Journal of
# Fisheries and Aquatic Science

ISSN 1816-4927

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Journal of Fisheries and Aquatic Science

ISSN 1816-4927
DOI: 10.3923/jfas.2017.106.116

# Research Article
# Reproductive Biology and Life History Patterns of the Claroteid, *Chrysichthys nigrodigitatus* (Lacépède: 1803) from a Man-made Lake in Southern Benin

[1]Alphonse Adite, [1]Houehanou Megnisse G.A. Gbaguidi and [2]Jean-Marc Ategbo

[1]Laboratory of Ecology and Aquatic Ecosystem Management (LEMEA), Department of Zoology, Faculty of Sciences and Technics, Abomey-Calavi University, BP 526 Cotonou, Benin
[2]Department of Animal Physiology, Faculty of Sciences and Technics, Abomey-Calavi University, BP 526 Cotonou, Benin

## Abstract

**Background and Objective:** The success of aquaculture and fisheries management of introduced key species requires knowledge on spawning biology. This study aimed to document the reproductive biological traits of *Chrysichthys nigrodigitatus* from a sand-dragged artificial lake. **Methodology:** During 15 months, about 1020 individuals were sampled and examined for its spawning characteristics. Sex ratio, gonadosomatic index (GSI), lengths at first sexual maturity ($L_{50}$) and batch fecundity ($F_b$) were computed and one-way ANOVA was performed using SPSS computer software. **Results:** *Chrysichthys nigrodigitatus* was a prominent species in Lake Ahozon and numerically made about 11.22% of the fish assemblages. The population was dominated by females (67.84%) and showed a sex-ratio of 1:2.1. A delayed maturation was recorded and lengths at sexual maturity ($L_{50}$) were 20 and 17 cm TL for males and females, respectively. In Lake Ahozon, *C. nigrodigitatus* spawned all seasons with a peak between April-June. Batch fecundities ($F_b$) ranged between 350-26040 eggs and significantly ($p<0.05$) increased with total length ($F_b = 0.314TL^{3.023}$, r = 0.81) and body weight ($F_b = 31.50B_W-203$, r = 0.74). Egg diameters ranged between 0.30-3.10 mm and frequency distributions evidenced the production of multiple cohorts of eggs with an important stock of offsprings for recruitment. *Chrysichthys nigrodigitatus* displayed a life history strategy closer to "k" selected that favored its propagation in Lake Ahozon. **Conclusion:** It is concluded that *C. nigrodigitatus* is a multiple spawner that reproduces all seasons in the man-made lake, with a peak in wet periods, April-June. The reproductive traits depicted in this special medium-environment are useful for fisheries management, aquaculture and species conservation.

Key words: Artificial lake, fisheries, "k" selection, $L_{50}$, multiple spawner, spawning season

Received: January 14, 2017 Accepted: March 27, 2017 Published: April 15, 2017

Citation: Alphonse Adite, Houehanou Megnisse G.A. Gbaguidi and Jean-Marc Ategbo, 2017. Reproductive biology and life history patterns of the claroteid, *Chrysichthys nigrodigitatus* (Lacépède: 1803) from a Man-made lake in Southern Benin. J. Fish. Aquat. Sci., 12: 106-116.

Corresponding Author: Alphonse Adite, Laboratory of Ecology and Aquatic Ecosystem Management (LEMEA), Department of Zoology, Faculty of Sciences and Technics, Abomey-Calavi University, BP 526 Cotonou, Benin



Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Knowledge on the reproductive biology and life history strategy of tropical fishes is crucial to evaluate population structure, potential of recruitment, species establishment, species ecological status and management needs[1-3]. In the Benin water bodies, *Chrysichthys* (Pisces: Siluriformes: Claroteidae) species are of high commercial and economic importance and consistently supports inland artisanal fisheries where this taxa contributed to about 7-26% of fish productions[4,5]. In Benin, the genus *Chrysichthys* consists of four known species, *C. walkeri*, *C. jonhelsi*, *C. auratus* and *C. nigrodigitatus*, the dominant species occurring in most Benin aquatic ecosystems[6]. Indeed, *C. nigrodigitatus* is moreless abundantly found in natural water bodies such as mangrove habitats, coastal lagoons, estuaries, freshwater lakes, creeks, streams and rivers where the stock is currently declining due to environmental degradations and overfishing[7]. Therefore, a short term solution to cope with stock decline and species recovery is to develop the aquaculture of this highly consumed claroteid in order to reduce the fishing pressures and to increase the grassroot income[8].

In Southern Benin, *C. nigrodigitatus* was introduced in a sand-dragged man-made Lake Ahozon and presently, as reported by Gbaguidi *et al.*[9], appears to be the second most prominent and dominant species in this water body after the cichlid *Sarotherodon galilaeus* and numerically accounting for about 11.22% of the lake's fish community. In natural inland waters, such as lake Nokoué, a coastal brackishwater of Benin, the lengths at sexual maturity of *C. nigrodigitatus* were 30.3 and 29.3 cm TL for males and females, respectively[10]. Offem *et al.*[11] reported that *C. nigrodigitatus* males and females from the Cross River in Nigeria matured at 11.5 and 16.7 cm TL, respectively. In Lake Ahozon, this claroteid foraged intensively on aquatic insects, substrate particles, detritus, seeds, algae, showed an opportunistic benthic and pelagic food habit and exhibited an allometric growth[7,12].

Despite its abundance and prominence in the sand-dragged artificial Lake Ahozon, nothing is known about the reproductive ecology and life history patterns of *C. nigrodigitatus* in this man-made water body considered as a non-conventional medium-environment for fish culture. However, in this special habitat, knowledge on the spawning biology is badly needed to develop an ecological sound fisheries/aquaculture management scheme.

Furthermore, though *C. nigrodigitatus* has a high potential in aquaculture, it does not reproduce or barely reproduce in captivity in small fishponds[7]. To date, very few scientific data is available on the captive breedings and artificial reproduction of *C. nigrodigitatus* for successful fisheries management and to provide fingerlings for fish culture centers. Therefore, the numerous abandoned and unmanaged sand-dragged man-made lakes (exemple: Lake Ahozon) throughtout the country could serve as alternative medium-environments and could be valorized for the developpement of *C. nigrodigitatus* aquaculture and particularly to serve as spawning and nursery grounds. In contrast with small fish ponds, the physical traits of such medium-environments, such as the relatively high water space and the successions of low-water and high-water seasons that stimulate gonad maturations and egg hatchings are some favorable conditions for the breeding success and the propagation of *C. nigrodigitatus* in the artificial Lake Ahozon[7]. Hence, this investigation will help to fill the gap of biological information needed to valorize the species in a sand-dragged man-made lake.

This study aimed to document the reproductive biology and life history characteristics of *C. nigrodigitatus* introduced in the sand-dragged man-made Lake Ahozon, in order to evaluate species propagation and establishment. Inferences were made on lake's valorization and fisheries/aquaculture development.

## MATERIALS AND METHODS

**Study region description:** The present study was conducted in the sand-dragged man-made Lake Ahozon located at the Southwest Benin (06°22'52"N, 002°10'34"E) in the coastal town of Ouidah. Lake Ahozon (0.165845 $km^2$) is a freshwater ecosystem that lies between the Benin coastal lagoon (60 $km^2$) and the freshwater Lake Toho-Todougba (15 $km^2$), both located about 5 km apart from Lake Ahozon. The Benin Southern region exhibits a sub-equatorial climate characterized by two wet seasons, April to July and mid-September to October and two dry seasons, December to March and August to mid-September. Rainfalls in the study area averaged 1310 mm, with June, the wettest month[13]. During the study period, Lake Ahozon showed depths and transparencies ranging between 16.2-240 cm (average: 80.19 cm) and 16.2-60.5 cm (average: 36.63 cm), respectively. Water temperatures ranged between 28.2-38.7°C (average: 33.25°C) and pH between 6.7-9.7 (average: 7.51). Salinities were nearly 0% and conductivity varied between 50-560 $\mu\ cm^{-1}$ (average: 240 $\mu\ cm^{-1}$). Mean dissolved oxygen was 5.43 mg $L^{-1}$ (range: 0.73-11.8 mg $L^{-1}$) with a mean percentage of saturation of 82.9% (range: 10.5-208.8%)[9].

Lake Ahozon is a neglected and abandoned water body that originated from sand-dragging activities. Like numerous artificial lake throughtout the country, Lake Ahozon is perennial because receives every wet season, an important volume of running waters. The lake was exempt of floating plants and dominant marginal aquatic vegetation were *Cyperus crassipes*, *Fuirena umbellata*, *Andropogon gayanus*, *Ludwigia perennis*, *Emilia praetermissa*, *Eleocharis complanata*, *Cyperus rotundus*, *Enydra fluctuans* and *Mariscus ligularis*[9]. Subsistence artisanal fisheries sporadically took place in Lake Ahozon with five species, *Sarotherodon galilaeus* (Cichlidae), *Oreochromis niloticus* (Cichlidae), *Tilapia guineensis* (Cichlidae), *Heterotis niloticus* (Osteoglossidae), *Clarias gariepinus* (Clariidae) and *C. nigrodigitatus* (Claroteidae), which comprised the lake's fish community[9].

**Sampling site selection:** *Chrysichthys nigrodigitatus* individuals were collected in four sampling sites: Two sites in the "Open water" habitat and two sites in the "Aquatic vegetation" habitat. The "Open water" habitat showed a relatively high depth and high water velocity, but exempt of aquatic vegetation and floating plants whereas, the "Aquatic vegetation", the edge of the lake is shallow with relatively dense vegetation and low water velocity.

***Chrysichthys nigrodigitatus* sampling, identification and morphometrics:** Fish samplings were performed twice a month from August, 2014 to October, 2015 in all habitats and sites using various fishing gears such as hooks (90 m length), seines (4.15 m length$\times$1.77 m width, 3 mm mesh), experimental gill net (40$\times$1.05 m, 40 mm mesh) and cast nets (9.80 m diameter, 4.90 m height, 40 mm mesh)[14]. Samplings were made with the help of fishermen. All subsamples from hooks, gill nets, seining and cast nets were put together by habitat and season to assess the relative abundance of *C. nigrodigitatus* in the fish assemblages of Lake Ahozon.

*Chrysichthys nigrodigitatus* identification was performed first *in situ* using references such as Paugy *et al.*[15]. After identification of each specimen, routine biometric traits such as Total Length (TL), Standard Length (SL) were measured to the nearest 0.1 mm with a measuring board and body weight ($B_W$) was weighted to the nearest 0.1 g with an electronic balance[14]. The fish samples were then preserved in 10% formalin and transported to the "Laboratory of Ecology and Aquatic Ecosystem Management (LEMEA)" and preserved in 90% ethanol for further observation.

**Laboratory analysis:** In the laboratory, preserved specimens were removed from the ethanol and dissected. Gonads of individual fish were removed from the abdominal region and length and width were measured with a vernier caliper ruler to the nearest 0.1 mm and weighted with an electronic balance to the nearest 0.1 g. Sexes were differentiated by observing anal and genital openings, the form of the head and gonads. Testis and ovary maturation stages were determined according to the modified Honji *et al.*[16] maturation scale that includes stages like (1) Immature, (2) Initial maturity, (3) Maturing, (4) Ripe, (5) Spent and (6) Recovering-spent. In addition, pressure was applied to the ventral abdominal wall to determine if gonads were fully mature[2]. Ovarian structure was appreciated by estimating batch fecundities and by constructing the frequency histograms of egg diameters. Thus, three subsamples of ovary (anterior, middle and posterior) were considered. For each subsample, the eggs were separated with a dissecting needle and counted. The batch fecundity was then expressed as following Eq. 1:

$$F_b = W \times \frac{N_1 + N_2 + N_3}{W_1 + W_2 + W_3} \tag{1}$$

where, $F_b$ is the batch fecundity, W is the total ovary weight, $W_1$, $W_2$ and $W_3$ are the weight of each subsample and $N_1$, $N_2$ and $N_3$ are subsample egg counts. In *C. nigrodigitatus* the oocytes showed an ovoid form comprising two dimensions, $d_1$ and $d_2$, measured with a calibrated eyepiece micrometer mounted to a dissecting stereomicroscope. Therefore, the theoric diameters (d) utilized to construct the frequency histograms of egg diameters were the geometric means (d) of $d_1$ and $d_2$, expressed as following Eq. 2:

$$d = (d_1 \times d_2)^{0.5} \tag{2}$$

**Data analysis:** All quantitative and qualitative biological collected data was recorded in Excel spreadsheet and analyzed with SPSS computer package version 17.0[17]. The size structure of *C. nigrodigitatus* population was examined by constructing the frequency histograms of Standard Length (SL) intervals. Ontogenetically, the three life stage categories (Juveniles, subadults and adults) were determined based on the smallest mature individual and the length at first sexual maturation[14]. Thus, juvenile, subadult and adult subpopulations included individuals of SL<110 mm, SL between 100-130 mm and SL>130 mm, respectively. Length-weight relationship was performed by establishing the logarithm-transformed linear model expressed as following Eq. 3[18]:

$$\text{Log}_{10} B_W = a + b\text{Log}_{10}TL \tag{3}$$

where, $B_W$ is the body weight (dependant variable), TL is the total length (independant variable), a is a constant and b is the slope or the allometry coefficient. One-way analysis of variance (ANOVA) was performed to test significance in slope. The sex ratio (1: r), the number of females (r) for one male was estimated by counting the number of males and females that constituted the population. Changes in population reproductive maturity were evaluated by computing the Gonado-Somatic Index (GSI) for both genders using the following Eq. 4:

$$GSI = \frac{\text{Gonad weight (G)}}{\text{Body weight (G)}} \times 100 \quad (4)$$

Monthly average GSI was then calculated and trends were examined to determine spawning periodicities of *C. nigrodigitatus* in the man-made Lake Ahozon. The lengths at first sexual maturity ($L_{50}$) for both genders were determined by plotting first the percentage of mature fish against their Total Length (TL) and by fitting a sigmoid curve to the scatter plot[19]. Then, the lengths ($L_{50}$) at which 50% of the individuals (adults/genitors) were mature and estimated from the sigmoid curve constructed[9]. In this study, ovaries and testes at stages (2) Initial maturity, (3) Maturing and (4) Ripe of the maturation scale were considered as sexually matures and were utilized to construct the sigmoid curve[19].

Also, for flood, dry and wet seasons, a ripe ovary was randomly selected and frequency histograms of egg diameters were constructed to examine egg maturation and cohort production trends[19]. Batch fecundity ($F_b$) was estimated for ripe ovaries and allometric relationships between fecundity and body length were examined by following Eq. 5[20]:

$$F_b = a_1 TL^{b1} \quad (5)$$

where, $F_b$ is the fecundity, TL is the total length, $a_1$ is a constant and $b_1$ is the allometry exponent. In addition, the linear relationship between fecundity and body weight was examined by following Eq. 6[20]:

$$F_b = b_2 B_W + a_2 \quad (6)$$

where, $F_b$ is the fecundity, $B_W$ is the body weight, $b_2$ is the slope and $a_2$ is the intercept.

## RESULTS

**Population characteristics:** *Chrysichthys nigrodigitatus* has been introduced in the artificial Lake Ahozon by the fishermen on December, 2011 in order to valorize this abandoned water body and to get substantial revenues. Current ichthyolgical surveys indicated that numerically, this species made about 11.22% of the fish community and total weight reached 29.40% of the lake's fish biomass. Consequently, this claroteid appeared to be the second dominant species after the tilapine cichlid, *Sarotherodon galilaeus* which numerically made 85.21% of Lake's Ahozon fish community.

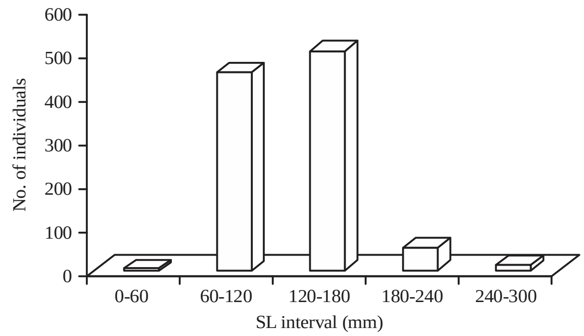


Fig. 1: Length frequency distributions of *Chrysichthys nigrodigitatus* (N = 1020) from the artificial Lake Ahozon

In Lake Ahozon, of 1020 individuals collected, 322 (31.57%) were males, 692 (67.84%) were females and 06 (0.59%) immature individuals were undetermined for genders. These results corresponded to a sex-ratio of 1:2.1, suggesting that in this sand-dragged water body, females consistently dominated the population of *C. nigrodigitatus*. Overall, the fish assemblages showed Standard Lengths (SL) varying from 52 mm (67 mm TL) to 285 mm (324 mm TL) and individual weight ranged between 3.6-456.1 g. Standard Length (SL) frequency histogram established for the whole population showed unimodal size distributions (Fig. 1). Ontogenetically, the three life stage categories (juveniles, subadults and adults) abundances that were determined based on the smallest mature individual and the lengths at first sexual maturity ($L_{50}$)[21], made respectively 20.49, 59.61 and 19.9% of the population. Linear regression performed between $\log_{10}$ (total length = TL) and $\log_{10}$ (body weight = $B_W$) gave a positive slope b = 2.99 (nearly b = 3), with a significant ($p \leq 0.01$) determination coefficient $r^2 = 0.92$, indicating that, in Lake Ahozon, *C. nigrodigitatus* exhibited an isometric growth pattern[18].

**Maturation and lengths at sexual maturity:** In Lake Ahozon, the highest proportions of mature females reached 39.58, 43.90 and 55.56% recorded in April, May and June, 2015, respectively. For the remaining months, these percentages

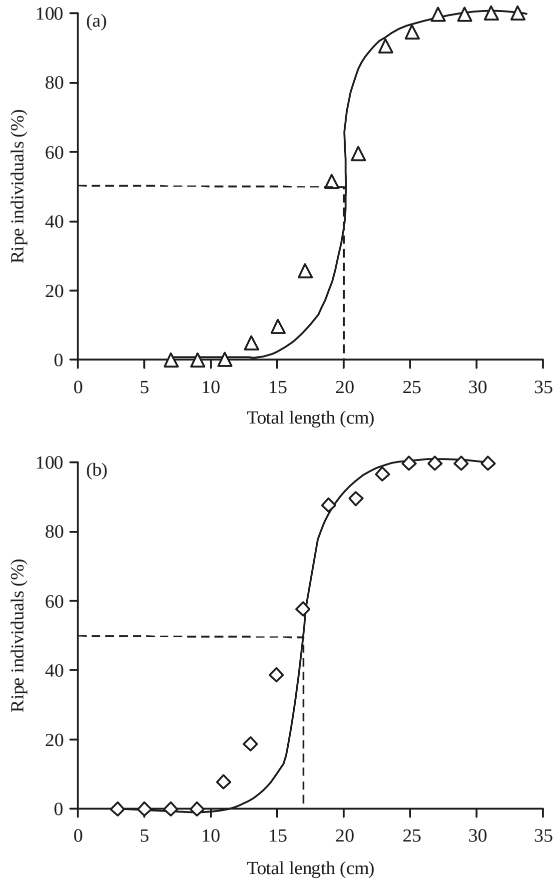


Fig. 2(a-b): Lengths at first sexual maturity ($L_{50}$) of (a) *Chrysichthys nigrodigitatus* males ($L_{50}$: 20 cm TL) and (b) *Chrysichthys nigrodigitatus* females ($L_{50}$: 17 cm TL) from the artificial Lake Ahozon

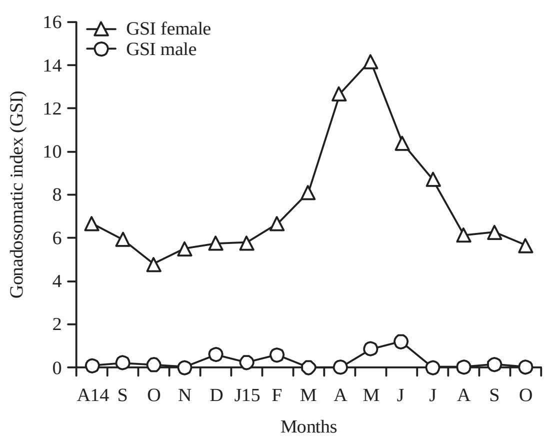


Fig. 3: Monthly variations of gonadosomatic index (GSI) of *Chrysichthys nigrodigitatus* males and females from the artificial Lake Ahozon

were moderate and ranged between 22.1-30%. In males, mature individuals were abundant in May and June, 2015 and reached 30.18 and 15.20%, respectively. The smallest mature male measured 132 mm TL (105 mm SL, $B_W$ = 37.8 g, GSI = 0.08) and the smallest mature female recorded measured 114 mm TL (90 mm SL, $B_W$ = 22.2 g, GSI = 3.60). Lengths at first sexual maturity ($L_{50}$) for *C. nigrodigitatus* males and females and extrapolated from sigmoid curves were about 20 and 17 cm TL, respectively (Fig. 2). In general, for both genders, the percentage of ripe testes and ripe ovaries significantly increased with Total Length (TL) to reach nearly 100% at length 270-324 mm TL for males and 230-308 mm TL for females. Indeed, for both genders, regressions lines fitted to the scatter plots of mature individuals against TL showed significant ($p<0.01$) positive slopes and linear regressions Eq. 7 and 8 for males and females were:

$$Y_{mm} = 5.001TL-45.95 \ (R^2 = 0.92, N = 14) \tag{7}$$

and:

$$Y_{mf} = 4.78TL-27.47 \ (R^2 = 0.89, N = 15) \tag{8}$$

where, $Y_{mm}$ and $Y_{mf}$ were the percentage of mature males and mature females, respectively.

In male subpopulation, Gonado-Somatic Indexes (GSI) were relatively low and varied between 0.004 (fish: TL = 276 mm, SL = 232 mm, $B_W$ = 258.9 g) and 5.74 (fish: TL = 152 mm, SL = 120 mm, $B_W$ = 38.3 g) with a mean GSI of 0.25±0.79. Also, monthly mean GSI ranged between 0.005-1.20 recorded in October, 2015 and July, 2015, respectively (Fig. 3). In males, GSIs were reduced from August to November, 2014 with values between 0.005-0.21 corresponding to stages spent and spent-recovering of the maturation scale, then increased from December, 2014 and peaked in May-June, 2015 at stage Mature with GISs between 0.86-1.20.

In female subpopulation, GSIs were relatively high and ranged between 0.41 (fish: TL = 205 mm, SL = 160 mm, $B_W$ = 97.4 g) and 16.07 (fish: TL = 243 mm, SL = 199 mm, $B_W$ = 211g ) with a mean of 7.27±4.53. Monthly averages were relatively high all months and ranged between 4.81-14.18 recorded in October, 2014 and May, 2015, respectively (Fig. 3). In general, GISs in females decreased from August-October, 2014 and remained nearly stable until January, 2015 at stages spent and spent-recovering of the maturation scale, then increased from January, 2015 to reach a peak of 14.18 in May, 2015 before decreasing again until October, 2015.

Table 1: Mean, range and relative fecundities of *C. nigrodigitatus* by length classes from the artificial Lake Ahozon

| TL class | N | Mean body weight (g) | Mean ovary weight (g) | Mean fecundity | Fecundity range | No. of eggs/gram ovary | Relative fecundity | Mean GSI |
|---|---|---|---|---|---|---|---|---|
| 110-160 | 44 | 38.23 | 2.59 | 1160 | 350-5292 | 448 | 30.33 | 6.85 |
| 160-210 | 26 | 67.87 | 4.93 | 2186 | 350-1832 | 443 | 32.21 | 6.88 |
| 210-260 | 10 | 185.06 | 13.83 | 3480 | 1881-6356 | 252 | 18.80 | 7.85 |
| 260-310 | 12 | 316.14 | 25.45 | 10434 | 4271-26040 | 410 | 33.01 | 9.15 |
| Total | 92 | 98.82 | 7.45 | 2912 | 350-26040 | 391 | 29.47 | 7.27 |

Table 2: Seasonal variations of mean egg diameters of *Chrysichthys nigrodigitatus* from the artificial Lake Ahozon, Southern Benin

| Season | Sampling date | Specimen fecundity | Maturation stage | GSI | Mean egg diameter (mm) | Egg diameter range | ±SD |
|---|---|---|---|---|---|---|---|
| Flood | 08-13-2015 | 5292 | Spent | 5.19 | 1.10 | 0.30-1.75 | 0.22 |
| Dry | 01-31-2015 | 26040 | Ripe | 11.79 | 1.74 | 0.89-2.90 | 0.32 |
| Wet | 07-14-2015 | 3923 | Ripe | 9.65 | 1.45 | 0.35-2.24 | 0.27 |
| Lake's mean | - | 2912* | - | 7.27* | 1.43* | 0.30-3.10 | 0.37 |

*Mean for Lake Ahozon

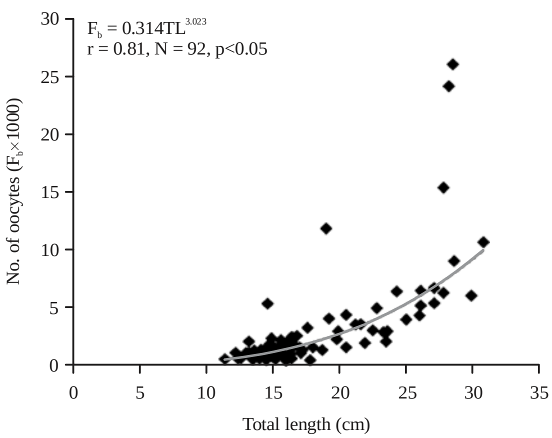


Fig. 4: Power relationship between batch fecundity ($F_b$) and total length (TL) of *Chrysichthys nigrodigitatus* from Lake Ahozon

In both males and females, gonado-somatic indexes varied with seasons. Indeed, males showed higher mean gonado-somatic index during wet (GSI = 0.68) and dry (GSI = 0.37) seasons, whereas, lower GSI = 0.09 was recorded during the flooding. The same trends were recorded for females exhibiting higher mean gonado-somatic index during wet (GSI = 10.08) and dry (GSI = 9.37) periods whereas, reduced mean GSI = 5.87 was recorded during the high-water season.

**Fecundity:** Fecundity was measured as the total number of oocytes in the ovary. In Lake Ahozon, *C. nigrodigitatus* showed batch fecundities varying between 350 eggs for a mature specimen of 178 mm TL (SL = 157 mm, $B_W$ = 88.3 g, GSI = 1.47) and 26040 eggs for a specimen of 285 mm TL (SL = 223 mm, $B_W$ = 368 g, GSI = 11.79). The population mean fecundity was 2912 ±4210 eggs and relative fecundities, the number of eggs per gram of body mass, ranged between 18.80-33.01 $g^{-1}$ for TL ranges of 210-260 and 260-310 mm, respectively (Table 1). Average number of eggs per gram ovary was 391 for the population and no specific trends were recorded with body size (Table 1). However, mean ovary weight tended to increase with body size. In general, power curve fitted to total length–fecundity scatter plot and linear regression fitted to body weight–fecundity scatter plot showed that batch fecundity ($F_b$) significantly ($p<0.05$) increased with Total Length (TL) and body weight ($B_W$) (Fig. 4, 5). The power and regression equations were $F_b = 0.314TL^{3,023}$ (r = 0.81, N = 92, $p<0.05$) and $F_b$ = 31.50 $B_W$-203 (r = 0.74, N = 92, $p<0.05$), respectively, with r, the correlation coefficient and N the number of ripe females.

**Ovarian structure and egg diameters:** Theoric diameters (geometric means) were computed to appreciate the ovarian structure because *C. nigrodigitatus* eggs display an ovoid shape. Overall, regardless of seasons, egg diameters ranged between 0.30 and 3.10 mm. Also, seasonal variations were observed with diameters varying between 0.30-1.75 mm (mean = 1.10±0.22), 0.89-2.24 mm (mean = 1.74±0.32) and 0.35-3.10 mm (mean = 1.45±0.27) during flood, dry and wet seasons, respectively (Table 2). Likewise diagrams of frequency distributions of egg diameters in ripe females (Fig. 6-8) indicated unimodal distributions of egg sizes during flood, dry and wet periods.

As shown by the histograms of egg diameter frequency distributions, a single ovary included groups of oocytes at immature stage (diameter <0.25 mm), initial maturity stage (diameter between 0.25-0.75 mm) and at mature stage (diameter >1.75 mm), indicating the production of multiple cohorts of eggs and offsprings during breeding seasons.

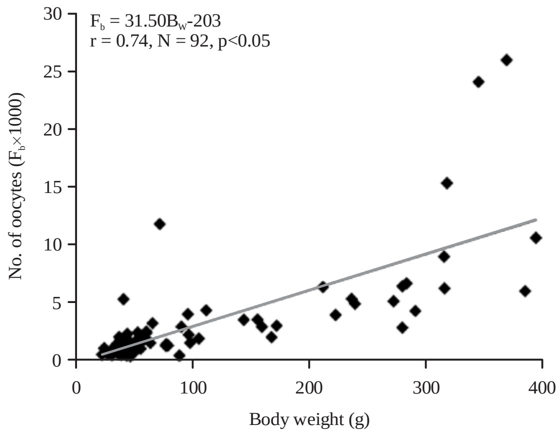


Fig. 5: Linear model between batch fecundity ($F_b$) and body weight ($B_W$) of *Chrysichthys nigrodigitatus* from Lake Ahozon

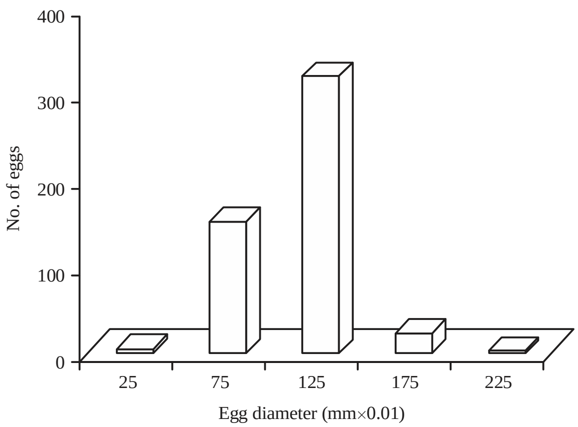


Fig. 6: Egg diameter frequency distributions of *Chrysichthys nigrodigitatus* sampled in lake Ahozon during the flooding season

Fish: TL = 14.6 cm, GSI = 5.19, Fecundity = 5292

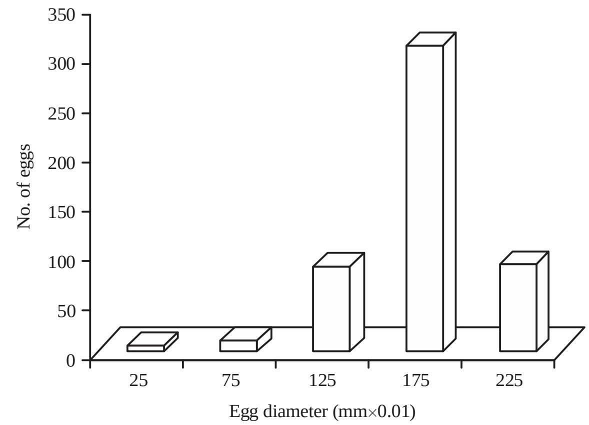


Fig. 7: Egg diameter frequency distributions of *Chrysichthys nigrodigitatus* sampled in Lake Ahozon during the dry season

Fish: TL = 28.5 cm, GSI = 11.79, Fecundity = 26040

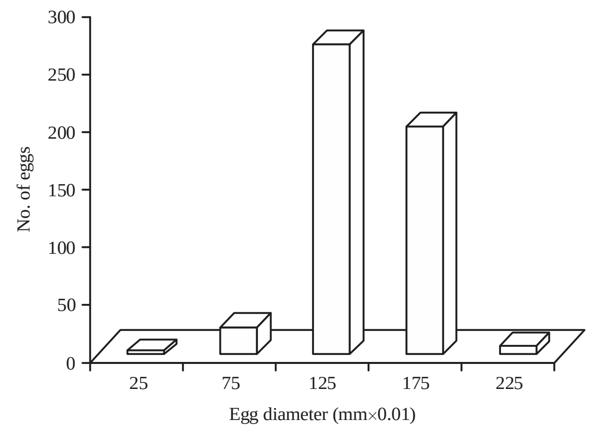


Fig. 8: Egg diameter frequency distributions of *Chrysichthys nigrodigitatus* sampled in Lake Ahozon during the wet season

Fish: TL = 25 cm, GSI = 9.65, Fecundity = 3923

## DISCUSSION

The current study documented aspects of the reproductive biology of *C. nigrodigitatus* and gave useful data for habitat protection, species conservation[7], fisheries management and fish culture in the man-made Lake Ahozon. Especially in fish culture, *C. nigrodigitatus* is known to barely reproduce in captivity in small fish ponds[7] and hence, the spawning traits depicted in this study indicated that Lake Ahozon was suitable for the propagation and the overall establishment of this introduced claroteid.

Lake Ahozon is an artificial sand-dragged water body that showed a favorable water quality[9,14]. In this alternative medium-environment, *C. nigrodigitatus* reproduce actively and appeared to be the second dominant species by making numerically about 11.22% of the lake's fish community. This relative abundance depicted is comparable to those recorded in the Benin Southern natural water bodies (Lake Nokoué, Porto-Novo lagoon, lake Ahémé, Coastal lagoon, Toho-Todougba) where the genus *Chrysichthys* made about 7-26% of the total inland fish production[4,5]. These findings are also similar to 10% reported by Eyo *et al.*[20] in the Cross River Estuary of Nigeria and 13.09% reported by Adaka *et al.*[22] in the Imo River of Nigeria. These results suggested that the man-made Lake Ahozon was a suitable medium-environment for the proliferation of *C. nigrodigitatus* which was perfectly established in this special habitat with abundances nearly close to those displayed by some natural inland waters. In contrast, the abundance recorded in Lake Ahozon was lower than 23.9% reported by Olaniran and Adeniran[23] for *C. nigrodigitatus* from Ogbomoso reservoir in the South-Western of Nigeria.

Indeed the study consistently showed a successful spawning and recruitment of *C. nigrodigitatus* in Lake Ahozon and all ovary maturation stages, immature, initial maturation, maturing, ripe, spent and recovering spent were recorded in the sample collected. In addition, the population was composed of all life stage categories, juveniles (20.49%), subadults (59.61%) and adults/reproductors (19.90%) suggesting that *C. nigrodigitatus* actively reproduced in Lake Ahozon. As results, with respect to environmental quality, a long-term viability of the population is garanted, indicating that Lake Ahozon could serve to provide seeds (juveniles) for aquaculture units and centers.

In both males and females, *C. nigrodigitatus* matured at relatively higher sizes and lengths at first sexual maturation ($L_{50}$) in Lake Ahozon were estimated at 20 and 17 cm TL, respectively (Fig. 2), corresponding nearly to 2 years old[24]. Similar findings of delayed maturation were reported by Laleye *et al.*[10] in Lake Nokoué, a coastal lagoon of Benin where *C. nigrodigitatus* males and females reached sexual maturity ($L_{50}$) at 30.3 and 29.3 cm TL, respectively. In the Cross River of Nigeria, Offem *et al.*[11] estimated a length at first sexual maturity at 16.7 cm TL for *C. nigrodigitatus* females. A delayed maturation was also reported by Yougone Bi[24] in the wild where these claroteid spawned at 3 years old (33 cm TL). These high disparities in the lengths of sexual maturity of *C. nigrodigitatus* were probably due to the stochasticity of the environmental condition and the variability in food resources availability of these habitats[19,21]. Indeed, females inhabiting low productive aquatic ecosystems often mature at smaller size than conspecific females living in highly productive ecosystems[24].

In Lake Ahozon, a great variability was recorded in the gonadosomatic index for both males (GSI: 0.004-5.74) and females (GSI: 0.41-16.07) during the study period. Also, monthly GSIs showed significant ($p<0.01$) variations in both genders (Fig. 3). Offem *et al.*[11] and Daniel and Sambo[25] reported similar findings in the Cross River of Nigeria whereas in Lake Nokoue, the maximum value recorded by Laleye[10] for *C. nigrodigitatus* females was GSI = 6.5, lower than our findings. Inversely, one-way analysis of variance (ANOVA) on GSIs across the three seasons (flood, dry and wet) did not show any significant ($p\geq0.05$) seasonal variations in both males and females. The computed F-values, along with degrees of freedom and p-values were $F_{2,14} = 3.641$, $p = 0.069$ for males and $F_{2,14} = 3.609$, $p = 0.071$ for females. Nevertheless, males showed higher mean gonadosomatic index during wet season (GSI = 0.68) and dry season (GSI = 0.37). The same trends were recorded for females showing higher mean gonadosomatic index during wet (GSI = 10.08) and dry season (GSI = 9.37). These results, with respect to hydrologic regime and water quality, indicated that in the artificial Lake Ahozon, *C. nigrodigitatus* reproduced all seasons with a peak in wet period (April-June), the optimal spawning season. This spawning period trend is also shown by the relatively high percentage of mature eggs (Fig. 6-8) recorded during flood, dry and wet periods, confirming that *C. nigrodigitatus* spawn all seasons in Lake Ahozon.

In fishes, fecundity is an important biological attribute utilized to evaluate the reproductive capacity of a species[26]. Also used as criteria to evaluate population dynamic in fishery and aquaculture sciences, fecundity appeared to be an important tool to design a suitable fisheries and aquaculture management scheme [20]. In Lake Ahozon, batch fecundity ($F_b$) varied between 350-26040 eggs and significantly ($p<0.05$) increased with total length ($r = 0.81$, $p<0.05$) and body weight ($r = 0.74$, $p<0.05$) (Fig. 5, 6). As reported by Eyo[20], these findings indicated that larger sizes of *C. nigrodigitatus* contributed to a higher egg numbers and small-sized individuals have a relatively low fecundity. These observed fecundities in Lake Ahozon were also found to be lower than 41,535.9 and 28,675 eggs reported respectively by Daniel and Sambo[25] and Abraham and Akpan[27] for the Cross river population of Nigeria. In contrast, the highest fecundities recorded for *C. nigrodigitatus* from Lake Ahozon were higher than 11,280 eggs, the highest number of eggs reported by Eyo *et al.*[20] in the Cross river Estuary of Nigeria. According to Daniel and Sambo[25] and Okwara[28], fish fecundity could be affected both by environmental conditions and food resources availability. In particular, the relatively great variations in fecundity and associated reproductive features (Table 1) of *C. nigrodigitatus* in Lake Ahozon were probably due to the stochasticity and instability of the ecosystem. Indeed, though favorable for the propagation and establishment of *C. nigrodigitatus* with regard to water quality, flood variations and sand retrieval around lLake Ahozon led to ecosystem perturbation and instability, causing great variations in spawning traits (Table 1). More investigations are required on ecosystem degradation impacts and the spawning ecology of *C. nigrodigitatus* to better understand the variations of these reproductive traits.

Examination of ovarian structure revealed a great variability in egg diameters that ranged between 0.30 and 3.10 mm (mean: $1.46\pm0.38$). One-way analysis of variance on egg diameters across ovaries regardless of seasons showed significant ($p<0.0001$) variations. The computed F-value with degrees of freedom and p-values were $F_{5,2986} = 461.054$, $p = 0.0001$. Likewise, egg diameters significantly varied with seasons (flood, dry and wet). The computed F-value with degrees of freedom and p-values from one-way ANOVA were $F_{2,1491} = 685.304$, $p = 0.0001$. Indeed, mean egg size ($1.10\pm0.22$) was relatively low during the flood season that corresponded more to spent-recovering stage whereas during the dry period, ovaries increased in maturation and the oocytes reached its higher size (mean = $1.74\pm0.32$ mm) and initiated massive reproduction during the wet period with decrease in mean egg size (mean = $1.45\pm0.27$ mm). Also, the significant ($p<0.05$) positive correlations recorded from the linear regressions between Total Length (TL) and mean ovary egg diameter (Egg size = 0.040 TL+0.582; r = 0.91) and between fish weight ($B_W$) and mean ovary egg diameter (Egg size = 0.002 $B_W$+1.191; r = 0.60) showed that egg diameter increased with fish sizes. These results are similar to those reported by Isa *et al.*[29] and Lefler *et al.*[30] which indicated that larger females produce large eggs.

In this study, as shown on the plots of egg diameter frequencies, a single ovary included eggs at different stages (Immature, maturing and ripe) of the maturation scale. The same trends were recorded for ovaries from flood, dry and wet seasons that included oocytes of varying diameters (Fig. 6-8). These findings evidenced the production of multiple cohorts at every spawning season in Lake Ahozon and hence, showed that *C. nigrodigitatus* is a multiple spawner[11,26]. As reported by Oboh *et al.*[26], these life history characteristics imply fractional spawnings and a long breeding season. According to Lefler *et al.*[30] and Teichert *et al.*[31], this biological trait is an adaptation to food resource supply and contributes to the preservation of *Chrysichthys* under harch environmental conditions. More data is needed on temporal variations of ovarian structure and prey availability to confirm this adaptive behavior.

Overall, the reproductive traits depicted during this investigation evidenced that *C. nigrodigitatus* displayed a life history strategy closer to "k-selected" than "r-selected"[32], characterized by a larger body, the highest of 32.4 cm TL observed in Lake Ahozon, but reached 95 cm TL in the New Calabar River from Nigeria[33]. *Chrysichthys nigrodigitatus* matured at relatively higher sizes, 20 and 17 cm TL, respectively for males and females and displayed a delayed maturation which was also reported by Yougone Bi[24] in the wild where this species reproduced at 3 years old at a size of 33 cm TL. *Chrysichthys nigrodigitatus* showed relatively large eggs with diameter varying between 0.30-3.10 mm. This great disparity observed in the egg diameter and maturation stages of a single ovary gave evidence of repeated reproductions in *C. nigrodigitatus*[19] and an indication of multiple cohort productions in Lake Ahozon[21]. The species showed a moderate fecundity ranging between 350 and 26,040 eggs in Lake Ahozon, but reached 41,535.9 eggs in the Lower Cross River in Nigeria[25].

As reported by Adite *et al.*[19], this type of life history pattern is associated with parental care to insure offspring survivorhips, high recruitments and sustainable population viability for the success of fisheries and aquaculture in Lake Ahozon. A sustainable exploitation and conservation of *C. nigrodigitatus* in the artificial Lake Ahozon requires a holistic approach of management including an ecological sound fisheries and aquaculture design, the protection of spawning and nursery grounds and a periodic ecological monitoring of the water body.

## CONCLUSION

This study documented the reproductive biology of *C. nigrodigitatus* in the artificial Lake Ahozon. The study indicated that females and sub adults were preponderant in the population. In Lake Ahozon, the species displayed a delayed maturation and spawned differently all seasons with a peak in wet periods, April-June. *Chrysichthys nigrodigitatus* showed a moderate fecundity, assure the production of multiple cohorts of eggs and provide an important stock of offsprings for recruitment. As results, *C. nigrodigitatus* displayed a life history strategy, closer to "k-selected" than "r-selected", that favored the perfect establishment of this claroteid in Lake Ahozon. An integrated approach of lake management is required to guaranty long-term offspring recruitments and a sustainable fisheries exploitation of *C. nigrodigitatus* in the artificial Lake Ahozon.

## SIGNIFICANT STATEMENTS

This study discovered the spawning characteristics of *Chrysichthys nigrodigitatus* from a non-conventional medium-environment, a sand-dragged man-made lake, which can be beneficial for aquaculturist, fishermen (Fisheries Department and Environmental Protection Agencies). This study will help the researcher to uncover the critical areas of spawning and establishment of delicate species (example: *C. nigrodigitatus*) in a critical habitat and that many researchers were not able to explore. Thus, new findings on species maturation lengths, spawning seasons, fecundity, abundances and recruitment in a sand-dragged man-made lake, may be arrived at.

**ACKNOWLEDGMENTS**

The author would like to thank the Laboratory of Ecology and Aquatic Ecosystem Management (LEMEA), Department of Zoology, Faculty of Sciences and Technics, Abomey-Calavi University for funding this study. Authors are grateful to Mr. Doukpo Célestin, the owner of Lake Ahozon for his collaboration. Authors sincerely thank Mr. Djihouessi Bernold and to Mr. Houessinon Geoffroy for their respective assistances in laboratory works and in fish sampling.

## REFERENCES

1. Wiedmann, M.A., R. Primicerio, A. Dolgov, C.A.M. Ottesen and M. Aschan, 2014. Life history variation in Barents Sea fish: Implications for sensitivity to fishing in a changing environment. Ecol. Evol., 4: 3596-3611.
2. Sossoukpe, E., F.K.E. Nunoo and A. Adite, 2013. Population structure and reproductive parameters of the cassava croaker, *Pseudotolithus senegalensis* (pisces, valenciennes, 1833) in nearshore waters of benin (West Africa) and their implications for management. Int. J. Dev. Res., 3: 37-45.
3. Ajang, R.O., C.B. Ndome, A. Ekwu, E.C. Uttah and C.I. Iboh, 2013. Population dynamics and gillnets selectivity of *Chrysichthys nigrodigitatus* (Lalepede 1803) in lower reaches of the Cross River Estuary, Nigeria. Ethiopian J. Environ. Stud. Manage., 6: 31-40.
4. Direction des Peches du Benin, 2008. Statistics of inland water fisheries: Year 2007. Projet Peche Lagunaire, GTZ-GMBH, Cotonou, Benin.
5. Gbaguidi, A.S. and V. Pfeifer, 2009. Statistics of inland water fisheries: Year: 2008. Services Etudes et Statistiques, Projet Peche Lagunaire, GTZ-GMBH, Direction des Peches-Cotonou, Benin.
6. Adite, A., I. ImorouToko and A. Gbankoto, 2013. Fish assemblages in the degraded mangrove ecosystems of the coastal zone, Benin, West Africa: Implications for ecosystem restoration and resources conservation. J. Environ. Prot., 4: 1461-1465.
7. Gbaguidi, H.M.A.G., A. Adite and Y. Abou, 2017. Trophic ecology and establishment of the silver catfish, *Chrysichthys nigrodigitatus* (Pisces: Siluriformes: Claroteidae) introduced in an artificial pond of Benin. J. Fish. Aquat. Sci., 12: 42-53.
8. Mustapha, M.K., 2010. *Heterotis niloticus* (Cuvier, 1829), a threatened fish species in Oyun Reservoir, Offa, Nigeria: The need for its conservation. Asian J. Exp. Biol. Sci., 1: 1-7.
9. Gbaguidi, H.M.A.G., A. Adite and E. Sossoukpe, 2016. Ecology and fish biodiversity of man-made lakes of southern benin (West Africa): Implications for species conservation and fisheries management. J. Environ. Protect., 7: 874-894.
10. Laleye, P., J.C. Phillipart and P. Poncin, 1995. Reproductive biology of two species of Chrysichthys (Siluriformes, Bagridae) of lake Nokoue and Porto-Novo lagoon in Benin. J. Afr. Zool., 109: 213-224.
11. Offem, B.O., Y. Akegbejo-Samsons and I.T. Omoniyi, 2008. Diet, size and reproductive biology of the silver catfish, *Chrysichthys nigrodigitatus* (Siluformes: Bagridae) in the Cross River, Nigeria. Revista Biologia Tropical, 56: 1785-1799.
12. Asuquo, P.E., U.I. Enin and B.E. Job, 2013. Ontogenetic Variation in the Diet of *Chrysichthys nigrodigitatus* (Lacepede, 1803) in a tropical estuarine ecosystem in Nigeria. J. Fish. Aquatic Sci., 8: 172-177.
13. ASCENA., 2010. Climate and hydrology. Agence pour la Securite de la Navigation Aerienne, Service de la Mereorologie Nationale, Cotonou.
14. Gbaguidi, H.M.A.G. and A. Adite, 2016. Abundance, length-weight relationships and Fulton's condition factor of the freshwater cichlid *Sarotherodon galilaeus* (Pisces: Teleostei: Perciformes) from a sand-dragged man-made lake of Southern Benin, West Africa. J. Biodivers. Environ. Sci., 8: 75-87.
15. Paugy, D., C. Leveque, I. Mouas and S. Lavoue, 2015. African Fishes and Poeple of Water. IRD Editions, Marseille, ISBN: 9782709917117, Pages: 320.
16. Honji, R.M., A.M. Vaz-dos-Santos and C.L.D.B. Rossi-Wongtschowski, 2006. Identification of the stages of ovarian maturation of the Argentine hake *Merluccius hubbsi* Marini, 1933 (Teleostei: Merlucciidae): Advantages and disadvantages of the use of the macroscopic and microscopic scales. Neotrop. Ichthyol., 4: 329-337.
17. Morgan, G.A., N.L. Leech, G.W. Gloeckner and K.C. Barrett, 2012. IBM SPSS for Introductory Statistics: Use and Interpretation. 5th Edn., Routledge, New York, ISBN-13: 978-1848729827, Pages: 256.
18. Migiro, K.E., E.O. Ogello and J.M. Munguti, 2014. The length-weight relationship and condition factor of Nile Tilapia (*Oreochromis niloticus* L.) broodstock at Kegati aquaculture research station, Kisii, Kenya. Int. J. Adv. Res., 2: 777-782.
19. Adite, A., K.O. Winemiller and E.D. Flogbe, 2006. Population structure and reproduction of the African bonytongue *Heterotis niloticus* in the So River-floodplain system (West Africa): Implications for management. Ecol. Freshwater Fish, 15: 30-39.
20. Eyo, V.O., A.P. Ekanem, G. Eni and A.P. Edet, 2013. Relationship between fecundity and biometric indices of the silver catfish *Chrysichthys nigrodigitatus* (Lacepede) in the Cross River Estuary, Nigeria. Croatian J. Fisher., 71: 131-135.

21. Gbaguidi, H.M.G.A. and A. Adite, 2016. Reproductive ecology and establishment of naturally colonized tilapine cichlid, *Sarotherodon galilaeus* (Pisces: Actinopterigii: Perciformes) from a man-made lake, Southern Benin, West Africa: Implications for sustainable fisheries and aquacultural valorization. Int. J. Fish. Aquat. Stud., 4: 278-287.
22. Adaka, G.S., I.N. Etim, A.A. Nlewadim, N.F. Olele and C.F. Ezefulukwe, 2015. Assessment of fish landed by artisanal fishers in Imo river at Owerri-Nta, Abia State, Nigeria. J. Fish. Aquat. Sci., 10: 587-591.
23. Olaniran, T.S. and A. Adeniran, 2009. Abundance, length-weight relationship and condition factors of fish species in Ogbomoso Reservoir, Ogbomoso South-Western Nigeria. Afr. J. Livest. Extension, Vol. 7.
24. Yougone Bi, D., 2008. Contribution to the study on effects of age on the reproduction of the catfish (*Chrysichthys nigrodigitatus*) reared at the experimental aquacultural station of Layo in Cote d'Ivoire. Ph.D. Thesis, Universite Cheikh Anta Diop de Dakar, Senegal.
25. Daniel, A.A. and U. Sambo, 2014. Fecundity, gonadosomatic index and spawning period of *Chrysichthys nigrodigitatus* of the lower cross River, Nigeria. J. Fish. Aquat. Sci., 9: 277-280.
26. Oboh, I.P. and M.O. Omoigberale, 2014. Fecundity and spawning frequency of *Chrysichthys furcatus* Gunther, 1864 (Osteichthyes: Bagridae) from Jamieson River, Nigeria. Peak J. Agric. Sci., 2: 21-29.
27. Abraham, J.T. and P.A. Akpan, 2012. Prevalence of Henneguya *Chrysichthys* and its infection effect on *Chrysichthys nigrodigitatus* fecundity. AFRREV STECH: Int. J. Sci. Technol., 1: 231-252.
28. Okwara, P.A., 2013. Aspects of the population biology of *Chrysichthys nigrodigitatus* of the lower cross river, Nigeria. M.Sc. Thesis, University of Calabar, Calabar.
29. Isa, M.M., N.S.M. Noor, K. Yahya and S.A.M. Nor, 2012. Reproductive biology of estuarine catfish, *Arius argyropleuron* (Siluriformes: Ariidae) in the northern part of Peninsular Malaysia. J. Biol. Agric. Healthcare, 2: 14-28.
30. Lefler, K.K., A. Hegyi, F. Baska, J. Gal, A. Horvath, B. Urbanyi and T. Szabo, 2008. Comparison of ovarian cycles of Hungarian riverine fish species representing different spawning strategies. Czeh J. Anim. Sci., 53: 441-452.
31. Teichert, N., P. Valade, A. Fostier, H. Grondin and P. Gaudin, 2015. Reproductive biology of an endemic amphidromous goby, *Cotylopus acutipinnis*, from La Reunion Island. Mar. Freshwater Res., 67: 526-536.
32. Mesquita, D.O., G.C. Costa, G.R. Colli, T.B. Costa, D.B. Shepard, L.J. Vitt and E.R. Pianka, 2016. Life-history patterns of Lizards of the world. Am. Naturalist, 187: 689-705.
33. Francis, A. and U. Elewuo, 2012. Aspects of the biology of trap caught *Chrysichthys nigrodigitatus* (Lacepede: 1803) from the New Calabar River, Nigeria. Int. J. Fish. Aquac., 4: 99-104.