastal waters of Tunisia and Ghana, Ismail *et al*. (2018) and Clottey *et al*. (2024), females of *P. caeruleostictus* were numerically more than males.

The difference in the sex ratio of the species could be due to differences in growth rate, sexual dimorphism, differential mortality rates and lifespan of male and female individuals (Vicenti and Araujo, 2003; Shin *et al*., 2023). Nonetheless, a skewed sex ratio is known to be a common feature among organisms (Fryxell *et al*., 2015). Furthermore, from the length distribution of the study, males dominated large sizes (>15 cm) as seen in Table 2. This aligned with findings by Clottey *et al*. (2024), suggesting the protogynous nature of the species which is characterized by small-sized females compared to males (Chakroun-Marzouk and Kartas, 1987; Ismail *et al*., 2018).

Maturity stages

From Figure 4, for both male and female individuals, immature stages I and II were documented during the sampling period with higher proportions found in males than female individuals. Matured stages including III and IV were documented with females accounting for a higher percentage than males for this study. Female individuals recorded the highest percentage of individuals at stage V (Figure 5). February, July and August were the months in which male and female individuals were dominated by individuals ready to spawn. For both male and female individuals, the maturity stages showed a significant relationship with the sampling period (Males; Chi-square goodness of fit = 174.95, df = 44, $p<0.001$; Female; Chi-square goodness of fit = 119.74, df = 44, $p<0.001$).

To comprehend the commencement and duration of reproduction, information about species maturity stages plays an essential role (Uehara *et al*., 2022). According to Tresnati *et al*. (2019), describing the gonad development of fishes, the five maturity stages based on macroscopic characteristics are effective. From the study, all five maturity stages of gonads for both males and females were recorded. A study by Clottey *et al*. (2024) did not identify male and female *P. caeruleostictus* at stage V. This may be due to the reason that determining individuals at stages I, II and V is very challenging (Tresnati *et al*., 2019). Nonetheless, the presence of all the maturity stages from the current study indicates the conduciveness of the coastal environment of Ghana in sustaining individuals of *P. caeruleostictus* at all stages of maturation.

Table 2. Display of monthly Chi-square test of sex ratio based on length measurement.

Length interval (cm)	Males	Females	X^2	df	p-value
10–15	3	0	–	–	–
15–20	51	15	19.64	1	<0.01
20–25	105	48	21.24	1	<0.01
25–30	119	81	7.22	1	0.01
30–35	58	41	1.15	1	0.28
35–40	11	20	0.62	1	0.43
40–45	4	2	0.68	1	0.41
45–50	0	1	–	–	–
50–55	0	0	–	–	–
55–60	0	1	–	–	–

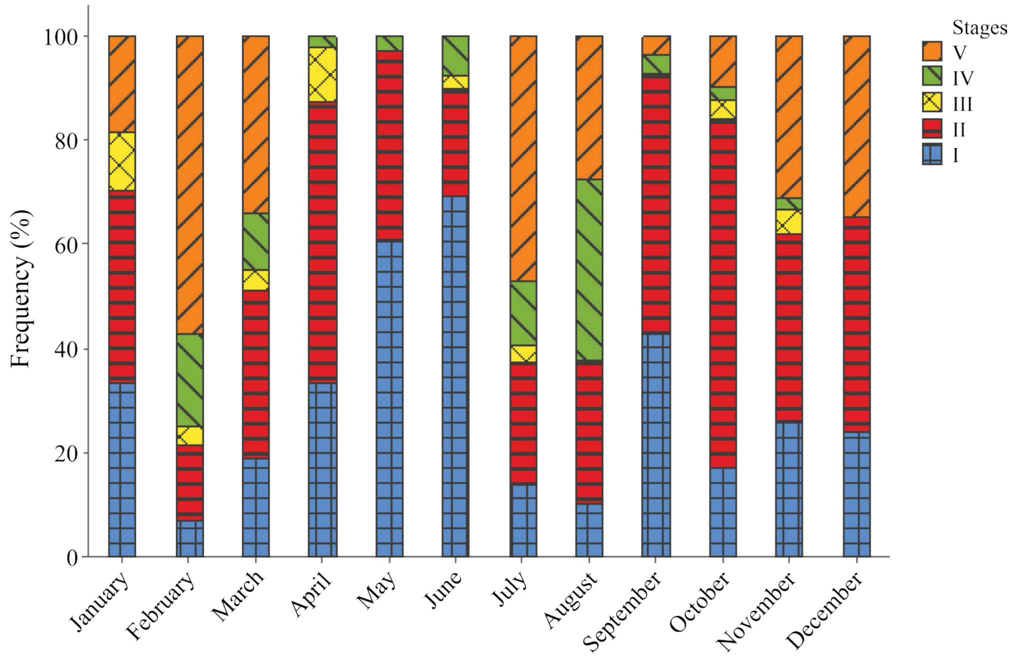

Figure 4. Percentage frequency of gonadal stages in male *Pagrus caeruleostictus*.

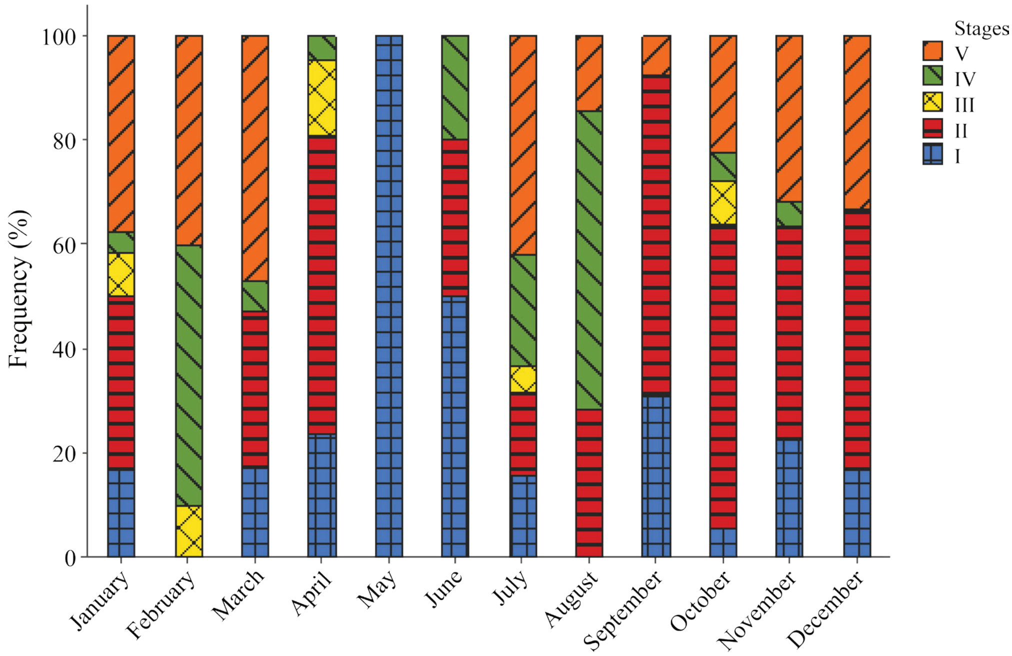

Figure 5. Percentage frequency of gonadal stages in female *Pagrus caeruleostictus*.

Spawning cycle

For female *P. caeruleostictus* (Figure 6), GSI increased from 0.57 in January to 1.96 in March, before rising sharply to 2.44 in April. However, GSI declined to 0.80 in May and further to 0.69 in June. In July, GSI value increased to 2.13 and increased sharply to 2.55 in August. After a sharp decline in September (0.97), and a brief rise in October (1.50), GSI decreased to 0.86 and further to 0.60 in December. For male *P. caeruleostictus* (Figure 6), GSI decreased from 0.62 in January to 0.28 in February. GSI increased sharply from 0.98 in March to 1.33 in April before dropping to 1.20 in May and further to 0.16 in June. From July to September, GSI increased from 0.31 to 0.68 and further to 0.97 before declining to 0.37 in October. After a brief increase in GSI during November (0.73), GSI declined to 0.49 in December. However, GSI values showed a significant difference between the sampling periods for both male and female samples (One-way ANOVA; Males: $F = 7.34$, $df = 9$, $p = 0.001$; Females: $F = 1.94$, $df = 10$, $p = 0.04$). Overall, the GSI of females was significantly higher than the GSI of the male individuals of the assessed fish species (Mann Whitney test, $W = 455$, $p<0.001$).

To assess the success of the reproduction of fish species, GSI is a biological parameter that provides an in-depth understanding of spawning time of aquatic fish species (Moslemi-Aqdam *et al.*, 2016). Based on the current study, an increase in ooplasm of developing oocytes, an increase in oocyte diameter and vitellogenesis may have accounted for the observed increase in GSI during the spawning period. However, discharge or reabsorption of yolky oocytes could have accounted for the decline in GSI among female *P. caeruleostictus*. From the study, the spawning phase of the female *P. caeruleostictus* was from February to April and July to August, with July–August being the major spawning season. However, for male *P. caeruleostictus*, the major spawning season was in March–April while the minor spawning season was in August–September. Studies by Owusu-Boateng (1994); Ismail *et al.* (2018); and Clottey *et al.* (2024) Ghana's coast revealed two spawning periods.

Furthermore, spawning seasons for both male and female *P. caeruleostictus* fell within the upwelling seasons (i.e. June–August and December–March) in Ghana, suggesting that the reproductive cycle of the species is annual (Kaur *et al.*, 2018).

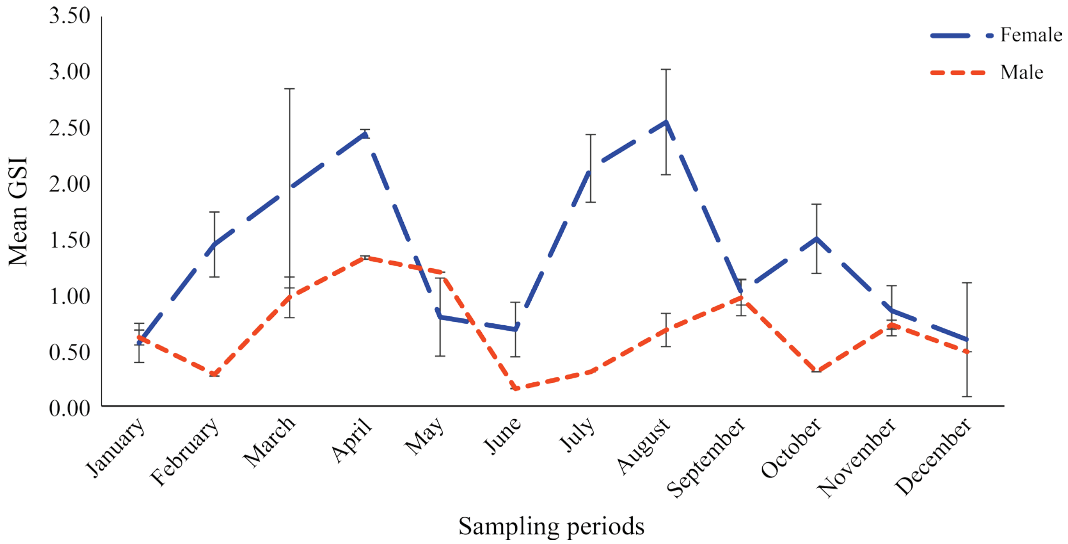

Figure 6. Average gonadosomatic index of *Pagrus caeruleostictus*.

The variation in GSI between male and female samples may be due to climate changes, particularly temperature and rainfall (Hasan *et al*., 2021). In addition, the different stages of oocyte development may be a factor contributing to the observed variation in GSI in the sampled species (Khamcharoen *et al*., 2023). In Ghana, the annual closed fishing season for artisanal fisherfolks is in July. However, from the study, the highest spawning peak for both male and female *P. caeruleostictus* fell outside the closed season period which may affect the recruitment potential of the species.

Size at first maturity

The estimated size at first maturity for *P. caeruleostictus* was found to be 21.1 cm for males (Figure 7a) and 18.4 cm for females (Figure 7b). Length at first maturity is crucial for establishing mesh size regulations aimed at sustaining fisheries resources (Mehanna, 2007). Previous studies have reported varying estimates: Clottey *et al*. (2024) identified L_{m50} values of 36.2 cm for males and 28.0 cm for females in Ghanaian coastal waters. Similarly, Owusu-Boateng (1994) estimated sizes

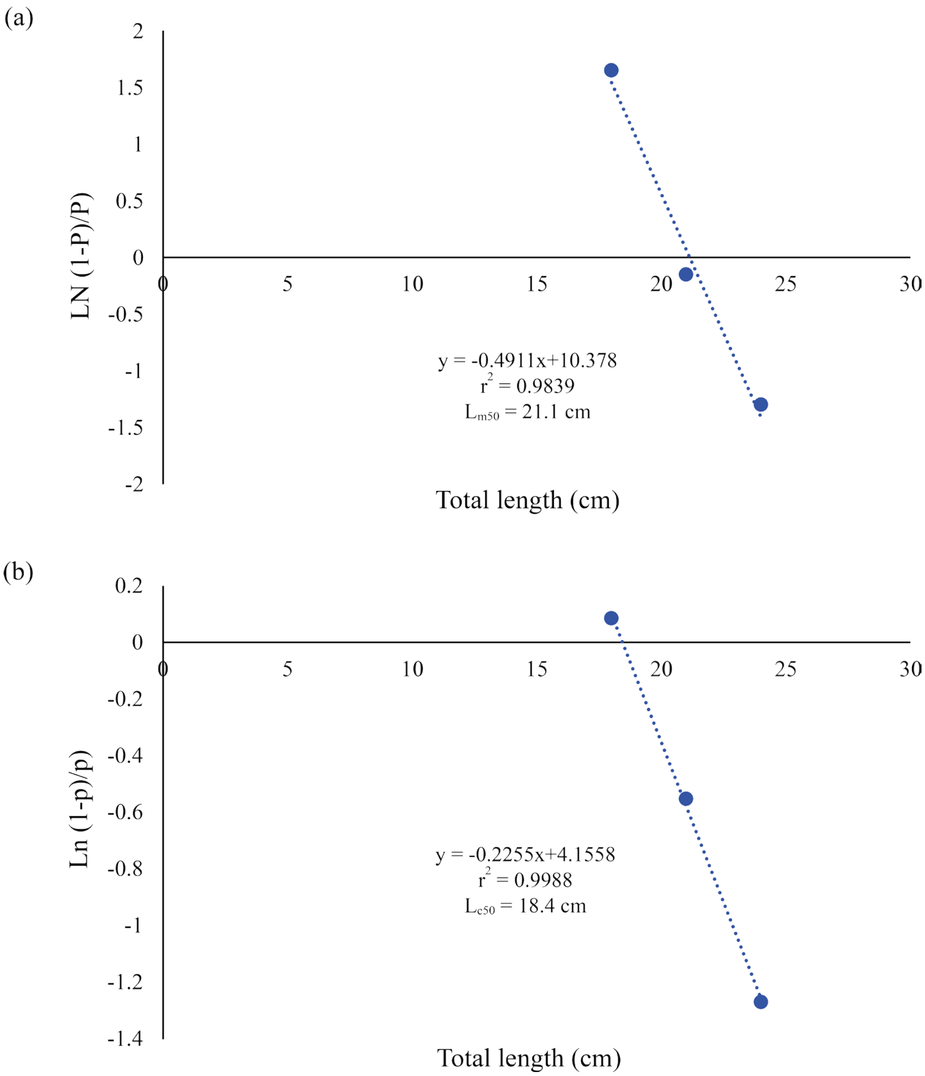

Figure 7. Length at maturity for male (a) and female (b) *Pagrus caeruleostictus*.

of 18.4 cm for males and 17.2 cm for females from the same region. In Egyptian coastal waters, Ismail *et al*. (2018) documented sizes of 27 cm for females and 29 cm for males. Moreover, Gandega *et al*. (2022) reported lengths of 28.4 cm for females and 28.6 cm for males in Mauritania's marine environment. The differences in length at first maturity across studies may be attributed to variations in environmental conditions, prey availability, fishing intensity, and sample sizes used in the estimates (Saoudi *et al*., 2017; Clottey *et al*., 2024). Additionally, factors such as hermaphroditic behavior and growth patterns may explain the observed variations between male and female individuals (Hadj Taieb *et al*., 2012).

CONCLUSIONS

This current study provides new insights into the reproductive biology of *Pagrus caeruleostictus* along the coast of Ghana. The findings reveal a male-biased sex ratio, extended spawning seasons with two distinct peaks, and that males reach maturity earlier than females. To strengthen these results, future research should include histological analysis and measurements of oocyte diameters to provide more detailed confirmation of the patterns observed in this study.

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