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Assessment of zootechnical classification of local populace of *Sarotherodon melanotheron* raised in confinement

Florence Souleymane[1], Christian Abdoul[2] and Maïmouna Hamidou[3]

[1]Research Unit in Aquaculture and Aquatic Biodiversity, Polytechnic University of Bobo-Dioulasso, Bobo-Dioulasso 01, Burkina Faso.

[2]Laboratory of Animal Sciences and Meat Technologies, Department of Animal Health and Production, University of Abomey-Calavi, Abomey-Calavi, Benin.

[3]Laboratory of Hydrobiology and Aquaculture, Faculty of Agronomic Sciences, University of Abomey -Calavi, Abomey-Calavi, Benin.

Abstract

Tilapia *Sarotherodon melanotheron* is naturally adapted to both fresh and brackish environments. In order to improve its farming potential, this study evaluated the growth, survival and reproductive parameters of individuals from three lakes of southern Benin according to their sex and age at experimental fishing. During fry rearing and breeding, fish were fed with commercial feed granulated. The chlorophyll a concentration and the abundance of plankton were determined by molecular absorption spectrometry and under a light microscope respectively. Physico -chemical parameters were within acceptable limits for good survival and growth of *S. melanotheron*. Together with chlorophyll a, three phytoplankton species and five zooplankton species were also available in the rearing tanks. At the end of the experiment (90 days post nursery), most of the growth parameters did not vary significantly according to the waterway of origin and the sex. However, the age at experimental fishing influenced significantly most of the growth parameters. The individuals from Lake Nokoué and Lake Toho were characterized by higher body weight, total length, standard length, weight gain, average weight gain, daily weight gain, nutritive quotient, survival rate, net biomass, biomass per square meter while Grand-Popo Lagoon individuals were characterized by higher ccondition factor and a weak ponderal and linear specific growth rates. Overall, reproductive parameters were higher in females than males. The majority of males were with empty testicles, while females with ova were expelled by manual pressure. S. melanotheron individuals from the considered lakes can be recommended for selective breeding program in fresh and brackish waters.

Keywords: Benin, *Sarotherodon melanotheron*, aquaculture, captivity, growth, reproductive parameters.

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INTRODUCTION

In many developing countries, fish is an important source of good quality protein food at moderate prices (FAO, 2014). In Benin, fish protein is mainly provided by fishing in water bodies and waterways (Sohou et al., 2009). However, fish catches fell about 15% from 2003 to 2008 (MAEP/JICA, 2009), due to overfishing. Thus fish farming became a suitable solution (Béné et al., 2015). Tilapias have become the dominant species used in commercial fish farming in Africa (FAO, 2014). Their species are also more appreciated by fish farmers (Ouattara, 2009) and consumers (Toguyeni et al., 2009; FAO, 2014). Tilapias have a great economic and ecological importance in African water bodies and waterways (Ahouansou-Montcho and Laleye, 2008; Kapute et al., 2016). The subfamily of tilapias belongs to the Cichlidae family and includes about 100 species grouped into three genera (*Oreochromis, Sarotherodon* and *Tilapia*) which differentiate themselves by their reproductive behavior and diet (Trewavas, 1984; Paugy et al., 2004). The main types used in aquaculture belong to *Oreochromis* and *Sarotherodon* genera and four species that are now farmed on a significant scale: *O. niloticus, S. melanotheron, O. aureus, O. mossambicus* and their hybrids (Li et al., 2006; Toguyeni et al., 2009; Lazard, 2009; FAO, 2010; Ansah et al., 2014). Among the tilapia species, *O. niloticus* is the most known and used most common commercial farming fish, being the object of immense research (Van Eer et al., 2004; Lacroix, 2004; Lazard, 2009) and extension programs in globally. Its characteristics (such as easy spawning and rearing, high growth rate and relatively adaptable diet) aided its introduction into several African countries, outside its natural areas of distribution, such as Benin, Côte d‟Ivoire and Niger (Lazard, 1990, 2006, 2013). Furthermore, despite a wealth of scientific information on all aspects of its rearing and numerous national development programs of its breeding, *O. niloticus* has not been a significant element of the aquaculture sector in Benin. Most projects initiated throughout the country for the development of its breeding have not been a success. Therefore, it seems essential to evaluate the breeding potential of autochthonous tilapia species. This is because *S. melanotheron* is likely the candidate that can promote a real boom of commercial tilapia farming in coastal countries of Africa. This species is naturally adapted to both fresh and brackish environments (Ouattara et al., 2005). It has a fast growth and easy reproduction (Hem et al., 1994). According to Ofori-Danson and Kumi (2009), this species also feeds at different trophic levels (Phytoplanktons: Cyanophyceae, Bacillariophyceae, Diatomophyceae, Chlorophyceae, and Chrysophyceae Conjugatophyceae; Zooplanktons: Rotifera, Cladocera, Copepoda, Euglenophyceae; incidentally preys: Fish larvae, detritus, bivalve larvae, scales, fish eggs, sand, etc.). In lagoon environment, *S. melanotheron’s* intensive rearing in floating cages showed weaker performances compared to Acadja. In natural environment, the species has a slow growth, due to the combined-influence of temperature and salinity. Indeed, the abrupt variations of habitat modify the fish‟s metabolism leading to the decrease of natural food consumption (Ouattara et al., 2009). However, the raising system seems to have more effect on the growth than the raising environment. In Côte d'Ivoire, the freshwater growth of *S. melanotheron* in floating cages (0.42±0.00 g.day-1) (Ouattara et al., 2005) was superior to the one recorded in lagoon water (0.38 g.day-1) (Gbaï et al., 2014). In concrete tanks, these values were 0.19±0.01 g.day-1 in freshwater and 0.21 g.day-1 in brackish water (Gilles, 1994). In concrete ponds fed with brackish water, Gilles (1994) showed that the growth of *S. melanotheron heudelotii* (subspecies coming from Senegal) is higher (0.66 g.day -1) than that of *S. melanotheron melanotheron* (subspecies from Côte d'Ivoire: 0.21 g.day-1) and *S. melanotheron nigripinnis* (subspecies from Congo: 0.19 g.day-1). Furthermore, among the three farming systems tested by Ouattara et al. (2005), ponds were found to be more interesting (0.47±0.02 g.day-1) than floating cages (0.42±0.00 g.day-1) and concrete tanks (0.19±0.01 g.day-1). It is therefore possible that the use of ponds gives interesting productions of *S. melanotheron melanotheron* or even *S. melanotheron heudelotii* which is the best performing subspecies. In addition, in mixed raising, the male of *S. melanotheron* grows less quickly than the female whereas the opposite was observed in mono-sex culture (Ouattara et al., 2009).

The present study is the first attempt to quantify effectively the zootechnical parameters of wild populations of *S. melanotheron* in Benin. Thus, the aim of this study is the zootechnical characterization of local populations of *S. melanotheron* in order to promote and improve its farming in Benin. More specifically, it is the assessment the growth, survival and reproductive parameters of this species‟ individuals coming from Lake Nokoué, Lake Toho and Grand-Popo Lagoon in relation with their sex and age at experimental fishing.

MATERIALS AND METHODS

Experimental design

The experiment was carried out from December 2014 to July 2015 at the fish farming station of the Department of Animal Health and Production of the University of Abomey-Calavi, (Benin). It was conducted in 4 identical tanks of immersed volume 4 m^3 (2 m

Figure 1. Specimen of *Sarotherodon melanotheron* (Amoussou et al., 2016b).

× 2 m × 1 m). All the 240 individuals of *S. melanotheron* (Figure 1) were manual-sexed. Fishing nets of 10 mm mesh size was used as hapas and allowed to keep separately individuals from the three waterways (Lake Nokoué, Lake Toho and Grand-Popo Lagoon). Indeed, each tank (containing one hapa) was split into 3 compartments (a compartment corresponded to a batch). Each batch contained individuals from the same waterway. Thus, individuals from all the three waterways were in the same tank but maintained separately. Each tank (or group) was duplicated. Each duplicate group was constituted by keeping separate the two sexes (male *vs* female), for example, for Lake Nokoué: Males from Lake Nokoué (tank 1) *vs* males from Lake Nokoué (tank 2) and females from Lake Nokoué (tank 3) *vs* females from Lake Nokoué (tank 4). The stocking density of each batch was 20 individuals.m^{-3}. Experimental groups were organized by *S. melanotheron*‟ fry with an average weight of 21.27 ± 11.57 g and descended from the first mating generation between wild broodstocks. Fry were tagged individually and were aged as 3 months 15 days. At the end of the experiment, all fish were aged 6 months 15 days.

During fry rearing, fish were fed with granulated commercial feed (Skretting®) (diameter 1 mm) containing 57% of proteins. For fingerlings breeding, fish were then fed with granulated commercial feed (diameter 3 mm), containing 35% of proteins (Skretting®). The different constituted groups were fed manually three times per day at 8.00 a.m., 12.00 p.m. and 5.00 p.m at 5% of the biomass (Gbaï et al., 2014). Controls of weight gain and survival were done every 15 days on 10 and 100% of the population in breeding respectively during the nursery and during the post nursery period.

Growth and physicochemical parameters

The zootechnical parameters were calculated according to the procedures used by Imorou Toko (2007) and Kapute et al. (2016). Physicochemical parameters such as conductivity (µS.cm^{-1}), pH, dissolved oxygen (mg/l), temperature (°C), salinity (mg/l) and total dissolved solids (TDS) (ppm) were measured twice per day (at 7:00 a.m. and at 5:00 p.m.).

Determination of microalgal biomass

Water samples (250 ml) were collected monthly at 7 a.m. in each tank. These samples were immediately transported to the laboratory where they were analyzed for chlorophyll «a». The chlorophyll «a» concentration was determined by molecular absorption spectrometry (T 90-117) according to the method of Lorenzen (1967). The optical density of each extract was measured in a spectrophotometer (WPA, S104), at 665 nm before and after acidification (0.1N HCl). The chlorophyll «a» concentration in each extract was determined by difference according to Marker et al. (1980) and Pechar (1987) using Equation 1.

$$Chl.a\,(ug\,l^{-1}) = \frac{v}{V * d} * (Db - Da) * 2.439 * 11.89 \qquad (1)$$

Db = optical density of extract before acidification; Da = optical density of extract after acidification; v = volume of total extract (ml); V = volume of water sample filtered (l); d = diameter of the optical cell used (cm).

A rough microalgal biomass was computed from the chlorophyll a values. Assuming that chlorophyll a constitutes, on the average, 1.5% of the dry weight of organic matter (ash-free weight) of algae, the algal biomass can be estimated by multiplying the chlorophyll a content by a factor of 67 (Raschke, 1993).

Determination of plankton abundance

Plankton net of 20 µm mesh size was used to determine the abundance of plankton. Sampling was done with a vertical plankton tow one per month. Species identification was performed under a light microscope. For each of the common identified species 400 individuals were counted for each species and the corresponding sampling volume was noted. Rare species were investigated and counted on the whole sample volume. The density of each species was calculated as in Houssou et al. (2015).

$$D = \left(n * \frac{Vs}{Vd} * S * P\right) * 1000 \quad (2)$$

D = Density per liter of water; n= Number of counted individuals; Vs = Total volume of sample; Vd = Sample volume corresponding to n; S = Base surface area of the plankton net; P = Depth of sampling; 1000 = Conversion factor (m^3 to l).

Total length-weight (TL-W) and condition factor

The Total length-weight relationships were used to determine the ponderal growth using the equation provided by Le Cren (1951) (Equation 3):

$$BW = aTL^b \quad (3)$$

BW = the total weight (g), TL = the total length (cm), a = the fish environment coefficient and b = the slope or the relative growth coefficient. The equation was used in its logarithmic form:

$LogBW = loga + blogTL$.

The condition factor was calculated for each individual using the equation of Ricker (1968) (Equation 4):

$$K = 100BW * SL^{-3} \quad (4)$$

K = the relative condition factor; BW = the total weight (g); TL = the total length (TL cm); SL = the total length (SL cm).

Determination of reproductive parameters

The maturity stages of gonads were determined by macroscopic analysis based on the 5 scales of gonad maturation (Plisnier et al., 1988). Gonado-Somatic Ratio (GSR) and Gonado-Somatic Index (GSI) correspond respectively to the gonad weight (GW) in percentage of the body weight (BW) (Equation 5) and the eviscerated fish weight (EW) (Equation 6). The Equation (7) was used to calculate the gonad weight-fish size ratio.

$$GSR = GW/BW * 100 \quad (5)$$

$$GSI = GW/EW * 100 \quad (6)$$

$$R = GW/TL^3 * 10^3 \quad (7)$$

GW = the gonad weight (g); BW = body weight; EW = the eviscerated fish weight (g), TL = the fish‟ total length (cm).

Data analysis

Data on feed, growth and survival parameters were analyzed using Microsoft Excel 2010. Fish performance and yield were calculated using the following formulae:

Weight gain (WG) = final weight - initial weight as in Kang‟ombe et al. (2006)

Average weight gain (AWG) = final mean weight/final number of fish as in Belal et al. (2015)

Daily weight gain (DWG) = AWG*breeding period^{-1} as in Imorou Toko (2007); Kapute et al. (2016)

Ponderal specific growth rate (PSGR) = 100*[ln((final mean fish weight)-ln(initial mean fish weight))*breeding period^{-1}] as in Gbaï et al. (2014)

Linear specific growth rate (LSGR) = 100*[ln((final mean fish total length)-ln(initial mean fish total length))*breeding period^{-1}] as in Gbaï et al. (2014)

Nutritive quotient (NQ) = quantity of dry food distributed*weight gain^{-1} as in Bamba et al. (2008)

Survival rate (SR) = 100*(final number of fish*initial number of fish^{-1}) as in Bamba et al. (2008)

Net biomass (NB) = final biomass - initial biomass as in Bamba et al. (2008)

Biomass per square meter (BPM) = net biomass*surface area^{-1} as in Kang‟ombe et al. (2006); Bamba et al. (2008).

The collected data were analyzed using the R software (http://cran.r-project.org). For physicochemical parameters, the factors of variation considered were the rearing tank, the time of the day and the period post nursery. For zootechnical parameters, the dual effect of the waterway of origin and age at experimental fishing, and, the dual effect of the sex and age at experimental fishing were tested. Interactions were significant only for the survival rate. The waterway, sex and age at experimental fishing are not therefore influenced via their interactions. The mathematical expression of the obtained model without interaction was (Equation 8):

$$Y_{ijkl} = \mu + W_i + S_j + Age_k + e_{ijkl} \quad (8)$$

Y_{ijkl}: Zootechnical performances of individual l, from i^{th} waterway, of the j^{th} sex and of the k^{th} age at experimental fishing; μ: Grand mean effect; W_i: Differential effect of the i^{th} waterway (Lake Nokoué, Lake Toho and Grand-Popo Lagoon); S_j: Differential effect of the j^{th} sex (male and female); Age_k: differential effect of the k^{th} age at experimental fishing (30, 60 and 90 DPN); e_{ijkl}: Residual effect of the zootechnical performances of individual l, from the i^{th} waterway, of the j^{th} sex and of the k^{th} age at experimental fishing.

The linear model procedure of R software was used for data analysis. The analysis was implemented with the R Commander package. The F test was used to determine the significance of each effect and the means were compared pairwise using the *t*-test of Student. The Principal Components Analysis (PCA) of zootechnical data was achieved by the *PCA* procedure of R. The *hclust* method of R was used to achieve the dendrogram.

RESULTS

Characteristics of rearing water

The physicochemical parameters of the water remained relatively stable during the 90 DPN (Table 1). The dissolved oxygen and the TDS did not vary significantly from a tank to another ($p>0.05$). In the morning, at 30 and 90 DPN (Days Post Nursery), the conductivity was similar between tanks 3 and 4. But it was lower ($p<0.05$) in these two latter tanks than in tanks 1 and 2. Every evening, the pH did not vary significantly in all tanks during all experiment. The same tendency was recorded for this

Table 1. Variation of the physicochemical parameters of the w ater according to the time of the day and the period post nursery.

Variable	Time	Period	Tank 1		Tank 2		Tank 3		Tank 4		ANOVA
			M	SD	M	SD	M	SD	M	SD	
Conductivity (µs/cm)	Morning	30DPN	7.07^{a}	0.12	6.99^{b}	0.09	6.95^{c}	0.15	6.95^{c}	0.14	***
		60DPN	7.07^{a}	0.75	6.82^{b}	0.17	6.74^{c}	0.16	6.66^{d}	0.29	**
		90DPN	6.84^{a}	0.33	6.6^{b}	0.09	6.52^{c}	0.11	6.52^{c}	0.16	***
	Evening	30DPN	6.99^{a}	0.14	6.99^{a}	0.21	6.96^{a}	0.11	8.52^{a}	9.88	NS
		60DPN	6.93^{a}	0.59	6.71^{b}	0.16	6.65^{c}	0.21	6.75^{b}	0.22	*
		90DPN	6.86^{a}	0.3	6.58^{b}	0.25	6.55^{bc}	0.2	6.52^{c}	0.17	***
pH	Morning	30DPN	6.67^{a}	0.31	6.55^{b}	0.25	6.44c	0.27	6.44c	0.31	***
		60DPN	6.92^{a}	0.35	6.71^{b}	0.32	6.58c	0.32	6.58c	0.33	***
		90DPN	6.63^{a}	0.29	6.46^{a}	0.25	6.43^{a}	0.36	6.41^{a}	0.32	NS
	Evening	30DPN	6.7^{a}	0.37	6.63^{a}	0.33	6.53^{a}	0.29	6.58^{a}	0.3	NS
		60DPN	6.84^{a}	0.36	6.74^{a}	0.32	6.73^{a}	0.28	6.65^{a}	0.33	NS
		90DPN	6.82^{a}	0.38	6.75^{a}	0.26	6.75^{a}	0.31	6.67^{a}	0.25	NS
Dissolved oxygen (mg/l)	Morning	30DPN	7.67^{a}	0.78	7.65^{a}	0.67	7.91^{a}	0.64	7.73^{a}	0.91	NS
		60DPN	8.01^{a}	1.3	7.91^{a}	1.35	7.81^{a}	0.93	7.93^{a}	1.39	NS
		90DPN	7.94^{a}	1.11	7.89^{a}	1.05	8.19^{a}	1.58	7.61^{a}	0.7	NS
	Evening	30DPN	7.8^{a}	0.81	7.88^{a}	1.09	7.49^{a}	0.82	7.7^{a}	0.87	NS
		60DPN	7.96^{a}	1.09	7.82^{a}	1.31	7.64^{a}	1.28	7.35^{a}	0.92	NS
		90DPN	8.2^{a}	1.7	7.65^{a}	0.94	8.92^{a}	2.03	7.54^{a}	1.24	NS
Temperature (°C)	Morning	30DPN	28.38^{a}	0.63	28.25^{a}	0.6	28.27^{a}	0.63	28.35^{a}	0.55	NS
		60DPN	28.9^{a}	0.69	28.87^{a}	0.63	28.83^{a}	0.64	28.86^{a}	0.67	NS
		90DPN	28.93^{a}	0.47	29.01^{a}	0.43	28.89^{a}	0.81	28.99^{a}	0.49	NS
	Evening	30DPN	29.21^{b}	0.86	29.51^{a}	0.61	29.54^{a}	0.58	29.66^{a}	0.68	*
		60DPN	30.07^{a}	0.6	29.9^{a}	0.53	30.32^{a}	0.57	30.11^{a}	0.49	NS
		90DPN	30.09^{a}	0.55	30.33^{a}	0.51	30.34^{a}	0.54	30.39^{a}	0.52	NS
Salinity (mg/l)	Morning	30DPN	0.34^{a}	0.01	0.34^{a}	0.01	0.34^{a}	0.01	0.34^{a}	0.01	NS
		60DPN	0.35^{a}	0.04	0.33^{b}	0.01	0.33^{b}	0.01	0.33^{b}	0.01	***
		90DPN	0.34^{a}	0.02	0.32^{b}	0	0.32^{b}	0.01	0.32^{b}	0.01	***
	Evening	30DPN	0.34^{a}	0.01	0.34^{a}	0.01	0.34^{a}	0.01	0.34^{a}	0.01	NS
		60DPN	0.34^{a}	0.03	0.33^{a}	0.01	0.32^{a}	0.01	0.33^{a}	0.01	NS
		90DPN	0.34^{a}	0.02	0.32^{b}	0.01	0.32^{b}	0.01	0.32^{b}	0.01	***
TDS (ppm)	Morning	30DPN	307.62^{a}	13.4	313.1^{a}	12.97	312.62^{a}	13.26	314.05^{a}	14.83	NS
		60DPN	294.29^{a}	12	291.43^{a}	7.05	292.14^{a}	5.68	293.57^{a}	7.8	NS
		90DPN	285^{a}	7.6	285.71^{a}	5.14	287.14^{a}	4.69	287.86^{a}	5.79	NS
	Evening	30DPN	309.52^{a}	14.31	313.1^{a}	14.73	313.33^{a}	13.73	315^{a}	14.86	NS
		60DPN	293.21^{a}	14.16	294.29^{a}	8.36	293.57^{a}	6.78	292.86^{a}	8.1	NS
		90DPN	286.43^{a}	7.45	287.86^{a}	8.02	288.57^{a}	5.35	287.86^{a}	5.79	NS

***: $p<0.001$; **: $p<0.01$; *: $p<0.05$; NS: $p>0.05$; TDS = total dissolved solids; M = mean; SD = *S*tandard deviation; DPN = days post nursery; ANOVA = analysis of variance.

parameter in the morning at 90 DPN. However, in the morning, at 30 and 60 DPN, this physicochemical parameter remained similar between the tanks 3 and 4, but lower than these tanks 1 and 2. At 60 and 90 DPN in the morning and at 90 DPN in the evening, the salinity did not vary significantly between tanks 2, 3 and 4. However, it was less elevated in these three tanks than in the tank 1 ($p<0.001$). It was similar ($p>0.05$) between all the tanks at 30 DPN in the morning and respectively at 30 and 60 DPN in the evening.

The production of chlorophyll a varied significantly in experimental tanks ($p<0.05$). Chlorophyll a concentration ranged from 1,113.12 to 1,956.51 µg.l^{-1} (Figure 2). Three phytoplankton species (*Scenedesmus quadricauda*,

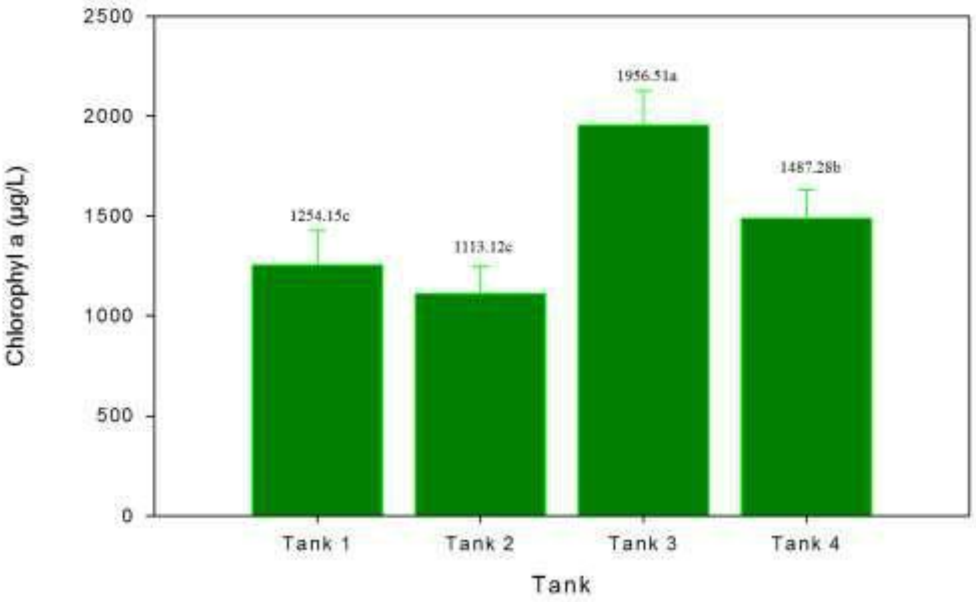

Figure 2. Concentration in chlorophyll «a» at each rearing tank (From a tank to another, the means w ith different alphabetic superscripts are different at the threshold of 5%).

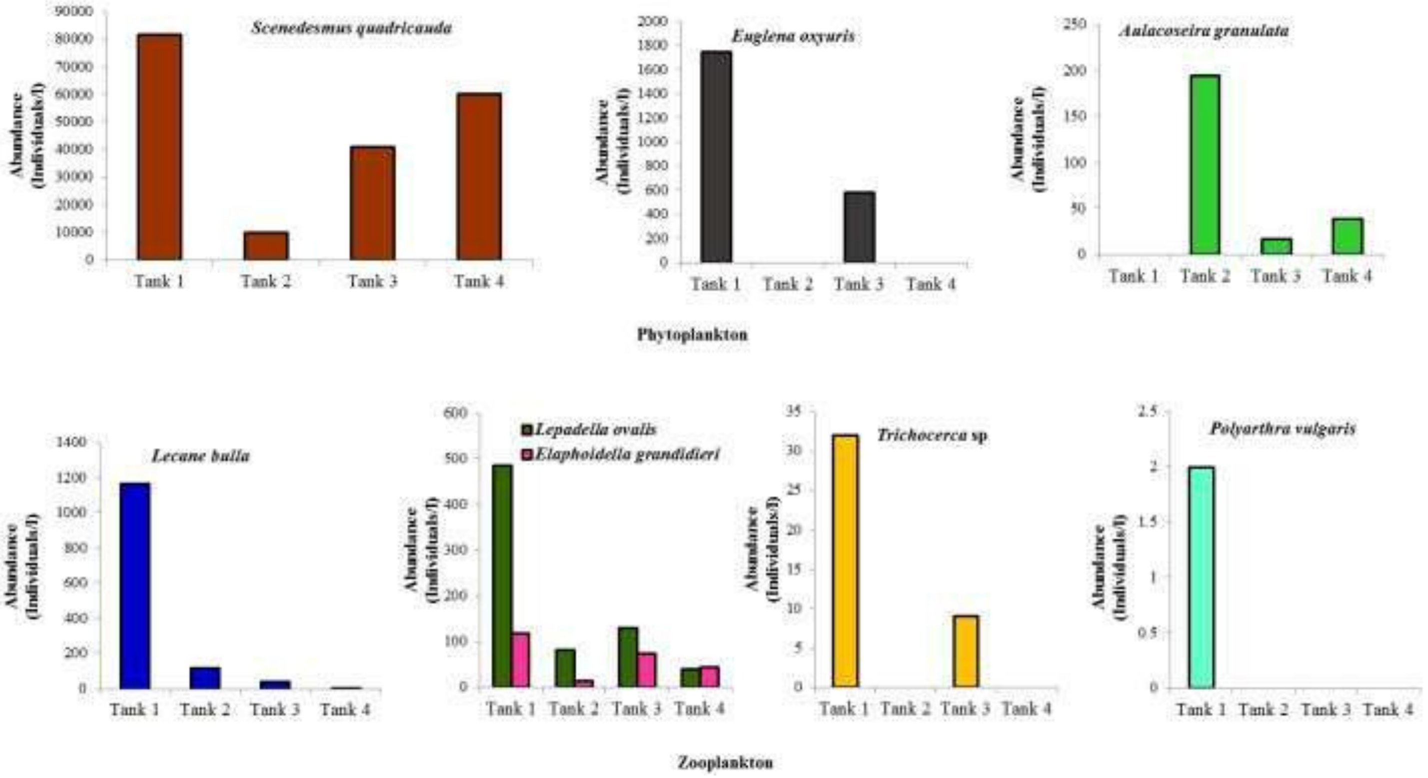

Figure 3. Abundance of planktons per tank and per species or group.

Euglena oxyuris, *Aulacoseira granulata)* and five zooplankton species (*Lecane bulla*, *Lepadella ovalis*, *Trichocerca* sp, *Polyarthra vulgaris*, *Elaphoidella grandidieri*) were observed in the rearing tanks (Figure 3). The most important phytoplankton and zooplankton species were *Scenedesmus quadricauda* (81,563

Table 2. Variation of the zootechnical parameters per waterway, sex and age at experimental fishing.

Variable	Waterway						Sex				Age at experimental fishing						Significativity		
	Lake Nokoué		Lake Toho		Grand-Popo Lagoon		Male		Female		30 DPN		60 DPN		90 DPN		Water way	Sex	Age
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD			
BW (g)	24.81^{b}	4.71	32.88^{a}	5.2	18.48c	3.8	26.49^{a}	7.99	24.28^{a}	6.89	23.98^{b}	6.53	27.1^{ab}	7.06	30.13^{a}	7.26	***	NS	**
TL (cm)	10.86^{b}	0.89	11.67^{a}	0.74	9.56c	0.83	10.85^{a}	1.29	10.55^{a}	1.09	10.46^{b}	0.97	11.06^{ab}	1.02	11.57^{a}	0.93	***	NS	***
SL (cm)	8.34^{b}	0.65	9.06^{a}	0.57	7.5c	0.62	8.42^{a}	0.97	8.16^{a}	0.8	8.07^{b}	0.75	8.51^{ab}	0.75	8.98^{a}	0.71	***	NS	***
WG (g)	7.23^{a}	3.63	6.94^{a}	4.15	5.63^{a}	2.85	7.64^{a}	3.43	5.57^{a}	3.45	3.43c	1.29	6.76^{b}	2.45	9.61^{a}	3.4	NS	NS	***
AWG (g)	0.8^{b}	0.3	1.88^{a}	0.45	0.58c	0.15	1.08^{a}	0.63	1.1^{a}	0.7	0.86^{a}	0.5	1.04^{a}	0.68	1.36^{a}	0.72	***	NS	NS
DWG (g.day $^{-1}$)	0.24^{a}	0.12	0.23^{a}	0.14	0.19^{a}	0.1	0.26^{a}	0.11	0.19^{a}	0.11	0.12c	0.04	0.23^{b}	0.08	0.32^{a}	0.11	NS	NS	***
PSGR (%.day $^{-1}$)	1.1^{a}	0.5	0.73^{a}	0.37	1.15^{a}	0.47	1.09^{a}	0.43	0.9^{a}	0.51	0.57c	0.18	1.03^{b}	0.31	1.39^{a}	0.47	NS	NS	***
LSGR (%.day $^{-1}$)	0.47^{a}	0.2	0.32^{b}	0.14	0.5^{a}	0.2	0.47^{a}	0.2	0.39^{a}	0.2	0.25c	0.07	0.45^{b}	0.14	0.59^{a}	0.18	*	NS	***
NQ	12.5^{b}	8.39	37.94^{a}	33.54	12.8^{b}	9.87	13.45^{b}	16.8	28.71^{a}	27.07	31.35^{a}	26.24	18.09^{a}	20.45	13.81^{a}	21.65	**	*	NS
K	4.13^{a}	0.2	4.27^{a}	0.26	4.3^{a}	0.27	4.2^{a}	0.25	4.27^{a}	0.26	4.34^{a}	0.18	4.21^{a}	0.3	4^{b}	0.19	NS	NS	***
SR (%)	88.17^{a}	15.97	90.37^{a}	10.53	82.73^{a}	11.16	90.65^{a}	7.15	83.53^{a}	16.16	95.22^{a}	5.85	90.85^{a}	8.65	75.2^{b}	13.2	NS	NS	***
NB (g)	7.23^{a}	3.63	6.94^{a}	4.15	5.63^{a}	2.85	7.64^{a}	3.43	5.57^{a}	3.45	3.43c	1.29	6.76^{b}	2.45	9.61^{a}	3.4	NS	NS	***
BPM (g.m $^{-2}$)	1.81^{a}	0.91	1.74^{a}	1.04	1.4^{a}	0.71	1.91^{a}	0.86	1.39^{a}	0.86	0.86c	0.32	1.69^{b}	0.61	2.4^{a}	0.85	NS	NS	***

***: $p<0.001$; **: $p<0.01$; *: $p<0.05$; NS: $p>0.05$; M = Mean; SD = standard deviation; DPN = days post nursery; The intra-class means of the same row followed by the same letters don't differ significantly with the threshold of 5%. BW = body weight; TL = total length; SL = standard length; WG = weight gain; AWG = average weight gain; DWG = daily weight gain; PSGR = Ponderal specific growth rate; LSGR = linear specific growth rate; NQ = nutritive quotient; K = condition factor; SR = survival rate; NB = net biomass; BPM = biomass per square meter.

individuals/l) and *Lecane bulla* (1,165 individuals/l) respectively. The details of planktons‟ abundance results were presented in Figure 3.

Influence of the waterway, sex and age at experimental fishing on the zootechnical characteristics of *S. melanotheron*

At the end of the experiment, the weight gain, DWG, PSGR, condition factor, survival rate, net biomass and the BPM showed no significant variation in relation to the waterway of origin. The body weight of individuals from Lake Nokoué was intermediate between the one of those from Lake Toho and Grand-Popo Lagoon ($p<0.001$). The same tendency was observed for the total length, standard length and AWG (Table 2). The LSGR and nnutritive quotient were similar ($p>0.05$) between individuals of Lake Nokoué and Grand-Popo Lagoon. However, these two parameters were less and more elevated among individuals of Lake Toho than those of Lake Nokoué and Grand-Popo Lagoon ($p<0.05$) respectively.

All zootechnical characteristics with the exception of the nutritive quotient did not differ significantly between males and females ($p>0.05$). The nutritive quotient was significantly higher in males than in females ($p<0.05$).

The body weight, total length and standard length were not only similar between the 30 and 60 DPN but also similar between the 60 and 90 DPN. The weight gain, DWG, PSGR, LSGR, net biomass and BPM were not only significantly less important during the 30 DPN than during the 60 DPN but also lower during the 60 DPN than during 90 DPN ($p<0.001$). The condition factor and survival rate were similar during the 30 and 60 DPN and higher during these two periods than during the 90 DPN ($p<0.001$). Furthermore, the AWG and nutritive quotient did not vary significantly during the three periods post nursery (Table 2).

Multivariate analysis based on zootechnical parameters

Principal components analysis (PCA) and

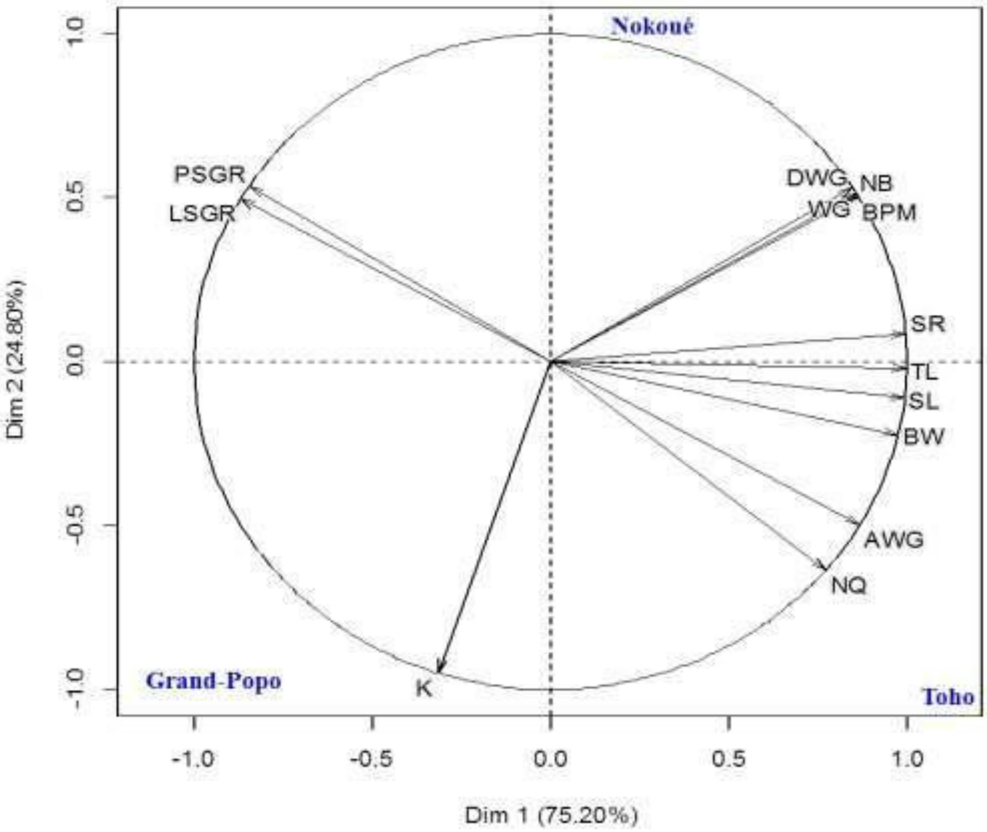

Figure 4. PCA analysis based on the zootechnical parameters of *S. melanotheron*. BW, Body weight; TL, Total length; SL, standard length; WG, weight gain; AWG, average weight gain; DWG, daily weight gain; PSGR, Ponderal specific growth rate; LSGR, linear specific growth rate; NQ, nutritive quotient; K, condition factor; SR, survival rate); NB, net biomass; BPM, biomass per square meter.

dendrogram applied on zootechnical characteristics of *S. melanotheron* stood out 2 groups: The group that is only constituted of Lake Toho and the one including the Lake Nokoué and Grand-Popo Lagoon (Figure 4). *S. melanotheron* individuals from Lake Nokoué and Lake Toho were characterized by higher body weight, total length, standard length, weight gain, AWG, DWG, nutritive quotient, survival rate, net biomass, BPM while Grand-Popo lagoon individuals were characterized by higher condition factor and a weak ponderal and linear specific growth rates (Figure 4). Lake Nokoué and Grand-Popo Lagoon were found closer in term of nutritive quotient and survival rate whereas Lake Toho was found very far from them.

Relative growth and reproductive parameters

The relative growth coefficient, b ranged from 1.35 to 2.74 for males and from 1.83 to 3.17 for females. The body and eviscerated weights were relatively bound to the total and standard lengths $0.34 \leq R^2 \leq 0.87$ for males and $0.6 \leq R^2 \leq 0.88$ for females. For both sexes, b ranged from 1.94 to 3.27 with $0.59 \leq R^2 \leq 0.93$ (Table 3). The highest values of gonads weight, gonado-somatic ratio, gonado-somatic index and gonad weight-fish size ratio were recorded among females of the Lake Toho but, their weakest values were observed in males of Lake Toho. Among males, all the reproductive parameters did not vary significantly (p>0.05) according to the waterway of origin. However, for females, these parameters were significantly higher for individuals from Lakes Nokoué and Toho than those from Grand-Popo Lagoon (p<0.05) (Figure 5). In all combined populations, the majority of males were at maturity stage V while females were at stage IV (Figure 6).

DISCUSSION

The tilapia species *S. melanotheron*, characteristic of West African estuarine ecosystems, has a tolerance to a variety of habitats, which could be explained by original physiological features, allowing its important adaptive skills. Indeed, this fish has a high tolerance to low dissolved oxygen levels (Ouattara et al., 2003; Ouattara,

Table 3. Parameters of w eight-length relationships of *S. melanotheron.*

Water way	Ratio	Sex	b	a	R²	N
Nokoué	BW/TL	M+F	2.05	0.21	0.82	30
		M	2.48	0.06	0.85	15
		F	2.42	0.08	0.74	15
	EW/TL	M+F	2.41	0.07	0.89	30
		M	2.51	0.05	0.85	15
		F	2.42	0.07	0.78	15
	BW/SL	M+F	1.94	0.47	0.85	30
		M	2.30	0.19	0.73	15
		F	1.83	0.60	0.80	15
	EW/SL	M+F	2.20	0.22	0.87	30
		M	2.31	0.17	0.71	15
		F	1.84	0.50	0.84	15
Toho	BW/TL	M+F	2.85	0.03	0.93	30
		M	2.46	0.08	0.87	15
		F	3.17	0.01	0.81	15
	EW/TL	M+F	3.27	0.01	0.92	30
		M	2.41	0.08	0.84	15
		F	3.07	0.01	0.77	15
	BW/SL	M+F	2.69	0.08	0.91	30
		M	2.22	0.26	0.80	15
		F	2.31	0.20	0.88	15
	EW/SL	M+F	3.01	0.03	0.87	30
		M	2.19	0.26	0.78	15
		F	2.21	0.21	0.82	15
Grand-Popo	BW/TL	M+F	2.13	0.17	0.59	30
		M	2.74	0.03	0.85	15
		F	2.99	0.02	0.67	15
	EW/TL	M+F	2.35	0.08	0.65	30
		M	2.60	0.04	0.78	15
		F	2.90	0.02	0.60	15
	BW/SL	M+F	2.02	0.40	0.60	30
		M	1.46	1.48	0.40	15
		F	3.12	0.03	0.88	15
	EW/SL	M+F	2.15	0.25	0.61	30
		M	1.35	1.71	0.34	15
		F	3.06	0.03	0.81	15

M = male; F = female; b = logarithmic slope; R^2 = linear regression coefficient; N= number of specimens; BW = body w eight; EW = eviscerated fish w eight; TL = total length; SL = standard length.

2009). Like most of tilapia species, in *S. melanotheron* faces no particular metabolic difficulties if the water‟s dissolved oxygen does not fall below 3 mg l^{-1} (Ouattara, 2009). This species also supports large variations in pH (3.5 to 7.6) of its environment (Ouattara et al., 2003), high tolerance to turbidity (Mélard, 2014), a good resistance to pollution and survives in an extended temperature range (eurythermal species) ranging from 22 and 32°C (Philippart and Ruwet, 1982). The optimal temperature range for its reproduction spreads between 17 and 32°C (Philippart and Ruwet, 1982). What is most characterizes this species is its strong euryhalinity (Panfili et al., 2006; Yoboué et al., 2012) that allows to survive at salinities superior than 0.3 mg l^{-1} (case of Lake Nokoué in Benin) (Chikou et al., 2013) and probably develop a normal gametogenesis and reproduce at high salinities (fry were observed up to $85{,}10^3$ mg l^{-1} in the wild) (Pauly, 1976). Very little is known about the reactions of *S. melanotheron* to hypersaline conditions, in terms of acclimatization and adaptation. Individuals transferred

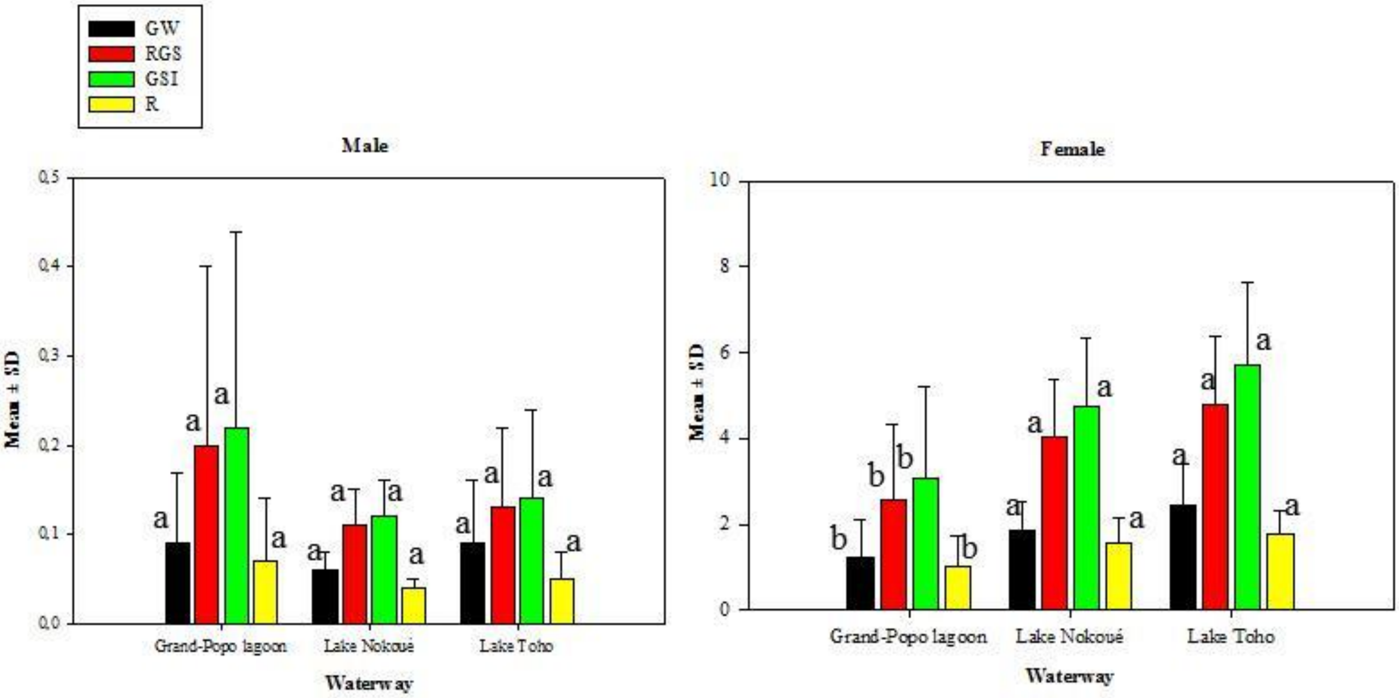

Figure 5. Gonado-somatic ratio, gonado-somatic index and gonad weight-fish size ratio of *Sarotherodon melanotheron* individuals at the end of the experiment (GW = gonad weight; GSR = gonado-somatic ratio; GSI = gonado-somatic index; R = gonad weight-fish size ratio; For each sex, the means of the same reproductive parameter with different alphabetic superscripts are different at the threshold of 5%).

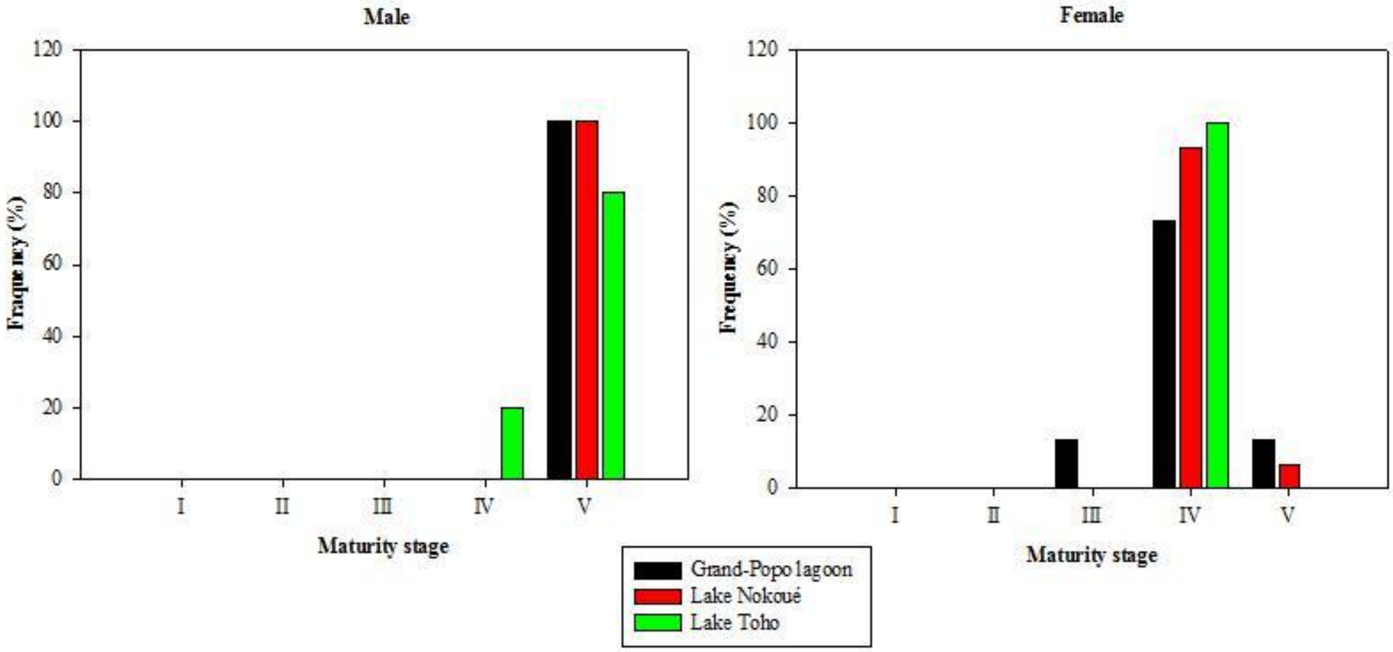

Figure 6. Stage of sexual maturity of individuals according to waterway of origin, at the end of the experiment.

directly from fresh water to sea water (35×10^3 mg l^{-1}) got acclimated to experimental conditions without any mortality (Gilles, 2005). However, other studies indicated that the high salinity could constitute a limiting factor for the species‟ growth (Panfili et al., 2004; Tine et al., 2007). Furthermore, studies led by Chikou et al. (2013) in

Beninese waterways like Porto-Novo Lagoon, Djègbadji‟s coastal Lagoon, Lake Ahémé and SUCOBE reservoir, indicate that the species can live comfortably in environments where dissolved oxygen rate varies from 0.35 to 9.74 mg l^{-1}. The same authors indicate that the species can withstand the relatively turbid habitat with water transparency ranging from 0.35 to 67.73 cm. The values recorded in this study for these physicochemical parameters are within limits compatible with good survival and growth of *S. melanotheron* individuals.

S. melanotheron is characterized by an opportunistic diet (Ofori-Danson and Kumi, 2009; Arizi et al., 2014). Juveniles feed on zooplankton while adults with herbivorous tendency, feeding on macrophytes, nekton, phytoplankton and sediment bacteria (Gilles, 2005). A study led on Sakumo Lagoon in Ghana showed that there is not a clear difference between types of plankton exploited by juveniles and adults with respective Shanno‟s diversity indices of 1.1 and 1.2 (Ofori-Danson and Kumi, 2009). However, it is necessary to note that juveniles have a preference for Cyanophyceae, Chlorophycae and Rotifera while adults prefer Cladocera, Bacillariophyceae and Cyanophyceae (Gilles, 2005; Ofori-Danson and Kumi, 2009). The majority of these plankton species were available in the rearing tanks during our juveniles rearing.

Growth parameters recorded in this study are similar to those enumerated in literature. Fish growth is influenced by many factors including food (quality and quantity) and environmental variables (Boyd and Tucker, 1998). This process‟ variability is also depending on the fish habitat. In lagoon environment, the intensive farming (based on composed feed supplying) in floating cages of *S. melanotheron* showed weaker performance compared to results recorded in Acadja (Ouattara et al., 2009). The rearing system seems to have more effect on the growth than the rearing environment. A study led in Côte d'Ivoire (Ouattara et al., 2005) showed that in floating cages, *S. melanotheron*„s growth (0.42±0.00 $g.day^{-1}$) was higher than the one recorded in lagoon environment (0.38 $g.day^{-1}$) (Gbaï et al., 2014). In concrete tanks, these values were 0.19±0.01 $g.day^{-1}$ in freshwater and 0.21 $g.day^{-1}$ in brackish water (Gilles, 1994). Among the three rearing structures tested by Ouattara et al. (2005), the earthen ponds were more interesting (0.47 ± 0.02 $g.day^{-1}$) than the floating cages (0.42±0.00 $g.day^{-1}$) and concrete tanks (0.19 ± 0.01 $g.day^{-1}$). In Ebrié lagoon to Côte d‟Ivoire, a sharp increase was observed in *S. melanotheron* male growth between mixed rearing and monosex rearing while female growth remained stable (Ouattara et al., 2009). This was confirmed in our study where DWG did not differ significantly between males and females (0.26 *vs* 0.19; $p>0.05$). In the wild *S. melanotheron*‟s growth is slow as a result of temperature influence combined with the one of salinity (their abrupt variations that alter the metabolism of fish and causing thus the decrease in natural food consumption) (Ouattara et al., 2009). According to Ouattara et al. (2005), the DWG of *S. melanotheron* increase with temperature, dissolved oxygen, transparency and pH ranged respectively from 25.3 to 32.1°C, 0.70 to 12.40 mg/l, 200 to 1,370 mm and 6.73 to 8.77 (weak correlation, $p<0.05$). Some zootechnical performances reductions appear at dissolved oxygen and pH below respectively 2.3 mg/l and 6 (Ross, 2000). These observations corroborate with the results reported in this study. The DWG observed for *S. melanotheron* remained lower to the values most often recorded for *O. niloticus*. At the Kou valley in Burkina Faso the values recorded by Amoussou et al. (2014) were ranged between 0.67±0.04 and 0.88±0.08 $g.day^{-1}$. A daily weight gain equal to 0.36 $g.day^{-1}$ was obtained for the indigenous tilapia *S. melanotheron* of Côte d‟Ivoire (Gbaï et al., 2014). In addition, our mean daily weight gains are similar to those recorded for the natural population of this species in Côte d‟Ivoire (0.18 and 0.22 $g.day^{-1}$) (Ouattara et al., 2004). As for the nutritive quotient, the smaller it is, the better quality the food is and the better the fish grow. The nutritive quotients recorded in our study are relatively similar to those obtained for *O. niloticus* (Ngokaka et al., 2010). However, our values showed that wild individuals of *S. melanotheron* have very poorly valorized the high quality feed (35 and 57% protein) used during the experiment. This may be due to the will origin of these individuals and the stocking density used during the study. The nutritive quotient may also be influenced by the quality of the natural food (plankton) available in the rearing tanks. Furthermore, the Lake Nokoué and Grand-Popo Lagoon are brackish waters while Lake Toho is a fresh waterway. As the rearing was carried out in freshwater, the individuals of Lake Toho seem to have quickly adapted to it while taking advantage of both the artificial feed used and the natural food (planktons) available in the tanks. This may justify their best performance.

The most desirable relative growth in fish farming is the isometric pattern ($b=3$). Overall, females had their b (relative growth coefficient) values superior to those of males and allometric ($b<3$) pattern of growth occurs among most of the reared populations. This remark is consistent with the findings of Amoussou et al. (2016a) on *S. melanotheron*‟s wild individuals coming from these waterways. Koné and Teugels (1999) observed significant variability of GSR in Lake Ayamé (Côte d‟Ivoire). Similarly, like the SGR, the maturity stage observed in this study is in conformity with those reported by these authors. Sexual maturation and reproductive behavior are controlled by an interaction of endogenous (internal/hormonal) and exogenous (environmental) parameters (Brummett, 1995; Toguyeni et al., 2009). Blay (1998) reported a maturity ages of 3 months in the estuary and 5 months in the lagoon for *S. m. melanotheron*. This could explain the presence of individuals at maturity stage III after 90 DPN (either 6 months of age) in the batch of individuals from Grand-

Popo lagoon.

CONCLUSION AND RECOMMANDATION

S. melanotheron individuals from Lake Toho performed more than those of Lake Nokoué and Grand-Popo Lagoon. The majority of the individuals indicated an allometric growth, which is less desirable for fish farming. Two populations are distinguished: The first constituted by the individuals of Lake Nokoué and the Grand-Popo lagoon and the second represented by those of the Lake Toho. Both groups obtained justify the water quality in the three waterways. Indeed, Lake Nokoué and Grand-Popo Lagoon are brackish waters whereas Lake Toho is a freshwater waterway. As the rearing was carried out in freshwater, the individuals of Lake Toho seem to have quickly adapted to it compared to those of Grand-Popo Lagoon and Lake Nokoué. *S. melanotheron* individuals coming from these lakes can be recommended for rearing. The implementation of a selective breeding program (in fresh and brackish waters) of these local populations will thus improve their zootechnical performances.

Conflict of Interests

The authors have not declared any conflict of interests.

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