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Some aspects of the biology of West African Ilisha (*Ilisha africana*, Bloch 1795) from the coast of Ghana, West Africa

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ABSTRACT

Some aspects of the reproductive biology of West Africa Ilisha, *I. africana* in the coastal waters of Ghana, were studied between August 2018 and July 2019 to enhance sustainable management and exploitation. The mean length varied significantly with sex (12.8 ± 0.2 cm in males, 13.9 ± 0.3 cm in females). Condition factor (K) varied significantly with sex (0.70 ± 0.01 in males, 0.73 ± 0.02 in females). The growth pattern for males and females was 2.93 and 3.02, respectively. The sex ratio of 1.3 male: 1.0 female was observed which deviated significantly from the theoretical 1 male: 1 female ratio, indicating that males were significantly more than females *(X^2 =14.0, df = 6; P = 0.029)*. The GSI varied significantly with sex throughout the study (2.29 ± 0.30 in males), (3.94 ± 0.25 in females). Five maturity stages were recorded for both males and females. The spawning period for males was August – December whereas in females, the spawning period was August – January. The length at first maturity for females and males was 16.0 cm and 15.9 cm, respectively. Fisheries management strategies such as closed fishing season should take into account the major spawning season to ensure the full realization of its objective which is to preserve the fish stocks in Ghana's waters and exploitation within biologically acceptable levels.

INTRODUCTION

Studies on fish biology are essential for sustainable management and conservation of fish biodiversity (**Solomon *et al.*, 2012**). Reproductive potential of a population is one of the basic elements to designate the individuals of that population with respect to their gonadal conditions (**Jhingran and Verma, 1972**). Knowledge of reproductive biology of fish is essential for evaluating the commercial potentialities of its stock, life history, culture practice and management of its fishery (**Doha and Hye, 1970; Cortes, 2000; Soofiani *et al.*, 2006; Dopeikar *et al.*, 2015**). The information on different aspects of the biology of *I. africana* is important in fishery research programmes as it plays a vital role both in the economy and nutrition.

West African Ilisha (*Ilisha africana*), is a clupeid belonging to the family Pristigasteridae (**Fischer *et al.*, 1981**). *I. africana* is native to the coast, lagoons and estuaries of Western Africa through the West Coast of Southern Africa from Senegal to Angola. It is mostly found in shallow waters, and unlikely to be found below 25 m while some individuals can reach 30 m, with the average closer to 18 cm (**Fischer *et al.*, 1981**). In Ghana, the species is known to be widely edible, often smoked, fried or cooked before it is eaten, thus aiding in food security especially among the poor and marginalized people. On average about 4,963.2 tonnes of *I. africana* is caught in the coastal waters of Ghana each year, making it an important fishery species in terms of catch. However, in span of two years, the catch of *I. africana* from the coastal waters of Ghana has declined tremendously from 12,994 in 2015 tonnes to 1,891 tonnes in 2017 (**FAO, 2019**). The few information on its reproductive biology is provided by **Yankson and Azumah (1993)**. The current study assesses the reproductive biology of *I. africana* with emphasis on growth patterns and reproduction to provide relevant information required for sustainable management and exploitation of this species in the West African sub-region.

MATERIALS AND METHODS

Study area:

The study focused on five important fishing communities along the Greater Accra region of Ghana. These are Kpone, Prampram, Tema, Sakumono and Nungua as shown in Figure 1. A two-stage sampling criterion was used in selecting the sites which included geographical location and the level of fishing activities. The geographical coordinates for the sampling stations are shown in Table 1. These sampling locations are noted for fishing with fishing activities contributing over 50% as a primary occupation.

Figure. 1. A map of the study area showing sampling areas

Table 1. Sampling sites and their coordinates

Sampling locations	**GPS COORDINATES**
Nungua Beach	05°35'42.56"N, 000°04'14.57"W
Tema Canoe Beach	05°38'39.48"N, 000°00'59.50"E
Sakumono Landing Beach	05°36'42.30"N, 000°02'34.40"W
Kpone	05°41'26.84"N, 000°03'52.76"E
Prampram	05°42'17.71"N, 000°06'51.57"E

Sample collection:

A minimum of thirty (30) samples were collected on a monthly basis from randomly selected fishermen who use multifilament fishing gears from fish landing sites for twelve (12) months (August 2018 to July 2019). The samples collected were preserved on ice and transported to the laboratory. The species were identified to the species level using the identification keys by **Fischer *et al.* (1981)** and measured for total length in centimeters and body weight in grams using measuring board and electronic scale, respectively.

Length- frequency distribution:

The recorded length (total length) of the individuals of the assessed fish species was pooled together and used in constructing percentage frequency histogram. In all, a total of four hundred and six (406) specimens of *I. africana* was examined for the present study with no samples retrieved during March, 2019.

Condition factor (K):

The condition factor (K) shows the physiological wellbeing of the fish. This was determined using the relationship:

$$K = \frac{W}{TL^3} x\ 100$$ (**Htun-Han, 1978**)

where K = Condition factor, W = Body weight of fish in grams and TL = Total Length of fish (cm)

Length-weight relationship:

The length-weight relationship shows the relationship between the weight and total length of the fish using the exponential plot. The exponential plot was done using the expression:

$$W = aTL^b$$ (**LeCren, 1951**)

where W=Weight of fish (g), TL = Total Length of fish (cm), a = Constant (intercept), *b* = growth pattern (slope).

Sex ratio:

The sex ratio of male to female individuals was assessed. Sex ratio was estimated as:

$$\frac{M}{F}$$ (**Pena-Mendoza *et al.*, 2005**)

where M = Number of males, F = Number of females

Maturity stages:

The gonadal maturation was studied macroscopically for both male and female gonads which have been grouped into different gonadal stages of development according to **Nikolsky (1963)**. For this study, the gonadal stages in Table 2 were used.

Table 2. Maturity stages of female and male specimens of *I. africana* (Bloch 1795)

Gonad maturity stage	Female	Male
I (virgin stage)	Sexes are indistinguishable by naked eye; gonads are thin, threadlike and transparent	Sexes are indistinguishable by naked eye; gonads are thin, threadlike and transparent
II (immature stage)	Ovaries are small, translucent or pale-yellow, more rod shaped than stage-I; oocytes are indiscernible	Testes are thin, white or gray and larger than stage-I
III (maturing stage)	Ovaries are swollen, orange in color and occupy 1/5 to 1/3 of the body cavity; vitellogenin oocytes are tightly packed in ovaries and can be visible from epithelium	Testes are firm, flat-shaped and ivory-white
IV (spawning stage)	Ovaries occupy 1/3 to 2/3 of body cavity; oocytes attain their maximum volume and can be released from genital pore with light abdominal pressure	Testes are ivory-white and milt can be released from genital pore with light pressure on the abdomen
V (spent stage)	Ovaries are flaccid and sometimes red with visible capillaries; there are often a few residual oocytes in ovaries	Testes are flaccid and decease in volume clearly; milt is found in some individuals

Gonadosomatic index (GSI):

This is an index for the reproductive cycle of the female individuals of the fish species. GSI was estimated using the expression:

$$\frac{GW}{BW} \times 100 \qquad \text{(Mbu-oben, 1995)}$$

where GW = Gonad weight in grams, BW = Body weight in grams

Gonad weight was estimated for individuals at maturity stages III to IV for female specimens while stages II and III were used for GSI estimation for male specimens.

Length at first maturity (Lm_{50}):

The length at first maturity which the size at which 50% of the female individuals of the fish species mature. The Lm_{50} was estimated using the log transformed equation of the logistic curve:

$$\frac{P}{1+e^{r(TL-Lm)}} \qquad \text{(Kings, 1995)}$$

where P = Adjusted population ripe, TL = Total length of fish (cm), Lm = length at first maturity.

Data analysis

Descriptive statistics including maximum, minimum and mean total length were estimated using the length-frequency distribution. For inferential statistics, both parametric and non-parametric tests were used depending on the normality of the data which was done using the Anderson Darling Test. Parametric test (t-test) was employed to assess the significant difference at 95% Confidence interval. Non-parametric test (Chi-square test and Mann-Whitney Test) were employed to assess the significant difference of sexes on a monthly basis. Table and charts were generated using Microsoft Excel 2016. The Minitab version 19 statistical Tool and Microsoft Excel Spreadsheet were the statistical tools used for statistical analysis.

RESULTS

Length-Frequency distribution

Table 3 indicates the length-frequency distribution for *I. africana*. From Table 3, the lowest mean length (12.8 ± 0.2 cm) was recorded by males with the minimum and maximum lengths of 5.5 cm and 22 cm, respectively. For females, the recorded lengths ranged from 7.0 cm to 22.0 cm with a mean length of 13.9 ± 0.3 cm. Mann-Whitney Test carried out revealed a significant difference between the length of male and female specimens (W-Value = 43593, p-value = 0.001). For combined sexes, the range of lengths was 5.5 cm to 22.0 cm with the mean length as 13.3 ± 0.2 cm.

Table 3. Length-frequency distribution of *Ilisha africana*

Sex	N	Mean	SE	Min	Max
Males	233	12.8	0.2	5.5	22.0
Females	173	13.9	0.3	7.0	22.0
Combined sexes	406	13.3	0.2	5.5	22.0

Condition Factor

Table 4 indicates the condition factor of both males and females. The lowest mean condition factor (0.70 ± 0.01) was recorded by male specimens with the minimum and maximum condition factor of 0.32 and 2.29, respectively. For female specimens, the recorded condition factor ranged from 0.33 to 3.62 with a mean condition factor of 0.73 ± 0.02 cm. Mann-Whitney Test carried out revealed a significant difference between the condition factor (K) of male and female specimens (W-Value = 40495, p-value = 0.000). For combined sexes, the range of condition factor was 0.32 to 3.62 with the mean condition factor as 0.70 ± 0.01 (Table 4).

Table 4. Condition factor of *I. africana*

Sex	N	Mean	SE	Min	Max
Males	233	0.70	0.01	0.32	2.29
Females	173	0.73	0.02	0.33	3.62
Combined sexes	406	0.70	0.01	0.32	3.62

Length-weight relationship

Table 5 indicates the length-weight relationship for both male and female specimens. From the Table, the males recorded the lowest growth pattern (*b*) of 2.93 while the females recorded the highest growth pattern (*b*) of 3.02. For combined sexes, the estimated growth pattern (*b*) was 2.98 as shown in Table 5.

Table 5. Length-weight distribution of *I. Africana*

Sex	a	b	R^2	N
Males	0.008	2.93	0.94	233
Females	0.068	3.02	0.95	173
Combined sexes	0.007	2.98	0.94	406

Sex ratio

From Figure 2, a total of 406 specimens of *I. africana* were collected throughout the sampling period which comprised of 233 (57%) males and 173 (43%) females. A chi square (X^2) revealed a significant departure (Chi-square's Test, *df* = 6, N = 406) = 14.00, p – value = 0.029) from the theoretical 1 male: 1 female sex ratio indicating males were significantly more than females with a ratio of 1.3 male: 1 female sex ratio. From Figure 2, males dominated the catch throughout the study period with the exception of December, 2018 and July, 2019 where the females dominated the catch.

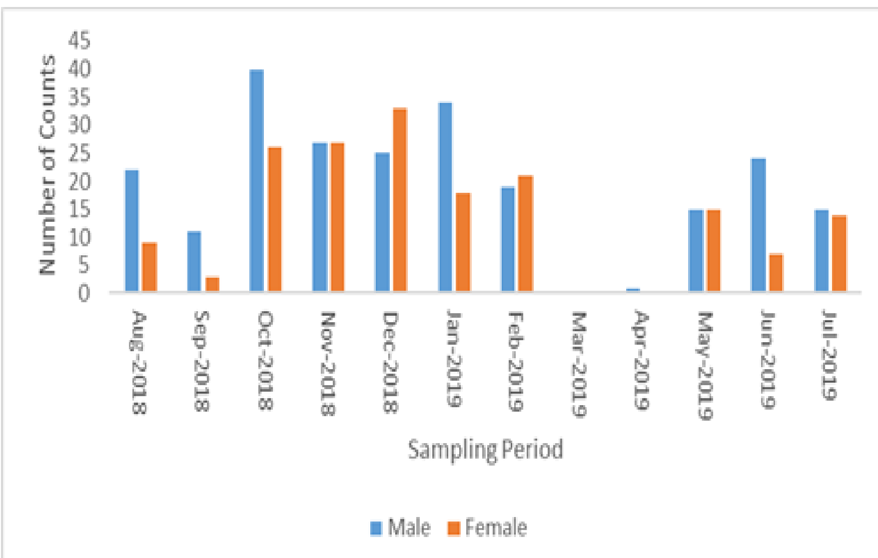

Figure 2. Number of males and females of *I. africana* recorded during the study period

Gonadosomatic Index (GSI)

In females, GSI has been observed to reach peaks twice a year, one during November and the other during January with the lowest value of GSI observed in March. The spawning period for females was from August to January (Figure 3). Females at maturity stages III and IV were observed during August, October, November, December and January. In males, two distinctive peaks were observed, one during August and October with the other peak during December. The lowest GSI value in males was recorded during November. The spawning period for males was from August to

December (Figure 3). No matured males at stages III and IV were recorded during the months of January, February, March, April, May, June and July.

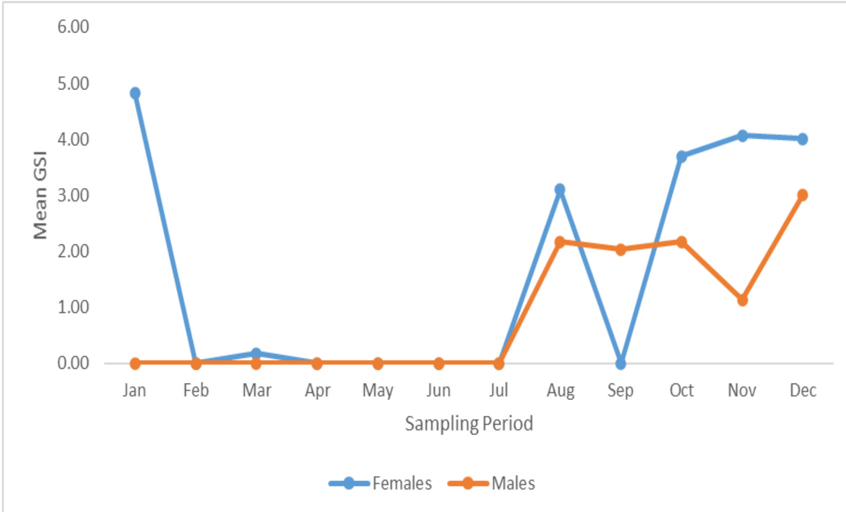

Figure 3. GSI of *I. africana* recorded during the study period

From Table 6, the gonadosomatic index (GSI) for females ranged between 1.46 and 7.99 with a mean of 3.94 ± 0.25 while it ranged between 0.78 and 5.13 with a mean of 2.29 ± 0.30 in males. A t-test carried out on GSI between male and female specimens revealed a significant difference (T-test [N = 61, *df* = 59] = 3.40, p-value = 0.001]).

Table 6. GSI of *I. africana*

Sex	N	Mean	SE	Min	Max
Males	14	2.29	0.30	0.78	5.13
Females	47	3.94	0.25	1.46	7.99
Combined sexes	61	3.56	0.22	0.78	7.99

Maturity stages and length at maturity

Figure 4 shows the maturity stages recorded for *I. africana* based on the gonads of female, male and both (i.e. male and female) individuals. Out of the five maturity stages recorded for female specimens, majority of the females were at Stage II followed by stage I with the minority of the female specimens at maturity stage V. From the five identified maturity stages for male specimens, the majority were at Stage 1 followed by stage II with minority at Stage V. Overall, all the five different maturity stages were identified during the study period.

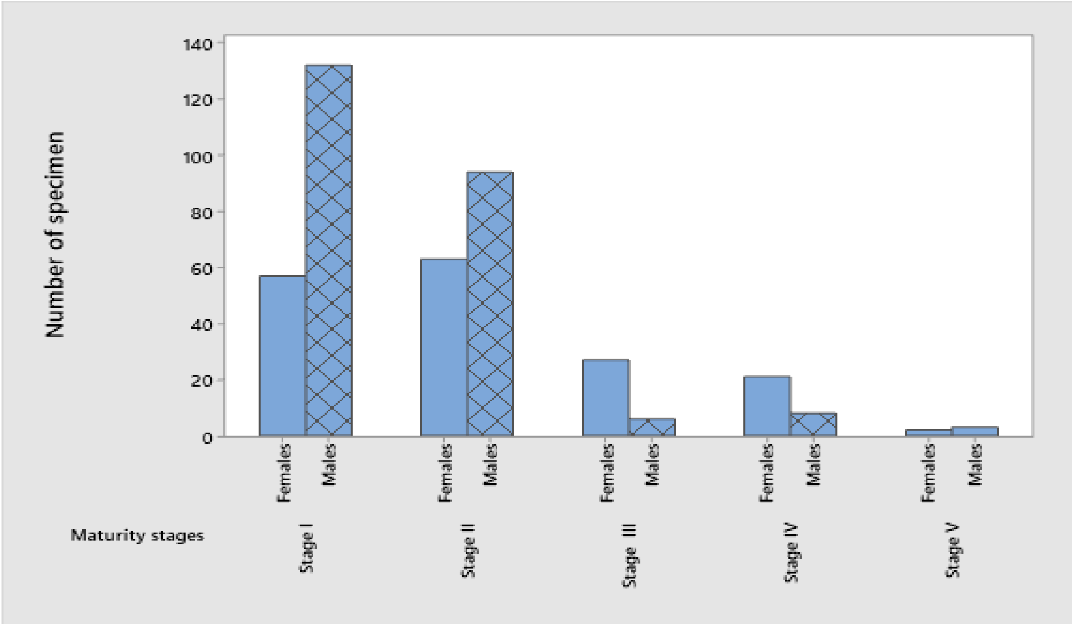

Figure 4. Maturity stages of *I. africana*

From Table 7 below, the length at first maturity for males and females was estimated at 15.9 cm and 16.0 cm, respectively. On average (i.e. for both sexes), the calculated length at first maturity was 16.1 cm.

Table 7. Length at first maturity of *I. africana* based on sexes

Sex	**Length at first maturity (Lm_{50})**
Males	15.9 cm
Females	16.0 cm
Combined sexes	16.1 cm

DISCUSSION

Length-Frequency distribution

The maximum length for the unsexed specimens of *I. africana* from the coastal waters of Ghana was slightly higher than observed by **George and Akpan (2011)** from the coastal waters of Nigeria who reported a maximum length of 16 cm. Similarly, it was slightly higher than the maximum length (20.3 cm and 21.8 cm) documented by **King (1991)** and **Yankson and Azumah (1993)** from the coast of Nigeria and Cape Coast, Ghana, respectively. However, studies by **Stokholm and Isebor (1993)** and **Marcus and Kasemiju (1984)** recorded maximum lengths of 25 cm and 25.4 cm, respectively, which are higher than results obtained from the current study. The physiology and the ecological conditions of the study areas may be factors accounting for the changes in these lengths (**Mahmood *et al.*, 2012**). Other potential factors accounting for the observed variation in maximum length from the current study in relation to previous works could be the intensity of fishing activity and the depth at which fishing is occurring. **Marcus (1982)** documented that small sizes are mostly found in shallow waters while large-sized fish inhabit deeper waters. It can, therefore, be suggested that fishes obtained for the current study were from relatively shallow depth (i.e. less than 25 m) or as a consequence of intense fishing activities in Ghana's coastal waters which is accelerated by the high demand for fish and fishery products. According to **Ricker (1981)**, most fisheries tend to target larger individuals which are therefore exposed to higher fishing pressure than smaller ones.

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Condition Factor

Condition factor is an index used for monitoring feeding intensity, age and growth rate in fish. It is strongly affected by both abiotic and biotic environmental conditions and can be a tool for assessing the status of the aquatic ecosystem in which fish inhabits **(Anene, 2005)**. A study by **George and Akpan (2011)** found the mean range of condition factor of *I. africana* from the Nigerian coastal waters which is also part of the Gulf of Guniea as 1.76 – 1.95. This result is relatively higher than the result obtained in the current study. **Adeyemi *et al.* (2009)** attributed the variation in condition factor to drivers such as sex, age, state of maturity, size, state of stomach fullness and the state of some environmental parameters affecting fish in aquatic systems. **Kareem *et al.* (2016)** reported that a fish living in a favourable environment in terms of food availability and good environmental conditions grow faster with $K \geq 1$. The estimated condition factor from the current study was below one, indicating that the *I. africana* from Ghana's coastal waters may be stressed, possibly due to anthropogenic factors (**LeCren, 1951**). **Froese (2006)** and **Treer *et al.* (2009)** concluded that different body forms of fish such as elongated, fusiform and short or deep body types have significant effect on condition factors. In view of this, the patterns of obtained results with the mean K been less than 1.00 might be owed to the fact that the species is streamlined.

Length-weight relationship

The '*b*' values in length-weight relationships determine the growth pattern of the fish species (**Osho and Usman, 2019**). The value of *b* estimated from the present study was not favorable with estimates by other researchers. For example, studies by **Sossoukpe *et al.* (2017)** from the Benin coastal waters estimated *b* to be 2.369. **Fafioye and Oluya (2005)** also documented the *b* to be 2.79 from the coastal waters of Nigeria. From the coastal waters of Benin, **Stockholm and Isebor (1993)** recorded the *b* in a range of 2.45 to 4.05. Further to this, **Marcus (1982)** from three coastal areas in Nigeria stated that the range of *b* for males, females and combined sexes was 3.017 – 3.12; 3.015 – 3.15 and 3.075 – 3.14, respectively. Factors accounting for changes in the *b* values as reported by **Obasohan *et al.* (2012)** include age, sex, sampling methods, sample size, as well as the prevailing ecological conditions. Studies by **Fulton (1904)** and **Kharat *et al.* (2008)** also reported that the *b* value of the species may vary at certain times of the year largely as a result of the reproductive cycle. **Morey *et al*. (2003)** indicated that in most of the fishes from both tropical and temperate waters, the b values are largely in the range of 2.7 to 3.3. The range of b values from the current study appears to be in this range, thus supporting the claim by **Morey *et al.* (2003)**. From the current study, the values of *b* for males were lower than females which conformed to findings by **Osho *et al.* (2014)** that the males of many tropical species grow faster and have more standard sizes than females, possibly due to the beneficial anabolism enhancing androgens which are higher in males.

Sex ratio

Throughout the study period, males dominated the catch (i.e. M:F = 1.3:1) except November, 2018, December 2018 and February 2019 where the females dominated the catch. In all, a total of 233 males and 173 females were recorded with a sex ratio of 1.3:1 in favour of males. The pattern observed from the current study compared favourably with studies from other marine space. For instance, a study by **Sossoukpe *et al* (2017)** from the Benin Coastal Waters (West Africa) showed the dominance of males over females. Also, research by **Marcus (1982)** off the coast of Nigeria reported that males were significantly more than females (i.e. sex ratio of 1:0.97 in favour of males) throughout the sampling period. Having more males than females from the current study, it can be deduced that males live longer than females. Again, with *Ilisha spp.* being anadromous, it could be conjectured that females spend more time at the spawning grounds than the males. This behaviour makes the males more vulnerable to capture than females **(Isangedighi and Umoumoh, 2011)**. However, a higher number of females than males coincided with the peak spawning period which demonstrates that a higher number of females encountered during the spawning period than males (**Marcus, 1982**). However, **Yankson and Azumah (1993)** studies from the coastal waters of Cape Coast, Ghana found that males were fewer than females with a sex-ratio of male to female as 0.98:1. Research by **Stokholm and Isebor (1993)** from the coastal waters of Benin revealed the dominance of females over males during their study period. Overall, the deviation from the theoretical deviation from 1:1 sex-ratio is always expected in nature **(Oniye and Onimisi, 2011).** Generally, the low number of females in relation to the males may be a strategy to ensure that there are more males to fertilize the fewer number of females to maintain good population equilibrium especially under environmental constraints of anthropogenic perturbations **(Opadokun and Ajani, 2015**).

Gonadosomatic Index (GSI)

Information about gonadal development and the spawning season of a species plays a significant role in determining the spawning frequency of its population, which is critical for its management (**Hasan *et al.*, 2018**). The mean GSI was higher in females than in males and this variation may be due to the physiology of the species. For instance, the relatively higher GSI of females than males may be linked to the uptake of fluid by ripe oocytes (**Marcus, 1982**). Studies by **Yankson and Azumah (1993)** off Cape Coast, Ghana reported a major spawning season to be between January and May. Also, **Marcus and Kusemiju (1984)** found that the major peak spawning period took place from May to December. **Hasan *et al.* (2018)** reported that a fall in GSI value from its maximum, reduction in the size of gonads (flaccid appearance), and occurrence of the spent fish act as an indicator of one spawning season. On that basis, the spawning period exhibited by the females was from August to January while for the males, the spawning season was from August to December. The extended spawning season could be a strategy to ensure that the offsprings of *I. africana* reach a relatively bigger size that enables them to predate on fry and fingerlings of other fish species that would breed later in the year **(Opadokun and Ajani, 2015)**. The maintained spawning period of males from the current study could be to facilitate and ensure successful fertilization (**Htun-Han, 1978**). Variation in spawning periods with regards to other studies (e.g. **Yankson and Azumah, 1993; Marcus and Kusemiju, 1984**) may be due to regional variation as well as other environmental factors (**Hasan *et al.,* 2018**). The major spawning seasons of male and females observed from the current study was found to have occurred during the upwelling periods which is also the period for the high increase in phytoplankton. As a result, the increase in phytoplankton biomass may be viewed as one of the environmental drivers for an approaching favourable season for better growth and survival of offspring (**Pena-Mendoza *et al.,* 2005**).

Maturity stages

With the exception of April, May, June and July (Figure 3), matured females and males were found throughout the sampling period. Studies by **Yankson and Azumah (1993)** off the coast of Cape Coast, Ghana as well as **Stokholm and Isebor (1993)** from the coast of Nigeria documented the presence of matured *I. africana* throughout the study period. **Marcus and Kasemiju (1984)** from the coastal waters of Nigeria also documented that ripe *I. africana* were caught in all the months, indicating that breeding of *I. africana* occurred throughout the year. The result from the current study conformed to the assertion by **Houd and Fores (1973)** that clupeids breed for the most part of the year. However, the lower number at the ripe and ripening stages may be linked to improper handling during harvesting and post-harvest period (**Marcus, 1982**).

Length at first maturity

The length at first maturity for *I. africana* based on gonad stages III and IV was estimated at 16.0 cm and 15.9 cm for females and males, respectively. These results were significantly higher than the estimates by **Yankson and Azumah (1993)** from the coast of Cape Coast, Ghana (i.e. 13.2 cm – male and 14.7 cm – female). **Marcus and Kasemiju (1984)** also recorded lesser estimates of length at first maturity for males and females (i.e. 11.5 cm and 11.7 cm, respectively) from the coastal waters of Nigeria. The observed variation with other studies may be reliant on the growth rate of the fish as well as the time elapsed. **Otobo (1978)** stated that the maturity of a fish relies on its growth rate, and for this reason, a stunted fish will be sexually mature at a small size whereas a fast-growing fish will attain maturity at a much larger size. **Amin *et al.* (2016)** documented that in the event of a large gap of time between previous and current studies, several environmental conditions might have changed and thus, affecting the sexual maturity of the fish.

For the sustainability of the fish stock, **Isangedighi and Ambrose (2015)** demonstrated that larger fishes are bound to produce more eggs. To support the claim by **Isangedighi and Ambrose (2015)**, **Marcus and Kusemiju (1984)** indicated that the fecundity of *I. africana* increased with fish length and weight. Based on this, the relatively large length at first maturity of the species (both male and female) in the current study may be viewed as a positive reproductive characteristic leading to the sustenance of its stock despite the declining status of marine fishes in Ghana.

CONCLUSION

The growth pattern indicated allometric growth for males and isometric growth for females. The sex ratio revealed a higher number of males than females. Maturity studies revealed that male specimens mature earlier than female specimens. The GSI studies demonstrated that *I. africana* has a spawning peak in January for females and December for males. The spawning period for males was from August to December whereas the spawning period for females was from August to January. Based on the finding, harvesting species with length less than the length at first maturity may alter the recruitment potential of the stock and consequently result in the collapse of the stock. Again, management strategies such as closed fishing season should take into account the major spawning season to ensure the full realisation of its objective which is to preserve the stock in Ghana's waters and exploitation within biologically acceptable levels.

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