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Analysis of Morphological Parameters of Wild Populations of *Oreochromis niloticus* (Linnaeus, 1758) of the Three Hydrographic Basins of Southern Benin

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Abstract: The morphological characteristics of a fish species are under the dual influence of environmental and genetic factors. This study aims to identify the local populations of *Oreochromis niloticus* to use in Beninese fish farming. Individuals of this tilapia species were collected from nine sampling sites of the main waterways of Southern Benin. The morphological parameters of these individuals were analysed in relation with their waterway of origin, hydrobiological sampling period and sex. The body weight, total length, standard length and interorbital width were on one hand significantly higher among individuals sampled at Ouémé River than those of Couffo River and on the other hand higher in these 2 waterways than Lake Toho. The head length, body height, prepectoral length, dorsal-fin base length, caudal peduncle height and the dorso-anal length were significantly higher among individuals of Couffo River than those of Ouémé River. The majority of the sampled fish had a size ranged from 10 to 15 cm with 53.15%, 49.29% and 68.60% respectively for individuals from Ouémé River, Lake Toho and Couffo River. Among males from Ouémé River, Couffo River and females of Lake Toho and Couffo River, the relative growth was allometric. The growth of males from Lake Toho and females from Ouémé River was isometric. At both sexes, the condition factor varied from 1.60±0.36 to 1.91±0.53 and 1.56±0.30 to 2.11±1.86 respectively. Two populations are observed: one grouping individuals from Ouémé River, and the second one grouping those of Couffo River and Lake Toho.
Keywords: Aquaculture, Fisheries, Hydrobiology, Morphometric characteristics.

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1. Introduction

Benin has inland waters constituted of rivers, lagoons and lakes which are very favourable to fishing [1]. The inland fishery is of fundamental importance in the country, since it represents more than 75% of the national fisheries production [2]. However, quantities of fish captured and imported did not cover the local demand [3]. In this context, the fish farming promotion remains one of the best alternatives to meet the national fish demand gap.

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Since the middle of the 20th century, aquaculture was introduced in the African continent's tradition [4] thanks to the discovery of performances for aquaculture of the group of tilapia's species in this case *Oreochromis niloticus*. This species has been introduced in Benin for aquaculture purpose in 1979 [5]. Nowadays, tilapia constitutes the basis of the Beninese fresh water fish farming and this was related to the massive production of the male tilapia fry's monosex by hormonal inversion of the sex these last years [2]. The growth performances of this species' populations are different in the various parts of the country [6]. The hydrological and environmental conditions most often do not allow fish species to express their full growth potential [7]–[9]. In *Oreochromis niloticus*, the metric characteristics are more dependent on environmental parameters (such as temperature, pH, dissolved oxygen,…) than any genetic factor [10]. Knowing that Benin has several hydrographic basins [11], these populations may have different origins which could explained the difference in zootechnic performances linked to inter and/or intra strain genetic variability. In addition, performances of these populations are little known across the country. Indeed, for aquatic organisms, geographical isolation factors such as waterfalls and expanses of land can prevent the movement of individuals between populations while diminishing gene flow [12] and affecting their performance. Furthermore, since their introduction in the Beninese waterways, the individuals have never been characterized morphologically or genetically. Even so, the knowledge of the diversity of these populations constitutes a previous to the sustainable management and for the improvement of the fish stocks [13]. In addition, the life history of a species can influence its morphology. In the same way, ecological variations are important in the structuring of natural populations [12]. However, the variation of some morphometric characters is phenotypic [14]. But, the morphological divergences observed between populations are generally sustained by genetic differentiations [13], [14].

The South Benin overflows many waterways constituted of lakes, rivers and lagoons. These waterways contain for most fresh waters. It seems that the introduced strains are not always the same and vary according to their origin. It is therefore interesting to bring out the features of this species in these different habitats, of which, some could promote a better taking off of fish farming. The present study aims to analyse the morphological parameters of the populations of *Oreochromis niloticus* in relation with their waterway of origin, hydrobiological period of sampling and sex.

2. Materials and Methods

2.1. Area of study:

Covering an area of 112,622 km^2, Benin (6°30'-12°30' North latitude and 1°-30°40' East longitude) is delimited in a set of large basins of the West African sub-region: the Niger River basin, Volta River basin, Ouémé River basin, Couffo River basin and Mono River basin. The study was conducted in Ouémé River (6°39' N, 2°28' E), Lake Toho (6°35' N, 1°45' E) and Couffo River (6°57' N, 1°38' E) in Southern Benin (Figure 1). All these waterways are constituted of fresh water. These are the main fresh waterways of the hydrographic basins of Southern Benin. The vegetation is mainly characterized by forest (Table 2).

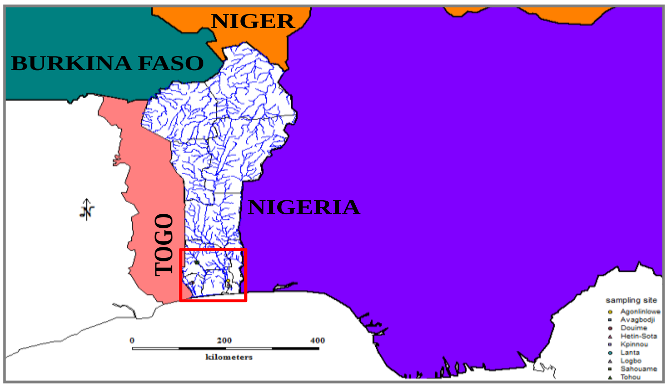

Figure 1: Map of the Benin hydrographical network, showing the geographical location of the study's areas.

2.2. Data collection:

A total of 459 *Oreochromis niloticus* individuals (Table 1) were sampled randomly from catches of fishermen in the three waterways during four campaigns (one campaign per month). The sampled catches are those of local fishermen using gill-nets, cast-nets, keep-nets, fish hooks and long lines. Two sampling campaigns were done during the rise of the water level and two others during the subsidence. Morphometric measurements and meristic counts were recorded on each individual according to [14]–[16]. For each specimen, 17 measurements and 10 meristic characters were recorded as in [17]. The sampled fish are weighed individually using an electronic balance (Ohaus®, precision: 0.1 g). The water quality of each waterway was assessed to see if this is related to the morphological distribution of the studied populations. Thus, physicochemical parameters of water were monitored as in [17]. The total length-weight relationships, standard length-body height relationships and condition factors were computed as described by [17].

2.3. Statistical analysis:

The averages of physicochemical, morphometric and meristic parameters were computed by the *summary* procedure of R software (http://cran.r-project.org). The F test was used to determine the significance of each effect (hydrobiological period and time of the day for physicochemical parameters, and hydrobiological period, waterway and sex for morphological parameters) and means were compared two per two using the t test of Student after checking the normality of the distribution and variances homogeneity. Correlations, on one hand, between physicochemical parameters and, on the other hand, between morphological parameters were calculated by the *cor* procedure of R. The significance of each correlation was estimated by the *cor.test* procedure of R. The Factorial Correspondences Analysis (FCA) of physicochemical, morphometric and meristic data was achieved by the *CA* procedure of R. The *hclust* method of R was used to achieve the Numeric Classification (NC). The accuracy of each linear relationship was estimated using the *lm* procedure of R software.

Hydrographic basin	Waterway	Sample size
Ouémé	Ouémé River	112
Mono	Lake Toho	140
Couffo	Couffo River	207
Total		**459**

Table 1: Number of individuals sampled.

3. Results

3.1. Physicochemical parameters:

The physicochemical parameters were summarised in the Figure 2. In the most of the case, no significant difference was observed for these parameters according to the time and the hydrobiological period of data collection. However, in the Couffo River the water's temperature was seen to be higher in the evening compared to morning ($p<0.05$). Otherwise, in the Ouémé River, conductivity, salinity and TDS were significantly higher during the subsidence than the rise of the water level ($p<0.001$). Furthermore, the dissolved oxygen was higher ($p<0.05$) during the rise of the water level than the subsidence (7.02 mg/l *vs* 5.56 mg/l).

Table 2: Characteristics of sampling sites based on the hydrographic basins**.**

Waterway	Sampling site	GPS co-ordinates		Climatic zone	Vegetation cover of the basin	Aquatic vegetation
Ouémé River	Agonlinlowé	06°39'54.0" N	002°28'57.0" E	Equatorial	Grasslands	Scarce
	Hêtin Sota	06°35'41.6" N	002°30'16.9" E	Equatorial	Grasslands	Abundant and diverse
	Avagbodji	06°31'30.3" N	002°31'55.7" E	Equatorial	Grasslands	Abundant and diverse
Lake Toho	Logbo	06°37'02.6" N	001°46'03.5" E	Subequatorial	Guinean forest-savannas	Scarce
	Douimè	06°37'33.1" N	001°46'59.0" E	Subequatorial	Guinean forest-savannas	Abundant and diverse
	Kpinnou	06°36'36.3" N	001°46'21.8" E	Subequatorial	Guinean forest-savannas	Abundant and diverse
Couffo River	Lanta	07°06'43.6" N	001°52'44.3" E	Subequatorial	Dry semi-deciduous forest and Guinean forest-savannas	Scarce
	Sahouamè	07°07'09.0" N	001°52'14.6" E	Subequatorial	Dry semi-deciduous forest and Guinean forest-savannas	Abundant
	Tohou	07°05'54.4" N	001°52'46.6" E	Subequatorial	Dry semi-deciduous forest and Guinean forest-savannas	Abundant

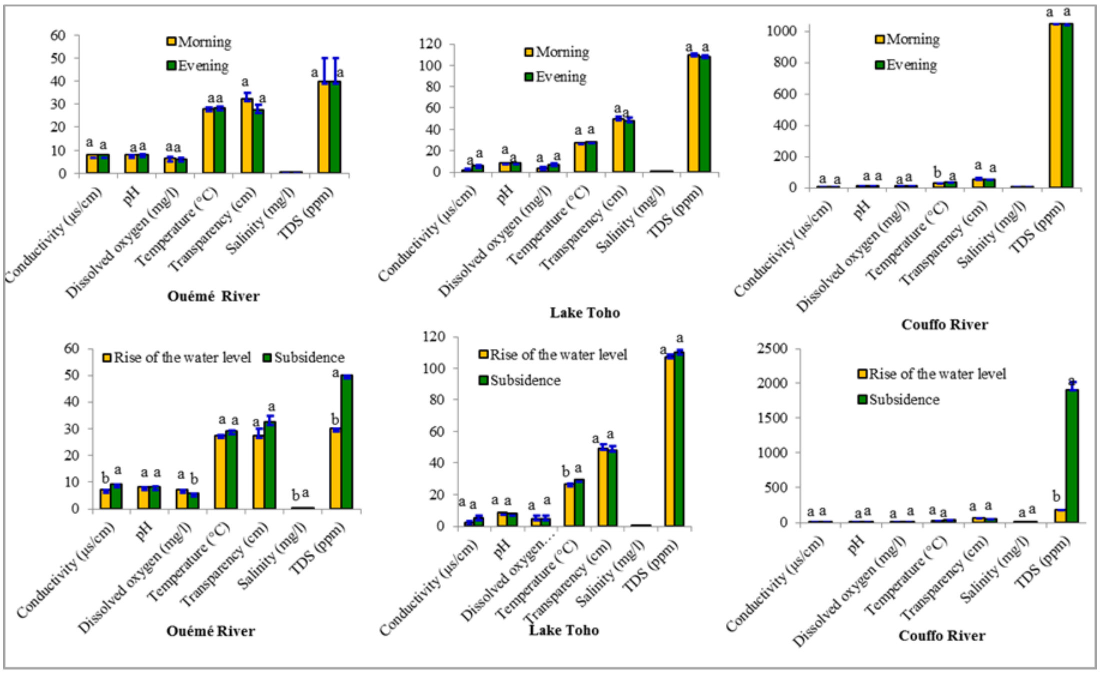

Figure 2: Physicochemical parameters per waterway according to the time of the day and the hydrobiological period. The means between classes of the same row followed by the same letter don't differ significantly with the threshold of 5%; M = Mean; SE = S

At Lake Toho, the temperature was significantly higher ($p<0.01$) during the subsidence than the rise of the water level. Similarly, in the Couffo River, the TDS level was significantly higher during the subsidence compared to the rise of the water level ($p<0.001$).

In the morning, percentages of the variance decreased suddenly with the first axis explaining 97.04% of variations between waterways, and the second axis 2.96% (Figure 3a). On the axis 1, the temperature, transparency and TDS allowed to bring closer the Ouémé River and Lake Toho and to move them away from Couffo River (Figures 3a and 4a). In the evening, percentages of the variance also decreased suddenly with the first axis explaining 95.51% of variations between waterways and the second axis 4.49% (Figure 3b). On the axis 1, the temperature, transparency and TDS also permitted to bring closer the Ouémé River and the Lake Toho and to move them away from the Couffo River (Figures 3b and 4b). When focusing on the physicochemical parameters, two groups were stood out: the group constituted on one hand by Lake Toho and Ouémé River and the group constituted on the other hand by Couffo River.

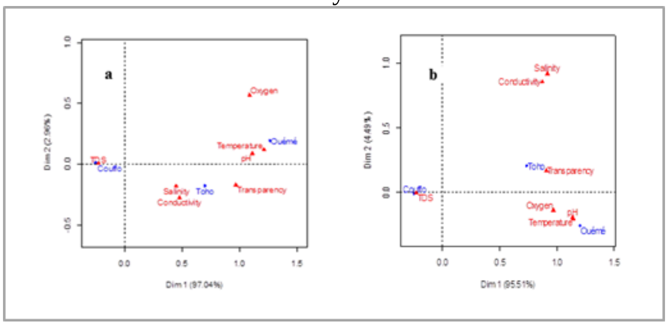

Figure 3: FCA analysis based on the physicochemical parameters according to the time of the day (a: morning *vs* b: evening).

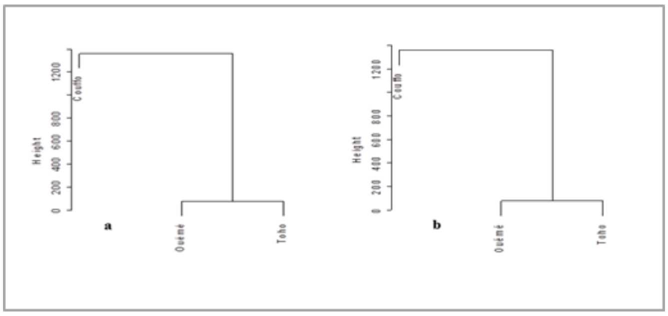

Figure 4: Numeric classification based on physicochemical factors, showing proximities of *Oreochromis niloticus* populations according to the time of the day (a: morning *vs* b: evening).

3.2. Distribution of sampled individuals per class of sizes:

Structures by size of *Oreochromis niloticus* individuals per waterway showed that the majority of the captured individuals were of small sizes (Figure 5). The modal class was from 10 to 15 for all the 3 waterways. Most of the sampled fish has a size ranged between 10 and 15 cm with 53.15%, 49.29% and 68.60% respectively in for Ouémé River, Lake Toho and Couffo River. Pearson's skewness was equal to 1.51 (>0) indicating that the distribution is skewed to the right.

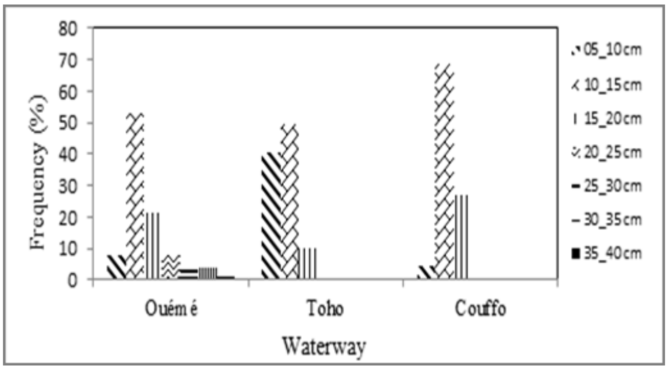

Figure 5: Fish sizes distribution in the sampled waterways.

3.3. Relative growth and condition factor:

The body height of *Oreochromis niloticus*' individuals was strongly and significantly associated to the standard length in all the three waterways ($p<0.001$). This relationship is linear and the determination coefficients (R^2) varied from 0.68 to 0.96 for males and between 0.57 and 0.79 for females (Table 3). However, the highest accuracy was obtained with males from Ouémé River ($R^2=0.96$; $p<0.001$). The relationship between the body weight and total length followed a power type equation (Table 4). Among males, the relative growth coefficients (b) varied from 2.0 to 3.0 with the determination coefficients that varied from 0.74 to 0.95 and from 2.5 to 3.0 for females. For this latter sex, the determination coefficients varied from 0.69 to 0.95. In each waterway, the condition factor didn't vary significantly ($p>0.05$) according to the sex (Table 5). The smallest and strongest values of K were recorded among females respectively at Ouémé River (1.56) and Lake Toho (2.11).

3.4. Metric and ponderal parameters:

Most of the metric and ponderal parameters didn't vary significantly between the rise of the water level and the subsidence (Table 6). The body height was higher among individuals caught during the rise of the water level than those of the subsidence (38.06 %SL *vs* 32.03 %SL; $p<0.01$). The same tendency was observed for the eye diameter (8.34 %SL *vs* 6.75 %SL; $p<0.001$) and the dorso-anal length (53.13 %SL *vs* 48.73 %SL; $p<0.05$). The weight was significantly higher among individuals sampled at Ouémé River than those of Couffo River ($p<0.05$) and higher in these 2 waterways than Lake Toho ($p<0.05$). The same tendency was obtained for the total length, standard length and interorbital width (Table 6). The head length, body height, prepectoral length, dorsal-fin base length, caudal peduncle height and dorso-anal length were higher among individuals of Couffo River than those of Ouémé River ($p<0.05$). Moreover, these metric parameters were more important in these 2 waterways than the Lake Toho ($p<0.05$). The pelvic-fin length was more important in the Couffo River than in the Lake Toho and in these 2 waterways than Ouémé River ($p<0.001$). The pectoral-fin length was similar among individuals of Ouémé River and those of Couffo River. However, it was higher at these two waterways than the Lake Toho ($p<0.001$). Otherwise, the snout length, eye diameter, predorsal length, preanal length, prepelvic length, anal-fin base length were similar from a waterway to another. With regard to the sex, the body weight, total length, standard length, snout length, anal-fin base length were higher in males than females ($p<0.05$) (Table 7).

3.5. Meristic parameters:

The dorsal-fin rays were significantly higher among *Oreochromis niloticus* individuals of Couffo River than those of the two other waterways ($p<0.05$). In addition, this meristic count was more important ($p<0.05$) at Ouémé River than Lake Toho (Table 8). In southern Benin, the dorsal-fin spines of *Oreochromis niloticus* individuals were intermediate between the Lake Toho and both Ouémé and Couffo Rivers but, they were more important at the Couffo River than Ouémé River ($p<0.05$). Furthermore, the anal-fin rays, anal-fin spines and around caudal peduncle scales didn't vary significantly from a waterway to another (Table 8). The upper lateral line scales were on one hand, less important at Ouémé River than the 2 other waterways and on the other hand, significantly higher at Lake Toho than Couffo River ($p<0.001$). The lower lateral line scales, the pre-dorsal scales and the first branchial arc's upper and lower gill rakers were significantly more important among individuals from Ouémé River than those of Couffo River and significantly higher at Couffo River than Lake Toho ($p<0.001$). Regarding the operculum scales, they were intermediate between *Oreochromis niloticus* individuals from Lake Toho and both Ouémé River and Couffo River ($p<0.05$). However, they were significantly higher ($p<0.05$) at Ouémé River than Couffo River (Table 8). Concerning the sex, only the lower lateral line scales varied significantly ($p<0.05$) from a sex to another. Indeed, they were significantly higher ($p<0.05$) among males than females (Table 9).

3.6. Correlations between meristic parameters:

With regard to the meristic parameters, the number of dorsal-fin spines and the upper lateral line scales were negatively and weakly correlated with the pre-dorsal scales ($r=-0.11$; $r=-0.12$; $p<0.05$). The dorsal-fin rays were positively and moderately bound to the pre-dorsal scales ($r=0.12$; $p<0.01$). The upper lateral line scales were negatively and moderately correlated with the around caudal peduncle scales ($r=-0.13$; $p<0.01$). Moreover, the lower lateral line scales were positively and moderately bound to the around caudal peduncle scales ($r=0.14$; $p<0.01$) and the operculum scales ($r=0.14$; $p<0.01$). Otherwise, the around caudal peduncle scales were negatively and moderately correlated to the operculum scales ($r=-0.13$; $p<0.01$) (Table 10). The dorsal-fin rays were positively and greatly ($p<0.001$) correlated to the anal-fin rays ($r=0.31$), the upper lateral line scales ($r=0.24$), the operculum scales ($r=0.16$) and the first branchial arc's upper and lower gill rakers ($r=0.19$) respectively. In addition, the anal-fin rays were positively and greatly ($p<0.001$) bound to the upper lateral line scales ($r=0.34$), the operculum scales ($r=0.27$) and the first branchial arc's upper and lower gill rakers ($r=0.20$) respectively. Otherwise, the upper lateral line scales were positively and strongly correlated with the operculum scales ($r=0.40$; $p<0.001$). The lower lateral line scales, the around caudal peduncle scales and the operculum scales were positively and greatly bound to the first branchial arc's upper and lower gill rakers ($r=0.19$; $r=0.26$; $r=0.27$; $p<0.001$) (Table 10).

3.7. Multivariate analysis of metric and meristic parameters:

In order to analyze the closeness between the 3 waterways, FCAs and NCs (Figures 6 and 7) were also achieved on metric and meristic parameters. Thus, percentages of the variance decreased suddenly, with the first axis explaining 96.65% of variations between waterways and the second axis 3.35%. On the axis 1, the total length, standard length and pelvic-fin length permitted to move away the Lake Toho from the Ouémé River (Figures 6a and 7a). With meristic counts, percentages of the variance also decreased suddenly, with the first axis explaining 71.70% of variations between waterways and the second axis 28.30%. On the axis 1, the dorsal-fin spines, the upper lateral line scales, the pre-dorsal scales and the operculum scales also allowed to move away the Lake Toho from the Ouémé River. On the axis 2, the first branchial arc's upper and lower gill rakers permitted to bring closer the Lake Toho and Couffo River (Figures 6b and 7b). AFCs and NCs of the metric and meristic variables permitted to stand out two groups: the group constituted on one hand, of Lake Toho and Couffo River and the group constituted on the other hand, of Ouémé River.

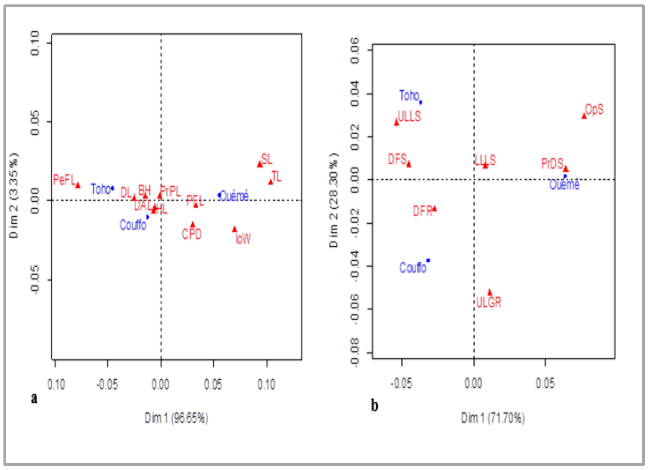

Figure 6: FCA analysis based on the metric and meristic variables. a=metric variables; b=meristic variables.

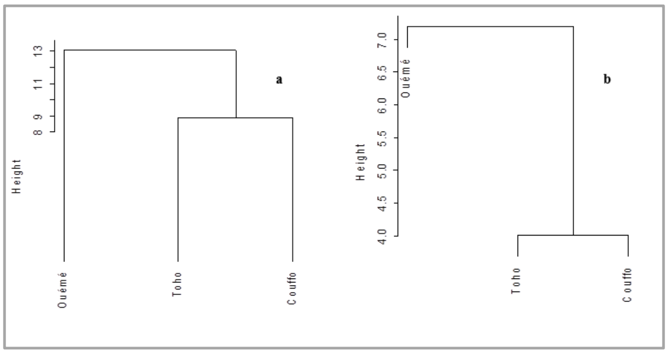

Figure 7: Dendrogram (Ward's method) based on the metric and meristic variables. a: metric variables; b: meristic variables.

4. Discussion

4.1. Relationship between environment and morphological parameters in *Oreochromis niloticus*:

According to the physicochemical parameters, the water quality remained in the limits recommended for tilapias [18]–[21]. Otherwise, most of the sampled fish size ranged between 10 and 15 cm whatever the waterways (Ouémé River, Lake Toho and Couffo River). These data may indicate overfishing in reference to data in the literature which show that under the right conditions, tilapia can reach sizes between 10 and 63 cm (Lake Nakuru, Kenya, [8]).

Table 3: Equations and determination coefficients (R^2) of the SL-BH relationships per sex in relation with the waterways.

Waterway		Male	Female
Ouémé River	**Equation**	y=2.409x+1.876	y=1.650x+4.590
	R²	0.96	0.57
	Intercept	1.88	4.6
	Slope	2.41	1.65
	RSE	1.01	2.61
	Test of significance	***	***
Lake Toho	**Equation**	y=2.007x+2.846	y=2.111x+2.524
	R²	0.82	0.78
	Intercept	2.85	2.52
	b	2.01	2.11
	RSE	0.95	1.14
	Test of significance	***	***
Couffo River	**Equation**	y=2.372x+0.928	y=2.055x+2.670
	R²	0.68	0.79
	Intercept	0.93	2.67
	b	2.37	2.1
	RSE	1.18	0.68
	Test of significance	***	***

*** = $p<0.001$; RSE = Residual Standard Error.

Table 4: Equations and determination coefficients (R^2) the TL-W relationships according to the sex in the samples in relation to waterways.

Waterway		Male	Female
Ouémé River	**Equation**	$y=0.014x^{2.0}$	$y=0.020x^{3.0}$
	R²	0.95	0.95
	Logarithmic equation	LogW=2LogTL-1.85	LogW=3LogTL-1.7
Lake Toho	**Equation**	$y=0.026x^{3.0}$	$y=0.067x^{2.5}$
	R²	0.91	0.69
	Logarithmic equation	LogW=3LogTL-1.59	LogW=2.5LogTL-1.17
Couffo River	**Equation**	$y=0.048x^{2.6}$	$y=0.035x^{2.7}$
	R²	0.74	0.78
	Logarithmic equation	LogW=2.6LogTL-1.32	LogW=2.7LogTL-1.46

W = Total weight; TL = Total Length.

Table 5: Condition factor (K) recorded during the study per waterway and sex.

Waterway	Male		Female		Test of significance
	Mean	SD	Mean	SD	
Ouémé River	1.60a	0.36	1.56a	0.3	NS
Lake Toho	1.91a	0.53	2.11a	1.86	NS
Couffo River	1.88a	0.79	1.85a	0.61	NS

The means between classes of the same row followed by the same letter don't differ significantly with the threshold of 5%; NS = $p>0.05$; SD = Standard Deviation.

Table 6: Variation of metric and ponderal parameters according to the sampling period and waterway.

Variable	Period					Waterway						
	Rise of the water level		Subsidence		ANOVA	Ouémé River		Lake Toho		Couffo River		ANOVA
	M	SE	M	SE		M	SE	M	SE	M	SE	
Weight	51.74a	3.06	54.88a	4.6	NS	91.31a	13.25	31.70c	1.96	49.09b	1.63	***
TL	13.16a	0.25	13.47a	0.23	NS	11.27c	0.55	15.57a	0.25	13.65b	0.15	***
SL	10.08a	0.19	10.45a	0.18	NS	8.95c	0.44	11.97a	0.2	10.44b	0.12	***
HL (%SL)	32.52a	0.17	34.85a	0.64	NS	29.69c	0.22	31.81b	0.51	34.01a	0.98	***
BH (%SL)	38.06a	0.25	32.03b	0.66	**	33.50c	0.95	34.98b	0.49	37.48a	0.91	**
SnL (%SL)	7.05a	0.14	7.75a	0.43	NS	7.63a	0.15	7.52a	1.01	7.56a	0.2	NS
ED (%SL)	8.34a	0.09	6.75b	0.15	***	7.04a	0.37	6.92a	0.12	7.35a	0.14	NS
IoW (%SL)	7.99a	0.17	8.45a	0.22	NS	6.99c	0.22	9.08a	0.27	8.83b	0.3	***
PrDL (%SL)	31.36a	0.21	32.53a	0.59	NS	32.07a	0.65	31.30a	0.46	32.84a	0.87	NS
PrAL (%SL)	69.26a	0.92	72.04a	1.28	NS	70.60a	0.46	68.73a	0.83	73.25a	2.1	NS
PrPL (%SL)	34.29a	0.2	33.17a	0.64	NS	31.01c	0.62	33.48b	0.34	35.09a	0.96	***
PrPeL (%SL)	39.38a	0.44	38.20a	0.72	NS	37.1	0.59	37.5	0.62	39.99	1.1	NS
DL (%SL)	53.84a	0.32	51.07a	0.94	NS	49.05c	0.69	49.95b	0.56	54.60a	1.46	***
AL (%SL)	13.51a	0.21	15.49a	0.83	NS	16.32a	0.4	14.42a	1.96	14.39a	0.36	NS
PFL (%SL)	34.98a	0.42	33.68a	0.65	NS	30.25b	0.71	35.60a	0.53	35.69a	0.93	***
PeFL (%SL)	26.46a	0.24	25.81a	0.59	NS	26.07b	0.5	23.21c	0.43	27.40a	0.89	***
CPH (%SL)	10.81a	0.14	10.19a	0.2	NS	9.09c	0.22	10.70b	0.19	11.01a	0.28	***
DAL (%SL)	53.13a	0.34	48.73b	0.99	*	45.96c	0.41	49.16b	0.78	52.84a	1.55	***

The means between classes of the same row followed by the same letter don't differ significantly with the threshold of 5%; *** = p<0.001; ** = p<0.01; * = p<0.05; NS = p>0.05; M = Mean; SE = Standard Error; ANOVA = Analysis of variance; TL = Total Length; SL = Standard Length; HL = Head Length; BH = Body Height; SnL = Snout Length; ED = Eye Diameter; IoW = Interorbital Width; PrDL = Predorsal Length; PrAL = Preanal Length; PrPL = Prepectoral Length; PrPeL = Prepelvic Length; DL = Dorsal-fin base Length; AL = Anal-fin base Length; PFL = Pectoral-Fin Length; PeFL = Pelvic-Fin Length; CPH = Caudal Peduncle Height; DAL = Dorso-Anal Length.

Table 7: Variation of metric and ponderal parameters according to the sex.

Variable	Female		Male		t test
	M	SE	M	SE	
Weight	46.56b	3.15	66.20a	7.58	**
TL	13.03b	0.19	13.98a	0.36	**
SL	10.07b	0.15	10.81a	0.29	**
HL (%SL)	32.03a	0.27	32.34a	1.17	NS
BH (%SL)	35.18a	0.43	36.42a	1.11	NS
SnL (%SL)	6.97b	0.1	8.54a	0.82	*
ED (%SL)	7.27a	0.16	6.95a	0.16	NS
IoW (%SL)	8.10a	0.12	8.71a	0.41	NS
PrDL (%SL)	32.16a	0.33	32.35a	1.03	NS
PrAL (%SL)	70.62a	0.55	72.51a	2.42	NS
PrPL (%SL)	33.59a	0.33	33.23a	1.13	NS
PrPeL (%SL)	38.37a	0.38	38.70a	1.31	NS
DL (%SL)	50.80a	0.4	53.34a	1.73	NS
AL (%SL)	13.76b	0.18	16.96a	1.6	**
PFL (%SL)	33.65a	0.35	34.58a	1.17	NS
PeFL (%SL)	25.34a	0.26	27.00a	1.08	NS
CPH (%SL)	10.19a	0.11	10.60a	0.36	NS
DAL (%SL)	48.82a	0.41	51.49a	1.86	NS

The means between classes of the same row followed by the same letter don't differ significantly with the threshold of 5%; ** = p<0.01; * = p<0.05; NS = p>0.05; M = Mean; SE = Standard Error; ANOVA = Analysis of variance; TL = Total Length; SL = Standard Length; HL = Head Length; BH = Body Height; SnL = Snout Length; ED = Eye Diameter; IoW = Interorbital Width; PrDL = Predorsal Length; PrAL = Preanal Length; PrPL = Prepectoral Length; PrPeL = Prepelvic Length; DL = Dorsal-fin base Length; AL = Anal-fin base Length; PFL = Pectoral-Fin Length; PeFL = Pelvic-Fin Length; CPH = Caudal Peduncle Height; DAL = Dorso-Anal Length.

Table 8: Variation of meristic characteristics according to the waterway.

Variable	Ouémé River			Lake Toho			Couffo River			ANOVA
	M	SE	Range	M	SE	Range	M	SE	Range	
DFR	12.11b	0.06	11-14	11.53c	0.08	9-15	12.16a	0.05	10-14	***
DFS	16.51c	0.13	7-18	16.74b	0.05	15-19	16.76a	0.04	15-18	*
AFR	9.12a	0.06	8-11	9.01a	0.06	07-11	9.19a	0.05	07-12	NS
AFS	3a	0	3-3	3a	0	3-3	3a	0	3-3	NS
ULLS	21.54c	0.13	17-25	22.72a	0.27	14-29	21.71b	0.21	7-32	***
LLLS	15.11a	0.21	11-21	13.64c	0.12	10-17	13.75b	0.15	8-25	***
PrDS	8.28a	0.22	5-18	6.63c	0.2	3-15	6.75b	0.14	2-17	***
CPS	14.75a	0.19	10-20	14.5a	0.28	10-22	15.24a	0.21	7-28	NS
OpS	21.88a	0.53	9-31	17.59b	0.67	3-34	16.8c	0.58	4-39	***
ULGR	24.61a	0.27	18-31	20.55c	0.42	9-29	24.01b	0.28	10-35	***

The means between classes of the same row followed by the same letter don't differ significantly with the threshold of 5% ; * = p<0.05; *** = p<0.001; NS = p>0.05; M = Mean, SE = Standard Error, ANOVA = Analysis of variance, DFR = Dorsal-Fin Rays; DFS = Dorsal-Fin Spines; AFR = Anal-Fin Rays; ULLS = Upper Lateral Line Scales; LLLS = Lower lateral line scales; PrDS = Pre-Dorsal Scales; CPS = around Caudal Peduncle Scales; OpS = Operculum Scales; ULGR = first branchial arc's Upper and Lower Gill Rakers.

Table 9: Variation of meristic counts according to the fish sex.

Variable	Female			Male			t test
	M	SE	Range	M	SE	Range	
DFR	11.95a	0.05	9-15	11.95a	0.07	9-15	NS
DFS	16.72a	0.03	15-19	16.65a	0.09	7-19	NS
AFR	9.14a	0.05	7-12	9.09a	0.05	7-11	NS
AFS	3a	0	3-3	3a	0	3-3	NS
ULLS	22.09a	0.17	7-32	21.8a	0.2	13.-29	NS
LLLS	13.88b	0.11	8-21	14.32a	0.17	9-25	*
PrDS	7.01a	0.13	2-17	7.21a	0.2	2-18	NS
CPS	14.57b	0.15	7-26	15.42a	0.25	8-28	**
OpS	18.68a	0.5	3-39	17.64a	0.53	3-34	NS
ULGR	22.83a	0.26	9-35	23.53a	0.33	9-33	NS

The means between classes of the same row followed by the same letter don't differ significantly with the threshold of 5% ; * = p<0.05; ** = p< 0.01; NS = p>0.05; M = Mean, SE = Standard Error, ANOVA = Analysis of variance, DFR = Dorsal-Fin Rays; DFS = Dorsal-Fin Spines; AFR = Anal-Fin Rays; ULLS = Upper Lateral Line Scales; LLLS = Lower lateral line scales; PrDS = Pre-Dorsal Scales; CPS = around Caudal Peduncle Scales; OpS = Operculum Scales; ULGR = first branchial arc's Upper and Lower Gill Rakers.

Table 10: Correlations between the different meristic parameters of *Oreochromis niloticus.*

	DFS	AFR	ULLS	LLLS	PrDS	CPS	OpS	ULGR
DFR	-0.06NS	0.31***	0.24***	-0.05NS	0.12**	-0.04NS	0.16***	0.19***
DFS		-0.02NS	-0.04NS	-0.07NS	-0.11*	0.06NS	-0.09NS	0.03NS
AFR			0.34***	0.01NS	0.01NS	-0.04NS	0.27***	0.20***
ULLS				-0.003NS	-0.12*	-0.13**	0.40***	0.05NS
LLLS					0.19NS	0.14**	0.14**	0.19***
PrDS						0.03NS	0.18***	0.05NS
CPS							-0.13**	0.26***
OpS								0.27***

*** = *P*<0.001; ** = *P*<0.01; * = *P*<0.05; NS = *P*>0.05; DFR = Dorsal-Fin Rays; DFS = Dorsal-Fin Spines; AFR = Anal-Fin Rays; ULLS = Upper Lateral Line Scales; LLLS = Lower lateral line scales; PrDS = Pre-Dorsal Scales; CPS = around Caudal Peduncle Scales; OpS = Operculum Scales; ULGR = first branchial arc's Upper and Lower Gill Rakers.

The same observations were done by [22] in the Ouémé River, [5] in Lake Toho and [23] in the Couffo River. But given that this species has been introduced, we can also think that the hydrological and environmental conditions do not allow it to express its full growth potential as suggested by many authors [7]–[9]. The maximum size of this species is more dependent on environmental conditions than any genetic differences [10]. In Côte d'Ivoire where the species was also introduced, some individuals reached the size of 46 cm at the Lake Kossou [8]. For example in the Lake Tchad, *Oreochromis niloticus* reaches 30 cm after 3 years while in the Lake Mariout (Egypt), 5 years are needed to reach the same size [10].
Analysis of the relationships between standard length and body height revealed that, the more an individual is fat, the better is its growth. For the two sexes, the relative growth coefficients (b) of the total length-weight (TL-W) relationships, varied from 2 to 3. This relationship is used to compare the growth of species between different regions [24]. For males of the Ouémé River and the Couffo River and females of the Lake Toho and the Couffo River, the growth of *Oreochromis niloticus* is allometric and the species grows more in length than weight. For males of the Lake Toho and females of the Ouémé River, the growth is isometric as b=3. These results are consistent with those generally found in the literature for this species. Indeed, the previous studies on *Oreochromis niloticus* from Benin, the found b value were 2.799 for Ouémé River [25], 3.06 for Lake Toho [5] and 2.86 for Couffo River [23]. The b value didn't vary significantly according to the sex and this is consistent with the observations of [5]. Otherwise, the analysis of a large number of length-weight relationships (L-W) from Fishbase shows that the values of the relative growth coefficient b ranged between 2 and 4 in general. Indeed, in his study, [24] showed that 90% of individuals had values between 2.7 and 3.4. Our results were in the same trend of the data obtained by [26] on two species of tilapia, *Oreochromis niloticus* and *S. melanotheron* in the Lake Ayamé in Côte d'Ivoire.
We also analysed the condition coefficient (K) which is used as an indicator of the variability attributable to growth coefficient (b). Indeed, for [27], the condition factor allows to characterize the physiological and nutritional state of fish. It also permits to appreciate the biological state and embonpoint of fishes. However, the length-weight relationships in fishes can be affected by several factors including habitat, gonad maturity, sex, health and stomach fullness [27], [28]. The data obtained in males and females, are similar to those observed by [5] in Lake Toho and [23] in Couffo River. Similary, among natural populations of this species, [29] noted the K values ranged from 0.11 to 0.75 (0.44±0.14). The observed values reveal a good adaptation of this species in these different waterways. Otherwise, [30] demonstrated on *T. zillii* and *O. urolepsi* that b is more important in brackish water than fresh water (3.3 *vs* 2.94 and 3.45 *vs* 2.81). The inverse tendency was observed for K (0.74 *vs* 2.07 and 0.53 *vs* 0.86). Thus the differences noticed at the level of each population would be due to their habitat, the available food resources, the individual's demographic structure, the selectivity of the fishing gears, the predation, the waterway surface area, the waterfall as suggested by previous studies [25], [31]–[34]. Our observations may suggest that these fish undergo both environmental effect and genetic drift.

4.2. Intra and inter population's morphometric variability in *Oreochromis niloticus*:

Since their introduction in the Beninese Rivers in 1979 for aquaculture purpose, no survey has been conducted on the morphological characterization of *Oreochromis niloticus*. The data obtained in this study could only be compared to those available in the literature. Several meristic counts (the dorsal-fin rays, the dorsal-fin spines, the upper lateral line scales, the lower lateral line scales, the operculum scales and the first branchial arc's upper and lower gill rakers) allowed to discriminate populations of Lake Toho and Couffo River and to differentiate them out of those of the Ouémé River. Similarly, many measurements combined (the total length, the standard length, the head length, the body height, the interorbital width, the prepectoral length, the dorsal-fin base length, the pectoral-fin length, the pelvic-fin length, the caudal peduncle height and the dorso-anal length) also allow to discriminate the populations of the Lake Toho and the Couffo River and those of the Ouémé River. The same trend were previously obtained by [35] on tilapia strains from Volta basin (Burkina Faso), Nile basin (Uganda) and Lake Manzaleh (Egypte). The differences observed between populations according to the number of some meristic variables could indicate that individuals used during the different fish stocking campaigns were probably not the same strain. Moreover, these differences might also revealed genetic mutations due to the physicochemical quality of the water in these three waterways. [36] underlined that, in the wild, fish from hypoxic areas tend to have larger gills than fish from normoxic areas, which is probably an adaptive response. These differences can be due to the smallness of the sampled individuals of this study and that could also be bound to the overfishing in these waterways. Indeed, apart from gill-net, keep-net, fish hook and long line, fishermen also use cast nets of which some variants contribute to catch fish at all levels of water (surface water, bottom water and deep water) contributing to the destruction of spawning grounds.
The inter population variability showed high significant differences ($p<0.01$) for weight, standard length, head length, body height, interorbital width, prepectoral length, dorsal-fin base length, pectoral-fin length, pelvic-fin length, caudal peduncle height and dorso-anal length. The same observation was made by [37] for the size at first sexual maturity of *Oreochromis niloticus* females from man-made lakes of Côte d'Ivoire. The FCAs show clearly that the metric variables are more discriminative than the meristic variables. These observations are consistent with those of [35] who consider these characters like an ecological key feature bound to the fish habitat. The works of [35] also show the metric variables as pertinent in the discrimination of *Oreochromis niloticus* in this case, the prepelvic length, the prepectoral length, the head length, the preanal length. For [38], the most discriminative metric characters in tilapias is the head length. According to [39], for tilapias, the eye diameter is one of the most discriminative metric variables. In our study, we found many discriminative measurements like total length, standard length, pelvic-fin length and dorso-anal length. These parameters identified as relevant, allowed discriminating studied populations in both groups. The first group consists of population from Lake Toho and Couffo River and the second, the one of the Ouémé River. Similar results were obtained in Southern Africa, in the Zambèze. The study of evolution of local cichlids of this basin revealed the presence

of isolated groups by biogeographic barriers [40]. According to [41], variations of some metric variables (body height, caudal peduncle height, snout length, pectoral-fin length) and meristic describers are phenotypic and are bound to the environment. Influence of these characters in the discrimination of the three populations justifies the similarity of some ecological or environmental factors of these waterways. However, although the climatic type is different, the Ouémé River and the Lake Toho meet in terms of physicochemical parameters. From this point of view, only the Couffo River remained isolated. In addition, [37] demonstred that the level of intra and inter population variations in age and size at first maturity of *Oreochromis niloticus* females might be explained by difference in environmental variables (phenotypic plasticity). In addition, morphometric closeness between Lake Toho and Couffo River could be explained by the geographical proximity of these waterways and the similarity of some ecological factors.

Overexploitation of the fishery resources exists in Benin. The analysis of populations permitted to identify 2 groups of *Oreochromis niloticus* to valorize in the Beninese aquaculture. The observed morphological divergences indicate that several strains of this species have been used at the time of his introduction in the country. The environmental and ecological factors influence the morphological variability of fish. While being based on the morphological variables, two populations to be managed differently are identified: the first constituted by the individuals of the Lake Toho and the Couffo River and the second represented by those of the Ouémé River. The molecular prospecting proves to be indispensable in order to clarify this species diversity in order to suggest sustainable genetic management strategies.

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