Research Article

Fecundity insights: the breeding habits of Atlantic mudskippers in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria

Abstract

Rationale: Fecundity estimation and reproductive biology of Atlantic mudskippers *(Periophthalmus barbarus)* in the Niger Delta region of Nigeria needs to be studied.

Objectives: To estimate fecundity, gonadosomatic index, and condition factor of *P. barbarus* and describe its reproductive biology.

Methods: *P. barbarus* specimens were collected from Ogbo-Okolo mangrove forest in Bayelsa State, Nigeria. Length, weight, and gonad weight measurements were taken. Fecundity was estimated by the gravimetric method. Length-weight relationship, condition factor, and gonadosomatic index were calculated. Ovarian developmental stages were identified.

Results: Highest mean fecundity of 9612.7 eggs was observed in females of 10.1-12.0 cm standard length and 20.0-27.9 g weight. Length-weight relationship showed specimens were in good condition. Gonadosomatic index was higher in smaller individuals. Four ovarian developmental stages were identified.

Conclusion: *P. barbarus* exhibits high fecundity. Reproductive potential is greater in intermediate sized individuals compared to smaller or larger fish.

Recommendations: Sustainable management practices should be implemented to conserve P. barbarus stocks in the Niger Delta region. Further research into reproductive behavior and ecology is needed.

Keywords: morphometry, length, weight, fecundity, mudskippers, fish breeding seasonality, gonadosomatic index, Ogbo-Okolo mangrove Forest, Niger Delta

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Introduction

The Atlantic mudskipper *(Periophthalmus barbarus)* is a species of mudskipper native to the tropical Atlantic coasts of Africa, the Indian Ocean, and the western Pacific Ocean. They inhabit fresh, marine, and brackish waters, including tidal flats and mangrove forests, where they readily move across mud and sand out of the water. Mudskippers are members of the genus *Periophthalmus*, which includes oxudercidae gobies characterized by dorsally positioned eyes and pectoral fins that aid in locomotion on land and in water. They skip, crawl, and climb using their pelvic and pectoral fins. As semi-aquatic animals, mudskippers transition between aquatic and terrestrial environments. They are carnivorous and utilize an ambushing strategy to capture prey using their hydrodynamic tongue to suction food into their mouths. Sexual maturity is reached at approximately 10.2 cm for females and 10.8 cm for males, and they can live for about five years. Mudskippers are used by people for food, bait, and medical purposes. They are primarily found in West African mangrove swamps and brackish water bodies along the coast.[1–9] The Atlantic mudskipper is found in several African countries including Angola, Democratic Republic of Congo, Cameroon, Nigeria and Ghana. Their distribution within these regions is influenced by the availability of food and shelter. Additionally, their hibernation capacity may impact their geographic distribution. The scientific name *Periophthalmus barbarus* originated from the Greek word's *'peri'* meaning 'around' and *'ophthalmos'* meaning 'eyes,' referencing the eyes positioned dorsally that provide a large field of vision. In Greek, *'barbarus'* means foreign, likely named for the mudskipper's unusual characteristics compared to other gobies.

The common name 'mudskipper' refers to their skipping movement across mudflats. They belong to the oxudercidae gobies, which inhabit both land and water. Mudskippers dig burrows for shelter and reproduction. Initially, oxudercidae was described as a monotypic family, with all members classified under the single species Oxuderces dentatus. Oxudercidae are small to medium in body size, with elongated bodies covered in smooth scales. They can be identified by their dorsally positioned eyes and pointed, canine-like teeth. Their dorsal, pectoral, and pelvic fins contain spines, varying in number. Within oxudercidae, the *Periophthalmus* genus comprises 12 species distinguished by having teeth in a single row on the upper jaw and a maximum of 16 spines on the pectoral fins. All *Periophthalmus* live in mangroves or mudflats. *P. barbarus* is further identified by spots or white spots on the back and over 90 scales along the sides.

P. barbarus grows up to 16 cm long. Its scale-covered body is coated in mucus to retain moisture. It has over 90 scales along the sides and stores water in its gill chambers, allowing breathing out of water. The gill chambers lack a membrane cover and can open/close through surrounding muscles or differences in partial pressure.[10] In addition to retaining moisture by storing water from the surface which

Fecundity insights: the breeding habits of Atlantic mudskippers in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria

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helps them to breathe through its skin, otherwise known as cutaneous respiration.[11] They have pair of caudal fins that aid in aquatic locomotion and pelvic fins in terrestrial locomotion.[12] Their pelvic fins are adapted to terrestrial-living by acting as a sucker to attach on land, their eyes are adapted closely together and can move independently of about 360 degrees, their eyes are also positioned further up on the head, enabling the eyes to remain above the water surface while their body is submerged underwater.[13,14] Cup-like structures that hold water are located beneath the eye which aids in lubricating the eyes when it is on land. They have chemosensory receptors that are located within the nose and on the skin surface.[15–18] While, mudskippers have a mouth that can reorient. Their short digestive system comprises an esophagus, stomach, intestine and rectum.[19] The intestinal surface is folded, increasing the surface area for enhanced nutrient absorption. They have a unique olfactory organ including a 0.3 mm diameter canal near the upper lip that expands into a chamber-like sac.

Genital papillae located on the abdomen differentiate females, which have less rounded papillae, from males.[20] As semi-aquatic animals, mudskippers inhabit slightly salty waters such as rivers, estuaries and mudflats. They spend most daylight hours on land in tidal regions, emerging at low tide to feed and hiding in burrows at high tide. These burrows can extend 1.5 meters deep providing refuge from predators.[14,17,18] The burrows may contain air pockets for breathing despite low oxygen. Mudskippers tolerate high concentrations of industrial wastes like cyanide and ammonia in their environment.[21–23] When exposed to high ammonia, they can actively secrete it through their gills even in highly acidic conditions (pH=9.0).[14] They survive varied environments including different water temperatures and salinities. Hot, humid climates optimally enhance cutaneous respiration and maintain their surface body temperature between 14-35°C. Mudskippers build mud walls around their approximately 1-meter territory to maintain resources from predators. While hunting, they submerge leaving only their eyes out to sight and locate prey. They then launch onto land using predominantly their pectoral fins and catch prey in their mouth. When land predators threaten, they exhibit flight behavior by jumping into water or skipping away on mud.[14,23] Therefore, the objectives are to assess the length-weight relationship and condition factor of *P. barbarus*, and determine its gonadosomatic index.

Materials and methods

Study area

The Ogbo-okolo mangrove Forest of Santa Barbara River is located in Nembe local government Area of Bayelsa State, Nigeria at 4.5328°N, 6.4037°E (Figure 1). The area lies entirely below sea level with a maze of meandering creeks around the mangrove forest. Ogbo-okolo mangrove Forest of Santa Barbara River is significant in the provision of suitable breeding sites for diverse aquatic organism that abound in the area, good fishing ground for artisan fishers as well as petroleum exploration and production activities by Aiteo company.

Study site

The vegetation of the Ogbo-okolo mangrove consists of the red mangrove Rhizophora racemosa and white mangrove Avicenna Africana ranging in height from 5 to 15 meters. The main sea flows into smaller tributaries during high tide when the water is salty. At low tide, the stilt-like prop roots of mangroves are visible and the intertidal mudflat is exposed, serving as a feeding ground for mudskippers. The mudskippers dig small burrows between 3.5-6 cm in diameter around the prop-roots of Rhizophora trees. These areas serve as hideouts for *Periophthalmus* species. Traps will be set around these burrows

to catch *Periophthalmus* specimens. Bacteria and microorganisms thriving in the mud produce sulfur gases, giving the mudflat a rotten egg odor. The study area has a tropical climate with average temperatures around 25°C and high humidity. Rainfall is heavy year-round, with peak precipitation from May to July averaging over 300 mm monthly as describe by studies from the Niger Delta region of Nigeria.[24–31] The abundant rainfall contributes to the mangrove swamps and muddy conditions ideal for mudskippers.
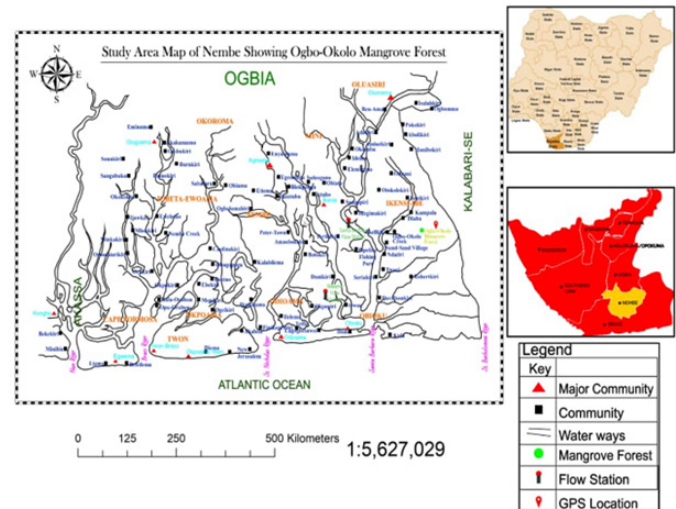

Figure 1 Map of Nembe showing Santa Barbara River and the Study Area Ogbo-okolo mangrove Forest.

Sample collection

Fish trapping method were used to collect 350 Specimen of Mudskippers *Periophthalmus barbarus* with standard length ranging from 5.5-11.9cm and total length ranging from 7.0-14.7cm respectively. The specimen was obtained in May 2021. The fishing gears used is hands made rubber container and basket traps woven with cane materials with a single conical in curved opened. Each basket trap was 40cm long and 30cm wide. These traps are nonselective and can catch both adults and Juveniles. The traps were set during the low tide using scattered and broken crabs like *Callinetes sapidu* (marine swimming crab), *Cardiosoma armatum* (terrestrial crab), and *Sesarma huzardi* (hairy mangrove crab) was used as bait for the traps. As soon as catches were made, the specimens were removed and put in a bucket containing 5% formalin and a little water. These were later taken to the laboratory. Standard length and total length of each sample was measured to the nearest 0.1 cm using a measuring board and the gutted weight of corresponding sample were measured to the nearest 0.1g. Specimens were dissected and the guts were carefully removed with the aid of a forceps after dissection. The gut and the liver were weighed together to the nearest 0.1g. The standard length, gutted weight and body weight of fishes were recorded into a data sheet for data analysis. In the analysis, the Total Length (TL) of the fish was measured from the tip of the anterior the (mouth part) to the caudal fin using an improvised measuring board made from wood. Fish weight was measured with an electronic scale, to the nearest 0.1g. The mean lengths and weights of the classes were used for data analysis. The relationship between the Standard Length (SL), TL, and total body weight (W)g of the fish is expressed by the equation below:

$$K = \frac{W \, x100}{L^3}$$

Where K = condition factor

Fecundity insights: the breeding habits of Atlantic mudskippers in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria

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W= weight of fish (g)

L = Total length (TL) of fish in (cm)

While, determining the Gonado somatic index of *Periophthalmus barbarus*. Biometric data of SL, TL to the nearest 0.01cm and body weight measurement (TW) and Gutted Weight (GW) to the nearest 0.01g were recorded. Further laboratory analysis was carried out by opening the stomach of the specimens to determine the opvaris of *Periophthalmus barbarus* to ascertain the gonad stages by use of naked eye examination of gonad development stage. Six biological stages of gonad development were identified as cited by Bagenal[32] Moreover, four stages of gonad development were identified in this study and the classification of gonadal stages using Udo[33] methods. Each specimen ovaries and specimen gut were measured to the nearest 0.1g. Gonado somatic index (GSI) of the specimen was calculated according to El-Sayed et al.,[41] method:

$$GSI = \frac{Weight\ of\ the\ Overies}{Gutted\ weight\ of\ the\ body} \times \frac{100}{1}$$

To determine the fecundity of Atlantic mudskipper *Periophthalmus barbarus* an unbiased sample of the specimen were obtained. Gonad stage IV and V were used in the fecundity estimation. The specimen with gonad stage IV and V were sorted out and the standard length measured to the nearest 0.01cm and gonad weight to the nearest 0.01g, the ovaries of each is removed and stored in specimen bottle containing 3% formalin and later place in plastic petri-dishes which were agitated at interval to ensure the eggs were separated from their connective tissue and spread after adding little water in the petri-dishes. Fecundity was estimated by taking the weight of the egg follow by the weight of subsample by Bagenal[32] to the nearest 0.01g.

Sum of eggs in subsamples x Total weight of egg

Total weight of subsample

Results

The assessment of the length-weight relationship of Atlantic Mudskipper *P. barbarus* is shown below

Table 1 and Figure 2 shows the observed data on fish measurements revealed that the Standard Length ranged from 5.0 to 12.0 cm, with mean values increasing progressively across size groups: 6.3, 7.7, 8.5, 9.5, and 11.8 cm. Correspondingly, the Total Length ranged from 7.0 to 14.9 cm, with mean values of 8.7, 9.5, 10.8, 11.3, and 13.6 cm. The Total Weight spanned from 3.4 to 30.9 g, with mean values of 7.5, 11.6, 17.5, 22.3, and 27.1 g. This data indicates a consistent positive correlation between the standard length, total length, and total weight across the size classes.

Table 1 Shows the length – weight relationship in *P. barbarous*

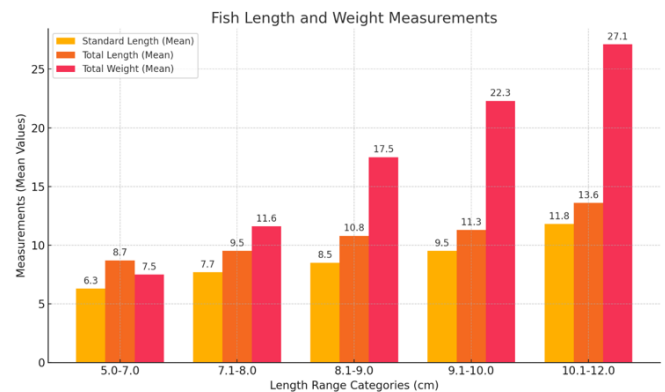| Standard length (cm)		Total length(cm)		Total weight (G)	
Range	Mean	Range	Mean	Range	Mean
5.0-7.0	6.3	7.0-9.0	8.7	3.4-10.0	7.5
7.1-8.0	7.7	9.1-10	9.5	10.1-15.0	11.6
8.1-9.0	8.5	10.1-11.0	10.8	15.1-20.0	17.5
9.1-10.0	9.5	11.1-12.5	11.3	20.1-25.0	22.3
10.1-12.0	11.8	12.6-14.9	13.6	25.1.30.9	27.1

Figure 2 Illustrating the mean values of Standard Length, Total Length, and Total Weight for each length range category. The bars represent the respective means for each measurement, with the categories labeled clearly on the x-axis.

Table 2 and Figure 3 shows the data on fish measurements and condition factors that shows the Standard Length ranged from 5.0 to 12.0 cm, with mean values of 6.3, 7.7, 8.5, 9.5, and 11.8 cm. Corresponding Total Length values ranged from 7.0 to 14.9 cm, with mean values of 8.7, 9.5, 10.8, 11.3, and 13.6 cm. Total Weight ranged from 3.4 to 30.9 g, with mean values of 7.5, 11.6, 17.5, 22.3, and 27.1 g. The Condition Factor showed a decreasing trend across size groups, with mean values of 3.0, 2.9, 2.8, 2.6, and 1.6. This suggests that as the fish grew larger, their relative weight in relation to their length declined.

Table 2 Relationship of length and weight to condition factor in *P. barbarous*

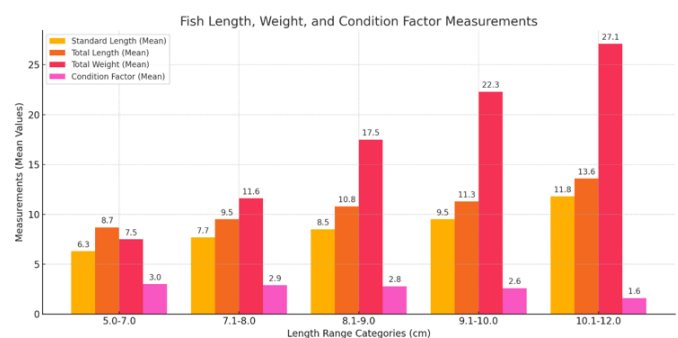| Standard Length (cm)		Total Length (cm)		Total Weight (G)		Condition Factor
Range	Mean	Range	Mean	Range	Mean	
5.0-7.0	6.3	7.0 - 9.0	8.7	3.4-10.0	7.5	3
7.1-8.0	7.7	9.1 – 10	9.5	10.1-15.0	11.6	2.9
8.1-9.0	8.5	10.1- 11.0	10.8	15.1-20.0	17.5	2.8
9.1-10.0	9.5	11.1- 12.5	11.3	20.1-25.0	22.3	2.6
10.1-12.0	11.8	12.6- 14.9	13.6	25.1.30.9	27.1	1.6

Figure 3 Shows the mean values of Standard Length, Total Length, Total Weight, and Condition Factor across the length range categories.

Table 3 and Figure 4 specimens revealed specimens' variations in length, weight, and maturation stages. A total of 4 specimens with a Standard-Length range of 7.0–8.0 cm and a Total Length range of 8.0–10.0 cm weighed between 4.0 and 10.0 g, corresponding to maturation stage II. Nineteen specimens with Standard Lengths of 8.1–9.0 cm and Total Lengths of 10.1–11.0 cm weighed 10.1–15.0 g and were at stage III. Eighteen specimens with Standard Lengths of 9.1–10.0 cm and Total Lengths of 11.1–12.0 cm weighed 15.1–20.0

Fecundity insights: the breeding habits of Atlantic mudskippers in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria

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g, reaching stage IV. Finally, 5 specimens with Standard Lengths of 10.0–12.0 cm and Total Lengths of 12.1–14.0 cm weighed 20.1–27.5 g, corresponding to maturation stage V.

Table 3 Relationship of length and body weight to stages of Gonad Maturation in *P. barbarus*

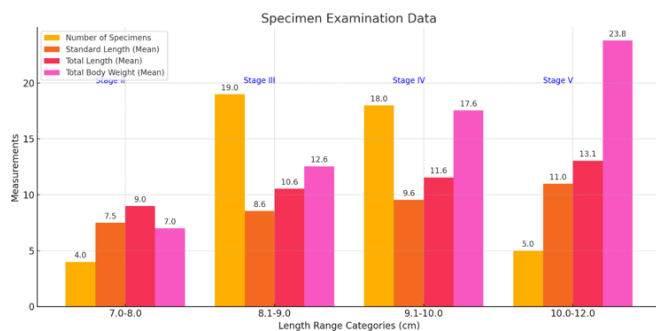| Number of specimen examined | Length (cm) | | Total body weight (G) | Stages of maturation |
	Standard Length Range	Total Length Range		
4	7.0 - 8.0	8.0 -10.0	4.0 - 10.0	II
19	8.1 - 9.0	10.1 - 11.0	10.1 - 15.0	III
18	9.1 - 10.0	11.1 - 12.0	15.1 - 20.0	IV
5	10.0 – 12.0	12.1 – 14.0	20.1 - 27.5	V

Figure 4 Display the number of specimens, mean values of Standard Length, Total Length, Total Body Weight, and their corresponding stages of maturation.

Table 4 and Figure 5 revealed body weight, ovary weight, and gonadosomatic index (GSI) shows that specimens with a Body Weight Range of 1.0–10.0 g had a mean ovary weight of 0.28 g and a GSI of 22.06. For those weighing 10.0–15.0 g, the mean ovary weight increased slightly to 0.29 g, with a GSI of 21.80. Specimens in the 15.1–20.9 g range had a mean ovary weight of 0.37 g and a GSI of 18.32. Lastly, specimens weighing 21.0–27.9 g had the highest mean ovary weight at 0.45 g, but the GSI further declined to 17.72. This trend suggests that while ovary weight increases with body weight, the relative reproductive investment (GSI) decreases.
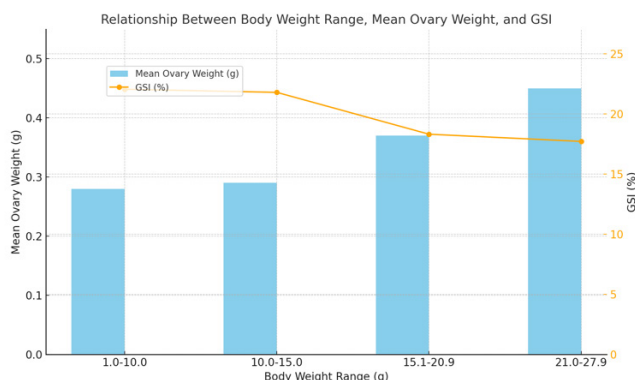

Figure 5 Shows illustrate the relationship between body weight ranges, mean ovary weight, and the Gonadosomatic Index (GSI). The blue bars represent the mean ovary weight (g) for each body weight range, while the orange line plot highlights the GSI values corresponding to these ranges. This figure 5 effectively demonstrates the trends and interplay between body weight, ovary weight, and reproductive health indicators.

Table 4 Gonadosomatic Index (GSI)

Body weight range (g)	Mean of ovary weight(g)	GSI
1.0 - 10.0	0.28	22.06
10.0 - 15.0	0.29	21.8
15.1 - 20.9	0.37	18.32
21.0 – 27.9	0.45	17.72

Table 5 and Figure 6 shows the fecundity data for examined specimens showing a relationship between size, weight, and reproductive potential. For 3 specimens with Standard Lengths of 7.0–9.0 cm, Total Lengths of 8.0–10.0 cm, and weights of 4.0–15.0 g, the mean fecundity was 7428.8, with a range of 5741.2–9766.3. Four specimens with Standard Lengths of 9.1–10.0 cm, Total Lengths of 11.1–12.0 cm, and weights of 15.1–20.0 g had a higher mean fecundity of 9612.7, ranging from 5484 to 14570.5. Finally, 3 specimens with Standard Lengths of 10.0–12.0 cm, Total Lengths of 12.1–14.0 cm, and weights of 20.1–27.5 g showed a mean fecundity of 8070.6, with a range of 5048–12818. This indicates a general increase in fecundity with size and weight, although variations exist within the ranges.

Table 5 Relationship of Fecundity in *P. barbarus* to length and body weight

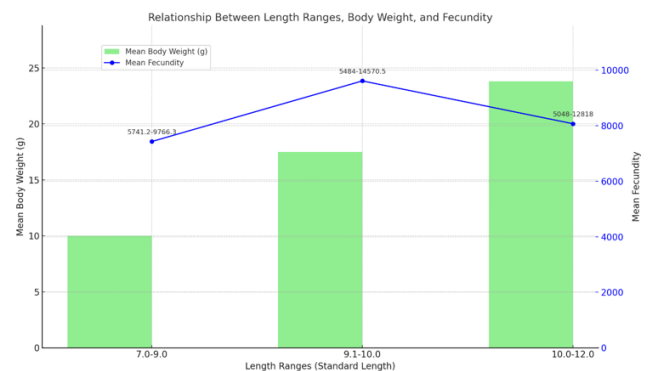| Number of specimen examined | Length in (cm) | | Total body weight (G) | Fecundity | |
	Standard Length Range	Total Length Range		Mean	Range
3	7.0 - 9.0	8.0 -10	4.0 - 15.0	7428.8	5741.2-9766.3
4	9.1 - 10.0	11.1 - 12.0	15.1 - 20.0	9612.7	5484-14570.5
3	10.0 – 12.0	12.1 – 14.0	20.1 - 27.5	8070.6	5048-12818

Figure 6 Illustrates the relationship between standard length ranges, mean body weight, and fecundity. The green bars represent the mean body weight (g) for each standard-length range, while the blue line plot depicts the corresponding mean fecundity values.

Discussion

Length-weight relationship of Atlantic mudskipper, *Periophthalmus barbarus* were standard length ranging from 5.0-11.9cm SL, total length ranging 7.0-14.9g and the body weight between 3.4 - 30.6g body weight (BW). The condition factor values greater than one indicates the *Periophthalmus barbarus* specimens were in good physical condition. Condition factor decreased as fish size increased (Table 1 and 2), aligning with the finding that condition

Fecundity insights: the breeding habits of Atlantic mudskippers in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria

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factor is inversely related to length. The estimated allometric coefficient (b) from the length-weight relationships fell within the expected range of 2.0 to 4.0 reported for most fish.[34] The b value reflects that weight increases curvilinearly relative to length. Overall, the length-weight relationship parameters estimated in this study for *P. barbarus* were consistent with typical ranges reported for other fish species. This provides evidence that the sampled population had normal growth patterns and physiological condition. However, Siddik et al.,[35] reported isometric growth of *A. bato* from a southern coastal river of Bangladesh. But varies with the findings in Lagos lagoon, mudskipper, *Periophthalmus papilio* which was grouped into unsex, males and females with size ranging from 30.0-190 mm TL and weighing between 0.5 and 65.3g BW. There was size variation across the three groups through unsex, 32-158mm; males, 69-180mm and females, 60-190mm total length.

Females attained higher growth and maturity at 69mm TL and males at 60mm TL in the study, males were significantly heavier in weight but shorter in body length than the females. Lawson[36] also contradicted with 102mm and 105mm total length at maturity which he reported for females and males respectively. Udo[33] also reported isometric (b is equal to 3) length weight relationship for both sexes of this species. However Abdoli et al.,[37] estimated values is between 2.10 and 2.86 for both sexes for three species of mudskipper in their study in the coastal areas of the Persia Gulf in Iran. Similar trends were observed in the specie by Lawson[36] who reported values between 2.56 and 3.50 in the coastal areas of Selangor, Malaysia. A positive correlation values of r = 0.9385 (unsex), 0.9684 (males) and 0.9784 (females) showed there was a strong correlation between the total length and body weight measurements of the fish, meaning the fish increase with body weight as it grows in total length. This may be more genetical than being ecological. Strong correlation between fish body size and otolith weight of a related species *Periophthalmodon schlosseri* was also reported by Sarimin et al.,[38] The parameters of length-weight relationship are influenced by a series of factor including season, habitat, gonad maturity, sex, diet, stomach fullness, health of the individuals in their natural habitats as well as the treatment of specimens and preservation techniques the condition factor of *P. barbarous* were found to be greater than one (1) which indicates that the specimen were relatively healthy.

However, this study showed that condition factor decreases with increase in size of the fish. The naked eye examinations of the gonads of *P. barbarous,* forty-seven (47) specimen that have eggs, four stages of gonad development were identified in this study. These includes Stage II Early developing or virgin stage ll which ovary is very small firm and pale-white, stage III Late developing or maturing stage - ovary is small graining orange-yellow heavy network of vessel appear laterally on the surface of ovary wall, stage IV matured stage - ovary is yellow, large and selling the body cavity, ripe or gravid stage – ovary is yellow, large with contour walls turgid, distend body cavity, eggs are clearly distinct. Gonadosomatic index (GSI) is higher in body weight ranging 1.0 to 10.0g with 22.06 (GSI) and lower in body weight ranging from 21.0 to 27.9g with 17.78 (GSI) increase with increase in body weight but decrease in mean of ovary weight (Table 4). This showed that Atlantic mudskipper *Periophthamus barbarus* is highly productive between May and June in the study area this is contradicted with observation made by Atiqullah et al.,[39] on *Pomadasys stridens* which range from 0.801 to 9.124. Lawson, (2011) who reported that (GSI) values of the fish varied between 0.01 and 0.48% in males and 0.11-8.40% in females. Higher GSI values indicate a better wellbeing for the fish, this difference in values can be attributed to the combination of one or more factors including habitat,

area, season, gonadal condition, sex, health, preservation methods and differences in the size and type of the specimens caught. fecundity in *P. barbarus* (Table 5) showed that fish with standard length range from 9.1 - 10.0cm and weight ranging from 15.1 - 20.0g have the highest mean fecundity of 9612.7eggs, but specimens range from 10.1-12.0 standard length and weight ranging from 20.0-27.9g are more fecund than those smaller or bigger than the bracket which have fewer eggs. This means fecundity estimated for the fish with this size range 9.1 to 10.0cm TL and 15.1 to 20.8 g W, are more fecund. This showed higher fecundity contributed to body weight. The fecundity of the species increased with fish length and body weights. This is in line with an observation made by Mfon and King[40] who suggest the egg production capacity of the gobiid mudskipper.[41–43]

Conclusion

The study on Atlantic mudskippers, *P. barbarus,* in the Ogbo-okolo mangrove forest demonstrated that reproductive output is associated with body size. Specimens with a standard length range of 9.1-10.0 cm and weight 15.1-20.0 g exhibited the highest mean fecundity at 9,612.7 eggs. Fish within the size range of 10.1-12.0 cm standard length and 20.0-27.9 g weight showed greater fecundity compared to smaller individuals, indicating that higher fecundity accompanies larger body weight. Overall, the fecundity of *P. barbarus* increased with fish length and body weight, which aligns with trends observed for many fish species. Larger females tend to produce more eggs due to having greater energy reserves for gamete production. The higher fecundity of intermediate sized *P. barbarus* may reflect an optimal balance of energy allocation for growth versus reproduction. Smaller individuals may invest more in somatic growth, while larger fish experience diminished returns on egg production. This study provides baseline data on the reproductive biology of *P. barbarus*, an important component of mangrove ecosystems in the Niger Delta region. The findings can inform sustainable management efforts for this species. Further research over broader geographic and temporal scales would clarify drivers of variability in fecundity and other reproductive parameters. Investigating the relationship between female body condition, environmental factors, and reproductive output could provide additional insights into the ecology of *P. barbarus.*

Policy implication

Atlantic mudskippers (*P. barbarus*) are economically and ecologically important components of Niger Delta mangrove ecosystems. This study found the fecundity and reproductive potential of *P. barbarus* populations in Bayelsa state is connected to adult body size, with implications for sustainable management. Overfishing and habitat loss threaten the sustainability of this fishery. To prevent declines in fish stocks, reproductive output, and future harvests, policy makers should implement science-based regulations on P. barbarus fishing. Required actions include:

I. Set minimum size limits to allow females to attain optimal size for reproduction before capture

II. Restrict harmful gears like dynamite fishing which indiscriminately kill juveniles and breeding adults

III. Designate protected mangrove areas as essential fish breeding habitat

IV. Support mangrove restoration to mitigate habitat losses

V. Provide education programs and incentives for sustainable fishing practices

Fecundity insights: the breeding habits of Atlantic mudskippers in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria

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VI. Improve monitoring and enforcement to ensure compliance

Urgent efforts are needed to balance economic demands for *P. barbarus* with maintenance of its ecological role. Sustainable management informed by research will provide long-term social, economic, and environmental benefits.

Recommendations

Based on the findings from this research work, the following recommendations were made:

I. Additional research on *P. barbarus* should be conducted across its full geographic range in Bayelsa state using standardized methods to allow for broader comparisons of reproductive parameters and population dynamics. Studies across multiple seasons would provide greater insight into temporal variability.

II. Sustainable management plans for *P. barbarus* should be developed and implemented by fisheries regulators in collaboration with local communities. These may include size limits, gear restrictions, spatial protections, and harvest quotas to prevent overexploitation.

III. Educational programs should be created to inform fishermen about sustainable fishing practices for *P. barbarus* and the importance of this species to the mangrove ecosystem. This knowledge can encourage voluntary adoption of responsible harvesting techniques.

IV. Mangrove habitat restoration efforts in areas degraded by pollution or development pressures are recommended to preserve critical nursery and breeding grounds for *P. barbarus*.

Significance statement

The findings highlight the significant fecundity of *P. barbarus*, with a peak observed in females of intermediate size. Additionally, the study identifies variations in gonadosomatic index among different size categories, shedding light on the reproductive potential of the species. These insights underscore the importance of sustainable management practices to conserve *P. barbarus* stocks in the Niger Delta region, emphasizing the need for further research into its reproductive behavior and ecological requirements to inform effective conservation strategies and ecosystem management. Thus, graphically it is represented (Figure 7).
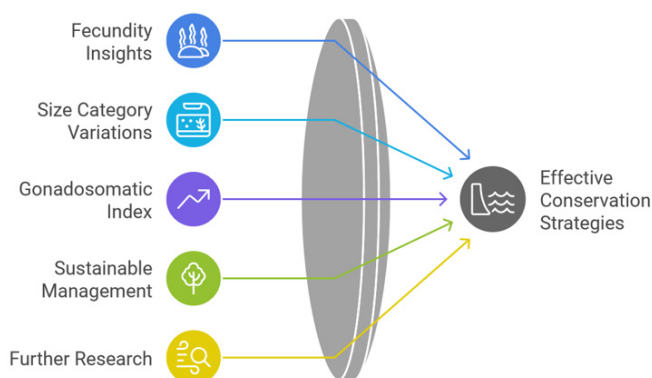

Figure 7 Path to Sustainable Ecosytem Management.

Statements and declarations

Competing interests

The authors have no relevant competing interests to disclose.

Life Science Reporting

No life science threat was practiced in this research.

Author contributions

All authors contributed equally to the development of the manuscripts including study conception and design, material preparation and data collection and analysis, and the first draft writing. All authors read and commented on previous versions of the manuscript and they approved the final manuscript.

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Conflicts of interest

The authors declare no competing interest.

References

1. Ezenwaji HMG, Offiah FN. Reproductive biology of *Periophthalmus barbarus* in Calabar River, Nigeria. 2003;1158–1161.

2. Hossain MY, Rahman MM, Fulanda B, et al. Length-weight and length-length relationships of five threatened fish species from the Jamuna Brahmaputra River Tributary River, northern Bangladesh. *Journal of Applied Ichthyology*. 2011;28:275–277.

3. Olalekan RM, Omidiji AO, Williams EA, et al. The roles of all tiers of government and development partners in environmental conservation of natural resource: a case study in Nigeria. *MOJ Ecology & Environ Sci*. 2019;4(3):114–121.

4. Raimi MO, Suleiman RM, Odipe OE, et al. Women Role in Environmental Conservation and Development in Nigeria. *Ecology & Conservation Science*. 2019;1(2):16.

5. Raimi MO, Abiola OS, Atoyebi B, et al. *The Challenges and Conservation Strategies of Biodiversity: The Role of Government and Non-Governmental Organization for Action and Results on the Ground*. In: Chibueze Izah S. editors. Biodiversity in Africa: Potentials, Threats, and Conservation. Sustainable Development and Biodiversity, vol 29. Springer, Singapore. 2022a.

6. Saliu AO, Komolafe OO, Bamidele CO, et al. The Value of Biodiversity to Sustainable Development in Africa. In: Izah SC et al., editors. Sustainable Utilization and Conservation of Africa's Biological Resources and Environment. Sustainable Development and Biodiversity, vol 888. Springer, Singapore. 2023.

7. Sylvester CI, Odangowei IO, Matthew CO, et al. *Historical Perspectives and Overview of the Value of Herbal Medicine*. In: Izah SC et al., editors. Herbal Medicine Phytochemistry, Reference Series in Phytochemistry. 2023.

8. Fubara GE, Dokuboba A, Ilemi JS, et al. The Niger Delta is Under a Pollution Warning: Hydrocarbon profiles in crude oil polluted soil remediated with Pleurotus ostreatus and Eisenia fitida. bioRxiv 2024.06.04.597352. 2024a.

Fecundity insights: the breeding habits of Atlantic mudskippers in Ogbo-Okolo mangrove forest of Santa Barbara River, Bayelsa State Niger Delta, Nigeria

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9. Fubara GE, Ukoima HN, Dokuboba A, et al. Evaluating Bioremediation Strategies on Microbial Diversity in Crude Oil-Contaminated Soil Over Three to Six Months in Port Harcourt, Nigeria., 14 May 2024, PREPRINT (Version 1) available at *Research Square*. 2024b.

10. Michel KB, Aerts P, Van Wassenbergh S. Environment-dependent Prey Capture in the Atlantic Mudskipper (*Periophthalmus barbarus*). *Biol Open*. 2016;5:1735–1742.

11. Kutschera U, Elliot M. Do mudskippers and lungfishes elucideta the early evoluto of four-limbed vertebrates? *Evolution and outreach*. 2013;6(1):8.

12. Pace CM, Gibb AC. Mudskipper pectoral fin Kinematics in aquatic and terrestrial environments. *J Exp Biol.* 2009;212(14):2279–2286.

13. El-Sayed AFM. *Tilapia culture*. CABI Publishing, Wallingford OX 108 DE. UK. 2006. p. 273.

14. Ansari A, Trivedi S, Saggu S, et al. Mudskipper: A biological indicator for environmental monitoring and assessment of coastal water. *Journal of Entomology and zoology studies.* 2014;5481–6035.

15. Etim, Lawrence. Breeding, Growth, Mortality and Yield of the Mudskippers *Periophthalmus barbarus* (Teleostei: Gobiidae) in Imo River estuary, Nigeria. *Fisheries Research*. 2002;56(3):227–238.

16. Chukwu K, Deekae S. *Length*-weight relationship, condition factor and size composition of Periophthalmus barbarus (Linneaus 1766) in New Calabar River, Nigeria. *Agriculture and Biology Journal of North America*. 2011;2(7):1069–1071.

17. Awogbami SO, Ogunyemi O, Adebayo PA, et al. Protecting the Health of Black Communities: Assessing the Impact of Environmental Hazards from Gold Mining Activities on Health Outcomes among Residents of Osun State, Nigeria. *JMIR Preprints*. 2024.

18. Clinton-Ezekwe I, Raimi MO, Ezekwe IC, et al. Ensuring Safety: Groundwater Quality and Its Potential Health Effects in the Mgbede Oil Fields Environment of South-South Nigeria. JMIR Preprints. 2024.

19. Wolczuk Katarzyna, Ostrowski Maciel, Ostrowska Angnieszka, et al. Structure of the alimentary tract in the Atlantic Mudskipper Periophthalmus barbarous (Gobiidae: Oxudercinae): anatomical, historical and ultrastructural studies". *Zoology*. 2018;128:38–45.

20. Kuciel M. The mechanism of olfactory organ ventilation in *Periophthalmus barbarus* (Go biidaeoxudercnae. *Zoomorphology.* 2013;132(1):81–85.

21. Emuebie Okonj Raphael. Physio Chemical Properties of Mudskipper (*Periophthalmus barbarus* (pallas) liver Rhodanese. *Australian Journal of Basic and Applied Sciences*. 2011;5(8):507–514.

22. Siddik MAB, Chaklader MR, Hanif MA, et al. Length-weight relationships of four fish species from a coastal artisanal fishery, southern Bangladesh. *Journal of Applied Ichthyology*. 2016;1–3.

23. Evans FG, Nkalo UH, Amachree D, et al. From Killer to Solution: Evaluating Bioremediation Strategies on Microbial Diversity in Crude Oil-Contaminated Soil over Three to Six Months in Port Harcourt, Nigeria. *Adv Environ Eng Res*. 2024;5(4):023.

24. Olalekan MR, Albert O, Iyingiala AA, et al. An environmental/scientific report into the crude oil spillage incidence in Tein community, Biseni, Bayelsa state Nigeria. *J Environ Chem Toxicol.* 2022a;6(4):01–06.

25. Olalekan MR, Olawale HS, Clinton IE, et al. Quality Water, Not Everywhere: Assessing the Hydrogeochemistry of Water Quality across Ebocha-Obrikom Oil and Gas Flaring Area in the Core Niger Delta Region of Nigeria. *Pollution*. 2022b;8(3):751–778.

26. Raimi M, Sawyerr H. Preliminary Study of Groundwater Quality Using Hierarchical Classification Approaches for Contaminated Sites in Indigenous Communities Associated with Crude Oil Exploration Facilities in Rivers State, Nigeria. *Open Journal of Yangtze Oil and Gas*. 2022;7:124–148.

27. Raimi MO, Sawyerr HO, Ezekwe IC, et al. *Toxicants in Water: Hydrochemical Appraisal of Toxic Metals Concentration and Seasonal Variation in Drinking Water Quality in Oil and Gas Field Area of Rivers State, Nigeria*. In: PH Saleh et al., editors. Heavy Metals - New Insights [Working Title]. IntechOpen. 2022b.

28. Raimi O, Ezekwe C, Bowale A, et al. Hydrogeochemical and Multivariate Statistical Techniques to Trace the Sources of Ground Water Contaminants and Affecting Factors of Groundwater Pollution in an Oil and Gas Producing Wetland in Rivers State, Nigeria. *Open Journal of Yangtze Oil and Gas*. 2022c;7:166–202.

29. Raimi OM, Sawyerr OH, Ezekwe CI, et al. Many oil wells, one evil: comprehensive assessment of toxic metals concentration, seasonal variation and human health risk in drinking water quality in areas surrounding crude oil exploration facilities in rivers state, Nigeria. *International Journal of Hydrology.* 2022d;6(1):23–42.

30. Glory R, Sylvester CI, Morufu OR, et al. Public and environmental health implications of artisanal petroleum refining and risk reduction strategies in the Niger Delta region of Nigeria. *Journal of Biological Research & Biotechnology*. 2023;21(1):1836–1851.

31. Raimi MO, Oyeyemi AS, Mcfubara KG, et al. Geochemical Background and Correlation Study of Ground Water Quality in Ebocha-Obrikom of Rivers State, Nigeria. *Trends Appl Sci Res*, 2023;18(1):149–168.

32. Bagenal TB. Fish fecundity and its relations with stock and recruitment. Rep. P.V. Renn. Cons Int. *Explore Mer*. 1973;164:186–198.

33. Udo MT. Tropic attributes of the mudskipper, *Periophthalmus barbarous* (Gobiidae: Oxudercinae) in the mangrove swamps of Imo Riverestuary, Nigeria. *J Environ Sci (China)*. 2022;14(4):508–517.

34. Froese R, Pauly D. Fish Base. World Wide Web electronic publication. 2006.

35. Siddik M, Hanif M, Chaklader M, et al. Fishery biology of gangetic whiting Sillaginopsis panijus (Hamilton, 1822) endemic to Ganges delta, Bangladesh. *Egyptian Journal of Aquatic Research*. 2016;41(4):307–313.

36. Lawson EO. Testicular maturation and reproductive cycle in mudskipper, *Periophthalmus papilio* from Lagos lagoon, Nigeria. *Journal of American Science*. 2011;7(1):48–59.

37. Abdohi LE, Kamrani A, Abdoli A, et al. Length weight relationships for three species of mudskippers (Gobndae: Oxudercinane) in the coastal areas of the Persian Gulf, Iran. *J Applied Ichthyol*. 2009;52:236–237.

38. Sarimin AS, Ghaffar MA, Mohammed CA. Variation of Ca, Sr, Ba and Mg in the Otolith of Mudskipper in West Coast of Peninuslar Malaysia. *Pak J Biol Sci*. 2009;12(3):231–238.

39. Atiqullah M, Hossain MM, Kamal MS, et al. Crystallization kinetics of PE-b-isotactic PMMA diblock copolymer synthesized using SiMe 2 (Ind) 2 ZrMe 2 and MAO cocatalyst. *AIChE Journal*. 2013;59(1):200–214.

40. Mfon Timothy Udo, King RP. Fecundity of the mudskipper Periophthalmus barbarus (Gobiidae) in Imo River, Nigeria. *Archive of Fishery and Marine Research.* 2001;49(2):117–124.

41. El-Sayed KH, Moharrams G. Reproductive biology of Tilapia zilli (Gerv, 1848) from Abu Qir Bay, Egypt. *Egyptian Journal of Aquatic Research*. 2007;33(1):379–394.

42. Khaironizam MZ, Norma Rashid Y. Length-weight relationship of mudskippers (Gobiidae: Oxudercinae) in the coastal areas of Selangor, Malaysia. *Global Ecol Biogeo Lett*. 2002;25(3–4):20–22.

43. Lawson EO. Length-weight Relationships and Fecundity Estimates in Mudskipper, *Periophthalmus papilio* (Bloch and Schneider 1801) Caught from the Mangrove Swamps of Lagos Lagoon, Nigeria. *Journal of Fisheries and Aquatic Science*. 2011;6:264–271.