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Aspects of Reproductive Biology of *Pseudupeneus prayensis* collected from the coast off Sierra Leone, West Africa.

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ABSTRACT
Objective: The study assessed aspects of reproductive biology of *Pseudupeneus prayensis* in Sierra Leone, aimed to support efficient management of its fishery.

Methodology and Results: One hundred and seventy one (171) specimens were randomly collected from January-June 2016 on-board a demersal trawler. Gonad stages were assessed macroscopically and absolute fecundity determined by gravimetry.Total length and weight were measured using a meter rule (cm) and weight balance (g) respectively. Results showed dominant males (56 %) with no significant difference between gender populations ($p < 0.05$), and female spawning gonads were exceptionally dominant in March and April. The estimated length at first sexual maturity (male, $L_{50\%}$ = 19.6 cm; female, $L_{50\%}$ =17.2 cm) was 30.7 % and 38.6 % less than the maximum length (L_{max} = 28 cm) respectively. Besides, Gonadosomatic Index of both sexes peaked in March and May whereas Hepatosomatic Index was at peak in April and May for females, and in April and June for the males. Both sexes showed consistently high Index of condition (K >1.0). Fecundity positively correlated with size (r >0.9) and ranged from 160 000 eggs (total length, 17cm; somatic weight, 65g) to 522 079 eggs (total length, 25 cm; somatic weight, 150g).

Conclusion and application of results: Sex ratios portrayed homogeneity in gender population of *Pseudupeneus prayensis* and females were key spawning indicators with notable spawning gonads in March and April. Moreover, both sexes of *P. prayensis* had delayed first sexual maturity with major spawning in March and May aided by well-developed liver (HSI) and improved conditions (K > 1.0). Besides, fecundity in *Pseudupeneus prayensis* increased with size, and female specimens were highly productive. The results of this study can be used to institute closed fishing seasons in the event of threat on the spawning biomass of the stock of *P. prayensis* in Sierra Leone.
Keywords: Absolute fecundity, gonad, maturity, somatic, spawning.

INTRODUCTION
The West African goatfish, *Pseudupeneus prayensis* (Cuvier, 1829) belongs to the family Mullidae, known from the eastern Atlantic (Ben-Tuvia, 1990; Azzouz *et al.,* 2011) from Morocco to Angola (Hureau, 1986; Ben-Tuvia, 1990) and from Palamos, Catalan Sea, Northwestern Mediterranean (Mercader, 2002). Records of *P. prayensis* have also be specifically made from the Gulf of Guinea (Séret and Opic, 1990; Sanches, 1991; Azzouz *et al.,* 2011).. The fish contributed

15.4 % to the total biomass (t) of demersal trawl catch in Sierra Leone (Sesay, 2014), and depth distribution of commercially important demersal species gave 9.7% (0-30m), 15.0% (31-50m), 23.0% (51-100m) and 15.4 % (101-200m) for *Pseudupeneus prayensis* (Sesay, 2014). Knowledge of the reproductive behaviour of fish species including sex, gonadal maturation, condition factor, size at first sexual maturity, spawning and fecundity is vital in planning for efficient management of their spawning stocks (Grandcourt *et al.,* 2009; Muchlisin *et al.,* 2010; Muchlisin, 2014). The study assessed some aspects of the reproductive biology of *Pseudupeneus prayensis* collected from the coast off Sierra Leone, aimed to complement management effort in planning for efficient management and rational exploitation of such critically important commercial species.

MATERIALS AND METHODS

Study Area : Sierra Leone occupies an area of 71 740 km^2 and geographically located between the latitude 7°10′N and longitude 10°14′W on the west coast of the African Continent (Coutin and Payne, 1989). The continental Shelf extends to about 30 000 km^2 and an Exclusion Zone (EEZ) of 155 700 km^2 (Coutin and Payne, 1989; Olapade, 2013; Neiland *et al.,* 2016).The climate mainly includes the rainy seson (May-October) and the dry season (November-April; Coutin and Payne, 1989). Figure 1 illustrates the collection localities of *Pseudupeneus prayensis* in the Continental Shelf of Sierra Leone.

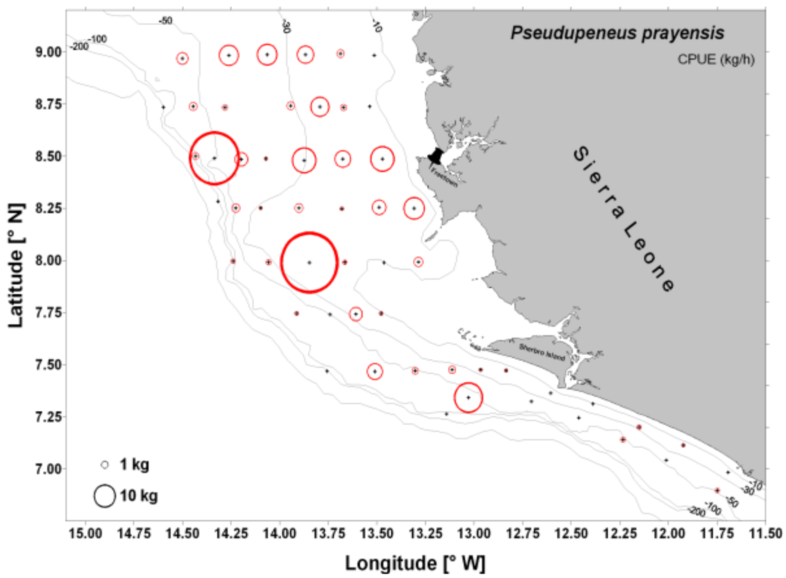

Figure 1: Showing sampling region in Sierra Leone

Data Collection : A total of 171 specimens of *Pseudupeneus prayensis* were randomly collected from January-June 2016 on-board a demersal trawler, which traversed both inner (10-50 m) and outer (51-100 m) continental shelf of Sierra Leone. Collection of specimens on-board a foreign deep-water fishing trawler employed methods described in Pauly (1980). Specimens collected using identification guide for the Gulf of Guinea (FAO, 2010) were preserved in a refrigeration system fitted in the vessel for further analysis in the laboratory of the the Institute of Marine Biology and Oceanography, University of Sierra Leone,.

Measurement of Length and Weights : Measurement of length (nearest 1cm TL) and somatic weight (nearest 0.1g) of the study species were measured with a one-meter fish measuring board and an electronic weight scale (ADAM-ACBPlus600H) respectively. Measurement of smaller weights (gonad and liver weight) were completed using a portable digital weight scale (Model: CS2000; Ohaus corporation, China) to the nearest 0.01 g.

Analysis of Indices of Reproduction:

Sex Ratio: Fish specimens were dissected and sexes macroscopically assessed based on differences in gonads as well as differences in urogenital systems whereby males had one urogenital opening while females had two separate openings for urine and for eggs as described in Malik *et al.* (2017). The ratio of female and male individuals gave estimate of the sex ratio of the assessed species. The percentage proportions of male and female specimens were calculated by the relation:

Proportion (%) = $\frac{n}{N} * 100$......... (1) (Where *n* = number of male or female; *N* = Sample size/combined sex).

Stages of Gonad Development: Gonads were macroscopically assessed, using mass and colour as indices of gonad maturation in line with the gonad maturity keys by Fontana (1969) given in Table 1.

Table 1: Developmental stages of fish gonads (Adopted from Ba *et al.,* 2016).

Stages	Description
I	**Virgin:** very small sexual organs and located near the the vertebral column. Ovary and testis about one-third the size of the body.. Testis and ovary transparent, colourless or grey. Eggs not macroscopic..
II	**Maturing virgin:** Testis and ovary semi-transparent, colours are between grey andred. Length of gonads halfthe length of anterior body cavity. Eggs are very visible with a magnifying glass.
III	**Ripening:** Testis and ovary not letting light through and reddish with minute blood vessels or capillaries. These take about half the anterior body cavity.. The eggs are macroscopically seen as whitish granular materials.
IV	**Ripe:** Testis is reddish-white and does not produce milt even when high pressure is applied.. Ovary orange-red with clearly visible blood vessels. Eggs disguised and hardly seen with the naked eye.. Testis and ovary occupy about 2/3 of anterior body cavity.
V	**Spawning:** Testis and ovary occupy the ventral cavity. Testis soft, cream-white and produce white milt under slight pressure.. Eggs round and trasnlucent,
VI	**Spent:** Testis and ovary very much reduced to half the size of the somatic cavity. Ovary sometimes have remains of either opaque and ripe or dark and near-transparent eggs. Testis tinged with blood and soft.
VII	**Resting:** Testis and ovary are reddish and empty, ovary sometime with very few ova.

Mature gonads (Stages 3-5) were pooled with corresponding total lengths to obtain variations in percentage mature gonads for different length groups. Plotting mature gonads (%) against length groups gave estimate for length at first maturity ($L_{50\%}$) as the length at which 50% of the fish attained sexual maturity as described in (El-Drawany, 2013; El-Regal, 2018). The identified ripe/spawning gonads were set aside for fecundity analysis.

Fecundity Estimate: Macroscopically identified ripe/spawning ovaries were used to investigate the fecundity of *P. caeruleostictus* following the gravimetric method by Bagenal (1978). As such, preserved eggs were bath in Gilson fluid for one hour to loosen and strengthen the eggs. These were then cleansed in distilled water, drained of excess water and then left to dry for 10-12 mins on filter paper. Following the gravimetric method, a fraction of the total ovaries was weighed and the number of ova therein noted. The absolute fecundity (F) was obtained according to the equation by Nikolsky (1963):

$F = \frac{Wt}{Ws * n}$........... (2) (Where *F* = Absolute Fecundity, W_t = Total Ovary Weight (g), W_s = Mean Weight of sub-sample (g), *n* = number of eggs in the sub-sample). In addition, the absolute fecundity relationships were derived by the least square method (Bagenal, 1978; Akponine and Ayoade, 2012) as follows:

$F = aX^b$ .... (3) (Where *F* = Absolute fecundity; *X* = Total length, Somatic Weight, Gonad Weight or Carcass Weight; *a* = intercept and *b* = regression coefficient).

Gonadosomatic Index (GSI): The GSI is the ratio of the gonad and body weights expressed as a percentage:

$\text{GSI} = \frac{\text{Gonad Weight}}{\text{Body Weight}} * 100$ ...... (4) Dadzie and Wangila (1980)

Hepatosomatic Index (HSI): This is the ratio of the liver and body weights of the fish expressed as a percentage:

$\text{HSI} = \frac{\text{Liver Weight}}{\text{Body Weight}} * 100$...... (5) Olapade (2013)

Fulton's Condition Factor (K)

The Fulton condition factor (Akponine and Ayoade, 2012) of the fish was calculated using expression:

$K = 100W/L^3$ …… (6) (Where W = somatic weight of fish, L = total length).

Statistical Analysis: Test for deviation between observed and hypothetical sex ratios was completed using the Ch-Square (ANOVA) test whereas tests of significant differences and regression analysis (for regression equations ($Y = ax^b$), coefficient of determination, R^2 and regression coefficient, b) were completed using the Microsoft (Vers. 2010) statistical tools for PCs. The correlation coefficient (r) was calculated thus (Konoyima *et al.* (2020): r = SQRT (R^2)……… (7). (Where SQRT = Square root; R^2 = Coefficient of determination).

RESULTS

Sex Ratio: The study obtained cumulative sex data for 78 female (45.60 %) and 93 male (54.40 %) specimens of *Pseudupeneus prayensis.* The cumulative male: female sex ratio gave 1:0.8 and did not significantly deviate from the hypothetical ratio of 1:1 ($X^2_{0.05}$ = 0.39; probability, p = 0.53; p >0.05; df. = 1; level of significance, α = 0.05). Figure 2 shows monthly variations in male and female proportions.

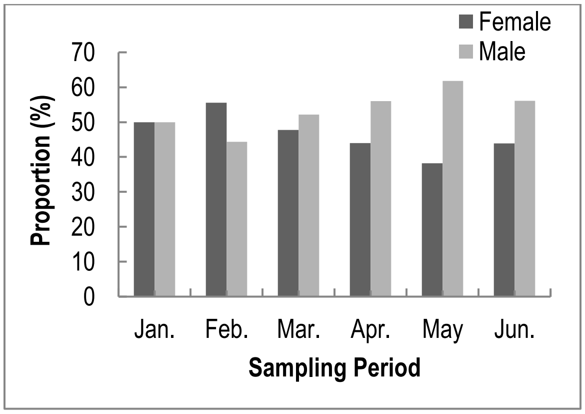

Figure 2: Monthly variation in sex of *Pseudupeneus prayensis*

No statistically significant difference occurred between monthly frequencies of male and female populations (at p >0.05; p-value = 0.37; t = 0.95; df. 8; α = 0.05; two-tailed test).

Gonadal Development and Length at First Sexual Maturity ($L_{50\%}$): Figure 3 illustrates the different stages of gonad maturation in *Pseudupeneus prayensis* during the periods of investigation, and spawning female gonads were exceptionally dominant in March and April.

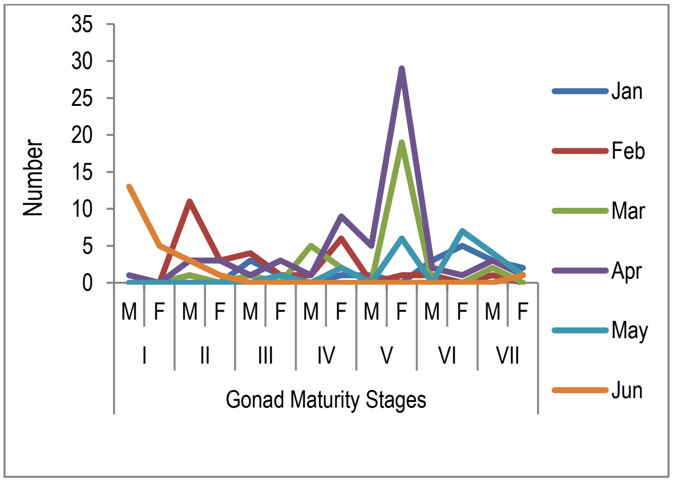

Figure 3: Gonad maturity in male (M) and female (F) specimens of *P. prayensis*

Moreover, the minimal length for male and female individuals to attain sexual maturity (Stage 3-7) was 13.0 cm whereas the estimated length at first sexual maturity ($L_{50\%}$) was 17.20 cm and 19.60 cm for female and male respectively, and sexual maturity increased with length (Figure 4).

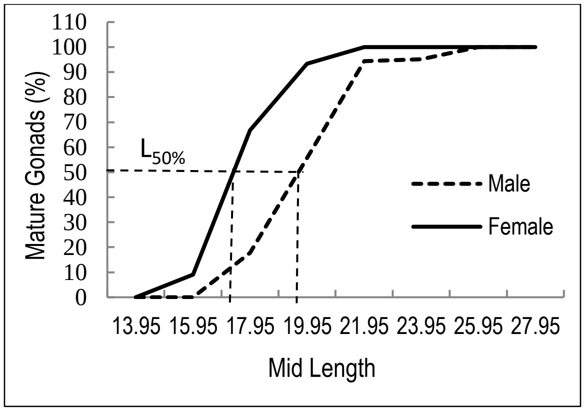

Figure 4: Length at first sexual maturity curve

Condition Factor: Monthly mean condition factor (K) of *Pseudupeneus prayensis* attained lowest value in February and increased exponentially between March and June for both sexes. However, K-value was above threshold (K > 1.0) throughout the sampling periods (Figure 5).

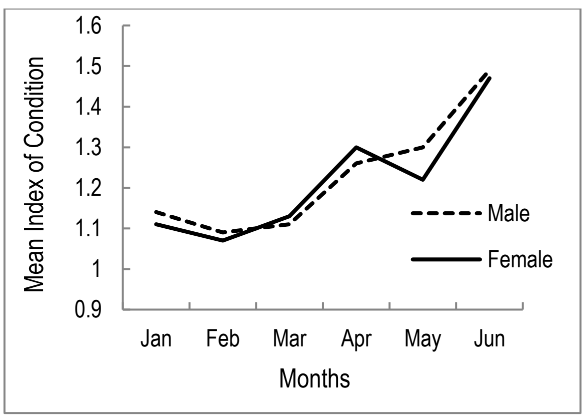

Figure 5: Variation in monthly mean condition factor of *Pseudupeneus prayensis*

Overall mean (±SE) male condition factor was 1.23±0.06 (95% Confidence level = 0.16) and the female, 1.22±0.06 (95% Confidence level = 0.16). The difference between male and female K-values was insignificant ($p > 0.05$; *p*-value = 0.87; *t* =2.23; α = 5 %; df. 10).

Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI) : Male and female GSI peaked in March and May, whereas HSI was at peak in April and May for females, and in April and June for the males. Figure 6(a-b) shows monthly trends in mean Gonadosomatic index (GSI) and Hepatosomatic index (HSI) for male and female specimens of *Pseudupeneus prayensis.*

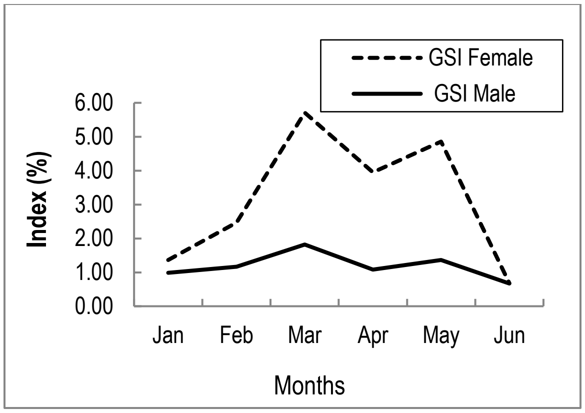

Figure 6a: Variation in mean monthly GSI

Overall mean (±SE) male GSI was 3.2±0.81 (95 % Confidence Level = 2.09) and females, 1.2±0.16 (95 % Confidence Level = 0.41), whereas overall mean (±SE) male HSI was 0.95±0.32 (95% Confidence level = 0.89) and female, 1.5±0.35 (95% Confidence level = 0.98).

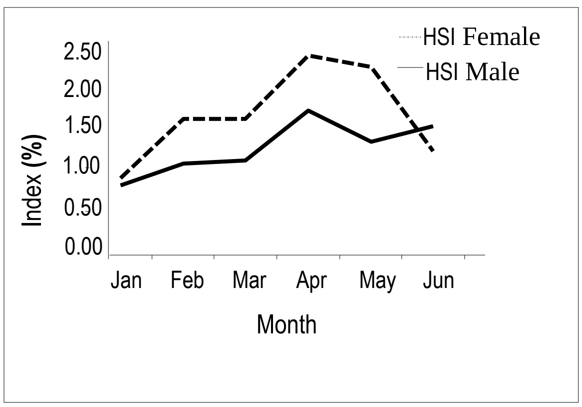

Figure 6b: Variation in mean monthly HSI

The difference between male and female HSI was not significant ($p > 0.05$; *p*-value = 0.28; $t = 2.31$; $\alpha = 5$ %; df. 10), whereas a significant difference occurred between GSI of both sexes ($p < 0.05$; *p*-value = 0.04; $t = 2.23$, $\alpha = 5$ %; df. 10).

Fecundity : The fecundity of *Pseudupenaeus prayensis* ranged from 160 000 eggs (in a fish of total length, 17cm; somatic weight, 65g; carcass weight, 59g and Gonad weight, 3.1g) to 522 079 eggs (in a fish of total length 25 cm; somatic weight 150g; carcass weight, 135g and gonad weight, 9.6g) and cumulative mean (±SE) fecundity (January-June) of 329 901.3±46375.60 eggs. Total fecundity (January-June) was 2 603 982 eggs. Figure 7 (a-d) shows the fecundity-length and weights relationships, coefficient of determination (R^2), regression coefficient (r), intercept (a) and slope/regression coefficient (b) of female specimens of *Pseudupeneus prayensis*.

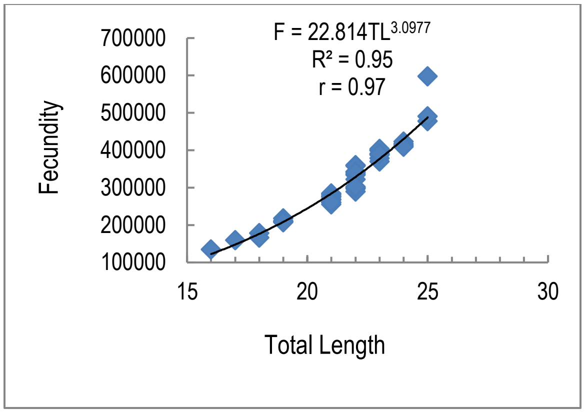

Figure 7a: Fecundity-Total Length

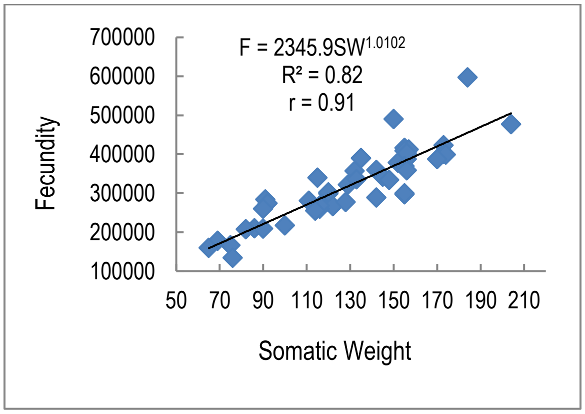

Figure 7b: Fecundity-Somatic Weight

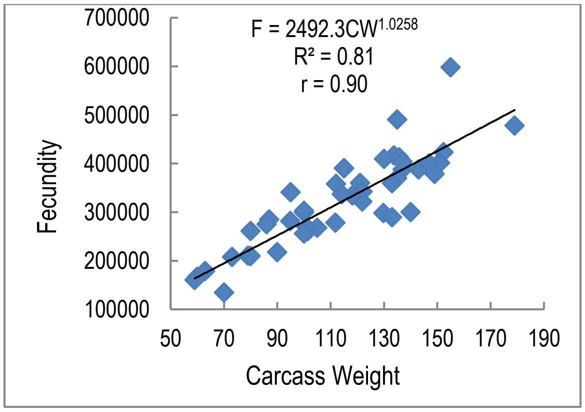

Figure 7c: Fecundity-Carcass Weight

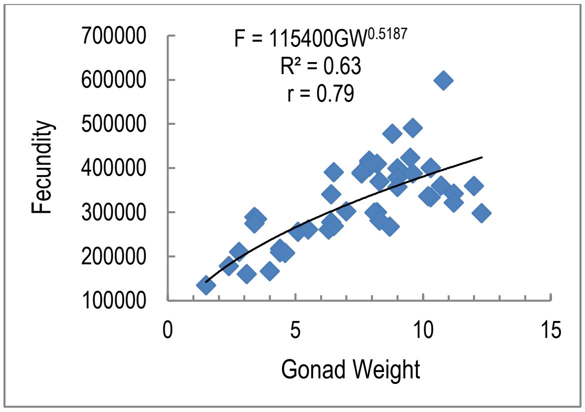

Figure 7d: Fecundity-Gonad Weight

DISCUSSION

Sex Ratio: The statistically insignificant difference between cumulative and hypothetical sex ratios ($p < 0.05$) was indicative of vast similarity in the population size of male and female specimens of *Pseudupeneus prayensis,* probably owing to equal growth and mortality conditions. Cheshire *et al.* (2013) concur that variability in fishing pressure, growth rates and environmental qualitycould lead to differences in sex ratios.Moreover, the cumulative sex ratio from this study was consistent with records for other Mullidae species such as *Pseudupeneus maculatus* (Munro, 1976), *Pseudupeneus grandisquamis* (Ramírez *et al.,* 2006), *Parupeneus barberinus* (Wahbeh and Ajiad, 1985) and *Upeneus pori* (Ismen, 2006; El-Drawany, 2013). According to Cheshire *et al*. (2013), variance in geographical locations is a key factor altering sizes of populations.. Vicentini and Araujo (2003) had also informed that the productivity of a fish species is reflective of the proportion of male and female individuals.

Gonadal Development and Length at First Sexual Maturity ($L_{50\%}$): Stages of gonadal development from this study portrayed abundance of spawning female gonads in March and April, and females may be the most relevant indicator of spawning in *Pseudupeneus prayensis*. Moreover, gonad maturity indicated that male and female specimen respectively attained dissimilar first sexual maturity at length that was 30.7 % and 38.6 % less than the maximum length of the samples (L_{max} = 28 cm), suggestive of fast growing individuals of the study species with delayed maturity, and it is plausible that immature individuals had length below 13cm. The estimated $L_{50\%}$ of both sexes of *P. prayensis* from this study exceedingly climaxed values for other goatfishes such as *Upeneus pori* ($L_{50\%}$ = 10 cmTL) off Libya (El-Drawany, 2013) and *Mulloidichthys flavolineatus* (male, $L_{50\%}$ = 12.5 cm TL; Female, $L_{50\%}$ = 14.5cmTL) off Egypt (El-Regal, 2018). Studies have shown that size at first maturity can vary between sex and between species due to environmental stressors (Wootton, 1998; Cheshire *et al.,* 2013), and fast growing fish species exhibit a shift to earlier sexual maturation (Cheshire *et al.* 2013).

Fulton's Condition Factor : Results indicated insignificant ($p > 0.05$) difference between the consistently high (K >1.0) K-values of male and female *Pseudupeneus prayensis*, suggesting that both sexes had favourable habitat conditions throughout sampling. The index of condition (K) is used to ascertain the comfortability of the fish in its habitat.(Bagenal and Tesch, 1978; Ighwela *et al.,* 2011).. Adebiyi (2013) had purported that condition factor connotes the environmental suitability for a fish species, reflective of it health status and reproductive potential. K >1.0 suggests healthy and fat individuals (Malik *et al.,* 2017; Konoyima, 2020; Konoyima *et al.,* 2020).

Gonadosomatic Index (GSI) and Hepatosomatic Index (HSI) : The peak periods of GSI indicated the occurrence of major spawning in March and May, and coincided with the hot season. The dry season may have been preferred by the fish probably because of better habitat conditions (K > 1.0) for food and survivability of larvae. Similar spawning peaks have been observed in another goat fish, *Upeneus pori* by other scholars (Ismen, 2006; Cicek *et al.,* 2002; El-Drawany, 2013), but different from observation for *Parupeneus multifasciatus* by Pavlov *et al.* (2011) and that for *Mulloidichthys flavolineatus* by El-Regal (2018). Such deviations in spawning peaks among goatfishes may be a result of differences in their ability to respond to changes in habitat conditions as inferred by other researchers (Uiblein, 2007; Muchlisin, 2014). Khallaf and Authman (1991) had earlier asserted that fecundity can fluctuate with changes in environmental conditions and species specific factors. Moreover, the steady increase in HSI throughout sampling with significantly (p <0.05) high values for females was indicative of better physiological conditions at such times to well develop the liver that supports spawning, buttressed by the consistently high K-values (K > 1.0) recorded from this study. Such improved hepatic condition may have supported gonad development and spawning in the assessed species, particularly the female specimens with consistently high GSI that was significantly different from the males (*p* <0.05). Sylla *et al.* (2016) concurred that liver weight of a fish increases prior to spawning through synthesis of lipids and proteins required for gonad development.

Absolute Fecundity: By implications, absolute fecundity positively correlated with size (r > 0.8), and the exceptionally high regression coefficient (b = 3.09) obtained for fecundity-total length relationship in the present study suggested that the quantum of oocytes produced by female gonads was largely dependent on increase in total length. Muchlisin (2014) concur that a strong connection exists between absolute fecundity and size or age of fish species.. Study by Bagenal (1978) further agrees that length is a much better index of fecundity than weight in a fish species. Similar proportional relationship between absolute fecundity and total length has been observed by several authors in other Mullidae species such as *Mulloidichthys flavolineatus (*El-Regal, 2018) and *Upeneus pori* (Ismen, 2006; El-Drawany, 2013). Also, the number of eggs produced by *P. prayensis* from this study far exceeded records for other Mullidae species such as *Mulloidichthys flavolineatus (*7720 eggs/ TL, 24 cm; El-Regal, 2018) and *Parupeneus multifasciatus (*26 423eggs; Pavlov *et al.,* 2011). This suggested that the study species is exceptionally productive. Studies have revealed that fecundity portrays the productivity and spawning stock biomass of fish stocks. (Gomez-Marquez *et al.,* 2003; El-Drawany, 2013). The fecundity-size relationships can be used to estimate the potential of egg output in a fish (Chondar, 1977).

CONCLUSION AND APPLLICATION OF RESULTS

Pseudupeneus prayensis may be having a homogenous gender population and notable spawning gonads of the key spawning indicators (females) in March and April. Both sexes of *P. prayensis* may be having delayed first sexual maturity, and the immature individuals may be having total length below 13 cm. Moreover, the study species portrayed two spawning peaks that occurred in March and May in the hot season, supposedly aided by well-developed liver (HSI) and improved environmental conditions (K > 1.0) whereas absolute fecundity increased with increase in size, with length being the key dependent factor owing to its exceptional correlation (r > 0.9) and regression (b > 3.0) coefficients, and the females may be highly productive. The results of this study can be used to institute closed fishing seasons in the event of threat on the spawning biomass of the stock of *P. prayensis* in Sierra Leone.

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