Ecology and Evolutionary Biology
2021; 6(1): 15-22
http://www.sciencepublishinggroup.com/j/eeb
doi: 10.11648/j.eeb.20210601.14
ISSN: 2575-3789 (Print); ISSN: 2575-3762 (Online)

Aspects of the Biology of *Periophthalmus barbarus* (Mudskipper), from Jaja Creek, Niger Delta, Nigeria

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To cite this article:
Nsikak Okon Abiaobo, IdopiseAbasi Ekpe Asuquo, Ifeanyi Ntasiobi Ejiogu, Etimfon Joseph James. Aspects of the Biology of *Periophthalmus barbarus* (Mudskipper), from Jaja Creek, Niger Delta, Nigeria. *Ecology and Evolutionary Biology*. Vol. 6, No. 1, 2021, pp. 15-22. doi: 10.11648/j.eeb.20210601.14

Received: December 28, 2020; **Accepted**: January 9, 2021; **Published**: March 10, 2021

Abstract: The mudskipper, *Periophthalmus barbarus* is reported to be a good delicacy for human consumption as well as for use in traditional medicinal preparations where aphrodisiac properties are attributed to its flesh. They are investigated for their biological and eco-toxicological studies, to determine its potential use as a bio-indicator in environmental assessments of coastal waters, tropical or subtropical soft bottom intertidal systems, and despite this; there is lacuna of scientific report on its biology and ecology. This research was undertaken to provide information on the aspects of the biology of the species, with reference to sexual dimorphism, sex ratio, size composition, gonad morphology and morphogenesis, length weight relationship and condition index. Monthly samples were collected at Jaja creek, Niger Delta, Nigeria and preserved in 10% formalin for further analysis. Length and weight of each specimen were measured and weighed to the nearest 0.1 cm and 0.001 g respectively; the specimens were later dissected to examine the gonads. Ovaries and testes from each specimen were measured and weighed to the nearest 0.001 g and 0.1 cm respectively. Paired comparison by the observation of the genital papilla on the postero-ventral surface of the abdominal region was used to determine sexual dimorphism in weight in similarly-sized females and males. The proportion of the two sexes relative to one another was used to calculate the sex ratio. Each specimen was measured using a fish measuring board to the nearest centimeter and weighed using a meter balance to nearest gram and recorded to obtain size composition. The length-weight (L-W) relationship was computed using empirical allometric equation. Findings reveal that the presence of spermatocytes and oocytes at different stages of development was an indication that this species belongs to the fish with prolonged and fractional spawning season and therefore, may spawn more than once during the spawning season. The mean condition index of 1.06 proved that the fish fed well and was in a good condition. The pattern of length-weight relationship revealed positive allometric growth.

Keywords: Length Weight Relationship, Sex Ratio, Gonads, Dimorphism, Spawning

1. Introduction

Fish is one of the most valuable sources of protein food worldwide; people obtain about 25% of their animal protein from fish. It is the most easily affordable source of animal protein to the average Nigerian. *Periopthalmus barbarus* is an amphibious fish and is commonly known as mudskipper [13]. This is a type of fish species that lives in burrows in the intertidal saline swamps in estuaries, creeks and lagoons [27]. Together with the other members of the subfamily Oxudercinae, they form a diverse group of species which colonized semi-terrestrial habitats in intertidal and supra-tidal coastal swamps [31]. It occupies a salient ecological niche and is a valued component of some artisanal catches being

exploited either for use as baits in hook and line fisheries, for human consumption or for use in traditional medicinal preparations where aphrodisiac properties are attributed to its flesh [11].

They are investigated for their biological and eco-toxicological studies, to determine its potential use as a bio-indicator in environmental assessments of coastal waters, tropical or subtropical soft bottom intertidal systems. Mudskippers are entirely different from many other fishes as they can breathe comfortably, in water as well as on land. Males and females can be differentiated using the genital papillae [38]. The species is usually cultured and studied ecologically because of their considerable tolerance to environmental stressors, organic and inorganic contaminants [27].

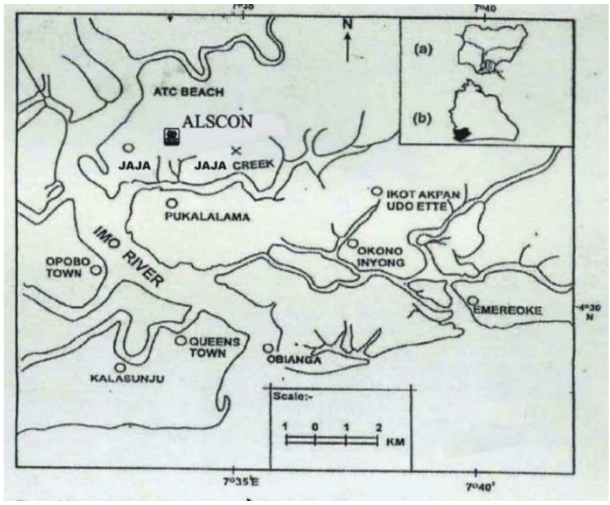
The oxudercine gobies provide a rich source for comparative studies in adaptation to the littoral habitat. In spite of the paucity of information on reproduction, culturing techniques have improved in recent years and the developmental stages of the Chinese and Japanese species are now known [35]. Aspects of the biology, ecology and early life history of mudskippers have attracted attentions of several authors [12, 39, 18, 19, 24].

There is still inadequate information on the biology of this species in some coastal waters of the Niger Delta hence the aim of this research is to investigate some aspects of the biology of *periophthalmus barbarus* in Jaja creek, a tributary of Imo River, Ikot Abasi, Akwa-Ibom state, Nigeria, with particular reference to sexual dimorphism, sex ratio, size composition, gonad morphology, stages of gonad development (morphogenesis), condition index and length-weight relationship as specific objectives

2. Materials and Methods

2.1. Study Area

This study was carried out in Jaja creek in Ikot Abasi Local Government Area, Akwa Ibom State, Nigeria (Figure 1). Jaja creek is located at latitude $40^0$32' to $40^0$52'N and longitude $70^0$25' to $70^0$45'E with elevation generally less than 30 m above sea level. The creek extends to the western bank of Enyong creek about 12 km from Imo River where the water breaks the coastal area into an irregular shaped tidal mud flat. The area is typical of an estuarine tidal water zone with fresh water input from the Imo River and extensive mangrove swamps and inter-tidal mudflats. The Jaja creek is bounded by thick mangrove mostly by Rhizophora species and interspaced by Nypa palm. It has a climate that can be differentiated into two seasons; the wet season which begins in April and ends in October, having an average annual rainfall varying between 2000 mm to 3500 mm, and dry season which spans from November to March [15]. The main occupations of the people are fishing, farming, firewood cutting and water transportation [10].



Legend: × Study area, O Towns

Figure 1. *Map of Ikot Abasi Showing Jaja Creek.*

2.2. Samples Collection

Monthly samples of the mudskipper, *Periophthalmus barbarus* (Figure 2) were caught between June, 2019 through November, 2019 with non-return valve basket traps from mudflats of the mangrove swamp of Jaja creek. Services of local fishers were employed in setting up traps and diurnal collections of the fish. They were preserved immediately after capture in 10% formalin solution in a plastic container prior to laboratory procedure. A total of 600 mudskippers were collected. The fish specimens were washed with water to remove any foreign debris such as leaf, mud, sand, that must have been attached to the body of the mudskipper. There after the samples were transported to Zoology Department laboratory, Akwa Ibom State University the same day and preserved for further analysis.

Figure 2. *Periophthalmus barbarus (Mudskipper).*

2.3. Sample Preparations

In the laboratory, the total length of each fish was measured using a measuring board and recorded to the nearest centimeter and weighed to the nearest 0.1g. total weight (TW) using a top loading weighing balance [39].

2.4. Sexual Dimorphism

The sexes of *P. barbarus* were differentiated by the observation of the genital papilla on the postero-ventral surface of the abdominal region [38].

2.5. Sex Ratio

Each specimen was dissected and the gonads were removed. The sex of each specimen was identified by examination of the gonads. The number of males and females specimen were counted and recorded. The proportion of the two sexes relative to one another was used to calculate the sex ratio. The ratio of the sexes (males: females) were calculated monthly, and for the entire period of study and the result was tested by chi square test for deviation from the hypothetical 1:1 ratio. (Unity) [39].

2.6. Size Composition

Each specimen was measured using a fish measuring board to the nearest centimeter and weighed using a meter balance to nearest gram and recorded [38].

2.7. Gonad Morphology

After dissection the gonads were removed and observed. Testes were present in males and ovaries in females [39].

2.8. Gonad Maturity Stages

The specimens were disserted to ascertain sex and sexed by examining the gonads. The stages of gonad maturation were established according to a classification system modified from [5; 20, 38]. The number of males and females in the different stages of gonadal development were counted and recorded

2.9. Condition Index

The condition factor of a fish is regarded as the fatness or well-being of the fish and it indicates the general metabolism of the fish. Condition factor depends on how well a fish feeds. Fish condition index (k) was determined by the formula [39].

$$K = \frac{TW}{TL^3} \times 100$$

Where, TW = somatic weight (g), TL = Total length of fish (cm).

2.10. Determination of Length-Weight Relationship

The length-weight (L-W) relationship was computed using empirical allometric equation of the form $Wt = a(TL)^b$ [22; 37; 8; 9]. Where Wt = Total weight of fish (g)

TL = Total length of fish (cm)

a = proportionality constant, and

b = Regression exponent

The values of a and b were estimated by least square linear regression using double log transformed into weight and length data according to the formula Log wt = Log a + b log TL [19]. Where wt is total weight of fish (g). Total length (TL) (cm), a is the intercept on the Y-axis and b is exponent or slope indicating growth pattern

3. Results

3.1. Sexual Dimorphism

The genital papillae on the postero-ventral surface of the abdomen of the female were more rounded than that of the male's counterpart. The papilla of the male was slightly pointed.

Figure 3. *Postero-ventral surfaces of the abdomen of male and female P. barbarus showing differences in genital papilla.*

3.2. Sex Ratio

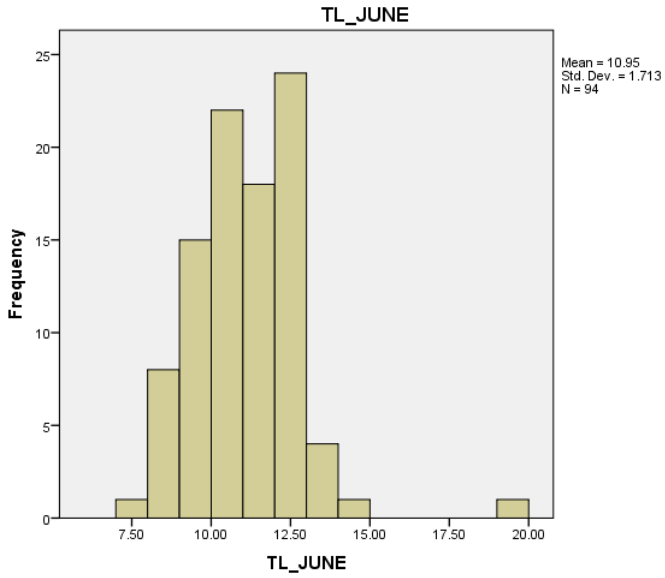
The monthly variation in sex ratio is presented in Table 1. A total of 526 specimens were collected, 239 (45.4%) males and 287 (54.6%) females giving a male: female of 1;1.2 which was different from unity in favour of the females.

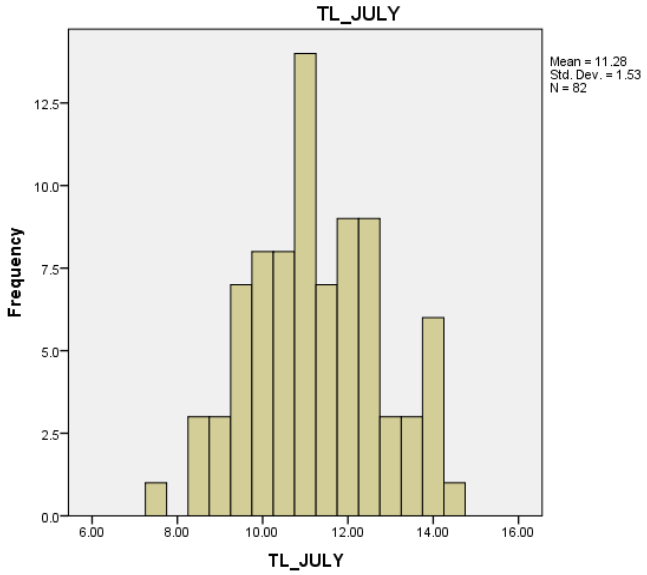
Table 1. *Monthly sex ratio of P. barbarus from Jaja Creek.*

Month	Sex (N)		Ratio		Calculated x^2 test	Sign
	Male	Female	Male	Female		
June	10	84	1.0	8.4	10.34	<
July	30	52	1.0	1.7	5.870	<
August	48	36	1.3	1.0	14.28	<
September	68	31	2.2	1.0	2.104	<
October	54	32	1.7	1.0	6.837	<
November	29	52	1.0	1.8	5.09	<

3.3. Size Composition

The length frequency distribution of males and females of *P. barbarus* showed no marked differences (Figure 4). Both sexes occurred over the entire range of body size examined. In combined sexes, total length ranged between 5.50 cm and 19.90 cm in October and June respectively while total weight varied from 2.70 g - 35.64 g in September and November respectively. The smallest fish (TL cm) was a male with 5.50 cm (TL) while the longest fish was a female with 19.90 cm (TL cm). The lightest fish by total weight was a female with 2.70 g (TW g) and while the heaviest was a male with 35.64 g (TW g).





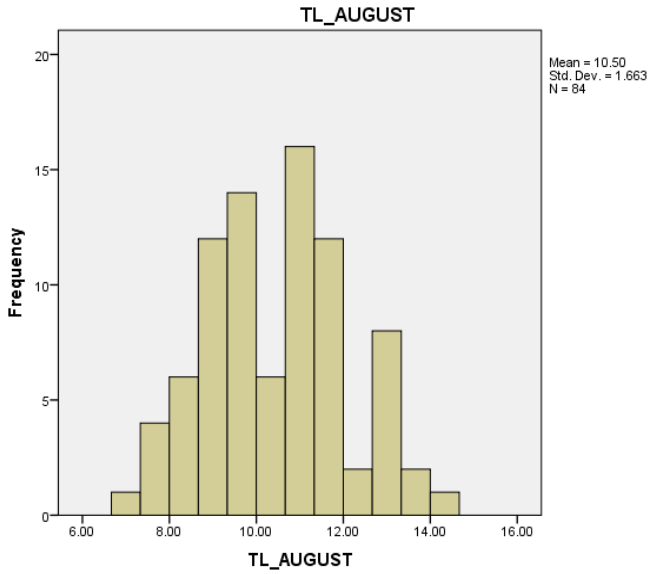
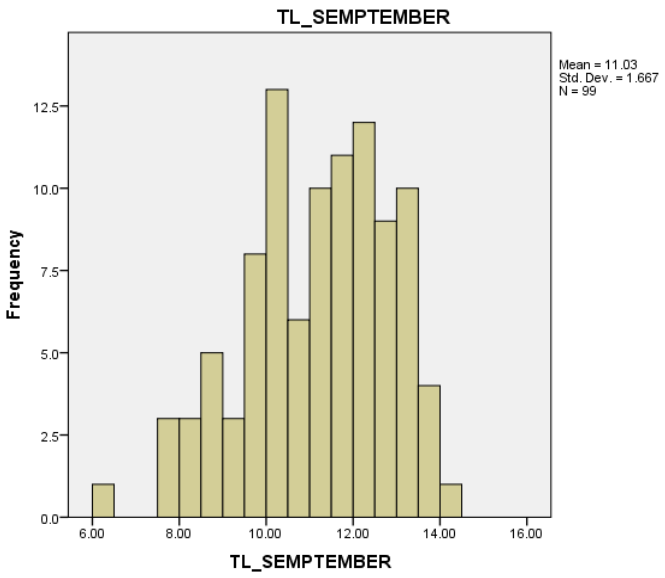
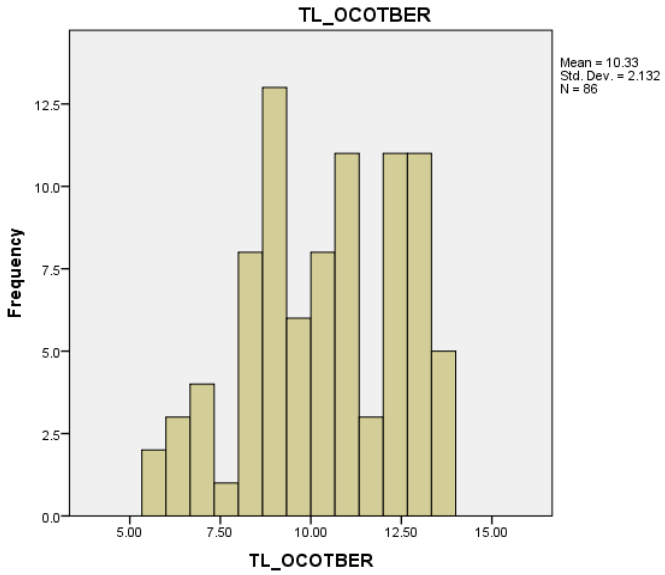


Figure 4. *Monthly Length frequency distribution of P. barbarus in the mangrove swamp of Jaja Creek.*





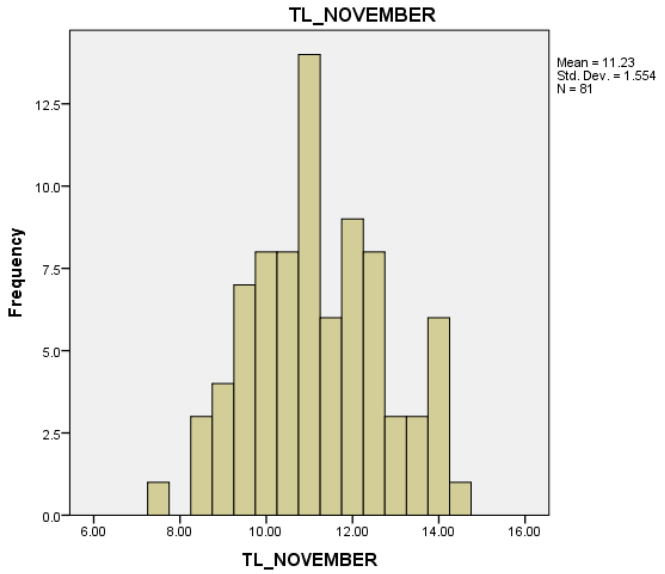


Figure 5. *Monthly Length frequency distribution of P. barbarus in the mangrove swamp of Jaja Creek continues.*

3.4. Gonad Morphology

The examination of the gonad morphology showed that the testes were a pair of small, pale-white, serrated, thin, elongated structures resting on the dorsal surface of the abdominal cavity. The left and the right lobes are joined posteriorly to form a Y-shaped structure and then open to the exterior through the vent. The ovaries were paired pale-white to yellow organs lying on the dorsal wall of the visceral cavity. The lobes were generally equal in size, but as maturity sets in, the left lobe was significantly longer than the right. Both lobes contain oocytes at the same stages of development. The right and left lobes joined posteriorly and open to the outside through the vent.

3.5. Gonad Morphogenesis (Stages of Gonad Development)

Six maturity stages were encountered for the *P. barbarus* [5, 20, 38, 39]. The macroscopic description of the maturity stages for the species is presented in Table 2.

Table 2. *Maturity scale of male and female P. barbarus in Jaja Creek.*

	Description	
Maturity stages	**Male**	**Female**
Stage 1 (Immature)	Testes were tiny, paired translucent, elongated threads close under the vertebral column.	Ovaries were tiny elongate threads, close under the vertebrate column.
Stage 2 (Early developing)	Testes pale, slightly white in colour, flattened, 1-2mm broad, and lobed. They occupied 1% of the body cavity and accessory sexual organs were visible	Ovaries very small, firm, pale-white
Stage 3 (Late developing or resting)	Testes small, white, serrated edges, slightly fatter with pointed ends and occupied about $\frac{1}{8}^{th}$ of the abdominal cavity.	Ovaries small, grainy, orange-yellow, a heavy network of vessels appeared laterally on the surface of the ovary wall. Yellowish Oocytes were slightly visible to naked eye through the ovary wall.
Stage 4 (Gravid or Mature)	Testes white, serrated edges, slightly broad at the ends and occupied about $^{1}/_{5}^{th}$ of the abdominal cavity.	Ovaries yellow, large and filling the body cavity. Ovary wall clearly transparent and eggs visible to naked eyes through the ovary wall.
Stage 5 (Ripe)	Testes fully swollen, multi-lobed, white, serrated edges, slightly longer and broader.	Ovaries yellow, larger with contour walls, turgid, distend body cavity. Eggs clearly distinct, when opened a number of eggs spilled out.
Stages 6 (Spent)	Testes shrunk having discharged sexual products, the testes relatively small in size, white walls were hard in texture.	The ovaries were reduced in size, flaccid but with tough and smooth wall no granulation. The colour was pale yellow and the residual oocytes were present and visible through flabby wall.

3.6. Condition Factor

Condition factor ranged between 0.902 (July and November) and 1.22 (August) with a mean condition index of 1.06.

3.7. Length-Weight Relationship

A plot of total weight ($TW_{(g)}$) against total length (TL_{cm}) of male and female *P. barbarus* during the period of study are shown in Table 3. There was a positive correlation between total length and weight throughout the period of study in both males and females specimens. The exponential values (b-values) were as follows for females 2.658, 3.234, 3.055, 2.983, 3.034 and 3.235 for June, July, August, September, October and November respectively while those of the males were 2.840, 3.268, 2.625, 3.071, 2.204 and 3.268 for June to November respectively. The combined sexes also recorded the following b-values 3.008, 4.928, 3.823, 3.168 and 4.918 for June - November respectively.

Table 3. *Length-weight relationship parameters of P. barbarus from Jaja Creek.*

FEMALE					**MALE**				**COMBINED SEXES**			
Month	**No.**	**a**	**b**	$\mathbf{R^2}$	**No.**	**a**	**b**	$\mathbf{R^2}$	**No.**	**a**	**b**	$\mathbf{R^2}$
JUNE	84	-3.669	2.658	0.707	10	-4.086	2.840	0.973	94	-17.55	3.008	0.690
JULY	52	-4.994	3.234	0.853	30	-5.109	3.268	0.968	82	-37.366	4.928	0.877
AUGUST	36	-4.586	3.055	0.943	48	-3.566	2.625	0.831	84	-25.507	3.823	0.827
SEPTEMBER	31	-4.456	2.983	0.914	68	-4.719	3.071	0.951	99	-26.097	3.776	0.882
OCTOBER	32	-4.599	3.034	0.902	54	-2.560	2.204	0.820	86	-18.610	3.168	0.837
NOVEMBER	52	-4.997	3.235	0.861	30	-5.109	3.268	0.968	82	-37.196	4.918	0.880

4. Discussion

The sexes of *P. barbarus* were differentiated on the basis of genital papillae on the postero-ventral surface of the abdomen. A similar sex differentiation was reported by [39] for *P. barbarus* in the mangrove swamp of Imo River estuary, Nigeria. The overall sex ratio in Jaja Creek was significantly female biased. This female dominance shows that sufficient females are always available to maintain good population equilibrium and reduce competition amongst the aggressive, territorial male [38]. In Jaja Creek, *P. barbarus* showed size variation throughout the period of study. The smallest fish was a male with 5.50 cm (TL) while the largest fish was a female with 19.90 cm (TL). The present results contradicts the findings of Turay *et al*. on the same species from the mudflat of Freetown Sierra Leone who observed the largest mudskipper to be a male with 15.4 cm while largest female measured 13.0 cm (TL) [36].

The presence of spermatocytes and oocytes at different stages of development was an indication that this species belongs to the fish with prolonged and fractional spawning

season [24]. Therefore, the fish may spawn more than once during the spawning season. In the present study, six maturity stages of gonad development were observed in the mudskipper. This finding was in tandem with that of [38] on the same species in Imo estuary. Although, [25] reported seven stages in *P. Papilio* from mangrove swamps of Lagos Lagoon which was similar to the present result, [6] reported four stages of gonad development in the same species in New Calabar River, Nigeria; while, [29] recorded three stages in *P. Papilio* in Cross River estuary. These results were similar but less detailed than the present work. Observations of the gonad stages of maturation in the study fish though with modifications were in conformity with that of most teleosts [3, 4]. [1] recorded three stages in Sompat Grunt, *Pomadasys jubelini*; [7] in the Goby *Pseudapocryptes elongates* in the coastal mudflat area of the Mekong Delta, Vietnam, recorded six stages of gonad development.

The mean condition index of 1.06 proved that the fish fed well and in a good condition, this may be attributed to the high availability of food resources in the water body regardless of seasons so that the species may have unlimited access and consumed them according to their needs and food requirement [30 and 23]. Condition factor (K) or ponderal index is another important parameter that is obtained from the length-weight (L-W) data. It is a measure of how well the fish is doing in the environment. It also allows for the conversion of fish length to weight and vice versa [39]. As a measure of condition of fish, K values below 1 for a fish indicate poor condition, which implies a thin and long fish probably poorly fed. Fish approaching sexual maturation and having many eggs usually have high condition factor values of about 1.4 (for trout) [32]. The condition factor which is an index reflecting interaction between biotic and abiotic factors in the physiological condition of fishes shows the populations welfare during various stages of its life cycle [2]. It also takes into consideration the health and general wellbeing of a fish as related to its environment; hence it represents how fairly deep bodied or robust fishes are [34]. Several factors affect the condition factor of fishes. They range from feeding, spawning, food nutrient composition, and fat accumulation [26].

The study of condition factor is important to understand the life cycle of fish species and contributes to an adequate management of the species and to the maintenance of the ecosystem equilibrium [14]. Condition index may be used to determine the reproductive time of fish species without sacrificing the organisms, and this could be a valuable tool to develop monitory programs for the species fisheries and culture programs [39] condition factors is also a useful index for monitoring of feeding intensity, age, and growth rates in fish [21]. In fisheries science, it is used to compare the "condition" fatness or wellbeing of fishes. It is strongly influenced by both biotic and abiotic environmental conditions and can be used to assess the status of the aquatic ecosystem in which fish live [2]. It is also used as an index of growth and feeding intensity and decrease with increase in length. It influences the reproductive cycle in fish and it is an important fishery management tool in estimating the relative wellbeing of a fish population in a particular river system [40].

The pattern of length-weight relationship of *P. barbarus* revealed that the length exponent showed negative allometric ($b < 3$), Isometric ($b = 3$) and positive allometric ($b > 3$) in certain months in both the males and the females during the study. However, the combined sexes depicted isometric growth ($b = 3.008$) in June and positive allometric growth in the rest of the study months. [15 and 28] observed that the value of the regression coefficient "b" usually lies between 2.5 and 4.0 and for ideal fish to maintain it shape, $b = 3$ is required. Isometric and positive allometric b values were recorded for combined sexes in the present research, this might account for the robustness of the species. b is exponent or slope indicating isometric growth when $b = 3$ [33]. Values other than 3 indicate allometric growth. If $b > 3$, its positive allometric and the fish becomes heavier for its length as it grows larger. If $b < 3$, its negative allometric and the fish becomes lighter and thin for its length as it grows larger.

The degree of association between the length and weight was expressed by a correlation coefficient "r". The correlation coefficient could take values ranging between -1 and +1. When "r" is negative, it means that one variable tends to decrease as the other increases. There is a negative correlation which corresponds to a negative value of "b" in regression analysis. On the other hand, when "r" is positive, it means that one variable increases as the other, which corresponds to a positive value of b in regression analysis [33]. A positive correlation values obtained in this research showed there was a strong correlation between the total length and body weight of the fish, meaning the fish increase in body weight as it grows in total length. Similar trends were observed in the species by [38] in Imo River and [11] in Cross River.

5. Conclusion

The study clearly identified both sexes of *P. barbarus* as well as revealed a preponderance of the male over the female populations, although different sizes were analyzed for both sexes. The males possessed a pair of testes while the females had a pair of ovaries. Seven maturity stages were also identified alongside with mean condition index of 1.06 which proved that the fish species fed well and was in a good condition. Overall growth exponent was isometric. The study has updated in-depth information which can be useful in optimum exploitation, conservation and management of this unique aquatic biodiversity.

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