International Journal of Forest, Animal and Fisheries Research (IJFAF)
[Vol-4, Issue-1, Jan-Feb, 2020]
ISSN: 2456-8791
https://dx.doi.org/10.22161/ijfaf.4.1.1

Aspects of life-history strategy of *Marcusenius senegalensis* (Pisces: Osteoglossiformes: Mormyridae; Steindachner, 1870) from Niger River in Northern Benin

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Abstract**—*Marcusenius senegalensis (Steindachner, 1870) is the dominant mormyrid in Niger River in Northern-Benin where this fish species constitutes an important component of artisanal fisheries. The current study documented the reproductive biology of M. senegalensis in order to contribute to management and sustainable exploitation. Monthly samplings were conducted between February 2015 and July 2016 using gillnets, cast net, and seine. Males dominated the population with a sex-ratio of 1:0.96 in favor of males. Sizes at first sexual maturity were 167.89 mm-TL for males and 163.81 mm-TL for females. Monthly gonadosomatic index (GSI) averaged 0.12 ± 0.09 for males and 1.32 ± 1.56 for female and peaks recorded indicated that spawning occured from June to September. Fecundity were moderate to low (844 – 12,643 eggs) and significantly (p < 0.05) increased with total length and body weight. The species showed egg diameters varying between 0.21 and to 1.77 mm and ovaries comprised oocytes at all stages (II-IV) of maturation indicating that M. senegalensis displayed a multi-spawning behavior. M. senegalensis displayed a life history strategy between r and K, yet more inclined towards K-selected strategy. In Niger River, reproduction grounds were being severely degraded. The current findings are valuable data to design a species management scheme that should includes spawning ground protection, species conservation and valorization and fisheries/aquaculture development.*

Keywords**— *K-selected, management, Marcusenius senegalensis, multi-spawning, spawning grounds.***

I. INTRODUCTION

The African bulldog fish, *Marcusenius senegalensis* (Steindachner, 1870) is the most common and widespread mormyrid species inhabiting African riverine and even lacustrine habitats where they constitute an important commercial component of the freshwater fisheries (Scheffel and Kramer, 1997). In particular, *M. senegalensis* is one of the top mormyrid occurring in most running waters from the African Western Region (Adjibade et *al*., 2019a). Taxonomically, the African bulldog fish belongs to Osteichthyes class, Actinopterygii sub-class, Osteoglossiformes order, Mormyridae family, *Marcusenius* genus and *Marcusenius senegalensis* species (Moyle and Cech 2004,).

The genus *Marcusenius*, the largest among mormyrids, comprised about 40 valid species that form a polyphyletic group (Boden *et al*., 1997). *Marcusenius* may be recognized by its moderately elongated body, grew silvery, a chin well developed, fleshy with globular swelling, a snout poorly developed and shorter than postorbital length, a fleshy submental swelling, a lower jaw slightly longer than upper, nostrils situated at about mid-distance between eye and snout tip, a caudal peduncle depth 2-5 times in its length, a dorsal fin with 19-36 rays,

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an anal fin with 25-43 rays, a pectoral fin with 10-12 rays, a pelvic fin with 6 rays, a distance between pectoral and pelvic fins shorter than distance between pelvic and anal fins, a caudal fin with 36-46 rays, 38-98 lateral line scales, 12-28 transversal line scales, 7-21 transversal line scales between dorsal and anal fins, 8-18 caudal peduncle scales, and 3-10 conical or bicuspid oral jaw teeth (Boden et *al.*, 1997). The maximal standard length (SL) observed for this species was 321 mm and the maximal total weight was 200g (Bigorne, 2003).

Marcusenius senegalensis, like other mormyrids, possesses an electric organ located in the caudal peduncle that generates a discharge that is species-specific and is used for communication, orientation and object location (Hopkins, 1981). The species is a nocturnal, benthic, egg-scattering pelagic spawners (Paugy, 2002). With regards to feeding habit, *M. senegalensis* is an invertivore consuming mainly aquatic insects, detritus, sand particles, crustaceans, mollusks and phytoplankton (Adjibade et *al.*, 2019b).

In Benin running waters, mormyrids are well-distributed from Northern to Southern regions and appear to be a commercially and economically valuable component of the inland water fisheries. As reported by the Benin Fisheries Department (Direction des Pêches, 1990) and Adjibade *et al*. (2019a), annual catches of mormyrids in Benin reached 248 tons. In Niger River in Benin, Koba (2005) reported that mormyrids were one of the most valuable fishes and numerically accounted for 12.65% of the fish assemblages. Also, a recent fisheries survey by Adjibade *et al*. (2019a) in Niger River in Benin revealed that *M. senegalensis* dominated Mormyrid assemblages and numerically made 43.74% of the Mormyridae fish community. Despite its great importance in artisanal fisheries in Niger River that currently undergoes severe habitat degradations, almost nothing is known about the life history strategy of *M. senegalensis* in this regional running water in Benin (Nwani et *al.*, 2006). Knowledge of reproductive ecology is crucial to evaluate maturation, spawning, recruitment, and reproduction ground status in order to conserve and protect the species and to assure its permanent establishment.

The current study documents the life history strategy and the reproductive ecology of *M. senegalensis* in Niger River in Benin in order to provide valuable data for species conservation and management.

II. MATERIALS AND METHODS

2.1. Description of the study region

The study area was located in Niger River in Benin around Malanville town, located at North-East Benin at latitude 11°52'216''N and longitude 3°21'111''E. The Niger River (4200 km) is the third-longest river in Africa after the Nile (6600 Km) and Congo (4700) (Aboubacar and Humphrey, 2007). This river crossed nine (9) African countries and serves as borderline between Benin and Niger Republics. Northern Benin shows a Soudano-Sahelian climate with a long dry season occurring from October to April, a wet season from May to July and a flood season from August to September (PDC Malanville, 2006) with an average annual rainfall of about 750 mm. The dominant wind (harmattan) blows from November to January (PDC Malanville 2006, Aboubacar and Humphrey 2007). In Benin, the Niger River showed a huge floodplain extending on about 300 ha that stood as an important reproduction ground for the fishes (Moritz et *al.*, 2006). The main aquatic plants were *Eichhornia crassipes*, *Echinochloa stagnina*, *Pistia stratiotes*, *typha australis*, *Mimosa sp*, *Mimosa pigra*, *paspalum serobiculatum*, *Ipomoea aquatica*, *Cyperus cyperoides*, *Ipomoea asarifolia*, *Senna occidentalis*, *Ludwigia senegalensis*, *Ludwigia abyssinica*, *Ludwigia adscendens*, *Ludwigia erecta*, *Achyranthes aspera*, *Azolla africana etc* (Adjibade et *al.*, 2019a). The Niger River was intensively exploited for artisanal fisheries by fishermen from South-Benin, Burkina Faso, Ghana, Mali, Togo, etc. The floodplain was used to grow rice, onion, maize, watermelon, pepper etc. that caused severe ecological disturbances to the river because of the use of chemical fertlizers and pesticides (Laë et *al.*, 2003).

2.2. Sampling sites

Marcusenius senegalensis individuals were sampled from five sampling sites according to anthropogenic disturbances. Site 1 (11°52'216''N, 11°52'216''N), located on Sota stream, was covered by aquatic vegetation where domestic wastes were rejected. Site 2 (11°52'112''N, 3°23'672''E) was also situated on Sota stream, at Tounga village and was under chemical pollution because of the use of fertilizers and pesticides in adjacent agriculture. Site3 (11°52'675''N, 3°25'329''E) was located at Gaya village (Niger Republic) on the main channel of Niger River. Less degraded, Site4 (11°52'987''N, 3°20'819''E) communicated with Alibori stream and was located on the main channel. Site5 (11°52'970''N, 3°21'111''E) was also located on the main channel of the river and under Benin-Niger bridge.

2.3. *Marcusenius senegalensis* sampling and identification

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Fish collections were done monthly from February 2015 to July 2016 in the aquatic vegetation habitat and in the open water habitat at the five sampling sites. Fishing gears such as gillnets (50 m × 1 m, 40 mm-mesh; 50 × 1 m, 30 mm-mesh; 50 m × 1 m, 20 mm-mesh), cast nets (6 m-diameter, 20 mm-mesh) and seine (6.15 m × 2 m, 16 mm-mesh) were used for collections (Adite and Winemiller 1997; Adjibade et *al.* 2019a). After collection, all harvested fishes were identified in situ using references such as Paugy et *al.* (2003) and Levêque and Paugy (2006). Fish individuals were then immediately preserved in 10% formalin and conveyed to the "Laboratoire d'Ecologie et de Management des Ecosystèmes Aquatiques (LEMEA)".

2.4. Laboratory procedure

In the laboratory, after seven (7) days the fish samples were removed from the formalin and preserved in 70% ethanol to facilitate further manipulations. Preserved fishes were removed from the ethanol solution and names were confirmed using fishbase (https://www.fishbase.org). Each individual of *M. senegalensis* was measured for total length (TL) and standard length (SL) with an accuracy of 0.1 mm using an ichthyometer, then weighed to 0.1 g accuracy with an electronic balance (CAMRY) and then dissected. After dissection, gonad of each fish was removed and length, width and weight were measured with a digital slide caliper. Genders and gonad maturity stages were visually examined. Like many mormyrids, males are recognized by a clear kink (Fig. 1) in the anal fin base which is straight and absent in females and juvenile males (Lamml and Kramer, 2007). This kink help to determine the maturation stage. Testes and ovaries were determined according to the modified maturation scale of (Oduol, 1986; Ouattara *et al.*, 2010). Females stages were : (1) Immature – small ovary, transparent to translucent, pinkish in color and lodged between the swim bladder and the abdominal wall. The oocyte was indistinguishable to the naked eye, (2) developing - ovary slightly increases in size and occupies 20% - 30% of the abdominal cavity. Ovary color change from pinkish to grewish due to the accumulation of yolk in the oocytes and now distinguishable with the unsided eye, (3) Mature (Fig. 2) - Ovary large, yellowish and occupies a considerable part of the abdominal cavity (4) Ripe - ovary large, yellowish and occupies a considerable part of the abdominal cavity and (5) Spent – flaccid (Fig. 3), with occasional residual eggs. The color changes to dirty-brown and characterize by empty follicles. Maturation stages of male were : (1) Immature - the testis is small, poorly developed, translucent, soon later the mid-point begins to acquire slight bulging appearance, (2) developing - the testis develops a more prominent bulge in the mid-point region and put a greyish coloration, (3) Mature - the organ is enlarged in his mid-point, occupies between 10 - 15% of the abdominal cavity and become creamish but milt is not emitted upon stripping, (4) Ripe - free flow of milt with slight pressure on the peritoneum. The testes occupy about 20% of the abdominal cavity, look creamish and (5) Spent - the testis is shrunken and bloody. The oocytes of *M. senegalensis* show cycloid form (Nzeh and Lawal, 2012; Paugy, 2002).

The fecundity was estimated using two methods: for small ovaries under 1 g, complete counts were made. For larger ovaries, a three subsample (anterior, middle and posterior) were taken, counted, and extrapolated to the total ovary weight. Egg diameters were measured with a calibrated eyepiece micrometer, mounted to a dissecting stereomicroscope. The diameters obtained were used to construct the egg diameters frequency histogram.

Fig. 1: Individual of mature Marcusenius senegalensis male showing a kink in the anal fin base.

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Fig. 2: Individual of Marcusenius senegalensis female showing mature oocytes.

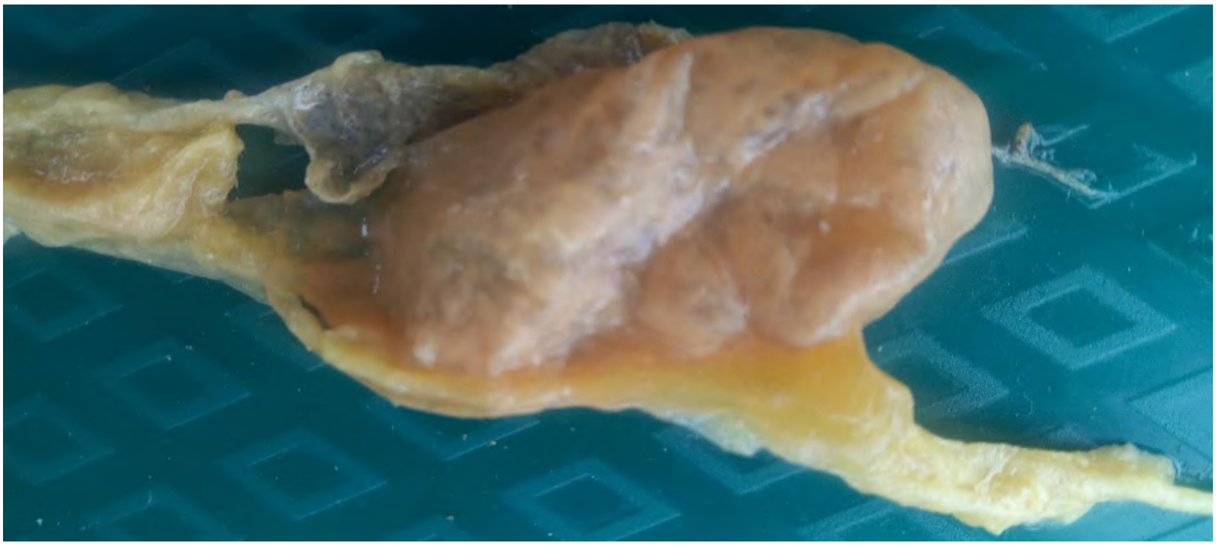

Fig. 3: Ovary of Marcusenius senegalensis female at "spent" maturation stage.

2.5. Data analysis

The sex-ratio was determined by computing the proportion of males and females. A chi-square test ($\alpha<0.05$) was applied to verify the existence of significant differences between the number of males and females of *M. senegalensis*. The reproduction period for males and females was established through the analyses of monthly variations of the mean gonadosomatic index (GSI) values.

$$\text{GSI} = \frac{\text{Gonad weight } (Gw)}{\text{Body weight } (Bw)} x\,100 \qquad (1)$$

Monthly average GSI was then calculated and used to determine the spawning period of *M. senegalensis*. The length at first sexual maturity (L_{50}), defined as the length at which 50% of the individuals of both sexes attain maturity, was estimated by the logistic curve following equation (Hosmer and Lemesgow, 1989):

$$P = \frac{1}{[1 + e^{-}(beta_0 + beta_1 * X)]} \qquad (2)$$

where P is the probability of an individual to being mature at a determinate X length, $beta_0$ (intercept) and $beta_1$ (slope) are estimated parameters. L_{50} is calculated as:

$$L_{50} = \frac{-beta_0}{beta_1} \qquad (3)$$

The lengths at first sexual maturity (L_{50}) were obtained for both genders by firstly plotting the percentage of mature fish individuals against their total length (TL) and by fitting a sigmoid curve to the scatter plot (Adite et *al.*,

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2017). For this study, testes and ovaries at stage II to IV of the maturation scale were considered sexually matures and were used to construct the sigmoid curves (Adite et *al.*, 2017). Besides, for flood, wet and dry seasons, a ripe ovary with the highest GSI were selected to design the frequency histograms of egg diameters and to examine egg maturation and cohort production trends (Adite et *al.*, 2017). Absolute fecundity was estimated for ripe ovaries and the relationship between fecundity and body length were examined using the following power function:

$$\mathbf{F_a = aTL^b} \qquad (4)$$

Where F_b is the fecundity, TL is the total length, "a" is a constant and "b" is the slope.

Also, a linear relationship between fecundity and body weight was examined following :

$$\mathbf{F_a = b_2B_w + a_2} \qquad (5)$$

Where F_a is the absolute fecundity, B_w is the body weight, b_2 is the slope and a_2 is the intercept.

III. RESULTS

3.1. Sex-ratio and population structure

Among the 2019 individuals of *M. senegalensis* collected during this study, 1032 (51.11%) were males and 987 (48.89%) were females. These abundances correspond to a sex ratio of 1:0.96 that differs significantly from a 1:1 ratio ($\chi^2 = 53.14$; $p < 0.05$). In the fish assemblages, females were larger than males and the maximum sizes recorded for both genders were TL = 280 mm (SL = 248 mm, W = 217.6 g) and TL = 275 mm (SL = 242 mm, W = 158.18 g), respectively. Ontogenetically, subadults and adults dominated the fish assemblages and numerically accounted for 59.14% and 30.51%, respectively, whereas juveniles showed moderate abundances of 10.35%. Total length and body weight model gave a positive allometric coefficient b = 3.3921 with a significant ($p < 0.05$) correlation coefficient r = 0.94 (Fig. 4).

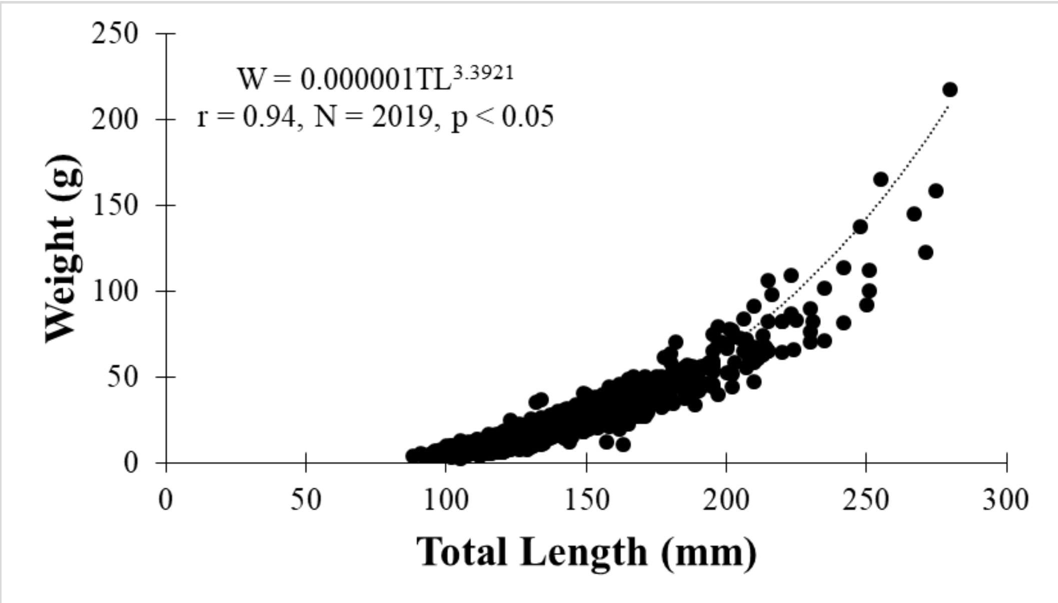

Fig. 4: Length-weight relationship of Marcusenius senegalensis (n = 2019) collected in Niger River (Northern Benin) from February 2015 to July 2016.

3.2. Spawning season

During the study period and with regards to the 2019 *Marcusenius senegalensis* collected, individual gonadosomatic index significantly ($p < 0.001$) varied in both genders and ranged between 0.01 (TL = 251 mm, SL = 225 mm, W = 100.1 g) and 1.12 (TL = 195 mm, SL = 172 mm, W = 53.8 g) in males and between 0.02 (TL = 195 mm, SL = 168 mm, W = 74.74 g) and 27.58 (TL = 166 mm, SL = 144 mm, W =11.28 g) in females. Monthly gonodosomatic index (GSI) ranged between 0.04 and 6.13 (mean = 1.32 ± 1.56) for females and peaked in July and August with GSI values reaching 6.13 and 5.88, respectively. In males, the GSI varied between 0.03 and 0.42 (mean = 0.12 ± 0.09) and like females, peaked in July and August with GSI = 0.37 and GSI = 0.38 (Fig. 5).

In both genders, gonadosomatic index significantly ($p < 0.001$) varied with seasons. GSI value of males was higher during the wet season (GSI = 0.26 ± 0.26) and flood season

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(GSI = 0.15 ± 0.13) and was reduced during the dry season (GSI = 0.09 ± 0.06). Identical trends were recoded for females subpopulation with the higher gonadosomatic index recorded in the wet season (GSI = 3.66 ± 3.91) and flood season (GSI = 4.52 ± 5.02) while the lowest GSI was found during the dry season (GSI = 0.20 ± 0.28). Also, the highest percentage of mature males and mature females were recorded in June, July, and August.

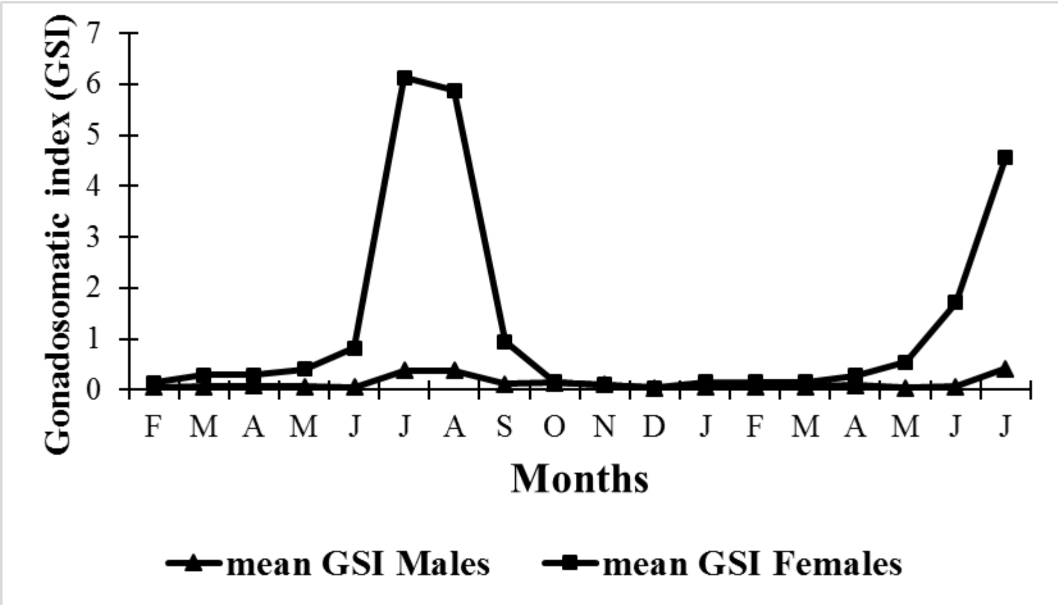

Fig. 5: Monthly variations of gonadosomatic index (GSI) of M. senegalensis males and females collected in Niger River (Northern Benin) from February 2015 to July 2016.

3.3. Length at first sexual maturity

In this study, the smallest mature male measured 104 mm-TL (90 mm, W = 6 g, GSI = 0.17) while the smallest mature female measured 115 mm-TL (98 mm SL, W = 14.56 g, GSI = 9.48). For males and females, the scatter plots of the percentages of mature individuals against total length (TL) are given in Figure 6 and Figure 7, respectively. Overall, the percentages of ripe testes and ovaries significantly ($p < 0.05$) increased with total length to reach nearly 100% at length 260-270 mm and 270-280 mm, respectively. Associated equations from the sigmoid curve fitted to scatter plots were:

$$P_m = \frac{1}{[1 + e^{-(7.85 \ + 0.047TL)}]} \quad (6)$$

and

$$P_f = \frac{1}{[1 + e^{-(-10.05627 \ + 0.06139TL)}]} \quad (7)$$

where P_f and P_m are the probability of an individual being mature males and mature females, respectively. Thus, the length at first sexual maturity (L_{50}) obtained from the sigmoid curve were 167.89 mm for males (Fig. 6) and 163.81 mm for females (Fig. 7).

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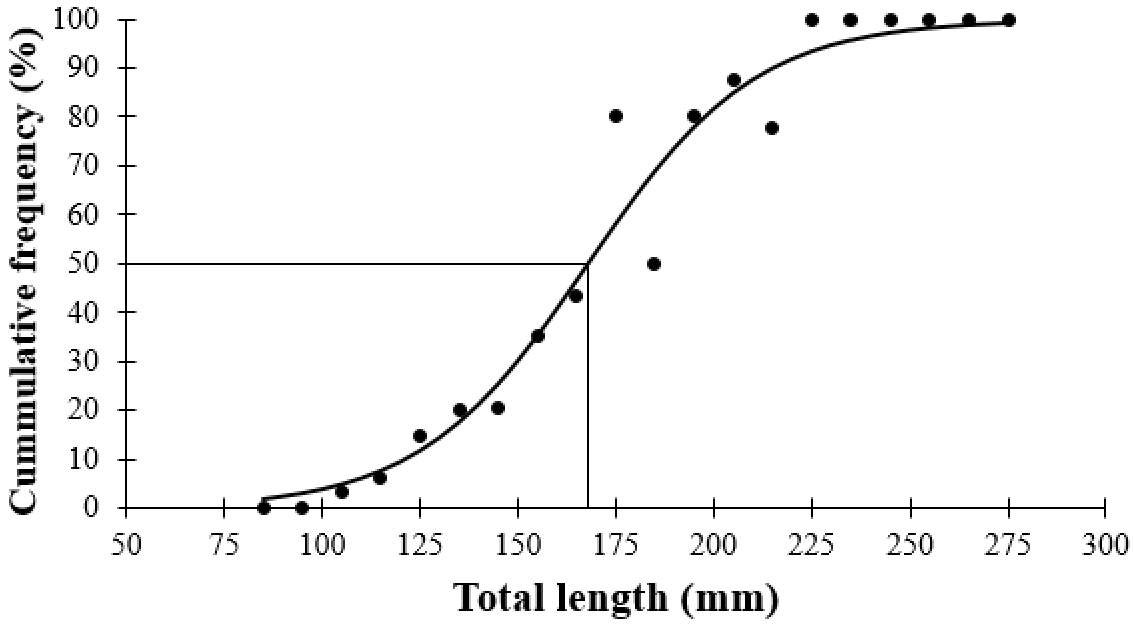

Fig. 6: Length at first sexual maturity (L_{50}) of Marcusenius senegalensis males collected in Niger River (Northern Benin) from February 2015 to July 2016.

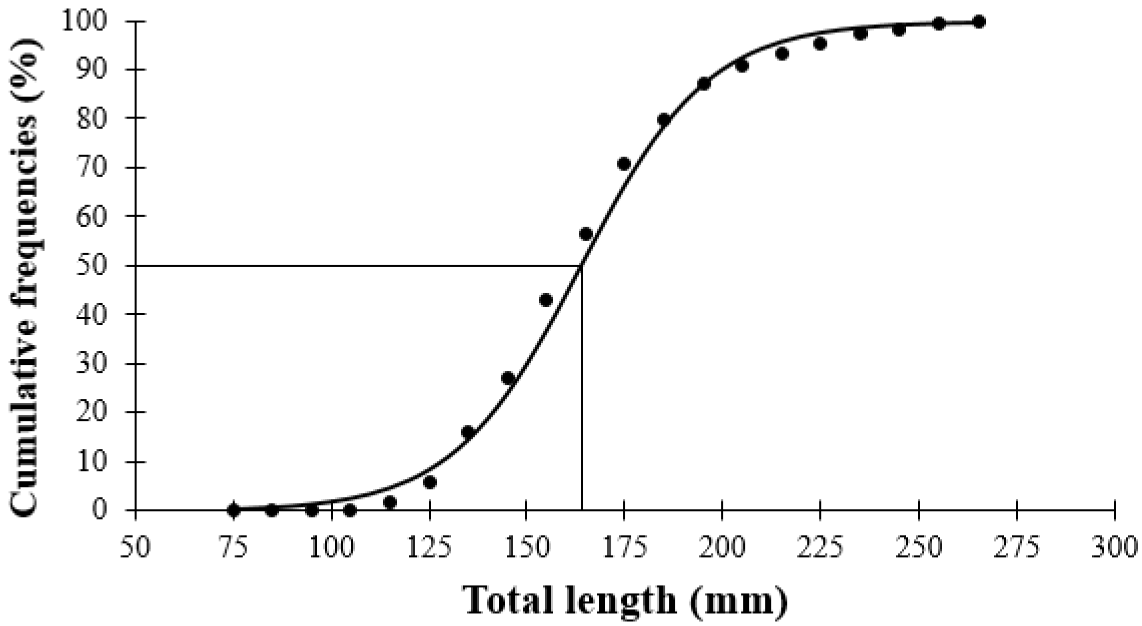

Fig 7: Length at first sexual maturity (L_{50}) of Marcusenius senegalensis females collected in Niger River (Northern Benin) from February 2015 to July 2016.

3.4. Fecundity

In Niger River in Benin, *M. senegalensis* showed absolute fecundity varying between 844 eggs for a female of 110 mm-TL (SL = 93 mm, W = 11.36, GSI = 8.27) and 12,643 eggs for a female of 248 mm-TL (SL = 211 mm, W = 137.3, GSI = 11.96) with a mean fecundity of 3204 ± 1950 eggs. Relative fecundities varied from 43 eggs/g for an individual of 172 mm TL, (SL =146 mm, W = 47.62 g, GSI = 0.42) to 196 eggs for an individual of 166 mm TL, (SL =144 mm, W = 40.9 g, GSI = 27.58) (Table 1). Power curve fitted to total length-fecundity scatter plot and linear regression fitted to body weight-fecundity scatter plot showed that fecundity significantly ($p<0.05$) increase with total length (TL) and body weight (W) (Fig. 8 & 9). The

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https://dx.doi.org/10.22161/ijfaf.4.1.1

power (Fig. 8) and regression (Fig. 9) equations were as follow :

$\mathbf{F_a = 0.014TL^{2.8341}}$ (***r* = 0.94, N = 177, *p* < 0.05**) (Fig. 8)

$\mathbf{F_a = 69.705W + 373.24}$ (***r* = 0.92, N = 177, *p* < 0.05**) (Fig. 9), with *r*, the correlation coefficient and N, the total number of ripe females.

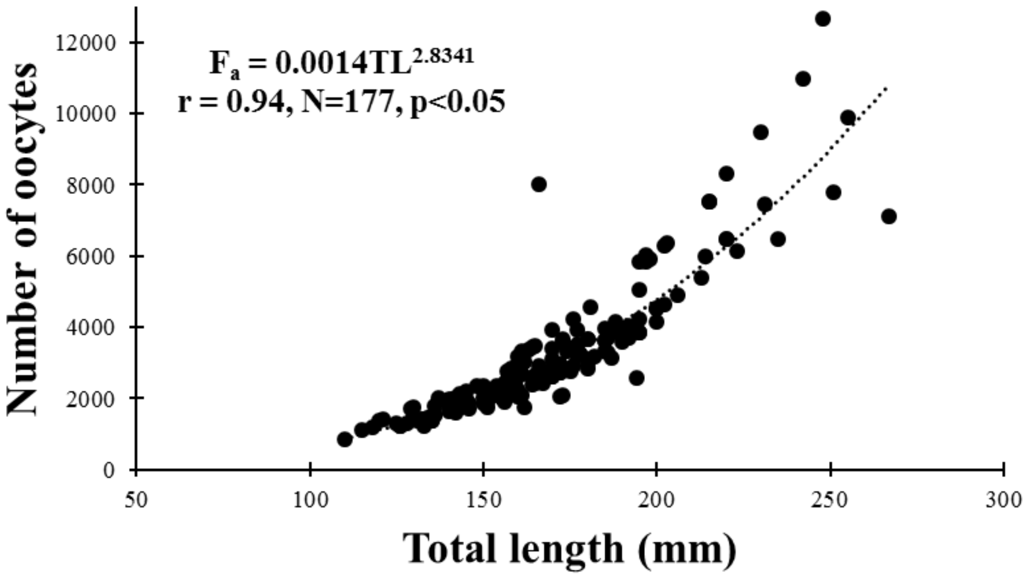

Fig. 8: Power function between fecundity (Fa) and total length (TL) of Marcusenius senegalensis collected in Niger River (Northern Benin) from February 2015 to July 2016.

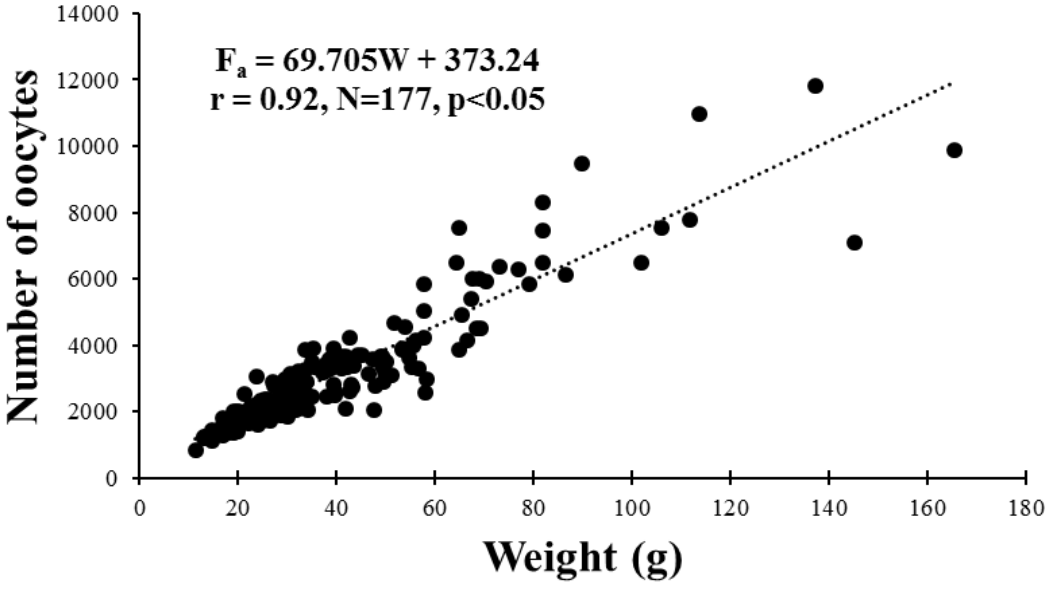

Fig. 9: Linear regression between fecundity (Fa) and body weight (W) of Marcusenius senegalensis collected in Niger River (Northern Benin) from February 2015 to July 2016.

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Table 1: Body weight (Bw), ovary weight (Ow), mean and range of absolute and relative fecundities and gonadosomatic index (GSI) of Marcusenius senegalensis by length classes collected in Niger river (Northern Benin) from February 2015 to July 2016.

TL class	N	Bw (g)	Ow (g)	Absolute fecundity		Relative fecundity		GSI	
		Mean±SD	Mean±SD	Mean±SD	Range	Mean±SD	Range	Mean±SD	**Range**
<150	48	18.91±3.47	3.07±2.59	1,629±319	844-2,346	86±11	65-113	4.08±4.05	**0.33-14.62**
150-200	106	39.10±11.95	1.17±1.83	3,092±1022	1,744-8,009	81±20	43-196	2.96±4.3	**0.22-27.58**
200-250	20	80.83±20.52	3.05±3.78	6,820±2199	4,139-12,643	84±15	62-116	3.55±3.33	**0.15-11.96**
>250	3	140.83±27.08	1.31±1.44	8,254±1444	7,105-9,875	59±10	49-70	0.84±0.82	**0.32-1.79**
Total	**177**	**40.07±25.03**	**1.27±2.04**	**3,204±3.19**	**844-12,643**	**89±10**	**43-196**	**6.25±3.63**	**0.15-27.58**

3.5. Ovarian structure

Figure 10 shows the histogram of eggs diameter frequency distributions during dry, wet and flood season. Overall, *M. senegalensis* egg diameters ranged from 0.21 to 1.77 mm with a mean of 0.95 ± 0.35 mm. Seasonally, egg diameters ranged between 0.21-0.95 (mean: 0.53 ± 0.15), 0.33-1.77 (mean: 1.09 ± 0.29) and 0.31-1.74 (mean: 1.07 ± 0.29) for dry, wet and flood seasons, respectively. Also, the analysis of variance shows significant ($F_{2,2039}$ = 768.49 p < 0.001) seasonal variations within egg diameters.

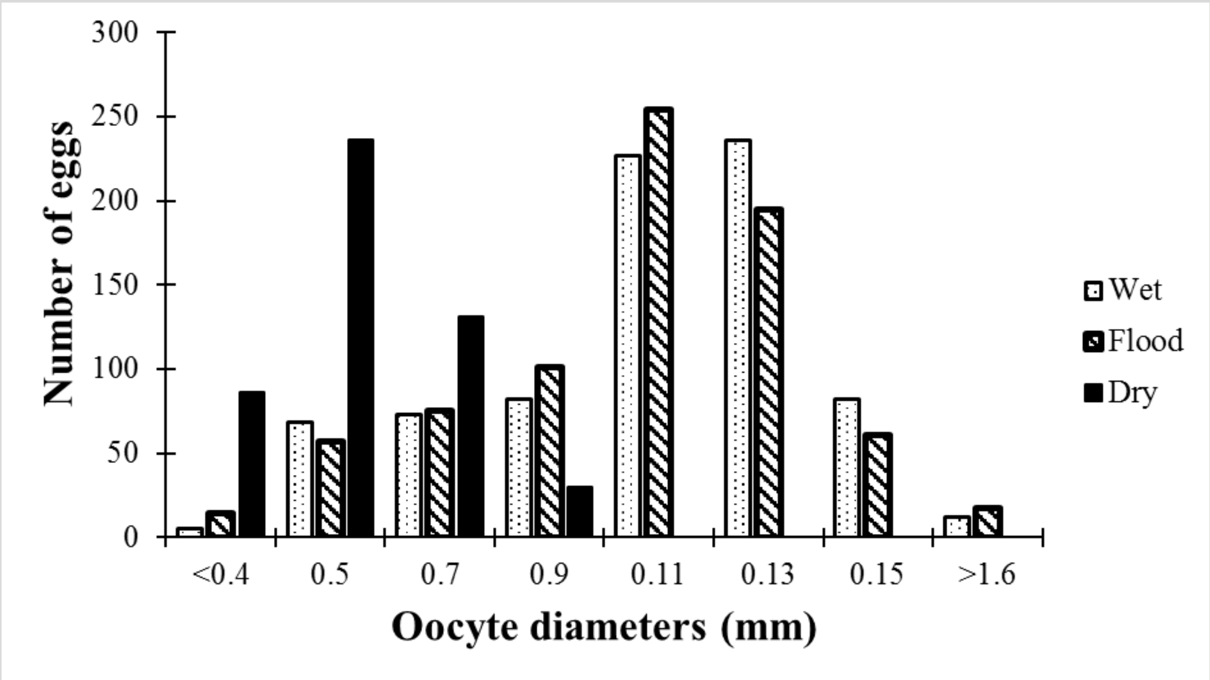

Fig. 10: Egg diameter frequency distributions for wet, flood and dry seasons of Marcusenius senegalensis collected in Niger River (Northern Benin) from February 2015 to July 2016.

IV. DISCUSSION

Knowledge of life history strategy and reproduction pattern of a fish species is crucial for spawning ground protection, species conservation/valorization and fisheries management. In this study, *Marcusenius senegalensis* showed a sex-ratio (1:0.96) in favor of males. This trend agreed with those reported for *Gnanthonemus senegalensis* from Asa lake in Nigeria where the sex-ratio was in favor

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https://dx.doi.org/10.22161/ijfaf.4.1.1

of males with 1:0.4 (Nzeh and Lawal, 2012). Likewise, three (3) mormyrids, *Marcusenius ussheri* from Bia River in Ivory Coast, *Mormyrus kannume* from Kamburu lake in Kenya, and *Hyperopisus bebe* from Warri River in Nigeria showed exhibited the same pattern with a sex-ratio of 1:0.84, 1:0.96 and 1:0.59, respectively (Oduol, 1986; Olele, 2013; Ouattara et *al.*, 2010). Nevertheless, *Chrysichtys nigrodigitatus* (sex-ratio = 1:2.1) from Ahozon Lake, exhibited some sex-ratio in favor of females (Adite et *al.*, 2017). As reported by Atse *et al.* (2009) and Adite *et al.* (2017), differential genetic, behavioral and morphological characteristics of both genders may play in favor of one sex as selective traits. Also, gender tolerance or resistance to environmental disturbances could affect the percentage of males and females in the population (Olele, 2013).

Because testes were in general reduced, the highest gonadosomatic indexes (GSI) of *M. senegalensis* males (1.12) were much lower than those of females (27.58). This trend was earlier reported by Levêque and Paugy (2006) for most African species. The same observation was made by Paugy (2002) in Baoule River where *Marcusenius senegalensis* females showed much higher GSI compared to those of male individuals (GSI_m = 0.5; GSI_f = 18.7). In Niger River, the remarkable increase of the GSI from June (GSI = 0.82), at beginning of the wet season to reach a peak (GSI = 6.13) in August is the result of the increase of water levels that stimulated gonad maturation and initiated spawning activities. The decrease of the GSI from mid-September implies that the reproduction of *M. senegalensis* covered the period of June-September, the wet and flood seasons. These spawning seasons of *M. senegalensis* seem to be nearly identical for most fish species dwelling African water bodies. Indeed, in Baoulé and Nile Rivers, Paugy (2002) and Nawar (1959) reported that ovaries and testes started to mature in May and continued their development to July before stopping in September. According to Albaret (1982), in Ivory Coast freshwater bodies, the majors reproductions activities for *Marcusenius bruyerei* and *Marcusenius furcidens* occurred in May and July, and particularly when water levels increase and conductivity decreases. In the principal course of River Bia in Ivory Coast, Ouattara *et al.* (2010) reported that *Marcusenius ussheri* exhibited many peaks of gonadosomatic index during the year. Also, Jégu and Lévêque (1984) reported that *M. ussheri* and *M. furcidens* reproduced from September to October in Bandama River, and from August – November in Comoé River when the water rise. These results suggested that *M. senegalensis* and most of the mormyrids displayed multiple spawning behavior leading to the production of many offspring cohorts during the spawning periods.

In the current study, the lengths at first sexual maturity (L_{50}) recorded for *Marcusenius senegalensis* male and female were 167.89 mm –TL and 163.81 mm-TL respectively, implying that females mature earlier and males displayed delayed maturation, though both values were not significantly (χ^2 = 0.053.14; p = 0.8227) different. This finding agreed with Ouattara *et al.* (2010) report, where *Marcusenius ussheri* females attained first sexual maturity at 168 mm-TL while males showed delayed maturation at 173 mm-TL. Also, males *Marcusenius macrolepidotus* from the Upper Zambezi showed sexual maturity at 12.1-15.9 cm-SL while females reached sexual maturity at 11.8-13.6 cm-SL (Lamml and Kramer, 2007). According to Paugy (2002), this observation in which females mature earlier than males were common for many African tropical fishes. As reported by Giora et *al.* (2014), in species *Brachyhypopomus gauderio* (Hypopomidae), males reached first sexual maturity at 108 mm while females mature earlier at 104.5 mm. Nevertheless, in the man-made lake of Kamburu, *Mormyrus kannume* male showed a lower size at first sexual maturity at 24.0 cm-SL compared to females that reached maturity at a higher size (24.8 cm-SL) (Oduol, 1986). Many authors (Blake, 1977; Kolding et *al.*, 1992; Kramer, 1997; Lamml and Kramer, 2007) stated that mormyrids reached their first sexual maturity when their size exceeded 40% of the maximum size for that species. However, according to Nikolsky (1963), Kirschbaum and Schugardt (2002) and Paugy (2002), environmental factors such as water temperature, turbidity, pH, dissolved oxygen, conductivity, seasons, food availability, habitat stochascity etc. and fishing pressure could greatly influence the length at first sexual maturity.

In Niger River, *Marcusenius senegalensis* showed a moderate to low absolute fecundity varying between 844 eggs and 12,643 eggs averaging 3204 ± 3.19 eggs. These estimates were higher than those reported by Okedi (1970) for *Marcusenius grahami* and *Marcusenius nigricans* whose fecundities in Lake Victoria in Uganda ranged from 248 eggs to 5,229 eggs and 206 eggs to 739 eggs, respectively. In contrast, in Bia River, Ouattara *et al.* (2010) reported for *Marcusenius ussheri*, a maximum fecundity of 53,897 oocytes, much higher than our findings. The positive and significant (b = 2.8341; r = 0.94; $p < 0.05$) power relationship between fecundity (Fa) and total length (TL) and the linear regression (b = 69.705; r = 0.92; $p < 0.05$) between fecundity (Fa) and body weight

ISSN: 2456-8791
https://dx.doi.org/10.22161/ijfaf.4.1.1

(W) indicated that fecundity increase with total length (Fig. 8) and body weigth (Fig. 9).

With regards to egg sizes, *M. senegalensis* showed oocyte diameters ranging between 0.20 mm and 1.77 mm (mean = 1.27). These values were higher than those reported by Scheffel and Kramer (1997) and Paugy (2002) in a river from West Africa and Baoulé River where *Marcusenius senegalensis* showed average egg diameters of 1.13 mm and 1.25 mm, respectively. In contrast, our findings were lower than Okedi (1970) records in Lake Victoria where oocyte diameters ranged between 1.3-1.8 m (mean = 1.52 mm) and between 2.1-2.9 mm (mean = 2.38 mm) for *Marcusenius grahami* and *Marcusenius nigricans*, respectively. Also, Ouattara *et al.* (2010) reported in Bia River, a higher egg diameters for *Marcusenius ussheri* (mean = 1.81 mm). Likewise, our findings were lower than those reported by Blake (1977) for *Marcusenius senegalensis* measuring (0.1-1.35 mm), *Campylomormyrus tamandua* (0.1-1.5 mm), *Mormyrops deliciosus* (0.1-1.9 mm), *Hyperopisus bebe* (0.1-1.58 mm) and *Hippopotamyrus pictus* (0.1-1.78 mm). In general, as stated by Obota et *al.* (2016), oocyte diameter vary with species and are affected by fish size, growth, density, food availability and mortality. According to Idowu (2017), egg diameters are greatly influenced by environmental factors such as physicochemical parameters and food availability.

In the current study, *Marcusenius senegalensis* showed moderate maximum size, TL= 275 mm and TL= 280 mm for males and females, respectively. The smallest mature male and female measured 104 mm-TL and 115 mm-TL, respectively and lengths at first sexual maturity (L_{50}) were 167.89 mm –TL for males and 163.81 mm-TL for females. These imply that this mormyrid displayed an moderately delayed reproduction associated with moderate to low fecundity (844-12,643 eggs). During wet and flood seasons (June-September), egg diameters frequencies showed that ovaries comprised oocytes at all maturity stages, indicating a repeated spawning leading to multiple cohort production with a relatively high recruitment and recolonization. Kirschbaum and Schugardt (2002) and Paugy (2002) confirmed this trend by reporting that *M. senegalensis* is a fractional spawner with an average of 2000 eggs laid at each spawning. These spawning traits suggest that *M. senegalensis* displayed a life history strategy between *r* and K, but more inclined towards K-selected.

Marcusenius senegalensis, like other mormyrids, seems to be well adapted to the changing conditions of their environment. The spawning occurred with the increase of water levels and the decrease of conductivity stimulate gonad development. Thus, their reproduction is linked to the beginning of the rain and the flood (Hopkins, 1986).

V. CONCLUSION

The current study documented some aspects of the reproductive biology of *Marcusenius senegalensis* from Niger River in Benin where mormyrids constitute highly commercial and economic fisheries resources. In this regional running water, *M. senegalensis* males dominated the population and showed a moderately delayed maturation with lengths at first sexual maturity reaching 167.89 mm-TL for males and 163.81 mm-TL for females. Gonadosomatic index peaked in August and reproduction occurred from June to September in the wet and flood periods. Fecundities were moderate to low and significantly ($p < 0.05$) increased with total length and body weight. The species showed a multi-spawning behavior and displayed a life history strategy between *r* and K, but more inclined towards K-selected. The current findings will serve as tools for species follow up, management and sustainable exploitation.

VI. ACKNOWLEDGEMENT

The authors would like to express their gratitude to the Government of the Republic of Benin for providing us a grant through the program "Appui aux Doctorants" and to the "Laboratoire d’Ecologie et de Management des Ecosystèmes Aquatiques (LEMEA)", University of Abomey-Calavi for its logistic assistance. Special thank to Oussa Abigail for her assistance in data collection and to all the fishermen and fisherwomen who help us during the different samplings missions conducted in the Niger River at Malanville.

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