Reproductive Assessment of *Clarias gariepinus* from Polluted River Oluwa, Ondo State, Nigeria

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Abstract
Fecundity, sex ratio and gonado-somatic index of fish have been proven to be vital indicators of fish reproduction potential, survival, and species continuation. This study was carried out to investigate the combine effect of bitumen seepage and other pollutants on some reproductive parameters of the commercially important catfish *Clarias gariepinus*, inhabiting Oluwa River located in the Nigerian bituminous sand field, Agbabu, Ondo State, Nigeria. The mean fecundity recorded for the fish species range between 1932.00-22420 eggs with a mean value of 11822 eggs. The gonado-somatic index and mean value recorded in this study for male and female specimens ranged from 0.10±0.01-0.45±0.21% (mean of 0.18±0.22%) and 0.53±0.21- 7.81±0.19% (mean of 5.49±0.64%) respectively. Both sexes of the specimen exhibited a range of 0.24±0.88-5.21±0.95% with a mean value of 2.99±0.42%. The fecundity recorded in the study was comparatively lower to that reported for other Clariid fishes and this could be as a result of the polluted nature of the river.

Keywords: *Clarias gariepinus*, Environment, Fecundity, Pollution, Season, Sex ratio

INTRODUCTION

Environmental pollution threatens the habitat of African catfish, raising health and consumer risks, affecting their vital food source for millions in Africa and beyond (Arojojoye et al., 2020S). River Oluwa in Nigeria presents a stark example, harbouring diverse pollutants like polycyclic aromatic hydrocarbons (PAHs) and bitumen (Ayandiran, Fawole and Ogundiran, 2022). Assessing the reproductive health of C. gariepinus in this polluted environment is crucial for both ecological and public health perspectives. Reproductive impairment is a significant consequence of exposure to environmental contaminants in fish (Kavanagh *et al.*, 2013). Pollutants can disrupt hormone production, alter gonadal development, and ultimately lead to reduced fecundity, egg quality, and hatching success (Pitman, Haddy and Kloser, 2014). In C. gariepinus specifically, studies have documented negative impacts of pollutants like chromium and PCBs on reproduction, highlighting the vulnerability of this species (Ezenwaji, 2002); (Afolabi, Oladele and Olususi, 2020).

Reproduction is one of the basic biological features in fishes which is a veritable means of ensuring maximum survival and species continuation. Determination of the sex ratio and of the sequence of changes in maturity stage during the year is also of considerable importance in building a thorough knowledge of the general biology of fishes (El-Kasheif, Shalloof and Authman, 2013). Detail description of reproduction procedures and the evaluation of fecundity are some of the most important aspects in the biology and population studies of fish which also deals with the reproductive capacity of individual fish species (Costache *et al.*, 2011). Changes in reproductive indicators like maturity and fecundity can directly influence overall egg production, which can cause potential false perceptions about reproductive potential and stock abundance (Pitman, Haddy and Kloser, 2014). Numerous studies have shown the relationships existing between potential fecundity and environmental factors such as food availability, temperature and humidity, fish density, salinity, presence of pollutants and biomass index (Kamler, 2005).

Previous studies on the reproductive activity and maturity patterns of fish species around the world have been carried out by various researchers (Olyott et al., 2006; (Rodrigues and Gasalla, 2008); (Pham *et al.*, 2009) most of which are based on the gonadosomatic index. However, more recently, some generalized additive models (GAMs), based on the gonad weight, have been proposed to better understand the reproductive activity of certain fish species (Sánchez & Demestre, 2010; Postuma & Gasalla, 2014), which is an indication that more robust fits to data can be obtained to explain the main factors affecting reproduction, while using the method. Several studies have also explored the seasonal distribution and condition factor of Clarias gariepinus in polluted river systems, emphasizing the need to understand the influence of environmental factors on the reproductive health of this species (Ayandiran and Fawole, 2014). Previous research has provided valuable insights into the reproductive parameters of Clarias gariepinus, including sex ratio,

fecundity, and aspects of reproduction (Ikpi *et al.*, 2012).
The reproductive assessment of Clarias gariepinus in the polluted River Oluwa, Nigeria, is a critical area of study due to the potential impact of pollution on the reproductive biology of this species. Given the potential implications for the conservation and management of Clarias gariepinus populations in polluted environments, further investigation into its reproductive biology in the context of pollution is warranted. This research will contribute to the understanding of how pollution may affect the reproductive parameters of Clarias gariepinus in the river providing valuable information for the development of effective conservation and management strategies. Therefore, understanding the reproductive status of C. gariepinus in River Oluwa is critical for several reasons as impaired reproduction in fish can lead to population decline (Alavi *et al.*, 2021), disrupt ecosystem stability (Mitra *et al.*, 2023), and pose health risks due to toxins bioaccumulation (Jamil Emon *et al.*, 2023). The study assesses the reproductive health of C. gariepinus in River Oluwa to identify potential pollution effects and severity, offering insights for pollution mitigation as a bioindicator species. The objective of this study is therefore to provide the preliminary data on the reproductive parameters and evaluate the possible relationship between the contamination of the river with bitumen and other pollutants and the reproductive ability of the indigenous *Clarias gariepinus*.

MATERIALS AND METHODS

Study Area

River Oluwa in Agbabu is located on the Okitipupa South-East belt of the bituminous sands field at latitude 060 29" to 060 45" North and 040 44" to 050 00" East of the Greenwich Meridian. Agbabu bitumen belt is made of the main Agbabu village inhabited by about close to 2,000 people beside other settlements among which is Temidire Village. Farmers in this area deal mainly in fishing along Oluwa River, which flows through the whole land. Some of those living in the villages and hamlets live on the shallow surface water of the river as source of portable water.

Description of sampling Sites

Two sampling Sites A and B 1 km apart were selected on Oluwa River. Site A is located upstream where there are high fishing activities and less domestic activities. Site B is located downstream where there are high domestic activities like bathing, swimming, washing of clothes and fetching the river water for drinking. The major pollutant of Oluwa River besides domestic sources is bitumen seepage especially during the afternoon and mostly in the dry season when temperature is above 37oC during when the bitumen occurs as a free-flowing liquid flowing into the river.

Collection of fish samples

Fishing was done during late night with the help of professional local fishermen. Gill nets about
12.192 m long and 1.828 m wide with a cork line at the top rope and metal line with the ground rope made locally of nylon were used for fishing. Two fishermen with the help of a wooden boat helped in the collection of fish samples from the two sampling Site. Fishing was done monthly over a two-year period starting from the month of July 2010 to June 2012. Samples were transported to the Ecotoxicology and fisheries Laboratory of Ladoke Akintola University of Technology in well aerated containers into which ice cubes were added to lower the temperature of the water before the commencement of further studies.

Sex Ratio Determination

Sexes were determined by visual inspection of the genitals and sex ratio determined.

Gonado-Somatic Index (GSI) determination

Each specimen was cut opened ventrally from the anus and the gonads were removed, dried and weighed, and the sexual cycle of females was divided into six stages. The monthly gonado- somatic indices (GSI) were calculated using the formula:

$$\% \text{ GSI} = \frac{\text{Gonad weight (g)}}{\text{Body weight (g)}} \times 100$$

Stages of gonadal maturation

Sexual maturity was determined by observation of the stages of the maturation of the gonads according to (Fawole & Arawomo, 2000; (Komolafe and Arawomo, 2007).

Developmental stages of egg

Stage 1: Immature, thin ovary, ribbon-like structure, creamy white and translucent.
Stage 2: Developing, small sac-like ovary that is red and smooth.
Stage 3: *Maturing*, ovary with large visible ova with much thinner walls.
Stage 4: *Ripe*, eggs are visible with naked eye, ovary membrane becomes very thin.
Stage 5: *Runing*, ova are at their largest, and the abdominal cavity becomes filled with the ovary.
Stage 6: *Spent*, ovary becomes flaccid and reduced in volume with little or no ova.

Fecundity Evaluation

The ovaries were dissected out and weighed on an electronic meter balance; model P1210 to the nearest 0.01g, to determine the ovary weight. The ovaries were then preserved in Gilson's fluid in well labeled sample tubes for one month. The ovaries were periodically agitated to facilitate separation of ova from the ovarian tissue. After the hardened ova has been totally separated from the ovarian tissue, the fluid was then decanted, and the ova washed by running clean water through the ova placed in a funnel with filter paper as a sieve.
Clumps of eggs were gently teased with dissecting needle. Sub-samples of ovaries were obtained and weighed. The number of eggs in each sub-sample was counted using an egg counter. The fecundity in each of the fish was estimated

from the relationship established by (Anene and Okorie, 2008) as:

$$F = ½ (N1/W1+N2/W2) W$$

Where: N_1 is the number of eggs in the first sub-sample with weight W_1
N^2 is the number of eggs in the second sub-sample with weight W_2
W is the total weight of the pair of ovaries from which the sub-samples were obtained.
A mean fecundity from all samples was calculated using a direct summation procedure by (Shoesmith, 1990). The relationship between fecundity (F) with the independent variables (X),
Standard length (SL) and ovarian weight (OW) was expressed according to (Bagenal and International Biological Programme, 1978) as;

$$F = aX^b$$

Where: (a) is a constant and b is the regression co-efficient.
The constant a and b were empirically determined after a logarithmic transformation, the equation becomes:

$$InF = b InL + a$$

Table 1: Frequency of occurrence and mean reproductive index for Clarias gariepinus from Oluwa River

TLR	F	MTL (cm)	Mean(g) weight	GW (g)	G.S.I (%)	Fecundity	RF
31.00-33.90	12	32.71±0.17	342.50±47.42	1.42±0.53	0.53±0.21	1932.00±66.81	6.95±0.51
34.00-36.90	25	35.60±0.17	503.20±57.79	12.24±4.03	2.07±0.52	2595.00±548.93	5.55±0.73
37.00-39.90	36	38.40±0.12	658.89±32.87	29.10±7.90	3.57±0.89	5594.40±998.15	7.31±0.98
40.00-42.90	31	41.16±0.14	689.03±32.66	36.39±8.15	4.67±0.93	6347.07±826.34	8.36±0.76
43.00-45.90	39	44.05±0.14	807.44±45.20	26.90±6.38	2.92±0.40	6443.40±799.51	7.66±0.57
46.00-48.90	35	47.73±0.15	1064.29±61.24	66.56±9.97	5.91±0.63	10528.50±857.15	10.08±0.52
49.00-51.90	15	50.01±0.20	1142.67±95.63	61.55±14.99	4.91±0.80	10791.50±1610.44	9.40±0.76
52.00-54.90	25	53.24±0.17	1255.60±61.39	89.92±12.26	6.57±0.60	12962.16±1110.46	9.92±0.44
55.00-57.90	20	56.48±0.19	1663.00±58.41	126.33±3.36	7.81±0.19	16258.54±924.35	10.14±0.57
58.00-60.90	15	59.02±0.20	1707.00±94.16	140.17±5.70	7.71±0.25	16790.00±948.74	9.31±0.61
61.00-63.90	15	62.52±0.23	1976.67±64.61	156.18±3.36	7.70±0.01	17658.00±859.00	8.71±0.42
64.00-66.90	14	65.24±0.25	1981.43±61.79	153.20±5.67	7.45±0.13	19747.67±1503.16	9.63±0.71
67.00-69.90	08	68.14±0.29	2125.00±75.00	169.10±4.49	7.35±0.08	22420.00±2944.48	9.70±1.10
70.00-72.90	03	70.47±0.12	2066.67±66.67	170.20±0.00	7.74±0.00	15442.00±0.00	7.02±0.00
Total		51.76±3.04	1284.53±168.14	88.44±16.69	5.49±0.64	11822.16±1740.49	8.55±0.38

Table 2: Monthly variation in the mean values of weight and G.S.I of Male Clarias gariepinus from Oluwa River

Months	Total length(cm)	Standard length (cm)	Weight (g)	Gonad weight(g)	G.S. I.
JULY '10	45.20 ± 3.90	39.98 ± 3.84	702.50±215.65	1.14 ± 0.37	0.16 ± 0.01
AUG. '10	58.84 ± 5.57	52.96 ± 5.33	1776.00±82.32	3.29 ± 0.21	0.18 ± 0.005
SEP. '10	44.54 ± 6.64	39.26 ± 5.76	856.00±308.84	1.53 ± 0.64	0.18 ± 0.04
OCT. '10	52.45 ± 3.16	46.25 ± 2.89	1390.00±242.83	2.56 ± 0.54	0.18 ± 0.01
NOV. '10	49.17 ± 4.71	43.43 ± 4.47	986.67±288.50	1.56 ± 0.54	0.14 ± 0.02
DEC. '10	51.87 ± 3.64	45.77 ± 3.55	1512.85±243.62	2.65 ± 0.53	0.17 ± 0.01
JAN. '11	51.25 ± 4.78	45.11 ± 4.77	1082.86±222.60	1.70 ± 0.49	0.19 ± 0.05
FEB. '11	43.70 ± 2.40	37.64 ± 2.40	646.25±43.26	1.26 ± 0.30	0.16 ± 0.02
MAR. '11	52.56 ± 4.86	45.90 ± 4.63	1400.00±219.58	2.55 ± 0.42	0.44 ± 0.27
APR. '11	48.02 ± 5.62	41.17 ± 5.47	1394.00±244.82	2.56 ± 0.69	0.17 ± 0.02
MAY '11	48.98 ± 3.09	42.56 ± 2.98	1144.00±186.91	1.84 ± 0.38	0.16 ± 0.01
JUN. '11	48.00 ± 3.09	41.75 ± 3.30	862.50±110.63	1.27 ± 0.18	0.50 ± 0.36
JUL. '11	36.07 ± 1.25	32.26 ± 1.22	345.00±34.70	0.36 ± 0.04	0.11 ± 0.007
AUG. '11	45.29 ± 4.00	39.38 ± 3.74	624.29±198.28	0.94 ± 0.48	0.13 ± 0.02
SEP. '11	51.57 ± 2.93	45.28 ± 2.79	1288.33±254.83	2.76 ± 1.15	0.50 ± 0.33
OCT. '11	40.84 ± 1.34	35.51 ± 1.23	487.14±52.86	0.80 ± 0.20	0.17 ± 0.05
NOV. '11	48.07 ± 3.09	42.57 ± 3.28	995.00±279.33	1.58 ± 0.54	0.15 ± 0.02
DEC. '11	45.10 ± 3.85	40.50 ± 3.83	860.00±95.60	1.22 ± 0.22	0.14 ± 0.01
JAN. '12	48.63 ± 3.73	41.92 ± 3.77	895.71±119.87	0.97 ± 0.17	0.10 ± 0.009
FEB. '12	40.85 ± 2.45	34.25 ± 2.57	867.00±176.53	1.12 ± 0.40	0.12 ± 0.01
MAR. '12	43.80 ± 2.92	37.42 ± 2.92	943.00±139.35	1.28 ± 0.33	0.12 ± 0.01
APR. '12	45.40 ± 4.48	39.17 ± 4.55	1250.00±215.47	1.72 ± 0.43	0.11 ± 0.01
MAY '12	41.10 ± 2.17	35.08 ± 1.98	1111.67±126.63	1.39 ± 0.30	0.12 ± 0.01
JUN '12	40.82 ± 2.85	35.13 ± 2.84	920.00±158.79	1.13 ± 0.24	0.12 ± 0.007

Table 3: Monthly variation in the mean values of weight, G.S.I and Fecundity of Female Clarias gariepinus from Oluwa River

Months	Total length (cm)	Standard length (cm)	weight (g)	Gonad weight (g)	G.S.I	Fecundity
JULY '10	39.45±2.94	33.42 ±2.75	633.33 ±166.34	36.74 ± 17.15	3.84 ±1.80	6,799.00 ±1015.89
AUG. '10	47.03 ± 4.70	40.91 ± 4.51	1165.71±189.99	80.39 ± 20.81	6.43 ± 0.96	11021.14±1282.76
SEP. '10	40.92 ± 1.81	36.10 ± 1.32	540.00 ±77.50	11.34 ± 6.54	1.76 ± 0.87	3542.33±558.61
OCT. '10	50.54 ± 4.41	43.84 ± 4.04	1086.00 ± 214.56	58.46 ± 25.76	4.57 ± 1.45	8577.80±1590.47
NOV. '10	51.28 ± 3.54	45.21 ±3.51	1321.11±214.06	85.61 ± 21.39	5.69 ± 0.88	11466.33±2723.35
DEC. '10	56.84 ± 4.16	50.30 ± 4.26	1620.00±304.29	115.29±26.82	5.95 ± 1.06	13977.57±2619.09
JAN. '11	53.56 ± 3.84	47.59 ± 3.76	1381.43±261.57	85.07 ± 25.44	5.38 ± 0.82	11903.57±2916.00
FEB. '11	48.09 ± 4.61	41.99 ± 4.17	1061.25±283.00	72.45±26.64	4.52 ± 0.99	9396.88±2910.76

MAR. '11	41.69 ± 1.73	35.37 ± 1.59	758.57±56.29	26.66 ± 3.60	3.48 ± 0.42	6356.29±1162.30
APR. '11	59.92 ± 2.74	53.96 ± 2.43	2010.00±200.25	152.18 ± 11.16	7.70 ± 0.40	17393.60±1611.88
MAY '11	50.25 ± 3.74	44.00 ± 3.74	1161.67±203.15	67.38 ± 21.17	5.25 ± 0.84	9574.83±2085.75
JUN. '11	52.59 ± 2.94	46.32 ± 3.16	1160.00±184.23	65.95 ± 21.22	4.78 ± 0.90	9103.25±1644.92
JUL. '11	51.80 ± 5.50	46.00 ± 4.00	1180.00±330.00	80.00 ± 30.00	6.60 ± 0.70	10975.00±3625.00
AUG. '11	47.23 ± 3.19	41.59 ± 2.84	836.00±168.09	44.33 ± 16.23	3.84 ± 0.93	8762.70±1978.60
SEP. '11	48.35 ± 2.99	41.92 ± 2.72	1006.66±212.00	58.65 ± 23.96	4.89 ± 1.15	10677.83±1830.70
OCT. '11	44.12 ± 3.63	39.16 ± 3.16	778.00±231.76	28.89 ± 23.20	2.24 ± 1.31	4829.00±418.34
NOV. '11	49.60 ± 4.32	43.50 ± 4.27	1168.00±198.05	57.46 ± 26.40	4.18 ± 1.47	9600.80±2004.12
DEC. '11	55.34 ± 3.15	50.22 ± 3.19	1348.00±160.82	102.14 ± 21.24	7.39 ± 1.39	16880.00±2331.18
JAN. '12	49.86 ± 3.84	47.26 ± 4.28	1374.00±231.76	87.86 ± 25.82	5.86 ± 0.98	13979.40±3175.61
FEB. '12	48.70 ± 3.07	42.51 ± 3.05	1312.50±225.26	82.35 ± 22.40	5.29 ± 0.96	11094.25±2514.94
MAR. '12	49.10 ± 4.58	42.48 ± 4.43	1272.00±244.32	93.74 ± 25.61	6.73 ± 1.08	12911.00±2918.24
APR. '12	52.62 ± 3.41	46.58 ± 3.40	1570.00±193.48	123.85 ±16.65	7.82 ± 0.66	15795.00±2170.26
MAY '12	53.93 ± 2.83	47.83 ± 2.78	1890.00±106.93	140.93 ± 8.95	7.45 ± 0.22	18560.67±2243.95
JUN '12	46.18 ± 3.13	40.56 ± 2.91	1276.00±202.70	110.40 ± 19.35	8.76 ± 1.31	15028.20±2729.01

Table 4: Monthly Variation in the Sex Ratio of *Clarias gariepinus* from Oluwa river

YEAR	MONTH	MALE		FEMALE		TOTAL	SEX RATIO	χ^2
		No	%	No	%			
2010/2011	JULY	8	57.14	6	42.86	14	01:00.8	0.286 NS
	AUG.	5	41.7	7	58.3	12	01:01.4	0.333 NS
	SEP.	5	45.5	6	54.55	11	01:01.2	0.091 NS
	OCT.	4	44.44	5	55.55	9	01:01.3	0.111 NS
	NOV.	6	40	9	60	15	01:01.5	0.600 NS
	DEC.	7	50	7	50	14	01:01.0	0
	JAN.	7	50	7	50	14	01:01.0	0
	FEB.	8	50	8	50	16	01:01.0	0
	MAR.	7	50	7	50	14	01:01.0	0
	APR.	5	50	5	50	10	01:01.0	0
	MAY	4	40	6	60	10	01:01.5	0.091 NS
	JUN.	4	33.33	8	66.67	12	01:02.0	1.333 NS
2011/2012	JUL.	8	80	2	20	10	01:00.3	3.600*
	AUG.	6	35.3	11	64.7	17	01:01.8	0.529 NS
	SEP.	8	66.67	4	33.33	12	01:00.5	0
	OCT.	7	58.33	5	41.67	12	01:00.7	0.333 NS
	NOV.	4	44.44	5	55.56	9	01:01.3	0.111 NS
	DEC.	6	54.55	5	45.46	11	01:00.8	0.091 NS
	JAN.	7	58.33	5	41.67	12	01:00.7	0.333 NS
	FEB.	6	42.86	8	57.14	14	01:01.3	0.286 NS
	MAR.	10	66.67	5	33.33	15	01:00.5	1.667 NS
	APR.	6	50	6	50	12	01:01.0	0
	MAY	6	66.67	3	33.33	9	01:00.5	1.000 NS
	JUN.	4	44.44	5	55.56	9	01:01.3	0.111 NS
Overall		148		145		293	01:01.0	4.000NS

* Significant @ P=0.1
NS = Not Significant

Table 5: Gonad Maturity stages in Clarias gariepinus from Oluwa river (July 2010 – June 2011)

								No. of Matured Gonads		**% Matured Gonads**	
MONTH	**SEX**	**I**	**II**	**III**	**IV**	**V**	**VI**	Male	Female	Male	Female
JULY	M	4	3	1	-	-	-	1	3	25	75
	F	1	2	3	-	-	-				
AUG.	M	-	-	5	-	-	-	5	4	56	44
	F	-	3	2	2	-	-				
SEPT.	M	3	1	1	-	-	-	1	0	100	0
	F	3	3	-	-	-	-				
OCT.	M	1	-	3	-	-	-	3	2	60	40
	F	-	3	2	-	-	-				
NOV.	M	4	0	2	-	-	-	2	5	28.6	71.43
	F	0	3	4	1	1	-				
DEC.	M	1	1	5	-	-	-	5	6	45.5	55.55
	F	-	1	1	5	-	-				
JAN.	M	2	3	2	-	-	-	2	5	28.6	71.43

	F	-	1	3	2	1	-				
FEB.	M	3	4	1	-	-	-	1	4	20	80
	F	-	4	1	3	-	-				
MAR.	M	1	1	5	-	-	-	5	4	56	44
	F	-	3	3	1	-	-				
APR.	M	1	-	3	-	-	-	3	4	42.9	57.14
	F	-	-	1	3	1	-				
MAY	M	1	2	2	-	-	-	2	5	28,60	71.43
	F	-	1	2	3	-	-				
JUN.	M	1	2	1	-	-	-	1	7	12.5	87.5
	F	-	1	4	3	-	-				

M = Male; F = Female

Table 6: Gonad Maturity stages in Clarias gariepinus from Oluwa River (July 2011 – June 2012)

								No. of Matured Gonads		**% Matured Gonads**	
MONTH	**SEX**	**I**	**II**	**III**	**IV**	**V**	**VI**	Male	Female	Male	Female
JULY	M	5	3	-	-	-	-	0	2	0	100
	F	-	-	1	1	-	-				
AUG.	M	2	4	-	1	-	-	1	6	14.29	85.71
	F	-	2	2	4	2	-				
SEPT.	M	4	-	1	-	-	-	1	5	16.67	83.33
	F	-	1	2	3	-	-				
OCT.	M	5	2	-	-	-	-	0	1	0	100
	F	-	1	-	1	-	3				
NOV.	M	3	-	1	-	-	-	1	1	50	50
	F	-	4	1	-	-	-				
DEC.	M	3	2	1	-	-	-	1	3	25	75
	F	-	1	2	1	1	-				
JAN.	M	4	3	-	-	-	-	0	4	0	100
	F	-	-	2	2	1	-				
FEB.	M	5	-	1	-	-	-	1	7	12.5	87.5
	F	-	1	3	4	-	-				
MAR.	M	7	1	2	-	-	-	2	5	28.6	71.43
	F	-	-	3	2	-	-				
APR.	M	2	-	4	-	-	-	4	6	40	60
	F	-	-	2	4	-	-				
MAY	M	1	2	3	-	-	-	3	2	60	40
	F	-	-	1	1	1	-				
JUN.	M	2	1	1	-	-	-	1	4	20	80
	F	-	-	2	2	1	-				

M = Male; F = Female

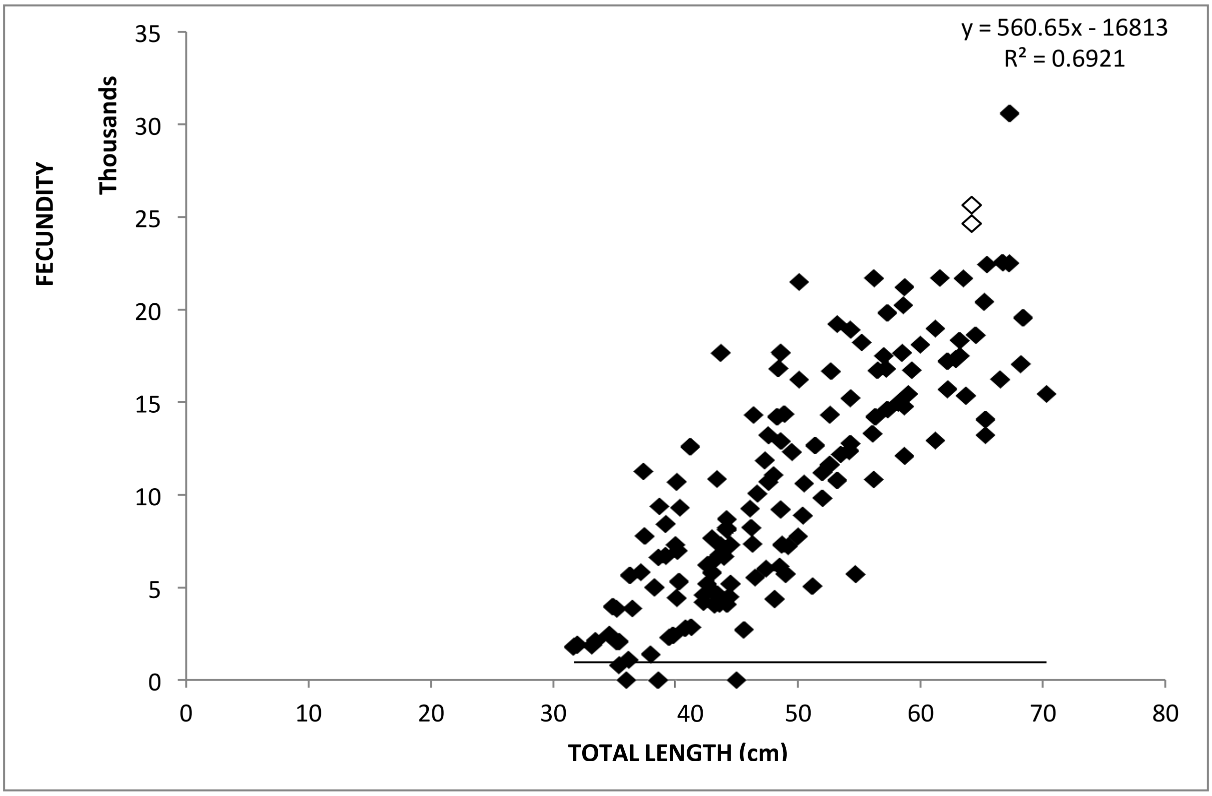

Figure 1: Linear regression showing relationship between fecundity and total length of Clariasgariepinus from Oluwa

River.

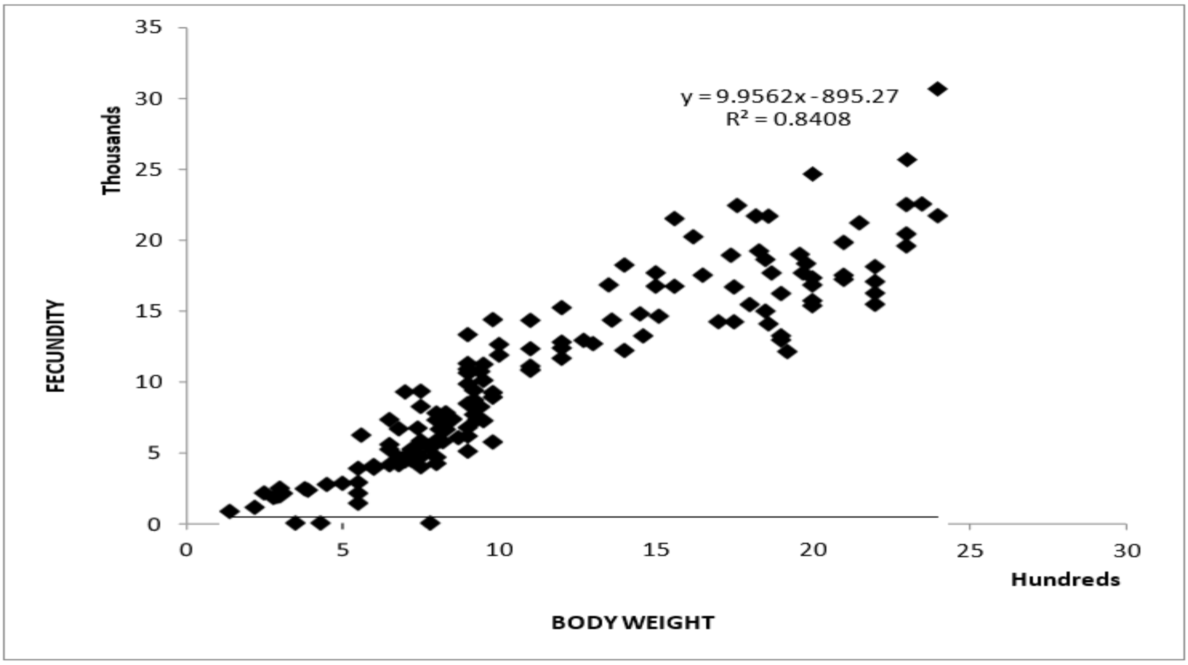

Figure 2: Linear regression showing relationship between fecundity and body weight of *Clariasgariepinus* from Oluwa River

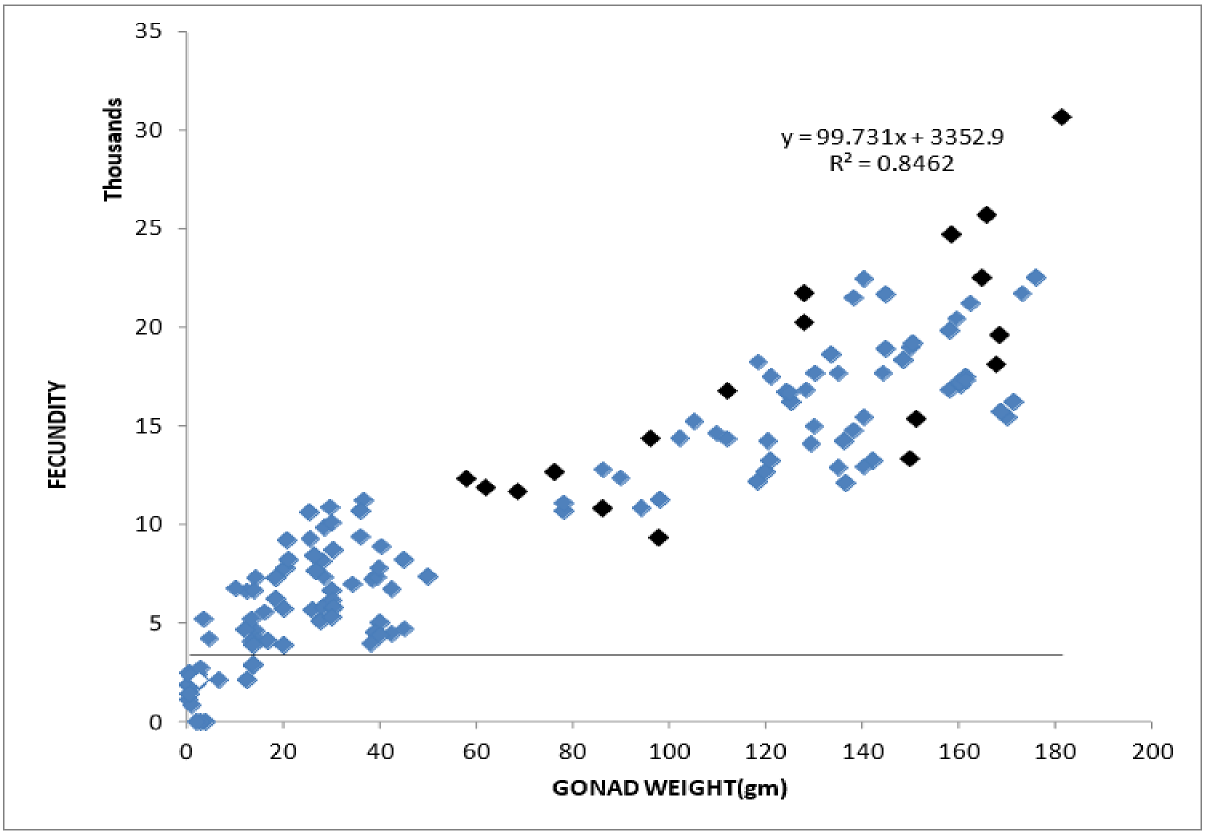

Figure 3: Linear regression showing relationship between fecundity and gonad weight of *Clariasgariepinus* from Oluwa River.

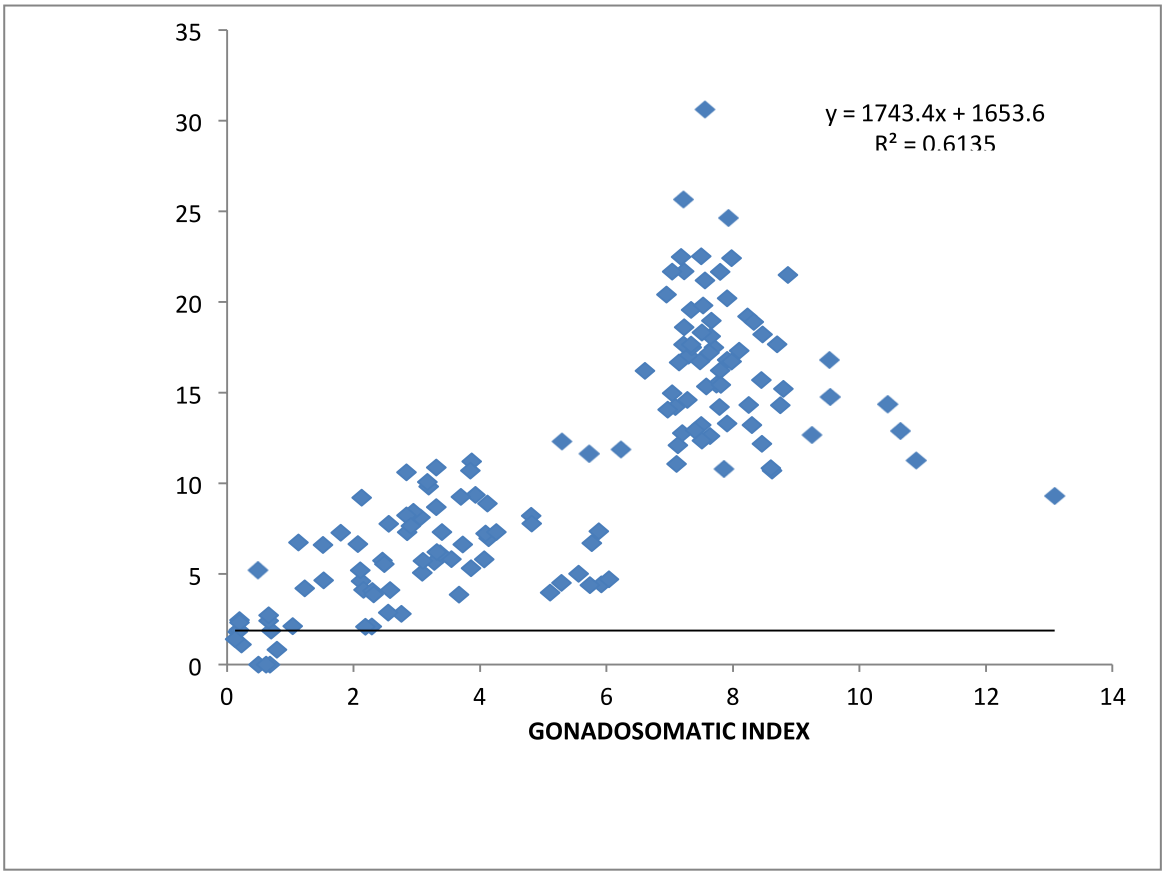

Figure 4: Linear regression showing relationship between fecundity and gonadosomatic index of *Clarias gariepinus* in Oluwa River.

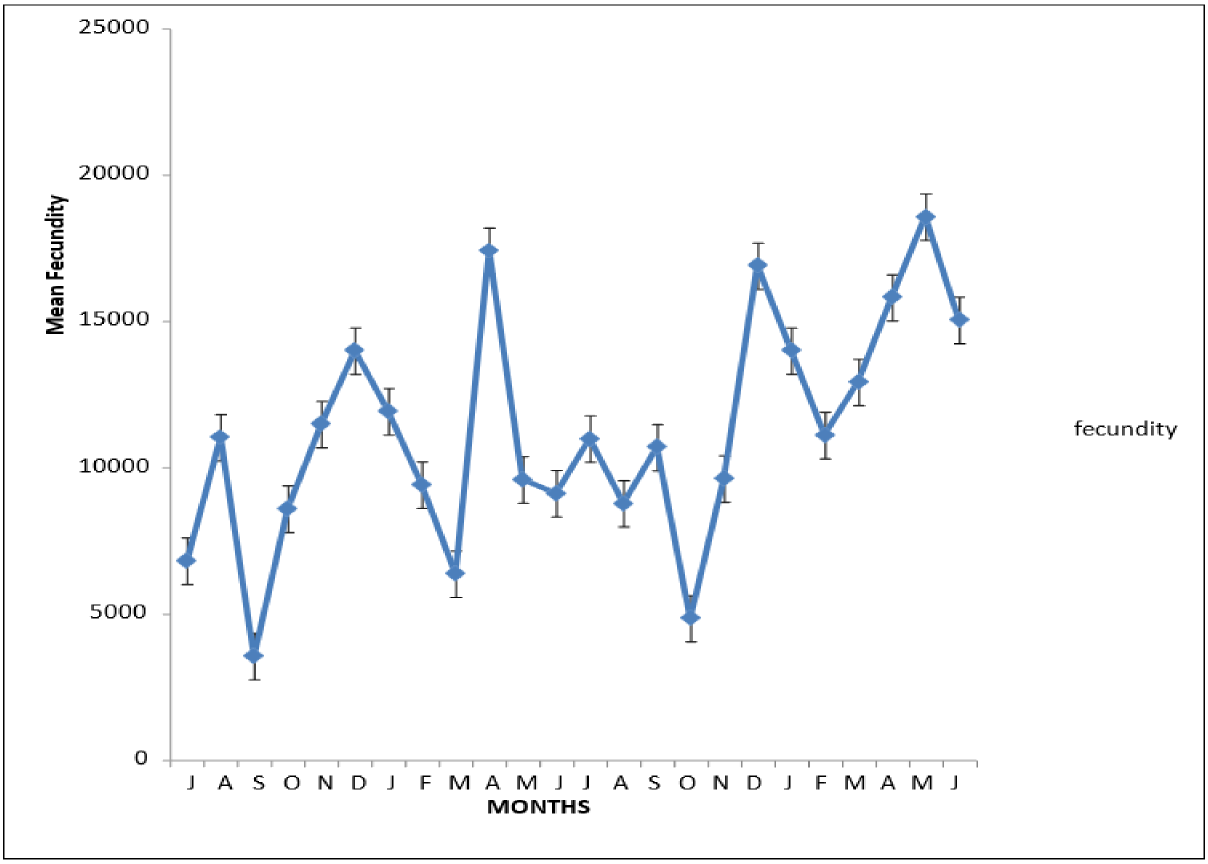

Figure 5: Monthly variation in mean fecundity of *Clarias gariepinus* from Oluwa River

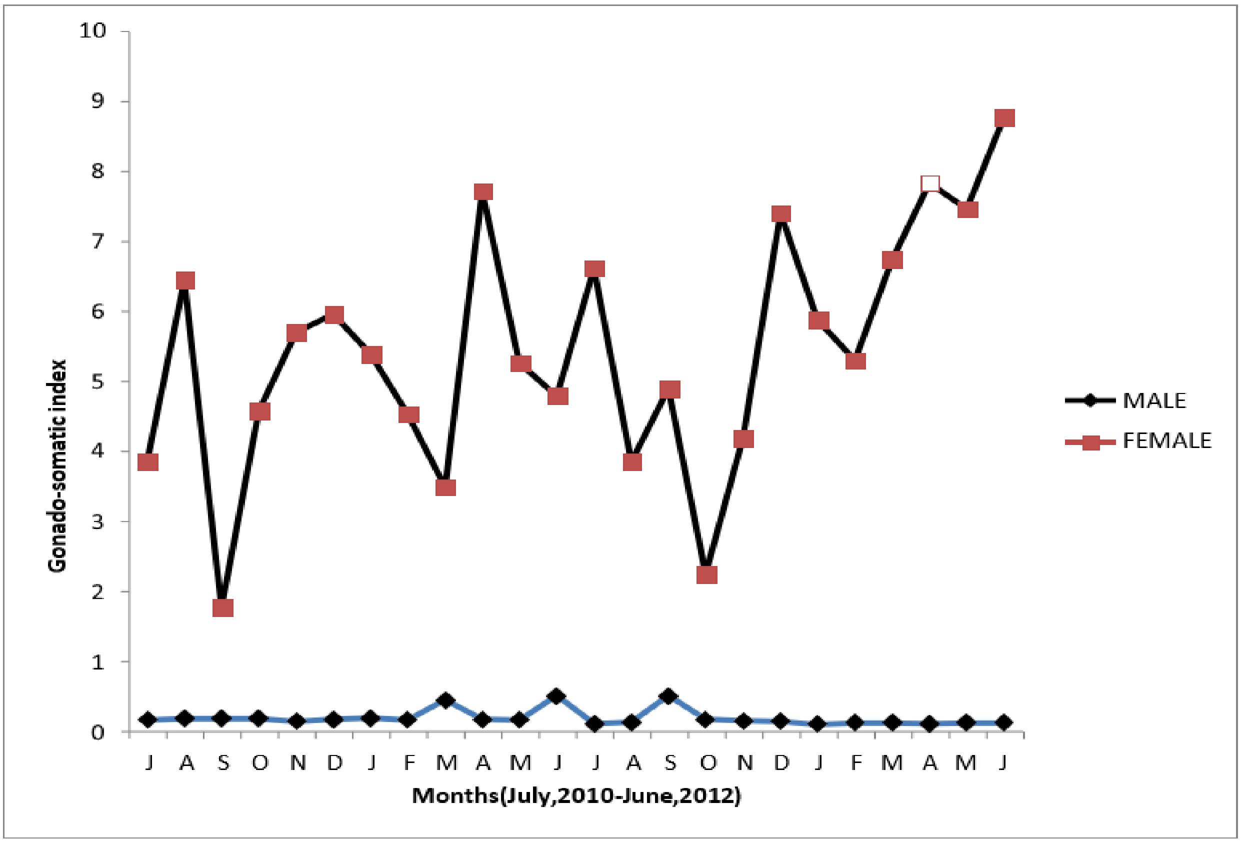

Figure 6: Monthly variation in the Gonadosomatic Index of *Clarias gariepinus* from Oluwa River

RESULT

Reproduction and Fecundity

In the present study, it was observed that mean fecundity ranged between 1932.00±66.81 to 22420±2944.48 eggs with a mean value of 11822.16±1740.49, corresponding to fish total length range of 32.60-70.30cm with a mean value of 51.69±3.29 (Table 1). Fecundity was found to increase with increase in body weight of the fish species.

The equation describing the relationship between fecundity and Total length, is given as

$F = aL^b$ (Ezenwaji, 2002))

Where F = Fecundity

L = Total Length

b = Slope of the regression line (regression constant)

a = intercept of the regression with y-axis (regression coefficient)

Through, a logarithm transformation the equation becomes:

LogF = Loga + bLogL

Where F = fecundity, L = Total length/weight, a = regression coefficient, b = regression constant.

The relationship between fecundity and Total length, Body weight, Gonad weight as well as gonado-somatic index recorded in this study is given as follows,

LogF = Log560-16,813LogTL (n=145, R^2 = 0.692).
LogF = Log9.95-895.27LogW (n=145, R^2 = 0.840).
LogF = Log99.73+3,352.90LogGW (n=145, R^2 = 0.846).
LogF = Log1, 743.4+1,653.6LogGSI (n=145, R^2 = 0.613).

As seen in figures 1, 2, 3 and 4. The fecundity of *Clarias gariepinus* in Oluwa River was related more linearly. The values of correlation coefficients (r) obtained showed very low correlation between fecundity and Total length (r^2 = 0.692) and Gonadosomatic index (r^2 = 0.613).

However, there was a closer correlation between fecundity and body weight (r^2 = 0.840) as well as Gonad weight (r^2 = 0.846) from the result obtained for fecundity, the heaviest individual females collected throughout the sampling period had its weight to be 2400g and Total length 67.30cm and produced the highest fecundity, 30,600eggs, while the smallest individual females collected had its weight to be 220g and Total length 36.20cm and it produced the lowest fecundity of 1,110 eggs.

It was observed that fecundity increased with increase in size of *Clarias gariepinus* in Oluwa River. Seasonal variations were also observed in fecundity of *C. gariepinus* in Oluwa River as shown in tables 2 and 3. The highest mean fecundity (18,560.67±2243.95) was recorded in the month of May, (Table 3) while the lowest mean fecundity (3542.33±558.61) was recorded in the month of September. It was observed that Peak in fecundity of the fish species coincided with the onset of rains and the rising flood April to June (figure 5).

Maturation Size and Sex Ratio

The result showed that, out of the 293 specimen, 148 (50.51%) were males while 145 (49.48%) were females, giving a ratio of 1:0.97. The population of males was higher than those of females in the river. A chi-square analysis of the result showed that there is no significant difference between overall preponderance of the male over female *Clarias gariepinus* (x^2 = 4.00@P = 0.05) Seasonal variations were also observed. Males were predominantly very high in July, May and September while females were predominantly high in the month of May, June and August,(Table 4). Monthly variations throughout the study were not significantly different at P= 0.1 and degree of freedom one (1) except for the month of July 2011 which is significant (x^2 = 3.60@ P=0.1) at hypothetical distribution of 1:0.3 male to female ratio.

Gonad Maturation Stages

Six stages of gonad development were observed in the specimens examined. The stages were:
Stage I = Immature, inactive
Stage II = immature, developing
Stage III = Maturity
Stage IV = Matured (Ripe)
Stage V = Ripe running
Stage VI = Spent (Ezenwaji, 2002)

The females showed all the stages of gonad development as classified by Ezenwaji (2002). However, males show only stages I-IV. Matured specimens (stages III and IV) were found to be very high between June to August, throughout the sampling period (Tables 5 and6).

Gonadosomatic Index

The gonad weight expressed as a percentage of the fish somatic weight (El-Kasheif, Shalloof and Authman, 2013) was used as the gonadosomatic index (G.S.I). It gives an indication of the percentage of the fish weight that is used in egg production. The gonadosomatic index recorded in this study for male specimen ranged from 0.10±0.01-0.45±0.21% with a mean value of 0.18±0.22% (Table 2). For female specimen, it ranged from 0.53±0.21-7.81±0.19% with a mean value of 5.49±0.64%(Table 1). Both sexes of the specimen exhibited a range of 0.24±0.88-5.21±0.95% with a mean value of 2.99±0.42% (Table 5).

Monthly variations in G.S.I revealed that several peaks of G.S.I values were observed during April, May and June, for female specimens (Table 3) with the highest G.S.I recorded in the month of June and the lowest in the month of October. This means that females could breed in the rainy period from April to June which represented the spawning period of *Clarias gariepinus*in Oluwa River (Figure 6). For male specimen, peak in G.S.I occurred only in the months of March, June, and September. It is also clear that females have highest values of G.S.I than males (Figure 6).

DISCUSSION

Sex Ratio

Sex ratio should be a consideration when choosing a species of freshwater fishes for culture and reproduction (Mekkawy and Hassan, 2011); (El-Kasheif, Authman and Ibrahim, 2012). In fishes the sex ratio varies from one species to another in most cases, it is close to one (Khallaf and Authman, 2010). The overall sex ratio (M: F) of *Clarias gariepinus* in this work is found in different numbers with obvious deviation from the expected ratio (1:1) where the number of males exceeded that of females. Male dominance was observed in the species as male: female (1:0.97) sex ratio over the entire study but however showed no significant difference. Also, seasonal variations in sex ratio were also observed.

The dominance of males over females could be explained by the fact that once the eggs were fertilized, the females hide under vegetation where incubation and protection of the young took place. This activity gives room to the males who then migrate to the feeding zones where they become vulnerable to catch (Ezenwaji, 2002; Peña-Mendoza et al., 2005; Shalloof & Salama 2008; Offem et al., 2010; Olele, 2010). Another factor could be the possibility of not setting gears closer to breeding grounds (Güçlü and Küçük, 2011). The overall sex ratio observed in the study revealed that both sexes of the fish species are available in Oluwa River.

Monthly variations in sex ratio observed in this study were not significantly different except for the month of July (Peak flood). This further revealed the preponderance of males which are moresusceptible to exploitation by fish farmer. The sex ratio of the fish species in the month was 1:0.3with Chi-square x^2 value 3.60 are highly significant at P=0.10. This also implies that males have a decisive influence on the reproduction of the fish species in Oluwa River.

Environmental conditions, such as temperature, can influence sex differentiation in fish species. Low temperatures can bias female sex differentiation, while elevated temperatures can skew sex ratios towards males in some species. Preponderance of male Clariid species over their female counterpart has been reported by (Offem, Ayotunde and Ikpi, 2008). They submitted that preponderance of male *Heterobranchus longifilis* was higher than that of the female (1:0.6). Generally, in African water bodies, it is common that population of males dominate because they present more growth than females without representing a risk situation for the fishery.

Gonad Maturity Stages

In this study, the monthly distribution of male and female gonad maturity stages revealed that immature, developing and maturing gonads occurred throughout this period. However, high percentages of matured specimen (stages III-IV) were found in the months of April to July in the first year of study (July 2010 - June 2011) and the percentages of the matured stages III-IV was also high in the months of April-August in the second year of study (July, 2011-June, 2012). Spent stages were more prominent in the early months of dry season throughout the study period. This observation, thus suggest that *Clarias gariepinus* of Oluwa river spawn, during the rainy months of the year before the inception of dry season. This result is in agreement with the submission of Ezenwaji (2002) where he found out that *Clarias ebriensis* in Anambra River basin bred from April to September, and he regarded the months as breeding season for the fish species. (Offem, Ayotunde and Ikpi, 2008) stated that, annual breeding season of the fish species and most Clariidae under natural conditions is limited to a few months. It was discovered that fish species with gonad stages I-IV appeared to be more recruited into artisanal fishery throughout the study period. This further confirmed the dominance of the fish species harvested in the study to size ranges of 37.00-39.90cm, dominated by males and 43.00-45.90 and 46.00-48.90cm dominatedby females.

These differences arises probably because sexual maturity is a function of the size and may be influenced by the abundance and seasonal availability of food, the temperature, photoperiod, and other environmental factors at different localities ((Peña-Mendoza *et al.*, 2005)). Also, a combination of physical, chemical and biological factors such as changes in water level, chemistry, pH, temperature, clarity and flow velocity, flooding of marginal plants, associated chemical changes and access to suitable spawning Sites is responsible for triggering the spawning of Catfish.

Gonado-Somatic Index (G.S.I)

The relatively high mean values of G.S.I (5.49±0.64%) recorded for female over that of males (0.18±0.22%) could be as a result of heavier gonads possessed by female fish species. Offem et al. (2008) submitted that the G.S.I for male species were always lower thanthose of females. Seasonal variations in G.S.I of *Clarias gariepinus* (figure 6) also revealed that female have higher G.S.I values than males.

Peak G.S.I of female *Clarias gariepinus* in the present study exhibited several peaks in April, May and June (figure 6). This further confirmed that the breeding of the fish species in Oluwa River is prominent in rainy months as recorded in this study thus characterizing a single annual spawning. The results obtained for gonado-somatic indices in this study is in agreement with the findings of Ezenwaji (2002); Offem et al. (2008) and El-Kasheif et al. (2013).

Catfishes however, generally present a single annual spawning period and that G.S.I for females is always higher than that of males probably due to heavier ripe female Gonads.

Fecundity

Fecundity values recorded in this study ranged between 1,932-22,420 eggs with a mean value of 11,822.16. The value was comparatively lower when compared with the observation from other Clariid catfishes. 650,625 eggs were reported by (Abayomi and Arawomo, 1999) in *Clarias gariepinus* in Opa reservoir. The result obtained could be as a result of the polluted nature of Oluwa River which might have altered the reproductive processes of the fish species. However, the mean fecundity 11,822 is an indication that the species is highly fecund in the river despite all odds. This is in line with the findings of (Eyo, Ekanem and Ajom, 2016) who described *C. gariepinus* as a highly fecund species fish that spawn easily under captive conditions. The disparity in the fecundity values could be due to the differences in the size, location and food availability (Lawrence Ejeh, 2017); (Olanrewaju *et al.*, 2017). In addition, the variations in fecundity of the fish species could be as a result ofreproductive strategies aimed at survival (Shalloof & Salama 2008).

It was mentioned that, in the mouth brooding Cichlids; where limited space is available for incubation of eggs and rearing of neonates in the buccal cavity; fecundity is considerably low because the parents assumed the survival of the offspring and consequently reduce mortality (Duponchelle *et al.*, 2008). Also, low fecundity was peculiar with specimens exhibiting either parental care and or prolong breeding habits (Fawole & Arawomo, 2000; Olele, 2010). This result, thus suggest that the fish species may lack any form of parental care. Koenigbauer & Höök (2023) observed that the fecundity of a fish is inversely related to the degree of parental care it exhibits. Fecundity was also discovered to increase with an increase in body weight and Total length ofthe fish species. However, several works on fecundity indicates similar trend. Abayomi & Arawomo (1999) obtained fecundity range of 15,667-650,625 eggs from *C. gariepinus* at size range of 39.50- 82.50cm total length. Fawole & Arawomo (2000) observed highest fecundity in the biggest specimen of *Sarotherodon galilaeus* in Opa reservoir, Ile-Ife.

Seasonal variations were also observed in the fecundity of the fish species in Oluwa River. High fecundity coincided with the rainy months April-June. When increased water volumes gave rise to flood. Most fish species tend to spawn during flood period in order to enable their offspring becomes distributed far and wide to regions where food could easily be found (Olele, 2010). The seasonal variations observed in this study agreed with the works of Ezenwaji (2002); Offem et al. (2010) and Olele (2010). Furthermore, the choice of a particular season in fishes for breeding is influenced by various factors among which is food supply, changes in water quality or level, interspecific interactions, availability of spawning Sites (Saidi *et al.*, 2022).

The values of correlation coefficients (r) obtained for the fecundity studies showed very low correlation between fecundity against total length (r^2=0.692) and against G.S.I (r^2=0.613). However, there was a closer correlation between fecundity against body weight (r^2=0.840) and fecundity against Gonad weight (r^2=0.846). This result further confirmed that fecundity increases as the body size increases. (Roberts *et al.*, 2021) and Koenigbauer & Höök (2023) submitted that fishes with a closer relationship between fecundity and body weight than what obtains between fecundity and length showed faster growth rate at the same time with higher fecundity and that the parameters largely depend on environmental conditions.

(Tsadu, Lamai and Oladimeji, 2003) also observed low relationship between fecundity and standard length of *Bargus bayad macropterus* (r^2=0.71). They however observed better relationship between fecundity and Gonad weight (r^2=1.00).

CONCLUSION

Fecundity results obtained for *C. gariepinus* in the study was comparatively lower than those reported for other Clariid catfishes which could be a pointer to the polluted nature of Oluwa River which might have altered the reproduction processes of the fish species. This study also becomes an additional data and information to already existed literature information on some Nigerian waters with high pollution rate and contaminants. This work has also provided for the first-time information on some studies on the ecology of indigenous catfish (*C. gariepinus*) inhabiting Oluwa River. Government and other stakeholders should show more seriousness to the enforcement of environmental laws banning anthropogenic and domestic activities around Oluwa River and other rivers in Nigeria, especially in areas where we have mineral deposits.

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References

1. Abayomi, O.S. and Arawomo, G.A.O. (1999) 'Sex-ratio and fecundity of catfish, Clarias gariepinus in Opa reservoir, Obafemi Awolowo University, Ile-Ife', in. *13th Annual Conference of the Fisheries Society of Nigeria (FISON)*, pp. 122–130. Available at: http://hdl.handle.net/1834/21425 (Accessed: 12 February 2024).
2. Afolabi, O.J., Oladele, O.O. and Olususi, F.C. (2020) 'Assessment of bacterial loads of Clarias gariepinus (Burchell, 1822) obtained from cultured and natural habitats', *The Journal of Basic and Applied Zoology*, 81(1), p. 32. Available at: https://doi.org/10.1186/s41936-020-00168-w.
3. Alavi, S.M.H. *et al.* (2021) 'A Review on Environmental Contaminants-Related Fertility Threat in Male Fishes: Effects and Possible Mechanisms of Action Learned from Wildlife and Laboratory Studies', *Animals : an Open Access Journal from MDPI*, 11(10). Available at: https://doi.org/10.3390/ani11102817.
4. Anene, A. and Okorie, P.U. (2008) 'Some aspects of the reproductive biology of Tilapia mariae (Boulenger 1901) in a small lake in southeastern Nigeria', *African Journal of Biotechnology*, 7(14). Available at: https://www.ajol.info/index.php/ajb/article/view/59048 (Accessed: 12 February 2024).
5. AROJOJOYE, O.A., NWAECHEFU, O.O. and AKINOLA, E. (2020) 'Effect of Environmental Pollution on African Catfish, Clarias gariepinus from Orioke River in Ondo State, Nigeria', *ISEE Conference Abstracts*, 2020(1). Available at: https://doi.org/10.1289/isee.2020.virtual.P-0457.
6. Ayandiran, T.A., Fawole, O.O. and Ogundiran, M.A. (2022) 'Polycyclic Aromatic Hydrocarbon Concentrations in Clarias gariepinus from Oluwa River, Ondo State, Nigeria', *Research Journal of Environmental Toxicology*, 16(1), pp. 1–11. Available at: https://doi.org/10.3923/rjet.2022.1.11.
7. Bagenal, T. and International Biological Programme, L. eng (1978) 'Methods for assessment of fish production in fresh waters - 3. ed.' Available at: https://agris.fao.org/search/en/ providers/122621/records/647396e5ce94 37aa76006300 (Accessed: 12 February 2024).
8. Costache, M. *et al.* (2011) 'Testing the Reproductive Potential of Nile Tilapia (Oreochromis niloticus) under Eco Technological Conditions from Nucet', *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Animal Science and Biotechnologies* [Preprint]. Available at: https://www.semanticscholar.org/ paper/Testing-the-Reproductive-Potential-of-Nile-Tilapia-Costache-Oprea/fa40937188f2a64e12d7a34dcfb3d96558b1eda3 (Accessed: 10 February 2024).
9. Duponchelle, F. *et al.* (2008) 'Parallel life history evolution in mouthbrooding cichlids from the African Great Lakes', *Proceedings of the National Academy of Sciences of the United States of America*, 105(40), pp. 15475–15480. Available at: https://doi.org/10.1073/pnas.0802343105.
10. El-Kasheif, M., Authman, M. and Ibrahim, S. (2012) 'Environmental Studies on Synodontis schall (Bloch and Schneider, 1801) (Pisces: Siluriformes: Mochokidae) in The River Nile at Gizza Sector, Egypt: Biological Aspects and Population Dynamics', *Journal of Fisheries and Aquatic Science*, 7, pp. 104–133. Available at: https://doi.org/10.3923/jfas.2012.104.133.
11. El-Kasheif, M., Shalloof, K. and Authman, M. (2013) 'Studies on Some Reproductive Characters of Tilapia Species in Damietta Branch of the River Nile, Egypt', *Journal of Fisheries and Aquatic Science*, 8, pp. 323–339. Available at: https://doi.org/10.3923/jfas.2013.323.339.
12. Eyo, V., Ekanem, A. and Ajom, V. (2016) 'Fecundity studies of the African catfish Clarias gariepinus (Burchell, 1822) fed Coppens feed and Unical aqua feed in circular concrete tanks', *Journal of Coastal Life Medicine*, 4. Available at: https://doi.org/10.12980/jclm.4.2016J6-45.
13. Ezenwaji, H.M.G. (2002) 'The biology of Clarias ebriensis Pellegrin, 1920 (Osteichthyes: Clariidae) in an African rainforest river basin', *Fisheries Research*, 54, pp. 235–252. Available at: https://doi.org/10.1016/S0165-7836(00)00291-5.
14. Güçlü, S.S. and Küçük, F. (2011) 'Reproductive Biology of Aphanius mento (Heckel in: Russegger, 1843) (Osteichthyes: Cyprinodontidae) in Kırkgöz Spring (Antalya-Turkey)', *Turkish Journal of Fisheries and Aquatic Sciences*, 11(2), pp. 323–327.
15. Ikpi, G.U. *et al.* (2012) 'Effect of Season on Catch rate, Diet and Aspects of Reproduction of Clarias gariepinus (Teleostei: Clariidae) in a Tropical Waterfalls', *Advances in Life Sciences*, 2(3), pp. 68–74.

16. Jamil Emon, F. *et al.* (2023) 'Bioaccumulation and Bioremediation of Heavy Metals in Fishes—A Review', *Toxics*, 11(6), p. 510. Available at: https://doi.org/10.3390/toxics11060510.
17. Kamler, E. (2005) 'Parent–egg–progeny Relationships in Teleost Fishes: An Energetics Perspective', *Reviews in Fish Biology and Fisheries*, 15(4), pp. 399–421. Available at: https://doi.org/10.1007/s11160-006-0002-y.
18. Kavanagh, R.J. *et al.* (2013) 'Reproductive and health assessment of fathead minnows (Pimephales promelas) inhabiting a pond containing oil sands process-affected water', *Aquatic Toxicology (Amsterdam, Netherlands)*, 130–131, pp. 201–209. Available at: https://doi.org/10.1016/j.aquatox.2013.01.007.
19. Khallaf, E. and Authman, M. (2010) 'Some biological aspects of the Nile mormyrid fish, (Mormyrus kannume, Forsskal, 1775), from Bahr Shebeen Nilotic Canal', 2, pp. 357–375.
20. Koenigbauer, S.T. and Höök, T.O. (2023) 'Increased offspring provisioning by large female fish and consequences for reproductive efficiency', *Ecology and Evolution*, 13(10), p. e10555. Available at: https://doi.org/10.1002/ece3.10555.
21. Komolafe, O.O. and Arawomo, G.A.O. (2007) 'Reproductive strategy of Oreochromis niloticus (Pisces: Cichlidae) in Opa reservoir, Ile-Ife, Nigeria', *Revista de biología tropical*, 55, pp. 595–602. Available at: https://doi.org/10.15517/rbt.v55i2.6034.
22. Lawrence Ejeh, I. (2017) 'Fecundity and Egg Size of Clarias Gariepinus in Pandam Lake, Quan-Pan L.G.A.Plateau State, Nigeria'.
23. Mekkawy, I. and Hassan, A. (2011) 'Some Reproductive Parameters of Synodontis Schall (Bloch and Schneider, 1801) from the River Nile, Egypt', *Journal of Fisheries and Aquatic Science*, 6, pp. 456–471. Available at: https://doi.org/10.3923/jfas.2011.456.471.
24. Mitra, A. *et al.* (2023) 'Climate Change and Reproductive Biocomplexity in Fishes: Innovative Management Approaches towards Sustainability of Fisheries and Aquaculture', *Water*, 15(4), p. 725. Available at: https://doi.org/10.3390/w15040725.
25. Offem, B., Ayotunde, E.O. and Ikpi, G. (2008) 'Dynamics in the Reproductive Biology of Heterobranchus longifilis Val, (Pisces: 1840) in the Inland Wetlands of Cross River, Nigeria', in. Available at: https://www.semanticscholar.org/paper/Dynamics-in-the-Reproductive-Biology-of-longifilis-Offem-Ayotunde/14b87df7dd835d273d0cd3bba967b386b6f34bca (Accessed: 12 February 2024).
26. Offem, B., Yemi, A.-S. and Tunde, O. (2010) 'Biological assessment of Oreochromis niloticus (Pisces: Cichlidae; Linne, 1958) in a tropical floodplain river', *African Journal of Biotechnology (ISSN: 1684-5315) Vol 6 Num 16*, 6. Available at: https://doi.org/10.5897/AJB2007.000-2300.
27. Olanrewaju, A.N. *et al.* (2017) 'Length-weight Relationships and State of Well-being of Parachanna obscura Gunther1861, in Eleyele Reservoir, Southwestern Nigeria', *Fisheries and Aquaculture Journal*, 8(3), pp. 1–9.
28. Olele, N.F. (2010) 'Reproductive biology of Sarotherodon galilaeus (Artedi, 1757) in Onah Lake, Delta State, Nigeria.', *The Journal of Applied Sciences Research* [Preprint]. Available at: https://www.semanticscholar.org/paper/Reproductive-biology-of-Sarotherodon-galilaeus-in-Olele/93c74bc0dee7e64b0d680e95abfadb2c2bc2595f (Accessed: 12 February 2024).
29. Olyott, L.J.H., Sauer, W.H.H. and Booth, A.J. (2006) 'Spatio-temporal patterns in maturation of the chokka squid (Loligo vulgaris reynaudii) off the coast of South Africa', *ICES Journal of Marine Science*, 63(9), pp. 1649–1664. Available at: https://doi.org/10.1016/j.icesjms.2006.06.011.
30. Oo, F. and Arawomo, G.A.O. (2000) 'Fecundity of Sarotherodon galilaeus (Pisces: Cichlidae) in the Opa reservoir, Ile-Ife, Nigeria', *Revista de Biología Tropical*, 48, pp. 201–204.
31. Peña-Mendoza, B. *et al.* (2005) 'Reproductive biology of Oreochromis niloticus (Perciformes: Cichlidae) at Emiliano Zapata dam, Morelos, Mexico', *Revista De Biologia Tropical*, 53(3–4), pp. 515–522. Available at: https://doi.org/10.15517/rbt.v53i3-4.14666.
32. Pham, C.K. *et al.* (2009) 'First description of spawning in a deep water loliginid squid, Loligo forbesi (Cephalopoda: Myopsida)', *Journal of the Marine Biological Association of the United Kingdom*, 89(1), pp. 171–177. Available at: https://doi.org/10.1017/S0025315408002415.
33. Pitman, L., Haddy, J.A. and Kloser, R. (2014) 'Fishing and fecundity: The impact of exploitation on the reproductive potential of a deep-water fish, orange roughy (Hoplostethus atlanticus)', *Fisheries Research*, 155, pp. 196–197. Available at: https://doi.org/10.1016/j.fishres.2013.06.008.
34. Postuma, F.A. and Gasalla, M.A. (2014) 'Reproductive activity of the tropical arrow squid *Doryteuthis plei* around São Sebastião Island (SE Brazil) based on a 10-year fisheries monitoring', *Fisheries Research*, 152, pp. 45–54. Available at: https://doi.org/10.1016/j.fishres.2013.12.011.
35. Roberts, B.H. *et al.* (2021) 'Faster juvenile growth promotes earlier sex change in a protandrous hermaphrodite (barramundi Lates calcarifer)', *Scientific Reports*, 11, p. 2276. Available at: https://doi.org/10.1038/s41598-021-81727-1.
36. Rodrigues, A.R. and Gasalla, M.A. (2008) 'Spatial and temporal patterns in size and maturation of Loligo plei and Loligo sanpaulensis (Cephalopoda: Loliginidae) in southeastern Brazilian waters, between 23°S and 27°S', *Scientia Marina*, 72(4), pp. 631–643. Available at: https://doi.org/10.3989/scimar.2008.72n4631.
37. Saidi, A. *et al.* (2022) 'Drivers of fish choice: an exploratory analysis in Mediterranean countries', *Agricultural and Food Economics*, 10(1), p. 29. Available at: https://doi.org/10.1186/s40100-022-00237-4.
38. Sánchez, P. and Demestre, M. (2010) 'Relationships between somatic tissues, reproductive organs and fishing

season in the commercially exploited European squid *Loligo vulgaris* from the western Mediterranean Sea', *Fisheries Research*, 106(2), pp. 125–131. Available at: https://doi.org/10.1016/j.fishres.2010.08.002.

39. Sh, K.A. and Salama, H.M. (2008) 'Investigations on Some Aspects of Reproductive Biology in Oreochromis niloticus (Linnaeus, 1757) Inhabited Abu-zabal Lake, Egypt', in. Available at: https://www.semanticscholar.org/paper/Investigations-on-Some-Aspects-of-Reproductive-in-Sh-Salama/6d74ad0785f932726c0b72532cab60f7fc00b72b (Accessed: 12 February 2024).
40. Shoesmith, E. (1990) 'A comparison of methods for estimating mean fecundity', *Journal of Fish Biology*, 36(1), pp. 73–84. Available at: https://doi.org/10.1111/j.1095-8649.1990.tb03521.x.
41. Tolulope, A. and Oo, F. (2014) 'Seasonal distribution and Condition factor of Clarias gariepinus from polluted Oluwa River, Nigeria', *IOSR Journal of Pharmacy and Biological Sciences*, 9, pp. 86–93. Available at: https://doi.org/10.9790/3008-09418693.
42. Tsadu, S.M., Lamai, S.L. and Oladimeji, A.A. (2003) 'Sexual maturity, fecundity and egg size of wild and cultured samples of Bagrus bayad macropterus', in. *16th Annual Conference of the Fisheries Society of Nigeria (FISON)*, pp. 112–126. Available at: http://hdl.handle.net/1834/21316 (Accessed: 12 February 2024).