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Riwayat reproduksi *Cynoglossus senegalensis* (Kaup, 1858) dari perairan pesisir Greater Accra, Ghana

Reproductive history of *Cynoglossus senegalensis* (Kaup, 1858) from coastal waters of Greater Accra, Ghana

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Abstract

Some life history aspects including the reproductive characteristics and population dynamics of Senegalese tongue sole (Cynoglossus Senegalensis, Kaup, 1858), in the coastal waters of Ghana, were studied between August 2018 and July 2019. The length data of 606 specimens from the coastal waters of the Greater Accra region of Ghana was analyzed for size structure, growth pattern, condition factor, sex ratio and length at first maturity. The mean length varied significantly (p -value < 0 .001) with sex (31.3 ± 0.4 cm in males, 34.3 ± 0.4 cm in females). Condition factor (K) did not vary significantly (p -value = 0.054) with sex (i.e. 0.466 ± 0.002 in males, 0.476 ± 0.004 in females). The gonadosomatic index (GSI) varied significantly p -value < 0 .001) with sex (2.29 ± 0.30 in males), (3.94 ± 0.25 in females) and spawning peaks in April and July. Five maturity stages were recorded for both sexes with the size at first maturity for females and males estimated at 44.1 cm and 38.3 cm, respectively. In conclusion, the assessed fish species is likely to experience recruitment failure in the future, if appropriate management measures are not in place. Reduction in fishing efforts ad establishment of closed season is highly recommended.

Keywords: Cynoglossus senegalensis; Ghana; Growth; Fisheries management; Life history.

1. Introduction

The global fisheries especially the wild stocks are in crisis coupled with numerous challenges in managing the fisheries, especially the small-scale fisheries (Castilla and Defeo, 2005; Chuenpagdee et al., 2005). This requires complex solutions that involve biological, economic, social and environmental. In this regard, understanding the life history of fish species is crucial. To manage fish stocks, information on their population characteristics and reproductive potential plays a vital role (Tsikliras et al., 2013). Important aspects of population characteristics of fishes that are concerned with reproduction (reproductive biology) include sex ratio, gonadosomatic index (GSI), stages of gonadal development and fecundity (Adebiyi, 2012; Mawa et al., 2022; Parvin et al., 2022). The ratio of male to female fish species or vice versa in any ecosystem relies on the sex ratio, which also reveals the dominant sex within a population (Adebiyi, 2012; Hossain et al., 2012). Identifying the reproductive potential and stock size of fish populations also is reliant on information from sex ratio (Vicentini and Araujo, 2003).

The gonadosomatic index indicates the spawning timing, level of gametes ripeness, percentage of body weight converted into gamete production and the reproductive seasonality of fish species (Hossain et al., 2010; Adebiyi, 2012; Tagarao et al., 2020). Similarly, the age at which fish species convert chemical energy into reproductive purposes is dependent on knowing the age or size at which the fish first becomes matured (Wootton and Smith, 2015). Given the paucity of information on the reproductive biology of *C. senegalensis*, assessing the impact of harvesting on the species population structure and devising appropriate management strategies becomes more difficult. The objective of this study was to assess some life history aspects such as GSI, stages of gonadal development, size at first maturity and spawning season of *C. senegalensis* in the coastal waters of Ghana. These findings will improve measures for the sustainable management of the assessed fish species in Ghana.

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2. Materials and Methods

2.1. *Study area*

Five important fishing communities along the Greater Accra region of Ghana including Kpone, Prampram, Tema, Sakumono and Nungua were selected as the study sites (Figure 1). Table 1 shows the geographical coordinates of the sampling locations. These sampling locations are noted for fishing with fishing activities contributing over 50% as a primary occupation (Berchie et al., 2020)

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*
Tema Fishing Harbour	*05°38'23.57"N, 000°01'00.38"E*
Kpone	*05°41'26.84"N, 000°03'52.76"E*
Prampram	*05°42'17.71"N, 000°06'51.57"E*

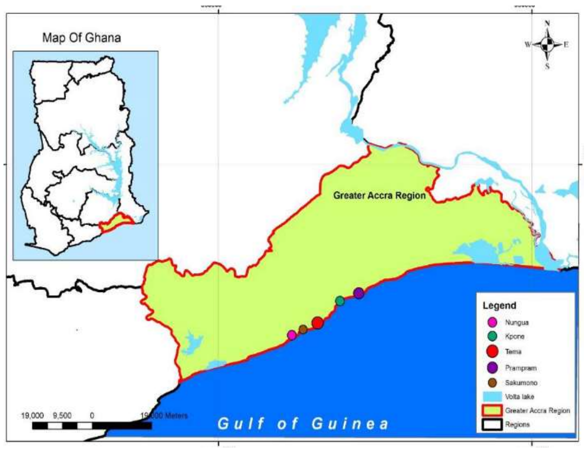

Figure 1. A map of the study area showing sampling areas

2.2. *Collection of specimens and sampling*

Samples of *C. senegalensis* were collected monthly from randomly selected fishers who use multifilament fishing gears from fish landing sites for twelve (12) months (i.e. from August 2018 to July 2019). These fishers predominantly use set nets and trawl nets with a mesh size between 0.5 inches and 1.25 inches. The collected samples were preserved on ice and transported to the laboratory where measurements for the total length in centimetres (0.1 cm) using a measuring board and body weight in grams (0.1 g) by electronic scale were taken. Samples of the fish species were identified using the identification keys by Fischer et al. (1981).

2.3. *Estimation of parameters*

Length- frequency distribution

The recorded length (total length) of the individuals of the assessed fish species was pooled together and used in constructing a percentage frequency histogram (e.g., Saha et al., 2021). In all, 606 individuals of *C. senegalensis* were examined for the present study.

Condition factor (K)

The allometric condition factor (KA) was calculated using the equation of Tesch (1968): KA = W/Lb, where W is the BW in g, L is the TL in cm, and b is the LWRs parameter. Fulton's condition factor (KF) was calculated using the equation: KF =100× (W/L3), where W is the BW in g, and L is the TL in cm. The scaling factor of 100 was used to bring the KF close to the unit. The relative condition factor (KR) for each individual was calculated via the equation of Le Cren (1951): $KR = W/(a \times L^b)$ where W is the BW in g, L is the TL in cm, a and b are LWRs parameters.

Length-weight relationship

The LWRs were calculated using the equation (Le Cren, 1951):

$$W = a \times Lb$$

where W is the body weight (BW, g), and L is the Total length (TL cm).

Sex ratio

The sex ratio of male to female individuals was assessed, using the equation (Peña-Mendoza, 2015):

$$\text{Sex ratio} = \text{Males}/\text{Females}$$

Maturity stages

The gonadal maturation was studied microscopically for both male and female gonads, which have been grouped into different gonadal stages of development according to Nikolsky (1963).

Gonadosomatic index (GSI)

This is an index for the reproductive cycle of the female individuals of the fish species. GSI was estimated using the equation (Mbu-oben, 1995):

$$GSI=GW/BW \times 100$$

where GW and BW represent gonad weight in grams and body weight in grams respectively.

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.

Modified gonadosomatic index (MGI) was estimated as Nikolsky, (1963).

$$(GW/W - GW) \times 100$$

Dobryal Index (DI) was computed as
$\sqrt[3]{GW}$ (Dobryal et al. 1999).

where W is whole fish mass in g, GW is gonad mass in g, L is fish length in cm.

Length at first maturity (Lm50)

The length at first maturity that 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 (King, 1995):

$$P/(1+e^{r(TL-Lm)})$$

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

Also, the relationship between the gonadosomatic index and standard length was used to estimate the crude value of the size at first sexual maturity of the individuals (Hossain et al., 2010).

2.4. *Data analysis*

Descriptive statistics including maximum, minimum and mean total length were calculated based on the length data. For inferential statistics, both parametric and non-parametric tests were used depending on the normality of the data that was done using the Anderson-Darling Test. A parametric test (T-test) was employed to assess the significant difference at a 95% confidence interval when the normality test was not significant. Non-parametric tests (i.e. Chi-square test and Mann-Whitney Test) were employed to assess the significant difference between sexes on a monthly basis when the normality test is significant. In addition, the Spearman rank test was used to correlate body measurements (e.g., TL, SL, and BW) with condition factors (KA, KF and KR,). Minitab version 19 and Microsoft Excel 2016 were used for statistical analysis.

3. Results and Discussion

3.1. Results

Length-Frequency distribution

Table 1 indicates the length-frequency distribution for *C. senegalensis*. The range of length recorded for males was 8.2 cm to 44.1 cm with the mean length as 31.3 ± 0.4 cm, which was the lowest. For females, the recorded minimum and maximum lengths recorded were 8.4 cm and 50.4 cm respectively with a mean length of 34.3 ± 0.4 cm. The Mann-Whitney Test carried out revealed a significant difference between the length of male and female specimens (W-value = 82636.50, p-value < 0.001). For combined sexes, the range lengths recorded ranged from 8.2 cm to 50.4 cm with the mean length as 32.5 ± 0.3 cm.

Table 1
Length frequency distribution for *C. senegalensis*

Sex	N	Mean	SE	Min	Max
Males	365	31.3	0.4	8.2	44.1
Females	241	34.3	0.4	8.4	50.4
Combined sexes	606	32.5	0.3	8.2	50.4

Length-weight relationship

The estimated growth pattern (b) with a constant value (a) to be 0.0043 for the combined sexes was 3.02. The mean allometric condition factor (Ka), Fulton's condition factor (Kf) and relative condition factor (Kr) were 0.005 ± 0.000161, 0.53 ± 0.0161 and 1.23 ± 0.0373 (Table 3). Based on the Spearman rank correlation, all three forms of condition factors used in the study were significantly correlated with total length (rs = -0.174, p < 0.001)

Table 2
Condition factor of *C. senegalensis*

Sex	N	Mean	SE	Min	Max	95% confidence limit
Ka	439	0.01	<0.01	0.002	0.04	0.0047 - 0.0053
Kf	439	0.53	0.02	0.17	4. 40	0.498 - 0.562
Kr	439	1.23	1.23	0.40	10.30	-1.181 - 3.641

Sex ratio

From Fig. 2, 606 specimens of *C. senegalensis* were collected throughout the sampling period which comprised 365 (60%) males and 241 (40%) females. A chi-square (X2) revealed a significant deviation (Chi-square's Test, df = 11, N = 606) = 103.6, p-value < 0.001) from the theoretical 1 male: 1 female sex ratio indicating males were significantly more than females with a ratio of 1.5 male: 1 female sex ratios. From Fig. 2, females dominated the catch only during November and February through to July while males dominated the rest of the year.

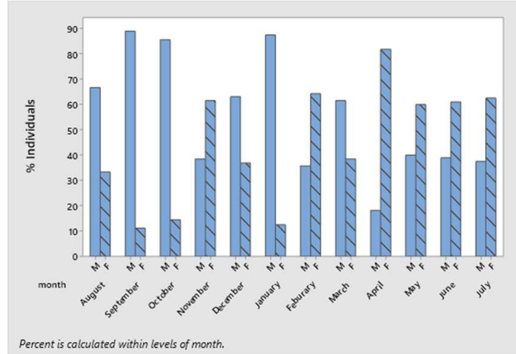

Figure 2. Number of males and females of *C. senegalensis* recorded during the study

Maturity

Fig. 3 shows the maturity stages recorded for *C. senegalensis* based on the gonads of females and males. Overall, five different maturity stages were identified during the study period for both male and female specimens. The majority of the females were at stage IV followed by stage III with the minority of the female at maturity stage II. The majority of the males were at stage II followed by stage I with the minority at stage IV.

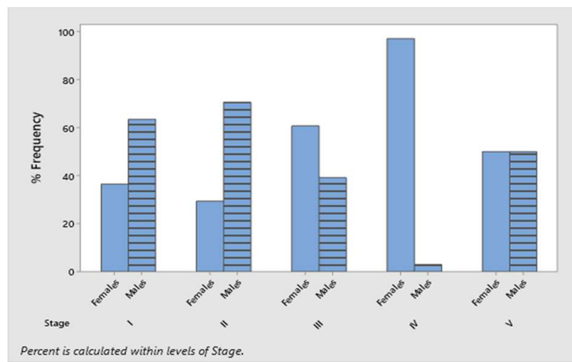

Figure 3. Number of individuals at the various maturity stages of *C. senegalensis*

Gonadosomatic Index (GSI)

Monthly changes of GSI, MGSI and DI for the species is shown in Figure 3. The lower values of GSI, DI and MGSI were recorded in August. However, higher values of GSI and MGSI were recorded in April while for DI, the highest value was found in July. The higher values of DI clarify the peak spawning period of the species to be in July while the higher values of GSI and MGSI signify March – July to be the spawning season.

Length at first maturity

From Figures 5, 6 and 7 below, the crude estimate of size at first maturity for the individuals were 36 cm. However, from the logistic curve procedure developed by Kings (1995), the length at first maturity was 44 cm. Therefore, it can be indicated that the size at first maturity of the species ranges from 36 cm – 44 cm.

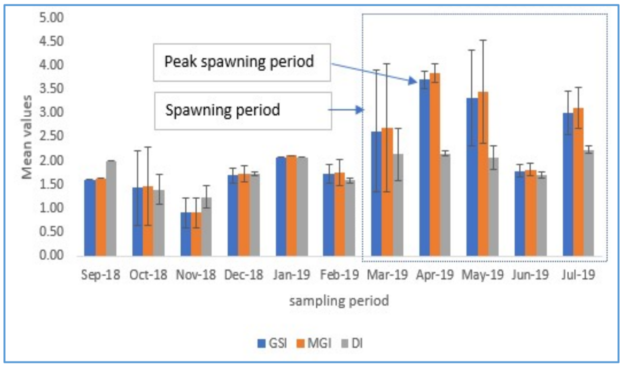

Figure 4. GSI, MGI and DI of *C. senegalensis* recorded during the study period

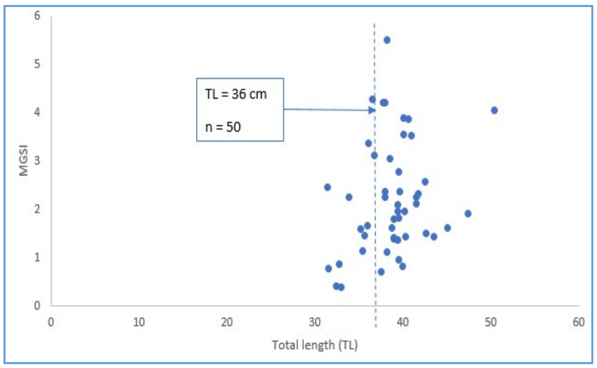

Figure 5. Relationship between modified gonadosomatic index (MGSI) with total length

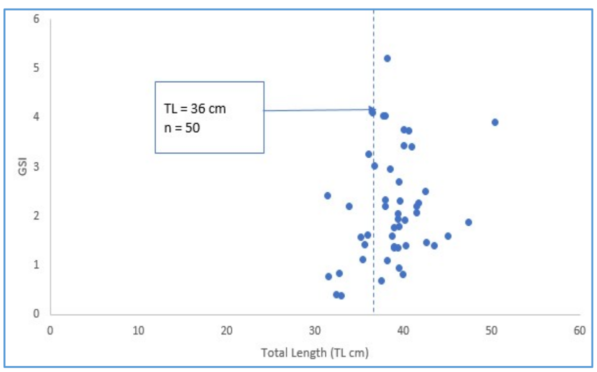

Figure 6. Relationship between gonadosomatic index (GSI) with total length

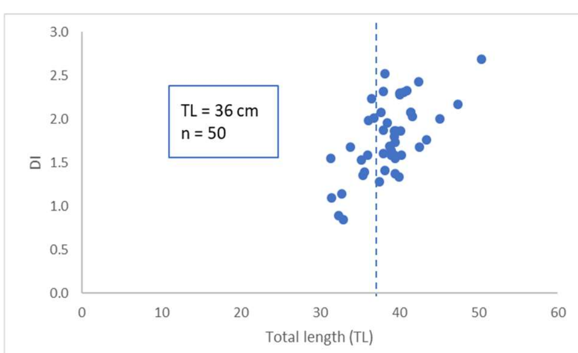

Figure 7. Relationship between Dobryal index (DI) with total length

3.2. Discussion

Length frequency distribution

The existence of the length structure of fish populations is key in the management of fish stocks (Johnson and Tamatamah, 2013). The length structure recorded from this study ranged from 8.2 cm to 50.4 with an average of 32.5 cm. The maximum length for the unsexed specimen of C senegalensis was slightly lower than that documented by (Udo, 2014; Ekpo and Effanga, 2018) from the coast of Nigeria. Factors accounting for the variation in maximum length may be the physiological and ecological conditions of the study areas (Mahmood, 2012). Another factor could be the intensity of fishing activity in the study area which has resulted in lower length in the fish population over time (Marcus, 1982; Hossen et al., 2019).

Condition factor

A study by Udo (2014) found the mean range of condition factor of *C. senegalensis* from the Nigerian cross-river estuary 0.28 – 0.36 while one by Akanse and Eyo, (2018) found the mean range of condition factor as 0.311 – 0.419. These results are relatively favourable with results obtained in the current study. Nonetheless, the variation in the mean condition factor may have been influenced by 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 (Adeyemi et al., 2009; Hossen et al., 2019). According to Kareem et al. (2016), a K value of 1 or more indicates the existence of abundant feed items and good environmental conditions which allows fish species to grow faster and with less stress. The estimated condition factor of *C. senegalensis* from this study was below one, indicating that the *C. senegalensis* from Ghana's coastal waters may be stressed, possibly due to anthropogenic factors (Le Cren, 1951).

Length-weight relationships

The pattern of growth for most fish species is mostly identified through the estimation of 'b' values (Abowei, 2009). *C. senegalensis* in the present study exhibited a positive allometric growth with a b value of 3.02. Abowei (2009) and Abowei and Hart (2009) obtained a positive allometric growth with b values of 3.5 and 3.5, respectively for the species from the Nkoro River and the lower Nun River, in the Niger Delta, Nigeria. However, Sanyang (2011) reported an isometric growth (b = 3.00) for *C. senegalensis* from the Gambia while Akanse and Eyo, (2018) reported a negative allometric growth with a b value of 2.3861 for the species from Akpa Yafe River, Nigeria. According to Obasohan et al. (2012), Rahman et al. (2021) and Hossain et al., (2022), age, sex, sampling methods, sample size, as well as the prevailing ecological conditions all have the propensity to influence the growth pattern of fish species. The range of b values from this study for the various classifications of sexes used in the study was 2.7 to 3.3. This range supports the claim by Morey et al. (2003) that most fishes from both tropical and temperate waters, largely have b in the range of 2.7 to 3.3.

Sex ratio, maturity stages and Length at first maturity

Sex ratio and size structure constitute basic information in assessing the reproductive potential and establishing stock size of fish populations (Quarcoopome, 2017). The sex ratio deviation significantly from the theoretical 1:1 male to female ratio ($p < 0.05$). According to Oniye and Onimisi (2010) and Hossain et al. (2012), the deviation from the theoretical deviation from 1:1 sex ratio is always expected in nature. The deviation may be attributed to the differential growth rate of males to females in the population (Quarcoopome, 2017). The low number of females in relation to males may also be a strategy to ensure that there are more males to fertilize the fewer number of females in order to maintain good population equilibrium, especially under environmental constraints of anthropogenic perturbations (Opadokun and Ajani, 2015). The length at first maturity for *C. senegalensis* based on gonad stages III and IV was higher than the length at first capture, indicating that the species was harvested before they matured and hence, a continuance of this could result in recruitment overfishing.

4. Conclusion

The study sought to assess the reproductive history of *C. senegalensis* from the coast of Ghana. From the study, *C. senegalensis* may be physiologically stressed. In addition, the assessed fish species is likely to experience recruitment failure in the future, if appropriate management measures are not in place. There is the need to i) extend the closed fishing season period, ii) strictly enforce the mesh size regulation and iii) conduct further studies for enhanced decision-making in managing this stock sustainably.

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Bibliography

Abowei, J.F.N. 2009. The abundance, condition factor and length-weight relationship of Cynoglossus senegalensis (Kaup, 1858) from Nkoro River Niger delta, Nigeria. *Adv. J. Food Sci. Technol*, 1(1): 57-62.

Abowei, J.F.N., and Hart, A.I. 2009. Some morphometric parameters of ten finfish species from the lower Nun River, Niger Delta, Nigeria. *Res. J. Biol. Sci.*, 4(3): 282- 288.

Adebiyi, F.A. 2012. Aspects of reproductive biology of big eye grunt *Brachydeuterus auritus* (Valenciennes, 1832). *Nat. Sci.*, 10(2):19-24.

Asiedu, B., Amponsah, S.K.K., and Commey, N.A. 2020. Some aspects of the biology of West African Ilisha (Ilisha africana, Bloch 1795) from the coast of Ghana, West Africa. *Egyptian Journal of Aquatic Biology and Fisheries*, 24: 1-14.

Adeyemi, S.O., Bankole N.O., Adikwu, I.A., and Akombo, P.M. 2009. Age, growth, mortality of some commercially important fish species in Gbadikere Lake, Kogi State, Nigeria. *IJLR*, 2(1): 63 – 69.

Akanse, N.N., and Eyo, V.O. 2018. Length-weight Relationship, Condition Factor and Length Frequency Distribution of the Tongue Sole Cynoglossus senegalensis from Akpa Yafe River, Bakassi, Cross River State, Nigeria. *Asian J. Agric. Res.*, 6(1): 1-8.

Anato, C. B. 1999. Les Sparidae des côtes béninoises: Milieu de vie, pêche, présentation des espèces et biologie de Dentex angolensis Poll et Maul, 1953. Thèse de Doctorat d'Etat es Sciences, Faculte des Sciences 1060 Tunis, Tunisie. 277 p.

Asiedu, B., Amponsah, S.K.K., Failler, P., and Commey, N.A. 2021. Population dynamics of Ilisha africana in Coastal Waters of Ghana. *Fisheries & Aqua. Journal*, 12(1): 288 1–7.

Beverton, R., and Holt, S. 1957. On the dynamics of exploited fish populations. Chapman and Hall, London.

Castilla, J.C., and Defeo, O. 2005. Paradigm shifts needed for world fisheries. *Science,* 309: 1324–1325.

Chuenpagdee, R., Degnbol, P., Bavinck, M., Jentoft, S., Johnson, D., Pullin, R., and Williams, S. 2005. Challenges and concerns in capture fisheries and aquaculture. In: Kooiman, J., Bavink, M., Jentoft, S., Pullin, R. (Eds.), Fish for Life. Interactive Governance for Fisheries. Amsterdam University Press, Amsterdam, pp. 25–37.

Edwards, A.J., Gill, A.C., and Abohweyere, P.O. 2001. A Revision of Irvine's Marine Fishes of Tropical West Africa. *Darwin Initiative Report 2*, Ref. 162/7/451:157 p.

Ekpo, I.E., and Effanga, E.E. 2018. Taxonomic composition, condition factor and length weight relationship of Cynoglossidae (Hamilton: 1822) in the Cross-River estuary, southeastern Nigeria. *Journal of Wetland & Waste Management,* 2(1): 1- 11.

Fischer, W.F., Bianchi, G., and Scott, W.B. 1981. FAO Species Identification sheets for Fishery purposes. Eastern-Central Atlantic; Fishing areas 34, 37 (in part). *Canada Funds-in-Trust by arrangement with the FAO*. Volume II. 54 pp.

Froese, R., and Pauly, D. 2019. FishBase. World Wed Web electronic publication. www.fishbase.org version (12/2019). Accessed on October 12, 2020.

Htun-Han, M. 1978. The reproductive biology of the dab Limanda limanda (L.) in the North Sea: Gonosomatic index, hepatosomatic index and condition factor. *J. Fish Biol.,* 13: 369-378.

King, M. 1995. Fisheries biology, assessment and management. Blackwell Science, London. 341 pp.

Georgiev, Z.M., and Kolarov, P. 1962. On the migration and distribution of horse mackerel (*Trachurus ponticus* Aleev) in the western p art of Black Sea. *Arbeiten des Zentralen Forschungs institutes fur Fishzught und Fisherei-Varna*, 2: 148-172.

Gheshlaghi, P., Vahabnezhad, A., and Taghavi Motlagh, S. A. 2012. Growth parameters, mortality rates, yield per recruit, biomass, and MSY of *Rutilus frisii* kutum, using length frequency analysis in the Southern parts of the Caspian Sea. *Iran. J. Fish. Sci.,* 11(1):48-62.

Johnson, M.G., and Tamatamah, A.R. 2013. Length frequency distribution, mortality rate and reproductive biology of Kawakawa (*Euthynnus affinis* - Cantor, 1849) in the coastal waters of Tanzania. *Pak. J. Biol. Sci.,* 16(21): 1270-1278.

Kareem, O.K., Olanrewaju, A.N., Osho, E.F., Orisasona, O., and Akintunde, M.A. 2016. Growth patterns and condition factor of *Hepsetus odoe* (Bloch, 1794) captured in Eleyele Lake, Southwest Nigeria. *Int. J. Fish. Aquac.,* 7: 178 – 185.

Kwei, E.A., and Ofori-Adu, D.W. 2005. Fishes in the Coastal Waters of Ghana. Ronna Publishers, Tema.112 pp.

LeCren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*), *J. Anim. Ecol.,* 20 (2): 201-219.

Mahmood, K., Zarrien, A., Moazzan, M., and Siddiqui, G. 2012. Length-Weight Relationship and Condition Factor of *Ilisha melastoma* (Clupeiformes: *Pristigasteridae*) of Pakistan. *Pak. J. Zool.,* 44 (1): 71-77.

Marcus, O. 1982. The biology of clupeid, Lisha africana of the African Coast. PhD Thesis, University of Lagos, Nigeria.

Mbu-oben, P. 1995. Age, growth and reproductive biology of some Mormyrid species in Lekki lagoon, Nigeria. Ph.D. Thesis. University of Ibadan.

Morey, G.Y., Moranta, E., Massuti, E., Grau, A., Linde, M., Reora, F., and Morales-Nin, B. 2003. Weight Length relationships of littoral to lower slope fishes from the western Mediterranean. *Fish. Res.,* 62: 89-96.

Nikolsky, G.V. 1963. The ecology of fishes. Academic Press. London., UK, 352 pp.

Obasohan, E.E., Obasohan, E.E., Imasuen, J.A., and Isidahome, C.E. 2012. Preliminary studies of the length-weight relationships and condition factor of five fish species from Ibiekuma Stream, Ekpoma, Edo State, Nigeria. *E3 Jol. of Agric. Research and Development,* 2(3): 61-69.

Oniye, S.J., Onimisi., and H.U. 2010. Some aspects of the reproductive biology of Hyperopisus bebe occidentalis (Gunther) in Zaria dam, Nigeria. In: 25th Annual Conference of the Fisheries Society of Nigeria (FISON), 25-29 Oct 2010, Lagos, Nigeria, 253- 257.

Opadokun, I.O. and Ajani, E.K. 2015. Some aspects of the reproductive biology of *Gymnarchus niloticus* Cuvier, 1829 (Knifefish) in Lekki Lagoon, Nigeria. *Int. J. Fish. Aquat. Stud.,* 2(3): 166-170.

Pauly, D. 1979. Theory and Management of Tropical Multi-Species Stocks: A Review, with Emphasis on the Southeast Asian Demersal Fisheries. ICLARM Studies and Review No. 1, International Center for Living Aquatic Resources Management, Manila, Philippines, 1-35.

Pauly, D. 1983. Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper (234):52 p.

Pauly, D., and Munro, J.L. 1984. Once More on the Comparison of Growth in Fish and Invertebrates. *ICLARM Fishbyte*, 2: 21.

Pauly, D., and David, W. 1981. ELEFAN 1, BASIC Program for the Objective Ex-traction of Growth Parameters from Length-Frequency Data. *Meeresforch*, 28, 205-211.

Peña-Mendoza, B., Gómez-Márquez, J.L., Salgado-Ugarte, I.H., and Ramírez-Noguera, D. 2015. Reproductive biology of *Oreochromis niloticus* (Perciformes: Cichlidae) at Emiliano Zapata dam, Morelos, Mexico. Rev. Biol. Trop., 53 (3-4): 515-522.

Mawa, Z., Hossain, M.Y., Hasan, M.R., Rahman, M.A., Tanjin, S., and Ohtomi, J. 2022. Life-history traits of *Mystus vittatus* in the Ganges River, Bangladesh: Recommendation for its sustainable management considering climate change. International Journal of Biometeorology (In press).

Parvin, M.F., Hossain, M.Y., Sarmin, M.S., Rahman, O., Tanjin, S., Samad, M.A., and Rahman, M.A. 2022. Reproductive performance of Asian stinging catfish *Heteropneustes fossilis* (Bloch 1794) in the Ganges River (NW Bangladesh) in relation to environmental factors. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-022-18816-9.

Hossain, M.Y., Ohtomi, J., Jaman, A., Jasmine, S., and Vadas, Jr. R.L. 2012. Life-history traits of the Monsoon River prawn *Macrobrachium malcolmsonii* (Milne-Edwards, 1844) (Palaemonidae) in the Ganges (Padma) River, northwestern Bangladesh. *Journal of Freshwater Ecology,* 27(1):131-142.

Hossain, M.Y., Ahmed, Z.F., Islam, A.B.M.S., Jasmine, S., and Ohtomi, J. 2010. Gonadosomatic index-based size at first sexual maturity and fecundity indices of the Indian River shad *Gudusia chapra* (Clupeidae) in the Ganges River (NW Bangladesh). *Journal of Applied Ichthyology,* 26(4):550-553.

Saha, N., Roy, P., Nadia, Z. M., Islam, S.M., and Hossain, M.Y. 2021. Life-history traits of Guntea loach, *Lepidocephalichthys guntea* (Hamilton, 1822) in the Payra River, southern Bangladesh. *Lakes & Reservoirs: Research & Management,* 26(3), e12378.

Khatun, D., Hossain, M.Y., Hossen, M.A., Rahman, O., Hossain, M.F., Islam, M.A., Rahman, M.A., Mawa, Z., Hasan, M.R., Rahman, M.A., and Vadas, Jr. L. 2020. Temporal variation of condition and prey-predator status for a schilbid catfish *Eutropiichthys vacha* (Hamilton, 1822) in the Ganges River, northwestern Bangladesh through multi-model inferences. *Indian Journal of Geo-Marine Sciences,* 49 (7), 1229-1237.

Hossen, M.A., Paul, A.K., Hossain, M.Y., Ohtomi, J., Sabbir, W., Rahman, O., Jasmin, J., Khan, M.N., Islam, M.A., Rahman, M.A., Khatun, D., and Kamruzzaman, S.K. 2019. Estimation of Biometric Indices for Snakehead *Channa punctata* (Bloch, 1793) through Multi-model Inferences. *Jordan Journal of Biological Sciences*, 12(2), 197-202.

Hossain, M.Y., Hossen, M.A., Islam, M.S., Jasmine, S., Nawer, F., and Rahman, M.M., 2017. Reproductive biology of *Pethia ticto* (Cyprinidae) from the Gorai River (SW Bangladesh. *Journal of Applied Ichthyology*, 33(5): 1007-1014.

Quarcoopome, T. 2017. Length-weight relationship, condition factor and sex ratio of two Chrysichthys species (Pisces: Claroteidae) of socio-economic importance from Kpong reservoir in Ghana. *Ghana J Sci,* 57: 13-22.

Qamar, N., Panhwar, S.K. and Brower, S. 2016. Population characteristics and biological reference point estimates for two carangid fishes Megalaspiscordyla and Scomberoidestol in the northern Arabian Sea, coast of Pakistan. *Pak. J. Zoology*, 48: 869-874.

Sparre, P., and Venema, S.C. 1992. Introduction to tropical fish stock assessment. Part 1. Manual, FAO Fisheries Technical Paper, 306. No. 1, Review 1, FAO, Rome, 376 p.

Then, A.Y., Hoenig, J.M., Hall, N.G., and Hewitt, D.A. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. *ICES J. Mar. Sci.,* 72 (1): 82-92. doi: 10.1093/icesjms/fsu136.

Udo, M.T., Ayua, G.P., Akpan, M.M., Umana, S.I., and Isangedighi, A.I. 2014. Abundance, condition factor, food and feeding habits of the sole fish, Cynoglossus senegalensis in the Cross-River Estuary, Nigeria. *Nigerian Journal of Agriculture, Food and Environment*, 10(3):43-48.

Sanyang, L., Kretsch, A. and Castro, K. 2011. Length weight relationships and condition factors of red sole, *Cynoglossus senegalensis* and black sole, *Synaptura cadenati* from The Gambia, Coastal Resources Center, University of Rhode Island, pp. 7.

Tagarao, S.M., Solania, C.I., Jumawan, J.C., Masangcay, S.G., and Calagui, L.B. 2020. Length-weight relationship (LWR), gonadosomatic index (GSI) and fecundity of *Johnius borneensis* (Bleeker, 1850) from lower Agusan River basin, Butan City, Philippines. *J. Aquac. Res. Dev.,* 11(6):598. doi:10.35248/2155-9546.20.11.598.

Tsikliras, A.C., Stergiou, K.I., and Froese, R. 2013. Editorial Note on Reproductive Biology of Fishes. *Acta Ichthyol Piscat*,43 (1): 1–5.

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, Brazil. *Braz. J. Biol. Sci.,* 63(4): 559-566.

Wootton, R.J., and Smith, C. 2015. Reproductive biology of teleost fishes. John Wiley & Sons Ltd, United Kingdom.