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Abundance, Distribution, Morphometric, Feeding Evaluation and the Reproductive Strategies of G*ymnarchus niloticus* in the Lower River Niger at Agenebode, Edo State Nigeria

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ABSTRACT: The study of the numerous areas of biology of fish produces ample and relevant information that aids scientist to explore, know and maintain the survival, growth, continuity and sustainability of life of various fish species. A total of 94 specimens of *Gymnarchus niloticus* were collected from River Niger at Agenebode during the sample period that ranged from 14 – 94 cm total length (54.88± 17.92); weighed 424 - 2281g (1569.61 ± 422.85). The length weight relationship (LWR) of *G. niloticus* in this study showed a negative (b<3) allometric growth pattern. Out of the 94 specimens analysed 54 males and 40 females were examined with a ratio of 1:1.4. Insects and decapods were the major food of the juveniles of *Gymnarchus niloticus* while the major food of preference of the sub adults and adults were Fish and insects with 27.12%, and 27.97% by FO. *Gymnarchus niloticus* possesses a single ovary in the female and single testis in the male which is often referred to as unpaired gonad. Fecundity ranged between 620 to 1378 eggs with a mean of 957.69 ± 112.31 eggs in females. The relationship between fecundity (F) and weight (W) and fecundity and standard length (SL) showed that fecundity is more related to weight than length of fish. Log F = 820.66 + 0.11 W and Log F = 151.23 + 5.31 SL. Fecundity had a positive significant correlation (P<0.05) with both somatic weight (r = 0.714) and standard length (r = 0.657) of fish. Ova diameter showed a ranged between 3.5 and 7.9 mm with a mean of 4.72 ± SD1.69 mm and it had significant relationship (P<0.05) with total weight, gonad weight and maturity stage. *Gymnarchus niloticus in the* Lower River Niger at Agenebode showed that *G. niloticus* has an unpaired gonad in both sexes, a gonochoristic reproductive pattern. Fecundity is low and the ova are large. They are small brood spawners with asynchronous breeding strategy. The attributes of *G. niloticus* obtained from this study reveals that the fish species is a good candidate for fish culture.

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The study of the biology of fish species enables the primary and relevant knowledge to be obtained for the survival, growth, continuity and sustainability of life. Inquiry into the size, age, morphometry, and nutrition and reproduction strategies will avail science on the rate of growth, ecological capacity, habitat sustainability, and the degree of survival of species. The state of fish species is often able to reveal its condition status in relation to its well being, growth, availability and abundance of food, digestive capability, the ability of species to reproduce, the gonadosomatic index, fecundity. It has been reported by Oluwole *et al.* (2019) that the size of fish increases with relation to its food and feeding habits, availability of food and fecundity. Consequently, there is a dire need to elucidate the factors on the biology of valuable fish species. Dietary composition and feeding habits of fish often vary with fish species, size, time, season, habitats and other factors all intrinsic links with the environment (Vahabnezhad *et al*., 2021). To this extent, dietary items of fish are often determined indirectly based on analysis of stomach contents. This may also furnish information on feeding habits besides associated feeding structural traits, for instance gut analyses are basal requirement for fish survival (Opadokun and Ajani, 2015). *Gymnarchus niloticus* belonging to the family Gymnarchidae is the only extant member of the order Osteoglossiformes (Freose and Pauly, 2021). The desire to commercialize and culture this fish species is gradually gaining attention of fisheries scientists. It's hard flesh, good taste, mineral and nutritious value, economic value and gradual decrease in distribution and catch gives a lead for worry. The bulk of the information regarding the *G. niloticus* is at taxonomy level. Comprehensive information of the food and feeding habits, condition factor, the morphometric, gonad morphology, fecundity and reproductive strategies and other biological features of the fish in the river at Agenebode is yet to be documented, this study will provide information for knowledge, documentation and its use in fisheries biology and management, fish culture,

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preparation and formulation of fed for growth stages of fish, its breeding practice, hence this study.

MATERIALS AND METHODS

Study Area: The River Niger at Agenebode is located at 706'N 642'E. Agenebode is a waterside town located by the banks of the River Niger. It is located at the lower River Niger, typically with a humid climate and weather of approximately 32 º C. The area is marked by 2 seasons, the wet season and the dry season. The wet season is from April to October while the dry season is from November to March. The River serves the people of Edo and its environs with a route for transportation to other neighboring communities; a fishing spot and fishery; market and a source of water for domestic purposes, farm, irrigation, industrial purposes and trading location for local traders and the riparian localities at the popular Agenebode Market.

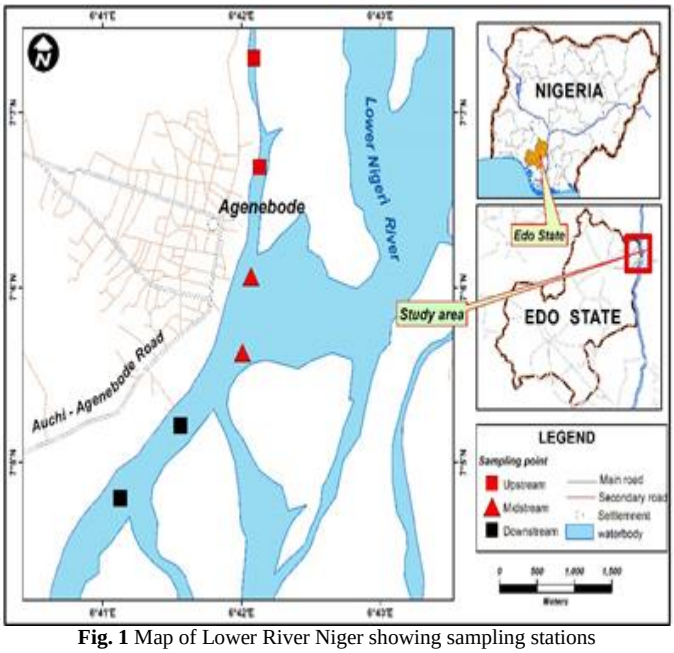

Fig. 1 Map of Lower River Niger showing sampling stations

Collection of specimens and sampling: A total of seventy three (73) fish species were collected fortnightly for 12 months from November 2019 to October 2020 from three stations (based on the landing sites of fishing localities) from catch landings of fisher folks by the use of canoes, gill nets, cast nets, drag nets, fish traps and calabashes. Samples of fishes were transported to the Laboratory of the Department of Biological Sciences, Edo State University Uzairue, Edo State. Fishes were rinsed, wiped dry and identified to species level using guides, keys and pictures provided by Froese and Pauly (2020) and Reed *et al*., (1967) and Pandey and Shukla (2005) and then preserved in 5% formalin.

Morphological Parameters: The standard length (cm), total length (cm), head length (cm), gape mouth (cm), girth length, and weight (g) of *G. niloticus* were obtained by using a graduated ruler and tape a measuring board and a digital electronic scale (Storius 177). These were recorded and analysed. Fin counts and measurements were also taken and recorded.

Determination of Sex: Sex could not be obtained from external observation. The stomach was split open from the lower abdominal region to determine the sex. Sex was determined by visual and microscopic observation of the gonads. Where there was the presence of one ovaries the fish was referred as females, the presence of a sperm sac was connoted as males.

Length – weight relationship: The Standard length (SL) and body weight (W) were measured from the fresh samples to the nearest 0.1 cm and 0.01 g respectively. The length – weight relationships were estimated from the formula, W = a L b, where W is total body weight (g), L is the total length (cm), a and b are the coefficients of the functional regression between W and L. This relationship was transformed into a linear form by the equation:

$$Log\ W = Log\ a + b\ log\ L$$

Condition Factor: The condition factor 'K' was calculated by the following formula given by (Pauly, 1983):

$$\frac{(K = 100\,W)}{L^3}$$

Where: W = total weight of fish in grams; K = condition factor; L= total length of fish in centimeters. It was calculated for both sexes separately and then for the combined sexes. Variations of K with season and size groups were also determined. Gonadosomatic Index (GSI).

Gonadosomatic Index (GSI): The Gonadosomatic Index of samples of *Gymnarchus niloticus* were determined according to Ugwamba *et al*., (1991) as follows

$$GSI = \frac{weight\ of\ gonad\ X\ 100}{weight\ of\ fish}$$

The monthly catches were sorted into sexes. The mature female ovaries were analysed and used to determine the GSI.

Fecundity: Ovaries of the mature fish were removed and placed gently in boiling water and allowed to boil for 20 minutes. The eggs became hard enough for easy counting. The boiled eggs were then stored in 5% formalin. 1.00g of the whole ovaries was cut off. The cut section of the eggs were carefully counted and multiplied by the total weight of the ovary to give the total number of eggs.

The maturity stages of the ovaries were classified according to Nikolsky (1963):
Stage 1 – Immature, Stage II-Quiescent, Stage III - Maturing, Stage IV-Mature,
Stage V - Running, Stage VI -Spent.

Egg diameter: Egg diameter (mm) was measured with an ocular micrometer. A stage micrometer was earlier used to calibrate the microscope. Diameters of twenty eggs randomly selected from each ovary were measured and their mean was taken as the average egg diameter.

Determination of Food and Feeding Habits: Each stomach was split open and the contents emptied into a petri dish. The contents were observed under a hand lens and the food materials and identified.

Frequency of occurrence method (FO): In the frequency of occurrence method the individual food matter in the stomach were sorted and identified. The number of stomachs in which each food item occurred was expressed as a percentage of the total number of stomachs with food examined.

Numerical method: This method involves counting the number of each food item present in the stomach of a fish and summing these numbers to obtain the total number of all food items found in the stomach. The number of each food item is then expressed as a percentage of the total number of all food items. It was expressed as

$$Percentage\ number\ of\ a\ food\ item = \frac{Total\ number\ of\ a\ particular\ food\ item}{Total\ number\ of\ a\ particular\ food\ item}\ x\ 100$$

Importance of food index (IRI): The importance of various food items were determined with the index of food importance following a method Ugwumba and Ugwumba (2007)

$$IRI = (Cn + Cw)\,X\,F$$

Where IRI = index of relative importance; Cn = percentage of numerical composition; Cw = percentage of gravimetric composition; F = percentage of frequency of occurrence

The dietary compositions for the species examined were expressed as percentages, that is

$$\%\,IRI = (Cn + Cw)\,X\,F\,X\,100$$

Food item with %IRI ≥ 3 are regarded as primary, ≥ 0.1 to <3 are secondary where as ≤ 0.1 are considered as incidental food items.

Prey-predator relationship: The relationship between the total body length and total weight of *G. niloticus* and prey body weight was determined and described by the equation;

$$YL = a + bXL\ (Ogari, 1988)$$

Where YL = Prey body weight (g), XL = *G. niloticus* body length (cm) or body weight (g).

Relative Importance Index (RI): This was calculated for each prey and group of preys based on the Absolute Importance Index (AI) (George and Hardley 1979). Gut lengths of specimen were measured with a rule (precision 0.1 mm) after internal dissection.

The Relative Gut Length (RGL): This was expressed as the ratio of total length of gut to total body length (Biswass 1993)

$$\text{RGL} = \frac{total\ lenght\ of\ gut}{total\ length\ of\ fish}$$

Where fish can be classified as herbivorous (RGL>1), carnivorous (RGL<1) or omnivorous (RGL =, or>, or <1).

Statistical analyses: Microsoft Excel was used to calculate and analyse statistical analyses

RESULTS AND DISCUSSION

Total lengths of *Gymnarchus niloticus* (n = 94) collected from River Niger at Agenebode during the sample period ranged from 14 – 94 cm total length (54.88± 17.92); weighed 424 - 2281g (1569.61 ± 422.85). The length weight relationship (LWR) of *G. niloticus* in this study showed a negative (b<3) allometric growth pattern, the LWR is presented as:

	a	b	r^2	R
LWR	**0.826**	**1.767**	**0.82**	**0.91**
K	**0.703**			

This growth *pattern* indicates that the fish grows more in length than its weight. This finding is in agreement with Odo *et al*., (2012); Odo *et al*., (2013): Ayoade, (2018) on the LWR of *G. niloticus* however, it is in contrast with the findings of Oluwale *et al*., (2019) with an isometric growth pattern for *G. niloticus*. There was no variation in the pattern of growth between juveniles, sub adults and adult species. All stages of growth showed negative allometric pattern during the period of this study. Differences in growth pattern observed within species and between species arise from variations in nature of habitat, availability of food, sexual maturity, condition factor of species at a particular time Kharat *et al*., (2008); Agbugui and Deekae (2013); Agbugui and Oniye (2016); Agbugui *et al*., (2014); Agbugui and Abhulimen (2018); Agbugui and Oniye (2019a); Agbugui *et al*., (2019b); Agbugui *et al*., (2021). Condition factor of *G. niloticus* in this study was lower in the rainy (July to September) season than in the dry season. Generally the mean condition factor was <1. However, fishes were in good condition throughout the study period.

Dietary composition: Out of the 94 specimens analysed throughout the sampling period, 54 males and 40 females were examined with a ratio of 1:1.4 which is a departure from the expected theoretical ratio of 1:1 (Oniye and Onimisi 2011). The stomachs examined, (49 %) had empty stomachs. Insects and decapods were the major food of the juveniles of *Gymnarchus niloticus* while the major food of preference of the sub adults and adults as recorded on (Table 1) were Fish and insects with 27.12%, and 27.97% by FO.

Table 1: Percentage composition of various food species consumed by *G. niloticus*

Species	%NO	%FO	%W	IRI	%IRI	%IGR
Fish	23.38	27.12	35.96	0.30	29.67	8.04
Shrimps	19.48	16.10	21.35	0.20	20.41	3.29
Crabs	14.29	10.17	17.98	0.16	16.13	1.64
Insects	35.06	27.97	17.98	0.27	26.52	7.42
Copepods	7.79	18.64	6.74	0.07	7.27	1.35
TOTAL	**100**	**100**	**100**	**1.00**	**100.00**	**100**

Crustaceans, insects and decapods were diets observed in the stomachs of juveniles, sub adults and adults were stomached with decapods and fishes. This finding was also reported by Olaoluwa *et al*., (2016). Consequently, this finding should be a driving factor in the preparation and formulation of artificial diets for *G. niloticus* to comprise of basic nutrients to correlate with the nutrient values of food and feed preferences at different growth stages. There is however limiting information on the diets of fish juveniles in the wild especially for *G. niloticus*.

The gut length of *G. niloticus* obtained in this study was 0.77. This result relates with the expectation of carnivorous species with regards to the relationship between length of *G. niloticus* fish and gut length and feeding habits. The gut morphometric then revealed a composite of elongated an extended git that is folded to fit the abdominal cavity. RGL according to Biswas (1993) classifies fish habits as herbivorous (RGL>1), carnivorous (RGL<1) or omnivorous (RGL =, or>, or <1). In any case, the food and feeding habits of *G. niloticus* reveals that a carnivorous feeding habit with a gut length 0.77 clearly fits it classification as omnivorous. The food and feeding habits of fish species will depend on its nature of gut, food availability, season and abundance of food, habitat, and condition factor, stages of gonadal development, inter and intraspecific competition (Stergiou and Karpouzi 2002; Elliott and Bellwood 2003; Olowale *et al*., 2016; Gurkan, S. and Taskavak, E. 2019; Vahabnezhad *et al*., 2021; Agbugui *et al*., 2021). These information obtained in this study are key to the basis of diet formulation for species in culture for optimal fish survival. In the study of the gobies, it was sated that gut morphology might not be a true representation of trophic levels as the omnivores species (*Amblygobius phalaena* and *Valenciennea sexguttata*) showed higher GL and RGL than the carnivore *Cryptocentrus cinctus*, as would be expected, the highly specialized herbivore Again,

Austrolethops wardi exhibited a short gut which was probably related to species evolutionary history. According to Biswass (1993) and Agbugui *et al*. (2021), gut length are expected to reflect diet as predators commonly have short and simple guts, while in omnivores and herbivores they are extended and complicated reflecting extensive digestibility and nutrient content and absorption of a species' preferred food item. The prey –predator relationship of *G. niloticus* revealed that fish weight was more related to prey size (Fig 2)

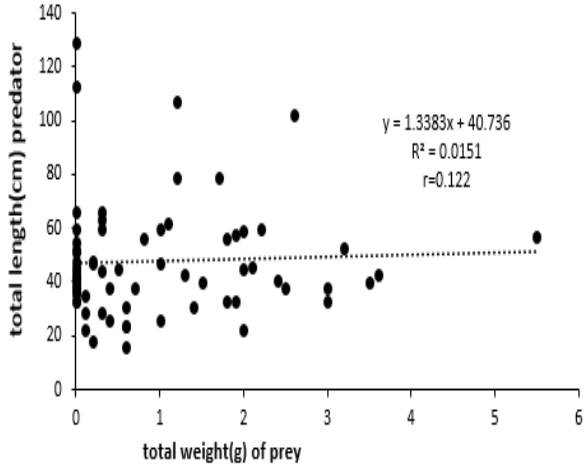

Fig 2. Relationship between prey body weight and total length of *G. niloticus*

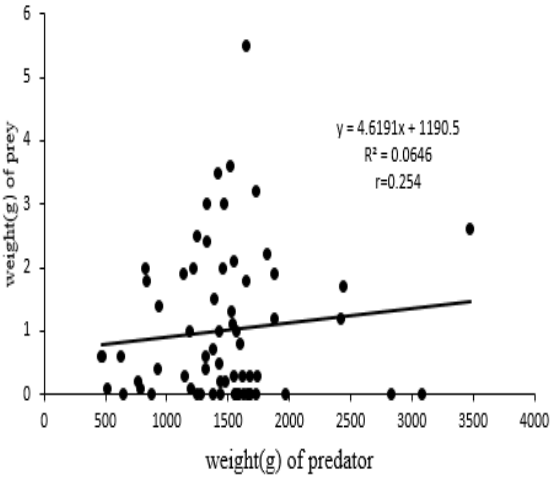

Fig. 3. Relationship between prey body weight and total weight of *G. niloticus*

Gymnarchus niloticus possesses a single ovary in the female and single testis in the male which is often referred to as unpaired gonad. Unpaired gonad are also reported in *Notopterus notopterus* and *Heterotis niloticus* and (Dalela *et al.*, 1976; Opadokun and Ajani 2015**;** Agbugui *et al*., 2021) unlike most species with paired gonad structure. In this study as reported earlier, more males were observed than females in a ratio of 1:1.4, this occurrence could be a reproductive strategy to successfully fertilize the small quantity of eggs laid, to assist in brooding and caring of young. In this study, the breeding period of *G. niloticus* was noticed to have two peaks (May to July and October to January). This extension in the breeding period could be a strategy to ensure that the offspring of *G. niloticus* relatively reaches large size to place them in a position where fish species are optimally available within the year. Only 13 gravid females and 5 mature males were recorded in this study. This could be as a result of the nature of the river, where breeding females and males are resigned in nest that are not easily reached by fisher men and fishing nest, furthermore, the adults continue to guard the young after hatching as also was report by (Opadokun and Ajani 2015; Opadokun *et al*., 2015). In this study mature and gravid fish species were from 1800g to 3000g and length of 60-110cm. Gravid species were reported from May to July and from November to January while other gonad stages were seen from March to May and from August to November. No spent gonad stages was observed in this study. The stages of gonad development in *G. niloticus* is presented in Table 2.

Fecundity ranged between 620 to 1378 eggs with a mean of 957.69 ± 112.31 eggs in females. The relationship between fecundity (F) and weight (W) and fecundity and standard length (SL) showed that fecundity is more related to weight than length of fish. Log F = 820.66 + 0.11 W and Log F = 151.23 + 5.31 SL. Fecundity had a positive significant correlation ($P<0.05$) with both somatic weight ($r = 0.714$) and standard length ($r = 0.657$) of fish. Ova diameter showed a ranged between 3.5 and 7.9 mm with a mean of 4.72 ± SD1.69 mm and it had significant relationship ($P<0.05$) with total weight, gonad weight and maturity stage. According to this study the fecundity of *G. niloticus* could be referred to as low when compared to fish species like the *Mormyrus rume* with 2991 eggs, P. jubelini, Protopterus annectens, *P. bichir*, and to those of high fecundity like *Synodontis schall* with 7130 to 73000 and *Clarias gariepinus* (Willoughby, 1974; Oniye and Onimisi 2011).

The breeding period of most tropical fishes coincided with the rainy season where and when the physicochemical parameters, conditions of the aquatic environment are favourable, and various food species are in abundant (Agbugui and Deekae, 2013; Oluwale *et al*., 2019). All year round breeding in fish species have been reported for *Pseudotolithus senegalensis* and *P. typus* (Anyanwu, 1990).

Table 2: Stages of gonad developments observed in *G. niloticus*

Gonad stage	Macroscopic character	
	Testis	**Ovaries**
I. Immature	Not encountered	Not encountered
II. Quiescent	Testis were small and creamy in colour	The quiescent stage had ovaries that were translucent and creamy in colour, oocytes were not visible to the naked eye, blood vessels were seen on the surface of ovaries.
III. Maturing	The males had small milt that was milky in colour.	The maturing stage had ovaries that were amber in colour with reddish patches indicating the presence of blood vessels. Oocytes were translucent and were not visible to the naked eye, blood vessels were seen on the surface of ovaries
IV. Mature	The mature stage had larger milt that could be released with some pressure while the	Oocytes were amber and sometimes reddish in colour. Oocytes could be seen with naked eye and counted easily.
V. Running	Milt could be released with little pressure	Eggs could be released with little pressure
VI. Spent	Not encountered	Not encountered

Table 3. Variation in Gonadosomatic Index of *G. niloticus* from the Lower River Niger at Agenebode in Edo State Nigeria

Parameters	N	Range of GSI	Mean ±S.D
Dry season	08	0.7-5.3	3.2±0.22
Rainy season	10	5.6-15.8	10.88±0.36
Sex			
Male	05	0.52-4.28	2.5±1.39
Female	13	5.1-15.86	8.66±2.13

Conclusion: Gymnarchus niloticus in the Lower River Niger at Agenebode showed that *G. niloticus* has an unpaired gonad in both sexes, a gonochoristic reproductive pattern. Fecundity is low and the ova are large. They are small brood spawners with asynchronous breeding strategy. The attributes of *G. niloticus* obtained from this study reveals that the fish species is a good candidate for fish culture.

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