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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

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Abstract
Some aspects of the reproductive ecology of *Sarotherodon galilaeus*, a freshwater tilapine cichlid, were examined to evaluate the establishment of the species in the man-made lake of Ahozon (South-Benin). *S. galilaeus* individuals were sampled monthly during wet, flood and dry seasons from August/2014 to July/2015. This species dominated Lake Ahozon and made 85.21% of the fish community. Among the 5,550 individuals sampled, 33.55% were juveniles, 12.25% were sub-adults and 54.20% were adults. *S. galilaeus* showed a sex-ratio of (0.60:1) and low batch fecundities (42-1,149 oocytes). Sizes at sexual maturity (L_{50}) in Lake Ahozon were 131 mm and 106 mm for males and females, respectively, and the species spawned all seasons. The favorable water quality and the life-history strategy between "*r*" and "*k*" selection of *S. galilaeus*, accounted for its rapid establishment in Lake Ahozon. A sustainable fisheries/aquaculture exploitation of *S. galilaeus* in Lake Ahozon requires a holistic management scheme.

Keywords: Establishment, Fisheries, Life-history, Man-made lake, Spawning seasons

1. Introduction

Cichlids dominate the inland water fisheries of tropical Africa where they appear to be the most economically and commercially important fish resources [1]. In the East African Great Lakes such as Tanganyika, Malawi and Victoria, the Cichlidae is the most speciose family and comprising about 185, 600 and 250 species, respectively [2, 3]. Likewise, cichlids occurred abundantly in the fisheries of many artificial freshwater lakes of Africa such as Kainji, Volta and the IITA lake in Nigeria [1, 4-6].

Though less speciose in the Benin water bodies, the 9 species of cichlids inventoried consistently remain numerically the dominant species in freshwater and brackish water fisheries. Indeed, from a total annual fish production of 23,067.2 metric tons estimated for inland waters, almost half (49.82%) were cichlids, evidencing its great commercial importance in the Benin aquatic ecosystems [7]. Among these cichlids, the freshwater tilapine species, *Sarotherodon galilaeus* (Linné, 1758) is a commercially and economically important fishery resource in some African natural freshwater lakes and particularly in Benin.

S. galilaeus (Linné, 1758) species belongs to the genus *Sarotherodon*, Cichlidae family, Percoidei sub-order and Perciformes Order. Previously, the species has been described under the names *Sparus galilaells, chromis galilaeus, Tilapia galilaea*. Because of tilapine sexual behavior, Trewavas (1983) has transferred in the genus *Sarotherodon*, the tilapia species in which males or females show mouth brooding. *S. galilaeus* showed a clear silvered grew color with a white abdomen [8]. Body ratio indicated that the head length is 32.5-39.0% the standard length. Meristic counts indicated 29-32 scales on the lateral line, 4-8 lines of teeths on the jaw and the lower pharyngeal bone possesses numerous small teeth. *S. galilaeus* forage mainly on algae and detritus, and minor diet items were protozoans and microcrustaceae. The species is characterized by an early reproduction with some spawning behaviors that guaranty offspring's survivorship.

In Benin, *S. galilaeus* dominated some natural lakes such as Toho-Todougba Lagoon (South-Benin) where the species made 73% (283 metric tons) of the total annual fish catches [7, 9, 10].

Also, in Southern Benin, *S. galilaeus* has naturally colonized and dominated a sand-dragged man-made freshwater lake of Ahozon Village (Ouidah City, county of Pahou) where the species made about 85.21% of the total fish catches [7, 11].

Notwithstanding the species' economic and commercial importance, and its high abundance in this sand-dragged man-made lake, little research has been conducted on the ecology and biology of *S. galilaeus* inhabiting the man-made lakes. In particular, nothing has been done on the reproductive ecology and biology of this tilapine cichlid in this abandoned and neglected artificial lake of the southern Benin. Akintunde et Imevbore [12] reported some aspects of biology of cichlid fishes from Lake Kainji with special references to *S. galilaeus* [12]. Fagade *et al.* [1, 13] described the food and feeding habit and aspects of the breeding cycle of *S. galilaeus* in the International Institute of Tropical Agriculture (IITA) lake of Ibadan in Nigeria. Adite & Van Thielen [9] reported some reproductive aspects of *S. galilaeus* in Lagoon Toho-Todougba, a natural freshwater lake, located about 5 km from the current study site, the sand-dragged artificial lake of Ahozon. Information on life-history and reproductive ecology are crucial for fisheries management and useful to evaluate the establishment of the species in this artificial habitat. Especially, search on fecundity, gonad maturation, spawning periodicity, recruitment, growth are important to appreciate the propagation and the establishment of the species in a man-made lake. Also, the development of aquaculture industries of a species depends on its breeding frequency and its capacity to produce fingerlings [14-16].

Furthermore, in rainfall dependant aquatic systems such man-made lakes, recruitment can be strongly influenced by seasonal and inter-annual variation in the flood pulse [17, 18]. Sustainable fisheries and extensive aquaculture require sufficient annual recruitment to balance population losses to harvest and to insure the growth and survival of many species [19, 20].

The current study was carried out to investigate the reproductive ecology of the freshwater cichlid, *Sarotherodon galilaeus* (Linné, 1758), that has naturally colonized a sand-dragged man-made lake of the Southern Benin, in order to evaluate the establishment of the species and to contribute to the fisheries and aquacultural management of the current man-made lake. Specifically, the study aims to investigate on (1) sex-ratio, (2) fecundity and relationships with size and weight, (3) sexual maturation and sizes at maturation (4) gonadosomatic index and spawning periodicity and (5) implications for the establishment, the conservation and the sustainable fisheries/aquaculture management of the species in the man-made lake of Ahozon.

2. Materials and methods

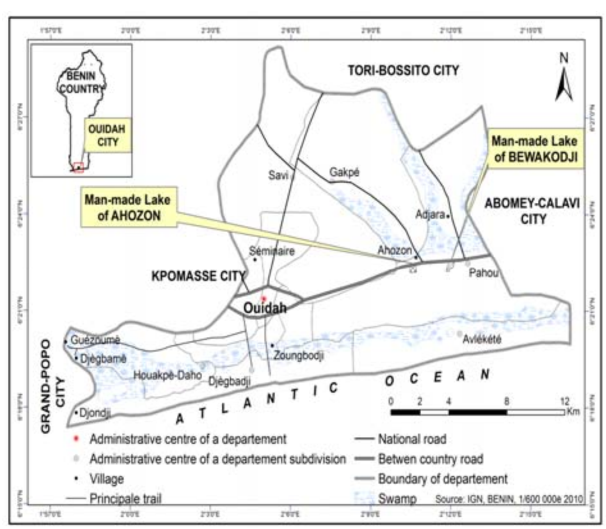
The current study on the spawning ecology of *S. galilaeus* in Lake Ahozon (South-Benin) encompassed twelve (12) months, from August 2014 to July 2015.

2.1. Study area

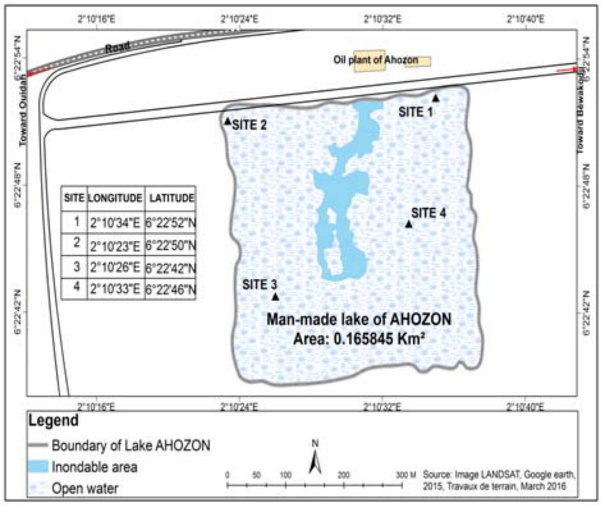
The study area is the artificial lake of Ahozon (06°22'52"N; 002°10'34"E) located in Southern Benin, Ouidah City, Pahou County (Fig. 1a). Ouidah City covers about 364 km² and comprises on its South, the Atlantic Ocean and the mangrove-lined coastal lagoon [21]. The climate is sub equatorial with two (2) wet seasons (April to July; mid-September to October) with a peak usually recorded in June, and two (2) dry seasons (December to March; August to mid-September). Annual mean rainfall was about 1307.3 mm. Ambient temperatures varied between 25 °C and 33.6 °C and monthly evaporation ranged between 59.2-145 mm [22, 23]. The study region comprises some sandy soils, red ferric soils and a vast swampy soil, located at the coastal zone, and extended from Cotonou city (South-Benin) to Ouidah. Currently, this swamp undergoes some sand-dragging activities, considered as an ecological disaster. Plantations such as *Elaeis guineensis* (palm tree) and *Coco nucifera* (coconut tree), producing oil for industries, were common in the study area [22, 23]. Also, intense agriculture dominated by corn, tomatoes, beans, groundnuts etc. occurred in the study region. Likewise multispecies fisheries dominated the environment of Ouidah and took place in the brackish coastal lagoon and in some freshwater lakes such as Toho-Todougba, Ahouangan and Dati. Though not widespread, fish culture was encountered with couple of fish ponds constructed in swampy areas.

2.2. Characteristics of the man-made lake of Ahozon

The man-made lake of Ahozon is located between two water bodies, Toho-Todougba (15 km²), a freshwater lake, and the coastal lagoon (60 km²), a brackish water, both about 5 km apart from Lake Ahozon (Fig. 1b). GPS tracking indicated that Lake Ahozon (06°22'52"N; 002°10'34"E) covered about 0.165845 km^2 (Fig. 1b). This lake originated from sand-dragging activities, and receives every wet season, a huge volume of running waters. After the excavation and the exploitation of sand, the resulting lake was neglected and abandoned by the owners. Dominant phytoplanktons in Lake Ahozon were *Navicula, Peridinium, Scennedesmus, Pinnularia, Spirogyra, Cosmarium, Melosira, Synechocystis, Microcystis, Oscillatoria, Euglena, Phacus, Surirella* and *Lychmophora*. Zooplanktons comprised mainly Copepods, *Trichocerca, Keratella, Brachiomus* and major benthic macro invertebrates recorded were chironomid (Diptera) larvae and a Gasteropod mollusk, *Melanoïde tubercularis*. Dominant aquatic plants were *Cyperus crassipes*, *Fuirena umbellata*, *Andropogon gayanus*, *Ludwigia perennis*, *Emilia praetermissa*, *Eleocharis complanata*, *Cyperus rotundus*, *Enydra fluctuans* and *Mariscus ligularis*. In Lake Ahozon, subsistence fisheries occurred and were practiced by migrant fishermen. Around Lake Ahozon, subsistence agriculture involving maize, beans, carrots lettuce, tomatoes, cucumbers and salads sporadically occurred.



(a)



(b)

Fig 1: Map showing: (a) Ouidah City in South-Benin and the study location, the man- made lake of Ahozon, and (b) the sampling sites: Site 1 and Site 2 = aquatic vegetation habitats; Site 3 and Site 4 = Open water habitats.

2.3. Sampling site selection

In Lake Ahozon, four (4) sites were sampled during the study period: 2 in the "aquatic vegetation" habitat and 2 in the "open water" habitat (Fig. 1b). The "aquatic vegetation" habitat is the edge of the lake and characterized by a low water velocity, a relatively dense vegetation and shallow depths. The "open water" habitat exhibited a relatively high depth and high water velocity, but exempt of vegetation.

2.4. Evaluation of water quality

The "aquatic vegetation" habitat and the "open water" habitat of the lake were evaluated for physicochemical conditions. Water depth was measured to the nearest millimeter using a graduated rope. Water transparency was measured to the nearest millimeter with a secchi disk. Water temperature and dissolved oxygen were measured to the nearest 0.1 °C and 0.1 mg.l^{-1} respectively, with a digital oxythermometer (Model HANNA). The pH was evaluated to the nearest 0.1 with a waterproof pH meter (Model HANNA). Salinity was measured to the nearest 1‰ with a model VISTA refractometer and conductivity was measured to the nearest 1.0 µs/cm with a conductimeter (Model HANNA). Also, evaluations were made on pollution source, substrate, water type, soil type, dominant terrestrial habitats and utilization of the lake and adjacent lands [11].

2.5. Fish sampling

Individuals of *S. galilaeus* were sampled in the "aquatic vegetation" and in the "open water" using appropriate set of fishing gears and techniques so that samples reflect the relative abundance of the fish community [24]. At the open water and aquatic vegetation habitats, samplings were made twice a month from August 2014 to July 2015 with cast nets (9.80 m-diameter, 4.90 m-height, 40 mm-mesh), seines (4.15 m-length x 1.77 m-width, 3 mm-mesh), hooks (90 m-length) and experimental gill net (40 m x 1.05 m, 40 mm mesh). Cast nets were used in the "open water" with the help of fishermen. The net, once casted cover a defined area, then the cast net was pulled out delicately in the boat and all trapped fishes were then removed by hands. Seine hauls in marginal aquatic vegetation were made by setting the seine stationary, and kicking the vegetation to drive the fish in to the net before lifting it [24]. At each sampling site, ten rounds of seining were done. Hooks and gill nets were set in the "open water", yet, contribute very little to the total sample. Samplings with gill nets and hooks were made by attaching the net to the sticks and left it for 12 hours. Aggregated samples from cast nets, seining, gill nets and hooks were gathered to assess the abundance of *S. galilaeus* in the fish community of the artificial lakes. Fish samples were preserved in 10% formalin and then transported to the "Laboratory of Ecology and Management of Aquatic Ecosystems" and preserved in 70% ethanol for further observation on the reproductive ecology of *S. galilaeus*.

2.6. Laboratory procedure

Ethanol preserved-fishes were identified and measured for total length (TL) and standard length (SL) to the nearest 0.1 mm with an ichtyometer, and then weighed to the nearest 0.1g with an electronic scale. Species identification was based on references such as Leveque *et al.* [8], Van Thielen *et al.* [25], and Lowe McConnell [26]. Gender was determined by examination of sexual orifices [27]: males possess a tinny sexual opening that also serves to as anal orifice whereas females possess two (2) distinct orifices. To explore gonad maturity, pressure was applied to the ventral abdominal wall to determine if gonads were fully mature. Specimens were dissected, and gonads were removed for length, width and weight measurements. Gonad maturation stages were estimated using a modified version of maturation scales described by Amon-Kothias (1980) and Adite *et al.* [15, 28]. Female stages were: (0) Immature – very small gonad, ovary translucent with oocytes invisible to naked eye; (1) Sexual pause – small gonad, ovary with some very small white-like oocytes visible to naked eye; (2) Early maturation – intermediate size ovary with small pale-yellow oocytes; (3) Maturing gonad, yellow ovary, partially yolked oocyte; (4) Advanced maturation– fully developed ovary, yellow and yolked oocytes; (5) Mature ovary– fully developed ovary fills ventral region of abdominal cavity, eggs have yellow color and are expulsed when external pressure is applied to the ventrum; (6) Post-laying– ovary is flaccid without significant presence of mature oocytes. Maturation stages of male were: (0) Immature – undeveloped testis consisting of a translucent filament; (1) Early maturation– intermediate size testis having a very light tan color; (2) Advanced maturation– large testis, opaque white or light tan color; (3) Mature testis– fully developed testis, pressure applied to ventrum expulses white milt; (4) Post-laying–flaccid testis without milt. The gonads were then measured to the nearest 0.1 mm for total length, maximum width, weighted to the nearest 0.1 g, and preserved in 90% ethanol. Oocytes from each mature ovary were separated with the aid of dissecting needles and oocyte diameters were measured using an ocular micrometer attached to a dissecting stereomicroscope. Batch fecundity was estimated as the total number of oocytes in a ripe ovary.

2.7. Data analysis

Both physicochemical and fish population data of the two habitats (aquatic vegetation, open water) were recorded in SPSS spreadsheet [29]. Means, ranges and standard deviations of physicochemical features were computed and recapitulated on a table. Species abundance and relative abundance were computed to indicate the numerical importance of *S. galilaeus* in the sample. Relative to fish population data, size ranges and means of fish standard length (SL) and weight (W) were calculated using SPSS computer software [29]. The size structures of *S. galilaeus* population were examined by constructing the frequency histograms of standard length (SL) intervals. Length-weight relationships were examined for the whole population, habitats, seasons, life stages and sexes, according to the curvilinear model:

$$W = aTL^b$$

where TL is the fish total length, W is the individual weight, *a* is a constant, and *b* is the allometry coefficient [30]. Univariate analysis of variance was used to test for between-group differences in slope. Sex ratio was estimated by counting the number of males and females, and by computing the ratio *r* = number of females: number of males. The sex ratio for the population is then (*r* : 1), which means *r* male for 1 female. To evaluate the reproductive maturity and the spawning season, the gonadosomatic indexes (GSI) for males and females were computed using the following formula:

$$GSI = 100 \text{ x } (\text{gonad weight: body weight})$$

Then, the mean monthly GSI was computed and trends were examined to evaluate the spawning periodicity of *S. galilaeus* in Lake Ahozon. The sizes at sexual maturity (L50) for *S. galilaeus* male and female was estimated as the length at which 50% of the individual were mature as predicted by a sigmoid curve fit to the data [9, 15, 31]. For *S. galilaeus*, gonads at stages 3, 4 and 5 of the maturation scale were considered as sexually mature [9]. The sizes at sexual maturity (L50) were estimated from a sigmoid curve constructed with the percentage of mature individuals and corresponding total length (TL) class categories [9]. For each season (flood, dry, wet), a gonad was randomly chosen and frequency distributions of oocyte diameters were plotted to examine the trends of egg maturations and weather or not there was production of multiple cohorts per spawning season. The batch fecundity was estimated for ripe ovaries, and the allometric relationship between fecundity and body length was examined following the curvilinear formula:

$$F = aTL^b,$$

where *F* is fecundity, *TL* is total length, *a* is a constant, and *b* is the allometry exponent. In addition, the linear relationship between fecundity and body weight was examined following linear regression:

$$F = bW + a,$$

where *F* is fecundity, *W* is body weight, *a* is the intercept, and *b* the slope.

3. Results

3.1. Water quality

Table 1 shows means (±SD) and ranges of the physicochemical parameters of the two habitats sampled, the "aquatic vegetation" and the "open water" of Lake Ahozon. Except water temperature and conductivity, the water features showed significant ($p\leq0.05$) variations across the two habitats. In the "aquatic vegetation", depths averaged 54.52±28.83 cm and mean transparency was 32.05±9.73 cm. Water temperatures ranged between 28.3-37 °C and mean pH was 7.39±0.74. Dissolved oxygen varied between 0.73-7.93 mg/l and conductivity averaged 249.41±120.18 µ/cm (Table 1). In the "open water habitat", depths averaged 104.43±66.29 cm and mean transparency was 40.95±10.96 cm. Water temperatures ranged between 28.2-38.7 °C and mean pH was 7.62±0.83. Dissolved oxygen varied between 3.8-11.8 mg/l and conductivity averaged 231.11±119.45 µ/cm (**Table 1**).

Table 1: Mean values (±SD) and ranges of the water parameters measured in the "open water" habitat and in the "aquatic vegetation" habitat of the artificial lake of Ahozon, Ouidah City, Southern Benin.

Physicochemical parameters	Artificial lake of Ahozon: Open water			Artificial lake of Ahozon: Aquatic vegetation		
	Mean	Range	±SD	Mean	Range	±SD
Depth (cm)	104.43	36.1-240	66.29	54.52	16.2-116	28.83
Transparency (cm)	40.95	23.4-60.2	10.96	32.05	16.2-60.5	9.73
Temperature (°C)	33.35	28.2-38.7	2.81	33.15	28.3-37	2.21
pH	7.62	6.8-9.7	0.83	7.39	6.7-9.2	0.74
Dissolved oxygen (mg/l)	6.63	3.8-11.8	2.02	4.15	0.73-7.93	2.41
O2 percent of saturation (%)	95.94	52.3-155.5	26.69	68.66	10.5-208.8	50.18
Conductivity (µ/cm)	231.11	60-560	119.45	249.41	240-550	120.18

3.2. Population Structure

The tilapine cichlid, *S. galilaeus* (Linné, 1758) has naturally colonized and dominated the artificial lake of Ahozon where this fish species, alone, accounted numerically for about 85.21% of the fish community comprising six (6) species, namely *Heterotis niloticus, Chrysichthys nigrodigitatus*, *Clarias gariepinus, Oreochromis niloticus*, *Tilapia guineensis* and *S. galilaeus*. In addition to the numeric abundance, *S. galilaeus* dominated the biomass and alone, made 55.46% of the total biomass. Of the 5,550 total individuals sampled, 37.33% were males and 62.67% were females which corresponded to a sex-ratio of (0.60:1). Ontogenetically, among the 5,550 individuals sampled, 33.55% were juveniles (TL ≤ 50mm), 12.25% were sub adults (TL between 50mm - 90mm) and 54.20% were adults (TL ≥ 90mm).

In general, standard length (SL) averaged 56.57 mm (range= 8-192 mm) and individual weight averaged 14.38 mg (range= 0.01-190 mg). Population size structure varied spatially and SL ranged between 17mm-192mm (mean: 75.90 mm) in the "open water" and between 8mm-76mm (mean: 18.65mm) in the "aquatic vegetation". Furthermore, seasonal variations were recorded with SL varying between 8mm-140mm (mean: 51.38 mm), 11-130mm (mean: 59.79mm) and 9-192mm (mean: 62.31 mm) during the wet, flood and dry periods respectively. Also, standard length (SL) frequency histograms established for the wet, flood and dry season sub populations exhibited unimodal size distributions (Fig. 2).

Overall, in the man-made lake of Ahozon, *S. galilaeus* showed condition factors (K) ranging between 0.07-40.96 (mean = 2.26) and highest values were recorded in the "aquatic vegetation" habitat and during the wet period [32]. Also, Log (standard length=SL) – Log (weight=W) relationships for the population showed positive slopes b =2.961 with significant ($p \leq 0.001$) correlation coefficient "r"= 0.99, indicating that *S. galilaeus* exhibited an allometric growth in Lake Ahozon [32].

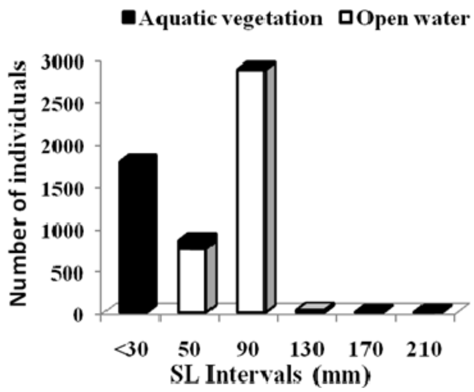


Fig 2: Size structure by habitat type of *Sarotherodon galilaeus* (n= 5550) collected in the artificial lake of Ahozon (South-Benin) from August 2014 to July 2015.

3.3. Maturation and size at sexual maturity

In *S. galilaeus*, sexually mature individuals were specimens with gonads at stages 3, 4 and 5 of the maturation scale [9]. The results showed that for both males and females, the percentage (%) of ripe gonads significantly ($P < 0.01$) increased with standard length (SL) and reached 100% at sizes 170-210 mm-SL for male and 150-190 mm-SL for female. Regression equations showed positive slopes b= 8.083 along with a correlation coefficient r = 0.94 for male, and b=7.105 with r = 0.95 for female. The sizes at sexual maturity (L50) were estimated as the length at which 50% of the individual were mature as predicted by a sigmoid curve fit to the data [9, 15, 31]. Extrapolations from the sigmoid curve (Fig. 3) generated indicated that the sizes at sexual maturity (L50) of *S. galilaeus* in the man-made lake of Ahozon were about 131 mm and 106 mm respectively, for male and female. The smallest ripe male and ripe female recorded measured 100 mm TL (75 mm SL; 20 g) and 77 mm TL (60 mm SL; 12.40 g), respectively.

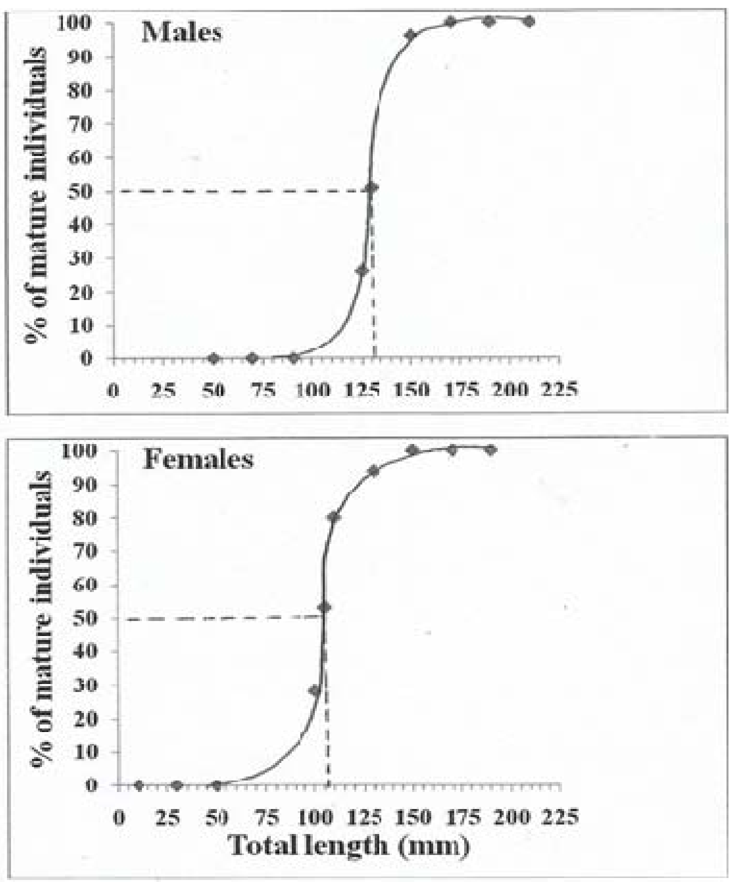


Fig 3: Scatter plots of the percentages (%) of *Sarotherodon galilaeus* male (on the top) and female (on the bottom) with ripe gonads from the artificial lake of Ahozon (South-Benin). The sizes at sexual maturation (L50) (SSM =131mm for male; SSM =106 mm for female), predicted by a sigmoid curve fit to the data, is estimated as the length at which 50% of individuals are mature.

3.4. Gonadosomatic index trends and spawning periodicity

Tables 2 and 3 showed monthly variations of gonadosomatic index (GSI) for both genders. Overall, the gonadosomatic index of males ranged between 0.09 – 2.33 (Mean = 1.01±0.35). The highest monthly average of the GSI (1.33±0.52) was recorded in May, and the lowest monthly average (0.87±0.13) was recorded in February. Also, the gonadosomatic index of females ranged between 0.001 – 9.62 (mean = 2.43±2.17). The highest monthly average of the GSI (4.47±3.00) was recorded in December, and the lowest monthly average (1.18±0.99) was recorded in July. Also, seasonal variations of GSI were recorded for both males and females. In males, seasonal variations were weak and the GSI averaged 1.09±0.51, 1.04±0.24 and 0.93±0.30 during wet, flood and dry seasons, respectively. Inversely, females showed a relatively high seasonal variation of the GSI with means GSIs of 2.06±1.83, 2.1±2.03 and 3.03±2.42 recorded for wet, flood and dry seasons, respectively. Though highest GSIs were observed in females during dry period, the GSIs were still high during the wet and flood seasons, indicating that *S. galilaeus* spawned all seasons.

Table 2: Monthly means of gonadosomatic index (GSI) of *Sarotherodon galilaeus* male from the artificial lake of Ahozon (South-Benin).

Month	Number of testis	Mean gonadosomatic index (GSI)	±SD	Minimum GSI	Maximum GSI
August 2014	15	0.96	0.08	0.83	1.12
September	11	1.06	0.20	0.93	1.65
October	10	1.03	0.31	0.78	1.87
November	10	1.15	0.36	0.93	1.92
December	12	0.96	0.05	0.84	1.02
January 2015	10	0.89	0.11	0.78	1.14
February	9	0.87	0.13	0.56	1.01
March	9	0.97	0.63	0.09	1.94
April	3	0.69	0.99	0.11	1.83
May	9	1.33	0.52	0.98	2.33
June	7	1.28	0.45	0.73	1.80
July	13	0.92	0.28	0.55	1.72
Total	118	1.01	0.35	0.09	2.33

Table 3: Monthly means of gonadosomatic index (GSI) of *Sarotherodon galilaeus* female from the artificial lake of Ahozon (South-Benin).

Month	Number of ovaries	Mean gonadosomatic index (GSI)	±SD	Minimum GSI	Maximum GSI
August 2014	8	2.61	2.26	0.02	7.95
September	11	2.88	2.17	0.74	7.12
October	13	1.47	1.82	0.00	7.59
November	9	2.73	1.61	0.98	5.14
December	9	4.47	3.00	0.06	9.62
January 2015	10	2.58	2.04	0.01	5.91
February	13	3.20	2.94	0.07	8.46
March	8	2.38	1.56	0.72	5.68
April	15	2.54	2.16	0.07	6.79
May	17	2.53	2.04	0.03	5.88
June	11	2.28	0.14	2.12	2.37
July	15	1.18	0.99	0.05	3.81
Total	139	2.43	2.17	0.001	9.62

3.5. Ovarian structure and oocyte sizes

Like in most fishes [33], internal anatomy of *S. galilaeus* showed 2 testes and 2 ovaries for males and females, respectively. These paired structures are suspended by mesenteries across the roof of the body cavity. Colors of male testes ranged from translucent in completely immature male to milk-like color for ripe individuals. In females, ovary colors ranged from translucent in juvenile females to yellow-green for ripe female. Both testes and ovaries are elongate, but ovaries show a cylindric form. Average length, width and weight of ripe testes were 28.16±7.34 mm, 1.21±0.05 mm and 0.11±0.04g, respectively, and those of ripe ovaries were 20.51±6.06 mm, 5.12±2.86 mm and 0.51±0.47g, respectively. Oocyte diameters in ripe female ranged between 1.5 - 3.6 mm (mean = 2.46 mm) during the flood season (Fig. 4), 0.3 – 1.8 mm (mean = 1.05 mm) during the dry season (Fig. 5) and 1.0 and 3.0 mm (mean = 2.09 mm) during the wet season (Fig. 6). Frequency distributions of oocyte diameter classes in mature females showed unimodal distribution of egg sizes during the flood, dry and wet seasons.

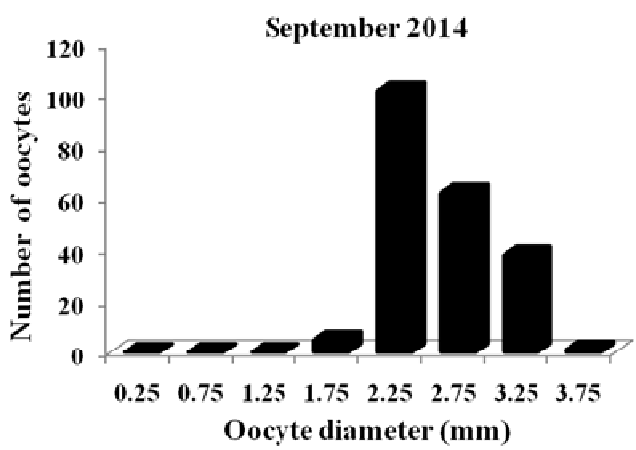


Fig 4: Oocyte diameter structure of a *Sarotherodon galilaeus* individual with ripe ovary (TL =120mm; GSI =3.125; Fecundity=207) sampled in the artificial lake of Ahozon (South-Benin) during the flooding period (September 2014).

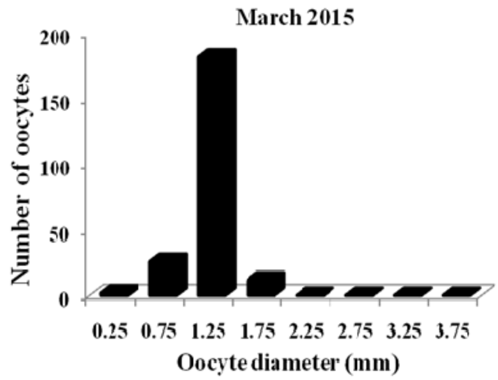


Fig 5: Oocyte diameter structure of a *Sarotherodon galilaeus* individual with ripe ovary (TL =104mm; GSI =2.47; Fecundity=232) sampled in the artificial lake of Ahozon (South-Benin) during the dry season (March, 2015).

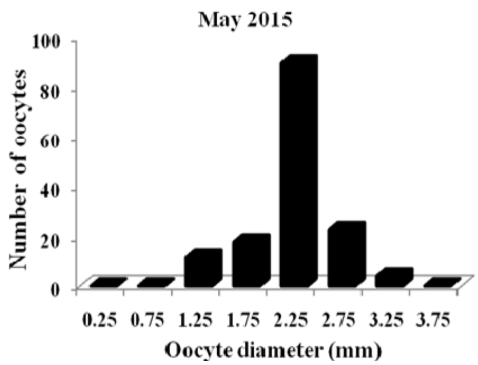


Fig 6: Oocyte diameter structure of a *Sarotherodon galilaeus* individual with ripe ovary (TL =85mm; GSI =3.53; Fecundity=145) sampled in the artificial lake of Ahozon (South-Benin) during the wet season (May, 2015).

3.6. Fecundity

A total of 139 ripe females of *S. galilaeus* were used to estimate the batch fecundity measured as the number of oocytes in the ovary. Overall, fecundity significantly increased with body length (r=0.85; P <0.01) and body weight (r=0.95; P <0.01) (Fig. 7 and 8). Regression equations were as follow:

$F = 0.076TL^{3.229}$, $r = 0.85$ N=139
$F = 8.685W- 56.77$, $r = 0.95$ N=139

where F is the fecundity (number of oocytes), TL is the total length, W the fish individual weight, r the correlation coefficient and N the number of ripe females. The computed mean fecundity was 79.40±174.23 oocytes. Lowest fecundity was 42 oocytes recorded for an individual fish measuring 75 mm-SL and weighting 20 g, and the highest fecundity observed was 1,149 oocytes for an individual fish measuring 143 mm SL and weighting 128.5g. Ovarian weight and the number of oocytes per gram of ovary increased with body size (Table 4). Relative fecundity (number of oocytes per gram of body mass) revealed no general association with body size.

Table 4: Fecundity of *Sarotherodon galilaeus* by size classes from the artificial lake of Ahozon (South-Benin).

TL class	N	Mean body weight (g)	Mean ovary weight (g)	Mean fecundity	Fecundity range	N° of eggs/ gram ovary	Relative fecundity	Mean GSI
70-100	70	18.28	0.51	107.63	42-184	211.09	5.89	3.04
100-130	55	25.98	0.56	151.67	84-500	268.84	5.84	2.23
130-160	10	64.65	0.89	554.6	495-642	623.15	8.58	1.38
160-190	4	108.70	1.20	878.5	750-1149	732.08	8.08	1.08

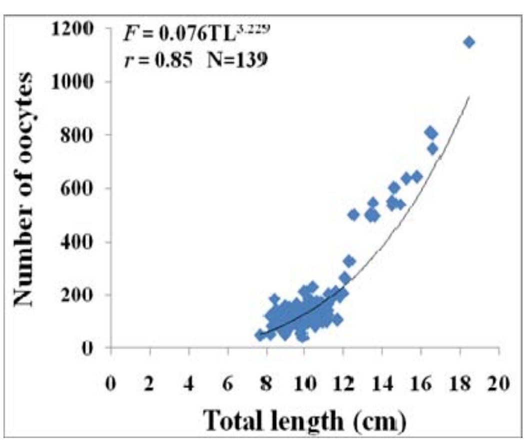


Fig 7. Curvilineair relationship between fecundity (F) and total length (TL) of *Sarotherodon galilaeus* from the artificial lake of Ahozon (South-Benin).

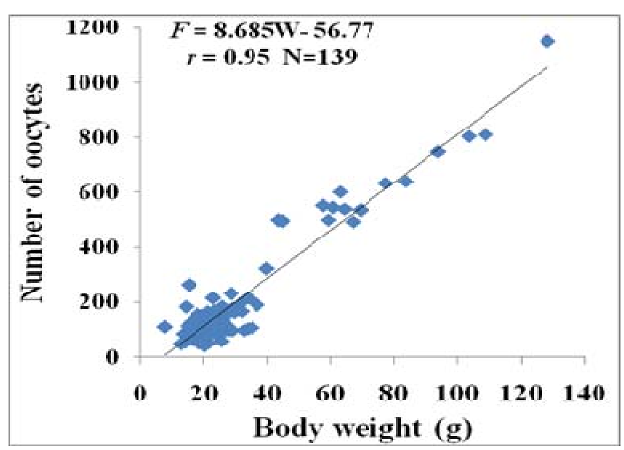


Fig 8: Lineair relationship between fecundity (F) and body weight (W) of *Sarotherodon galilaeus* from the artificial lake of Ahozon (South-Benin).

4. Discussion

Fisheries and aquaculture valorization of a man-made lake require knowledge on the spawning ecology of introduced or naturally-colonized species in order to evaluate the propagation and the establishment of inhabiting fish species in this artificial water body. The current study on the reproductive ecology and the establishment of *S. galilaeus* in the man-made lake of Ahozon (South-Benin), gave insight on the differential environmental quality of the two habitats sampled, and aspects of spawning traits such as sex-ratio, maturation, gonadosomatic index and breeding periodicity, ovarian structure, batch fecundity and the reproduction strategy of *S. galilaeus* that has naturally colonized Lake Ahozon.

In Lake Ahozon, though both habitats (open water, aquatic vegetation) exhibited favorable water quality for the growth and survival of *S. galilaeus*, significant spatial variations were recorded in physicochemical parameters. Indeed, one-way analysis of variance on the water physicochemical parameters indicated that depth, transparency and dissolved oxygen across the two habitats (open water versus aquatic vegetation) were significantly different ($p \leq 0.05$). The computed *F*-values, along with degrees of freedom and *p*-values were $F_{1,32} = 7.399$, $p = 0.010$ for depth, $F_{1,32} = 6.749$, $p = 0.014$ for transparency, $F_{1,32} = 11.398$, $p = 0.002$ for dissolved oxygen. Nevertheless, one-way ANOVA fail to show any significant variation ($p > 0.05$) between the open water habitat and aquatic vegetation habitat for temperature ($F_{1,32} = 0.016$, $p = 0.899$), conductivity ($F_{1,32} = 0.595$, $p = 0.446$) and pH ($F_{1,32} = 0.495$, $p = 0.487$). The favorable water condition of the lake accounted for the high abundance (85.21%) and dominance of *S. galilaeus* in the lake's fish community.

The record of all life stage categories, such as juveniles (33.55%), sub adults (12.25%) and adults (54.20%) in the population suggested successful reproduction and recruitment of *S. galilaeus* in Lake Ahozon. In particular, juveniles with SL between 8mm-76mm (mean: 18.65mm) were mostly recorded in the aquatic vegetation indicating that spawning occurred in this habitat.

In Lake Ahozon, *S. galilaeus* female exhibited a relatively low size of sexual maturation (SSM =106 mm) compared to those reported by Adite&Van Thielen [9] in Lagoon Toho-Todougba of Southern Benin, and by Fagade *et al*. [13] in the IITA Lake of Ibadan (Nigeria) where the SSM reached 123 mm and 134 mm, respectively. These differences in the size of sexual maturation were probably due to the difference in food availability and primary production that may be likely higher in Toho-Todougba lagoon, an ancient and large natural water body (16 km^2) and in the IITA Lake. Indeed, females living in low productive system often mature at smaller size than conspecific females in highly productive ecosystems [34]. Also, in the artificial lake of Ahozon, the smallest ripe female of *S. galilaeus* had size (7.7 cm –TL) lower than that of Toho-Todougba lagoon (9.1cm –TL) and lower than that of the IITA Lake (10.6 cm –TL), probably because of the relatively low food availability and primary production [9, 13].

Though always relatively high in both male and female, monthly gonadosomatic index (GSI) of *S. galilaeus* showed significant variations in Lake Ahozon. Indeed, one-way analysis of variance on the gonadosomatic index (GSI) of *S. galilaeus* male indicated that the GSIs across the twelve (12) months of the years were significantly different ($p \leq 0.05$). The computed *F*-values, along with degrees of freedom and *p*-values were $F_{11,106} = 1.938$, $p = 0.042$. However, one-way ANOVA fail to show any significant variations ($p > 0.05$) for season ($F_{2,115} = 2.137$, $p = 0.123$). Also, one-way analysis of variance on the gonadosomatic index of *S. galilaeus* female indicated that the GSIs across the twelve (12) months of the years and across the three (3) seasons were significantly different ($p \leq 0.01$). The computed *F*-values, along with degrees of freedom and *p*-values were $F_{11,127} = 3.248$, $p = 0.0001$ for monthly GSIs and $F_{2,136} = 4.892$, $p = 0.008$ for seasons. Nevertheless, the GSIs were always relatively high in both male and female, regardless or months and seasons.

In *S. galilaeus* female, egg diameter significantly varied ($p \leq 0.0001$) across the three (3) seasons. The computed *F*-values, along with *p*-values were $F_{2,574} = 10007.486$, $p = 0.0001$. Also, frequency distributions of oocyte diameter classes in mature females recorded during flood, dry and wet seasons evidenced the production of multiple cohorts every spawning season (Fig. 4, 5 and 6). As results, the relatively higher gonadosomatic index (3.81-9.62) recorded every month and seasons, and the relatively high oocyte diameters recorded during flood, dry and wet seasons indicated that *S. galilaeus* spawned all seasons (Fig 4, 5 and 6). This was shown by the presence of juveniles (8mm-76mm SL) regardless of seasons and mostly recorded in the "aquatic vegetation" habitat. Nevertheless, spawning peaked in December considered as the beginning of the dry season and when water begin to recess allowing construction of numerous nests on the reproduction grounds. Though the gonadosomatic indexes were relatively higher in the flood period, this season in considered as stressful for genitor because of the instantaneous change in water level causing nest destructions and reconstruction of new nests.

In general, ovarian weight and the number of eggs per gram of ovary increased with body size (Table 4). Also, the results indicated that fecundity significantly increased with body length ($r = 0.85$; $P < 0.01$) and body weight ($r = 0.95$; $P < 0.01$) (Table 4). However, in relation with body size, no specific trend was recorded for relative fecundity and the number of oocytes per gram of body weight.

In the man-made lake of Ahozon, the relatively rapid establishment and propagation of *S. galilaeus* was the result not only of the favorable water quality of the lake, but also is due to the demographic or reproduction strategy of the species. Indeed, *S. galilaeus* matures early and begin to spawn at about six (6) months [27]. The species exhibited a low batch fecundity ranging between 42 and 1,149, but spawn all seasons. *S. galilaeus* is characterized by a relatively small body size, but exhibited a rapid development. Hence, the species displays a life-history strategy between "*r*" and "*k*" selection [35] that allows a high recolonization. Such species shows diverse reproductive behaviors such as mouth brooding, nest construction, nest guarding and parental care to insure early life stage survivorship and high recruitment for long-term population viability and propagation [36-38]. An economic and sustainable exploitation of *S. galilaeus* in the man-made lake of Ahozon requires the protection of foraging and spawning grounds, the introduction of predators to control the species population and the periodic ecological monitoring of the lake.

5. Conclusion

The current investigation on *S. galilaeus* gives valuable information on aspects of the reproductive ecology and the establishment of the species in the man-made lake of Ahozon. The favorable environmental conditions of Lake Ahozon coupled with the spawning strategy characterized by the high offspring survivorship, the high recruitment and recolonization, accounted for the prominence and the rapid establishment of *S. galilaeus* in the man-made lake of Ahozon. A sustainable fisheries exploitation of *S. galilaeus* in Lake Ahozon requires a periodic ecological biological monitoring of the lake, the protection of foraging and spawning grounds and the introduction of predators to control the population of this tilapine species. Also, catchable stock of *S. galilaeus* should be regulated and planned to prevent the overharvest of both juveniles and genitors in order to insure the long-term exploitation and the conservation of the species.

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