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Some aspects of reproductive biology of *Hydrocynus forskahlii* in the lower river Benue

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Abstract
This study examined the reproductive biology of *Hydrocynus forskahlii* in the Lower River Benue with specific objectives of estimating sex ratio, gonadosomatic index (GSI) and fecundity. A total of 134 fish samples were collected biweekly at Wadata landing site between November 2022 to January 2023. Samples were collected from catches of fishermen and were immediately placed in ice boxes and transported to the laboratory for analysis. Results showed a female-to-male sex ratio of 1.52:1. GSI was highest in December with corresponding increases in gonad weight (2 g) and body weight of 600 g. Fecundity ranged from 3,700 to 9,059 eggs ($p < 0.05$) with December recording the highest mean fecundity (9,059±723 eggs). R^2 value of 0.9536 was recorded between body weight and fecundity. Larger females contributed more significantly to the population of *H. forskahlii* with seasonal GSI peaks that were stimulated by favourable environment factors.

Keywords: Gonadosomatic index, fecundity, sex-ration, *Hydrocynus forskahlii,* lower river Benue

1. Introduction

Knowledge of the reproductive biology of fish is a crucial aspect of fisheries science (Lowerre-Barbieri, 2019) [26]. It is instrumental in guiding the conservation of aquatic biodiversity and sustainable management of fish stocks (Mayer and Pšenička, 2024) [28]. Biological studies that focus on reproduction often provide crucial data on life history traits such as spawning periods, fecundity, sex ratio, and gonadosomatic index (Hasan *et al*., 2020; Akhter *et al*., 2024) [20, 2]. These information help in evaluating the health and productivity of fish populations. Additionally, researchers and managers are able to assess recruitment rates while predicting the population dynamics of fish species using these biological parameters (Zimmermann *et al*., 2019) [44]. By this, the formulation of conservation strategies for specific fish species can be easily undertaken. Factors that influence the reproductive features of fish could be genetic, ecological and/or environmental (Valdebenito *et al*., 2015; Carnevali *et al*., 2018; Koch and Narum, 2021) [40, 9, 24]. It therefore becomes necessary to study these reproductive parameters in order to optimize the production of fishery resources and development of aquaculture systems (Bahamon *et al*., 2022) [8]. For instance, knowing the fecundity (potential reproductive capacity of female fish) is required to understand possible reproductive success of the fish species. Fecundity data help in establishing the relationship between maternal size and reproductive output (McBride *et al*., 2015; Rollinson and Rowe, 2016; Hagmayer *et al*., 2018) [29, 34, 18]. This is crucial for determining the optimal size of fish which is a still guide towards fisheries management. Furthermore, through the study of fish fecundity, the reproductive behaviour of fish such as batch spawning or total spawning which has effect on the timing and methods of stock assessment is better understood (Wright and Rowe, 2019; Chen *et al*., 2022) [41, 11].

Another key parameter that could aid in understanding the reproductive dynamics of fish populations is the sex ratio (Xu *et al*., 2021; Casas and Saborido-Rey, 2023) [42, 10]. Deviations from a balanced sex ratio can have a significant effect on reproductive success (Schacht *et al*., 2022; Purayil *et al*., 2024) [35, 32].

This is because the number of offspring produced depends on the availability of mates (Kappeler *et al*., 2023) [22]. There is need to regularly monitor environmental and anthropogenic factors such as pollution, habitat degradation, and overfishing which are often responsible for deviations from a balanced sex ration (Shalloof and Salama, 2008; Zhang *et al*., 2023) [38, 43]. In this way the population stability of the fish species is more assured in the ecosystem. Studies on sex ratios also provide comprehensive information on the ecological roles and adaptive strategies of fish (Kappeler *et al*., 2023) [22]. These include mate selection, competition and parental behavior. The gonadosomatic index (GSI) on the other hand is mostly used as an indicator of reproductive readiness and spawning activity (Jamal *et al*., 2024) [21]. GSI provides a quantifiable measure of reproductive investment and can reveal the timing of spawning events by evaluating the correlation between the weight of gonads and the total body weight of fish (Hasan *et al*., 2022) [19]. Environmental factors such as temperature, photoperiod and food availability are usually responsible for season variation in GSI values (Alvarez-Garcia, *et al*., 2024) [4]. These environmental variables often trigger reproductive cycles of many fish species (Servili *et al*., 2020) [37]. So, having an understanding of these variations help identify critical periods for protection such as peak spawning seasons which goes a long way in the implementation of targeted conservation measures (de Mitcheson, 2016; Alglave *et al*., 2024) [15, 3].

The elongate tigerfish (*Hydrocynus forskahlii*) is a predatory species belonging to the family Alestidae (Dahdul *et al*., 2010; Abdulkarim *et al*., 2021) [14, 1]. The fish species holds ecological and economic significance across African freshwater systems (Kasozi *et al*., 2024) [23]. This potamodromous fish plays a crucial role as top predator in rivers, lakes, and floodplains, thus maintaining the balance of these aquatic ecosystems (Gerber *et al*., 2016) [17]. The diet of the fish species has been reported to primarily comprise smaller fish which is characteristic of an apex predator which facilitates energy transfer within trophic networks. Apart from the ecological importance of *H. forskahlii*, it is also a valuable resource for artisanal fisheries. The fish species form a substantial part of the catches of fishermen, thus contributing significantly to food security and livelihoods in rural communities. The fish species however faces growing threat as a result of overfishing, habitat degradation, and pollution and as such there is need to carry out a comprehensive study on the reproductive biology of the fish species. Information on the reproductive biology of *H. forskahlii* particularly in Nigerian waters remains limited. Previous studies (Lewis, 1974; Dadebo and Mengistou, 2008; Segun *et al*., 2022; Tsevenda *et al*., 2024) [25, 13, 36, 39] have focused more on its food and feeding habits, length-weight relationship and condition factor with little information on its reproductive strategies. It is pertinent to address this gap in order to balance the ecological roles of the fish species with its economic. The Lower River Benue which is a major tributary of the Niger River serves as an important habitat for *H. forskahlii* (Tsevenda *et al*., 2024) [39]. It supports diverse fish communities and provides spawning grounds for numerous species including *H. forskahlii*. The current study aims to provide valuable information on life history of the fish species by investigating the reproductive behaviour of species with specific focus on the analysis of sex ratio, GSI and fecundity which are crucial in making informed conservation strategies.

2. Materials and Methods

2.1 Study Area: The study was carried out in the Lower River Benue which is situated in Makurdi, Nigeria. This segment of the river forms an important part of the Benue-Niger system. It is characterized by extensive floodplains and seasonal fluctuations in water levels (Olayinka-Dosunmu *et al*., 2022) [30] which provide critical habitats for numerous fish species, including *H. forskahlii*. The tropical rainfall patterns of the region form seasonal variations in flow of the river thus creating optimal conditions for fish breeding and feeding (Reid & Sydenham, 1979) [33]. The Lower Benue habours high biodiversity which supports significant artisanal fisheries by improving the livelihoods of the fishing communities in the area.

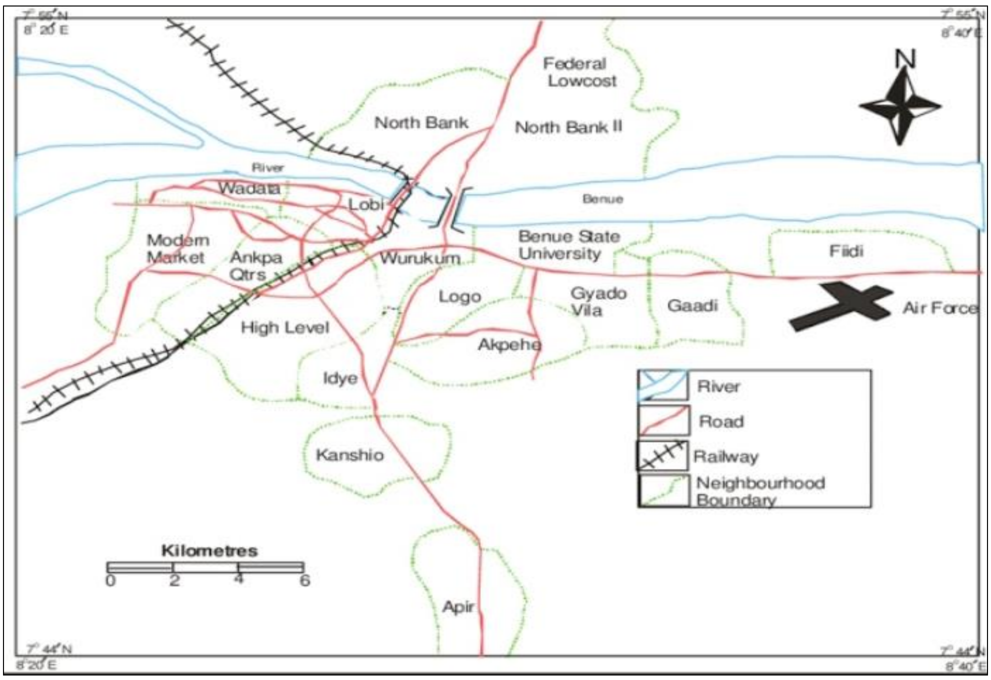

Fig 1: Map showing Lower River Benue basin

2.2 Collection of Sample

Fish samples were collected biweekly between November 2022 and January 2023 at the Wadata landing site in Makurdi. The fishermen made catches using fishing gears including gill nets, cast nets, hooks, and traps. Collected fish samples were preserved in ice boxes and transported to the Fisheries Laboratory of the Department of Fisheries and Aquaculture, Joseph Sarwuan Tarka University, Makurdi for analysis. A total of 134 samples of *H. forskahlii* were collected during the study period.

2.3 Morphometric Measurements

Morphometric parameters such as total length and body weight were measured for each specimen. The total length (TL) was measured from the tip of the snout to the tip of the caudal fin) using an ichthyoboard to the nearest ±0.1 cm while the body weight was measured to the nearest ±0.01 g using an electronic weighing balance (MH-999) according to Dienye *et al.* (2021) [16]. These measurements were important in calculating the gonadosomatic index (GSI) and assessing the relationship between body size and reproductive parameters.

2.4 Determination of Sex and Examination of Gonads

Visual examination of the external and internal morphology of the gonads was performed to determine the sex of each fish specimen. Mature males were identified by the presence of milt while females were distinguished by the size and appearance of their ovaries. Gonads were carefully dissected using a pair of scissors. They were further weighed and preserved in 10% formalin to maintain their structural integrity for subsequent analyses. The maturity stages of the gonads were classified based on size, colour, and texture according to Armstrong *et al*. (2004) [7].

2.5 Calculation of Gonadosomatic Index

The breeding season of all sampled fishes was determined from the percentage of fishes with ripe gonads sampled in each month, which was calculated as:

$$\%\ MS_i = \frac{MS_i}{\sum MS_i} \times 100^4 \text{ (Armstrong and Witthames, 2012)} \qquad (1)$$

Where: % MSi = the percent of fish with maturity stage 1, MS_i = number of fish in maturity stage 1 and $\sum MS_i$ = total number of fish of all maturity stages

The gonadosomatic index (GSI) was computed to determine their breeding season (Armstrong *et al*. 2004) [7,] as:

$$GSI = \frac{GW}{TW-GW} \times 100 \qquad (2)$$

Where, GSI = Gonadosomatic index, GW = fresh gonad weight in g and TW = Total weight in g.

Monthly variations in GSI were analyzed to identify peak spawning periods and assess reproductive readiness.

2.6 Estimation of Fecundity

The fecundity of females with fully developed ovaries (maturity stage V) was determined by weighing the ovaries. A subsample of eggs was then taken for counting. The ripe gonads of matured female fishes were removed and preserved in Gilson's fluid (Arafat and Bakhtiyar, 2022) [5]. In the laboratory, after vigorous shaking, gonads (eggs) of each ripened female fish specimen was weighed to the nearest 0.01 g using a sensitive balance. The total fecundity was estimated using the equation:

$$N = \frac{nW}{w} \text{ (Osei } et\ al.\text{, 2020)} \qquad (3)$$

Where, N-Total number of eggs, n - Number of eggs in sub sample (=1000), W - Weight of all eggs (g) and w - Mean weight of the sub sample (g).

2.7 Statistical Analysis

Statistical analyses were performed using Microsoft Excel (version 2021) and SPSS software (version 20.0). One-way ANOVA was used to determine the monthly variations in GSI and fecundity while regression analysis evaluated the relationship between body weight and fecundity at 5% significance level.

2.8 Ethical Considerations

All the laboratory procedures were done using ethical guidelines for the use of animals in research. Specimens were handled with care to minimize stress and dissection was performed based on the institutional protocols approved by the ethics committee of Joseph Sarwuan Tarka University, Makurdi.

3. Results

Table 1 shows the sample characteristics of *H. forskahlii* from Lower River Benue. A total of 134 specimens were examined out of which 81 were females and 53 males. This gave an overall female-to-male ratio of 1.52:1. Monthly variations of sex ratio of *H. forskahlii* during the study period showed that the highest number of males (21) was obtained in November, while the lowest number (12) was in December. On the contrary, the highest number of females (34) were recorded in January and the lowest value (20) was recorded in December. The variations between male and female were much during January when the running stage was recorded for both sexes.

Table 1: Summary of Sample Characteristics of *Hydrocynus forskahlii*

Months	Sex		Sex Ratio (M: F)
	Male	Female	
November	21	27	1:1.28
December	12	20	1:1.66
January	20	34	1:1.70
Total	53	81	1:1.52

Results showed that there were significant variations in the monthly GSI values (Figure 1). The highest body weight and gonad weight was recorded in December, 600 g and 2g respectively This means that the spawning period was stimulated by favourable environmental factors such as water temperature and food availability.

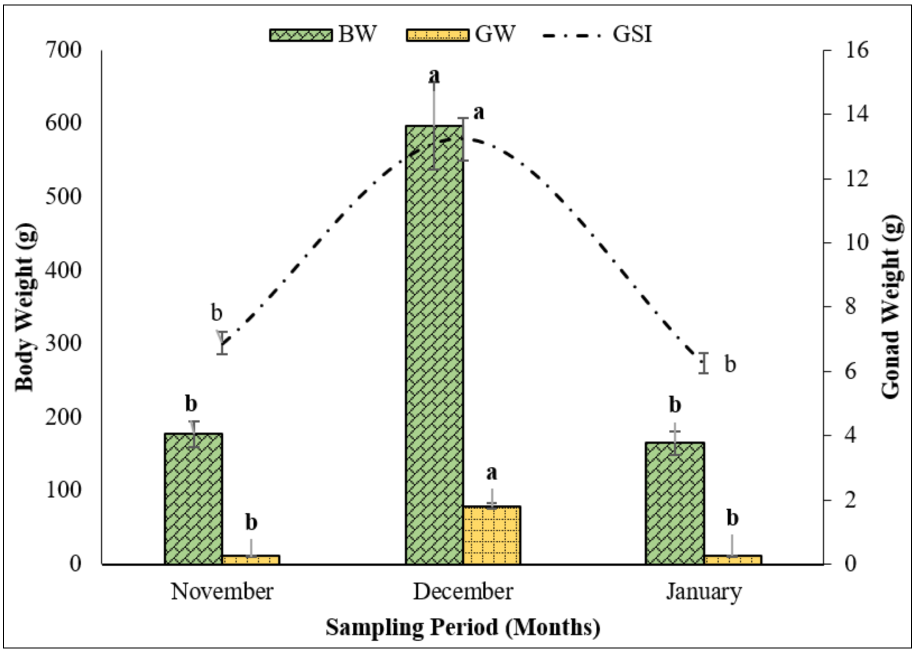

Fig 1: Trends in Gonadosomatic Index (GSI) of *Hydrocynus forskahlii*

Fecundity estimates varied widely among individuals, ranging from 3,700 to 9,059 eggs per female (Table 2). The highest mean fecundity was recorded in December (9,059±723 eggs) which coincided with the peak GSI values. The lowest mean fecundity was recorded in November (3,700±418 eggs). There was a significant difference ($p< 0.05$) the mean fecundity of *H. forskahlii* across the sampling months. Figure 3 shows the regression analysis between body weight and fecundity which was strongly positive (R^2 = 0.9536). This means that larger females contributed more to the reproductive potential of the population.

Table 2: Fecundity Estimates of *Hydrocynus forskahlii*

Sampling Period (Months)	Fecundity
November, 2022	$3700±418^b$
December, 2022	$9059±723^a$
January, 2023	$3921±345^b$
Mean total	4626±853
P - value	0.03

Hint: Mean values with different superscript are statistically different.

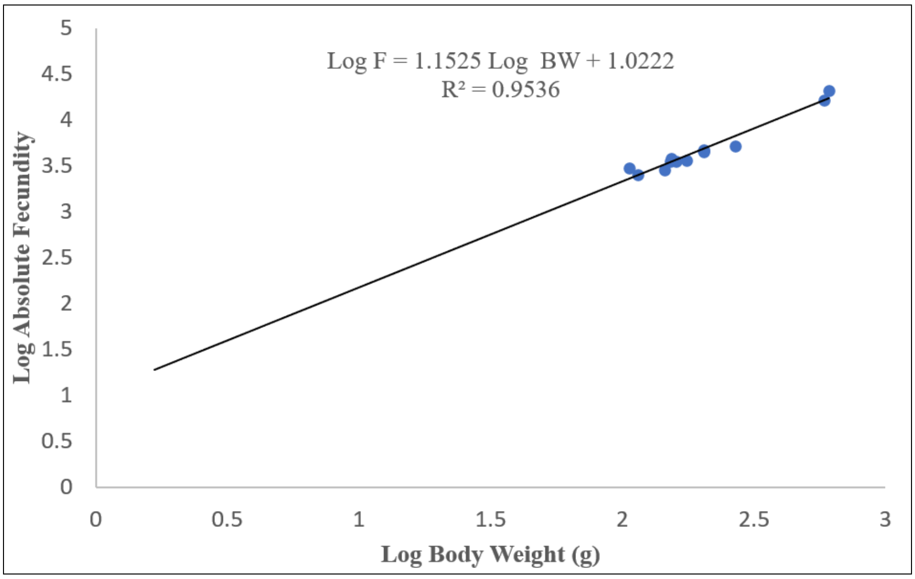

Fig 2: Relationship between Absolute Fecundity and Body Weight of Hydrocynus forskhalii

4. Discussion

The reproductive biology of *Hydrocynus forskahlii* in the Lower River Benue was studied using the analysis of sex ratios, gonadosomatic indices (GSI) and fecundity. The dominance of female *H. forskhalii* showed the extent to which females contribute to reproductive dynamics. This result is in agreement with the findings of Dadebo and Mengistou (2008) [13] in Lake Chamo, Ethiopia. They reported 79.3% of female contribution to the population of *H. forskhalii* in lake. Similarly, Kasoki (2024), documented a sex ratio of 1:4.5 (male to female) for the same fish species from Lake Albert. These differences could be due to adaptive strategies by the female fish that enhance reproductive success favourably stimulated by factors such as habitat preferences, differential mortality rates or environmental stressors during spawning. These findings emphasize the need for sustainable management strategies which gives priority to the protection of sexually mature females for stable population structure. The seasonal trend in Gonadosomatic index values further explains the reproductive readiness of *H. forskahlii* with peak values in December. This means that there was higher synchronization of reproductive activity possibly stimulated by environmental factors such as water temperature and food availability. Mangi *et al*. (2024) [27] emphasized the role favorable environmental conditions in stimulating reproductive cycles in fishes. The synchronization of reproductive peaks with environmental factors corroborates the findings of Kasoki (2024), who identified feeding and reproductive health for being responsible for the gastrointestinal morphology of the fish species. The relative gut length of 1.27 cm recorded in the study showed that *H. forkskahlii* is an omnivore. This could be a similar dietary adaptability in *H. forskahlii* from the Lower River Benue which supports reproductive success in dynamic environments. The presence of mucous-secreting goblet cells in the digestive system, as noted by Kasoki, could also be responsible for enhanced nutrient absorption of the fish species which positively improved the fecundity and overall health of the fish.

The result of fecundity estimates from this study varied significantly across the sampling months showing strong correlation between body weight and fecundity. This means that larger females contribute more significantly in maintaining population productivity. Dadebo and Mengistou (2008) [13] documented a wider range of fecundity of 35,564 to 411,810 eggs in Lake Chamo. They also estimated a curvilinear model of $F = 0.0184TL^{4.08}$, $R^2 = 0.61$ between fecundity and total length. Similarly, the linear relationship between fecundity and total weight, and fecundity and ovary weight were positively strong with R^2 values of 0.70 and 0.88, respectively. The higher fecundity recorded in their study as compared with the present study may be due to regional variations in environmental conditions, food availability or genetic factors. Alvarez-Garcia *et al*. (2024) [4] stated that environmental factors such as water temperature and food availability influence fish health and reproductive success and as such making habitat conservation necessary for sustaining reproductive potential of fish.

5. Conclusion

This study provides critical information on the reproductive biology of *H. forskahlii* in the Lower River Benue. The female fish species where significantly higher that the males with seasonal GSI peaks coinciding with favourable environmental factors while fecundity was size-dependent. These indices establish the need for integrated management strategies which are necessary in ensuring the sustainability of *H. forskahlii* populations in the Lower River Benue.

6. Recommendation

There is need to focus conservation measures on the protection of spawning grounds, particularly during periods of peak reproductive activity as indicated by seasonal GSI variations. When larger, more fecund females are protected from overfishing, the recruitment of *H. forskahlii* will be better sustained which will result to a stable population. Future research should consider exploring the effect of environmental factors such as water temperature, nutrient availability, and habitat structure on reproductive parameters of the fish species for informed conservation strategies.

7. Acknowledgements

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8. Conflict of Interest Statement

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other journal for publication.

9. References

1. Abdulkarim M, Magaji IM, Nayaya AJ, Yusuf ZA, Jibril SA. Fisheries and Wildlife; c2021.
2. Akhter M, Hasan MM, Khan ABS, Ullah MR, Bosu A, Yasmin F, *et al*. Reproductive biology and feeding habit of *Coilia dussumieri* Valenciennes, 1848 (Actinopteri: Engraulidae): A review. International Journal of Science and Technology Research Archive. 2024;6(1):051-056.
3. Alglave B, Olmos M, Casemajor J, Etienne MP, Rivot E, Woillez M, *et al*. Investigating fish reproduction phenology and essential habitats by identifying the main spatio-temporal patterns of fish distribution. ICES Journal of Marine Science. 2024;81(8):1563-1574.
4. Alvarez-Garcia IL, Abadia-Chanona QY, Arellano-Martinez M, Avila-Poveda OH. Maximum gonad investment reveals male bias when temperature decreases or latitude increases for a broadcast-spawning intertidal chiton (*Polyplacophora*: Chitonida). Hydrobiologia; c2024. p. 1-20.
5. Arafat MY, Bakhtiyar Y. Reproductive pattern and maturity phases of indigenous Kunar snowtrout *Schizothorax labiatus* inhabiting Vishav Stream in Kashmir Himalaya, India. Environmental Biology of Fishes. 2022;105(2):247-260.
6. Armstrong MJ, Witthames PR. Developments in understanding of fecundity of fish stocks in relation to egg production methods for estimating spawning stock biomass. Fisheries Research. 2012;117:35-47.
7. Armstrong MJ, Gerritsen HD, Allen M, McCurdy W, Peel JA. Variability in maturity and growth in a heavily exploited stock: cod (*Gadus morhua* L.) in the Irish Sea. ICES Journal of Marine Science. 2004;61:98-112.
8. Bahamon N, Domínguez-Petit R, Paramo J, Saborido-Rey F, Acero A. Iberoamerican Fisheries and Fish Reproductive Ecology. Scientia Marina. 2022, 86(4).
9. Carnevali O, Santangeli S, Forner-Piquer I, Basili D, Maradonna F. Endocrine-disrupting chemicals in aquatic environment: what are the risks for fish gametes? Fish Physiology and Biochemistry. 2018;44:1561-1576.
10. Casas L, Saborido-Rey F. A review of an emerging tool to estimate population parameters: the close-kin mark-recapture method. Frontiers in Marine Science. 2023;10:1087027.
11. Chen X, Liu B, Lin D. Sexual maturation, reproductive habits, and fecundity of fish. Biology of Fishery Resources; c2022. p. 113-142.
12. Cochrane KL. A fishery manager’s guide book. Management measures and their application. FAO Fisheries Technical Paper No. 424. Rome: FAO; c2000. p. 231.
13. Dadebo E, Mengistou S. Feeding habits, ontogenetic dietary shift and some aspects of reproduction of the

tigerfish *Hydrocynus forskahlii* (Cuvier 1819) (Pisces: Characidae) in Lake Chamo, Ethiopia. Ethiopian Journal of Biological Sciences. 2008;7(2):123-137.
14. Dahdul WM, Grande T, Poyato-Ariza F, Diogo R. Review of the phylogenetic relationships and fossil record of Characiformes. Gonorynchiformes and ostriophysan relationships: A comprehensive review. 2010. p. 441-464.
15. de Mitcheson YS. Mainstreaming fish spawning aggregations into fishery management calls for a precautionary approach. BioScience. 2016;66(4):295-306.
16. Dienye HE, Olopade OA, Amadiree ET. Growth parameters and exploitation of endangered Ladyfish (*Elops lacerta* Valenciennes, 1847) in the Obama Creek, Rivers State, Nigeria. Journal of Aquatic Biology and Fisheries. 2021;9:92-98.
17. Gerber R, Smit NJ, van Vuren JH, Wepener V. Metal concentrations in *Hydrocynus vittatus* (Castelnau 1861) populations from a premier conservation area: Relationships with environmental concentrations. Ecotoxicology and Environmental Safety. 2016;129:91-102.
18. Hagmayer A, Furness AI, Reznick DN, Pollux BJ. Maternal size and body condition predict the amount of post-fertilization maternal provisioning in matrotrophic fish. Ecology and Evolution. 2018;8(24):12386-12396.
19. Hasan MR, Hossain MY, Mawa Z, Hossain MA. Reproductive biology of *Heteropneustes fossilis* in a wetland ecosystem (Gajner Beel, Bangladesh) in relation to eco-climatic factors: Suggesting a sustainable policy for aquaculture, management and conservation. Saudi Journal of Biological Sciences. 2022;29(2):1160-1174.
20. Hasan M, Hosen MHA, Miah MI, Ahmed ZF, Chhanda MS, Shahriar SIM, *et al*. Fecundity, length at maturity and gonadal development indices of river catfish (*Clupisoma garua*) of the old Brahmaputra River in Bangladesh. The Egyptian Journal of Aquatic Research. 2020;46(3):259-263.
21. Jamal R, Asad F, Naz S, Hussain SM. Comparative assessment of natural and synthetic reproductive inhibitors in *Oreochromis niloticus*. International Journal of Agricultural and Biological Engineering. 2024;17(5):284-292.
22. Kappeler PM, Benhaiem S, Fichtel C, Fromhage L, Höner OP, Jennions MD, *et al*. Sex roles and sex ratios in animals. Biological Reviews. 2023;98(2):462-480.
23. Kasozi N, Iwe GD, Langi S, Namulawa VT, Walakira JT. Histological features of the gastrointestinal tract of elongate tigerfish, *Hydrocynus forskahlii* (Cuvier, 1819), from Lake Albert. The Journal of Basic and Applied Zoology. 2024;85(1):11.
24. Koch IJ, Narum SR. An evaluation of the potential factors affecting lifetime reproductive success in salmonids. Evolutionary Applications. 2021;14(8):1929-1957.
25. Lewis DSC. The food and feeding habits of *Hydrocynus forskahlii* Cuvier and *Hydrocynus brevis* Günther in Lake Kainji, Nigeria. Journal of Fish Biology. 1974;6(4):349-363.
26. Lowerre-Barbieri SK. Reproduction in relation to conservation and exploitation of marine fishes. In: Reproductive Biology and Phylogeny of Fishes, Vol 8B: Part B: Sperm Competition Hormones CRC Press; c2019. p. 371-394.
27. Mangi HO. Water level fluctuation effect on fish reproduction success. International Journal of Ecology. 2024;1:4876582.
28. Mayer I, Pšenička M. Conservation of teleost fishes: application of reproductive technologies. Theriogenology Wild. 2024;100078.
29. McBride RS, Somarakis S, Fitzhugh GR, Albert A, Yaragina NA, Wuenschel MJ, *et al*. Energy acquisition and allocation to egg production in relation to fish reproductive strategies. Fish and Fisheries. 2015;16(1):23-57.
30. Olayinka-Dosunmu DN, Adzandeh AE, Hamid-Mosaku IA, Okolie CJ, Nwilo PC, Ogbeta CO, *et al*. Assessing River Benue flow data for flood mitigation and management in Adamawa catchment, Nigeria. Scientific African. 2022;16:e01205.
31. Osei IK, Blay J, Asare N. An update of the reproductive biology of Sardinellas (Family: Clupeidae) in the coastal waters of Ghana. Journal of Fisheries Research. 2020;5(1):01-09.
32. Purayil SBP, Thomas SM, Kumar R, Anirudhan A, Praveen ND, Gopal VN, *et al*. Spatial variation of the broodstock availability of *Acanthopagrus berda* (Forsskal 1775) with emphasis on seasonality, lunar periodicity, and sex ratio for facilitating efficient breeding program. Regional Studies in Marine Science. 2024;69:103304.
33. Reid GM, Sydenham HA. A checklist of Lower Benue river fishes and an ichthyogeographical review of the Benue River (West Africa). Journal of Natural History. 1979;13(1):41-67.
34. Rollinson N, Rowe L. The positive correlation between maternal size and offspring size: fitting pieces of a life-history puzzle. Biological Reviews. 2016;91(4):1134-1148.
35. Schacht R, Beissinger SR, Wedekind C, Jennions MD, Geffroy B, Liker A, *et al*. Adult sex ratios: causes of variation and implications for animal and human societies. Communications Biology. 2022;5(1):1273.
36. Segun ADS, Ijabo OS, Yusuf B. Length-weight relationship and condition factor of *Hydrocynus forskahlii* (Cuvier, 1819) in River Yobe, Northeast, Nigeria. Aceh Journal of Animal Science. 2022;7(2):53-58.
37. Servili A, Canario AV, Mouchel O, Muñoz-Cueto JA. Climate change impacts on fish reproduction are mediated at multiple levels of the brain-pituitary-gonad axis. General and Comparative Endocrinology. 2020;291:113439.
38. Shalloof KAS, Salama HM. Investigations on some aspects of reproductive biology in *Oreochromis niloticus* (Linnaeus, 1757) inhabited Abu-zabal Lake, Egypt. Global Veterinaria. 2008;2(6):351-359.
39. Tsevenda CA, Annune PA, Olufeagba SO, Ataguba GA. Food and Feeding Habits of Three Selected Fish Species of Lower River Benue, Benue State, Nigeria. Nigerian Journal of Fisheries and Aquaculture. 2024;12(1):1-15.
40. Valdebenito II, Gallegos PC, Effer BR. Gamete quality in fish: evaluation parameters and determining factors. Zygote. 2015;23(2):177-197.
41. Wright PJ, Rowe S. Reproduction and spawning. In: Atlantic Cod: A Bio-Ecology. 2019. p. 87-132.
42. Xu Q, Jiang Y, Fang LP, Liu M, Jiang XB. Reproductive dynamics of three important Clupeiform food fishes in

the Min River Estuary and its adjacent nearshore waters, China. Marine and Coastal Fisheries. 2021;13(6):679-692.

43. Zhang T, Du N, Geng Z, Wang S, Gao Y, Yang G, *et al*. Estimation of estuarine habitat degradation and its influence on the reproduction process of the crab *Eriocheir sinensis* in the Yangtze River Estuary. Ecological Processes. 2023;12(1):59.
44. Zimmermann F, Claireaux M, Enberg K. Common trends in recruitment dynamics of north-east Atlantic fish stocks and their links to environment, ecology and management. Fish and Fisheries. 2019;20(3):518-536.