PANAMJAS
Pan-American Journal of Aquatic Sciences

Morphometric analysis of populations of *Chromidotilapia guntheri* (Sauvage, 1882) (Cichlidae, perciformes) in four coastal rivers of Côte d'Ivoire (West Africa)

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Abstract: *Chromidotilapia guntheri* specimens from four coastal rivers (Soumié, Eholié, Ehania and Noé) located in south east of Côte d'Ivoire were compared in terms of morphometric and meristic characters in order to test the hypothesis of this population fragmentation in these ecosystems. The multivariate discriminant analysis performed on 19 morphometric and 9 meristic variables revealed segregation between population from Noé and those from the remaining rivers, which appeared morphologically closer. Morphometric characteristics were much more adequate than meristic characters for the separation of these populations. The most pertinent morphometric characters for separation of these populations were body height and snout length. This study also showed that *C. guntheri* mature females exhibit beads on their dorsal fin. Thus, occurrence of dark spots on *C. guntheri* dorsal fin should be a female secondary sexual characteristic.

Key-words: spotted dorsal fin, *Chromidotilapia guntheri*, morphometric variations, Côte d'Ivoire

Resumen: Análisis morfométrico de las poblaciones de *Chromidotilapia guntheri* (Sauvage, 1882) (Cichlidae, perciformes) en cuatro ríos costeros de Côte d'Ivoire (oeste de Africa). Las características morfométricas y merísticas de los especímenes de *Chromidotilapia guntheri* de cuatro ríos del sur-este de Côte d'Ivoire (Soumié, Eholié, Ehania y Noé) fueron comparadas para probar la hipótesis de una fragmentación de la población en estos ecosistemas. Los análisis multivariantes realizados con 19 variables morfométricas y 9 merísticas han mostrado una segregación morfológica entre la población del río Noé y las de los 3 otros ríos (Ehania, Eholié y Soumié) que aparecen morfológicamente más cercanos. Morfométricas variantes fueron más importantes en la discriminación de las poblaciones. Las características más pertinentes para la separación de estas poblaciones eran altura del cuerpo y longitud del hocico. El estudio actual ha mostrado también que las manchas aparecen en la aleta dorsal de las hembras de *C. guntheri* sexualmente maduras. Así, la ocurrencia de puntos oscuros en la aleta dorsal de *C. guntheri* debería ser una característica sexual secundaria de las hembras.

Palabras claves: aleta dorsal manchada, *Chromidotilapia guntheri*, variationes morfométricas, Côte d'Ivoire

Introduction

Many animal and plant species are subdivided into morphologically and genetically distinct groups, which can be recognized as races or subspecies. Most of such groups are thought to have adapted to different ecological conditions through different selection regimes acting on geographically separated populations (Largiadér *et al.* 1994). However, geographic and/or ecological subdivisions allow establishment of population traits representing suitable models for biogeographic, taxonomic, ecological and genetic studies. In such cases, morphometric analyses can produce valuable information about phenotypic plasticity of species and possible effects of genetic changes on morphological variation (Molina *et al.* 2006). The study of morphological meristic and morphometric characters, with the objective of defining and characterizing populations, has a long tradition in ichthyology (Gabriel and Sokal 1969; Thorpe 1976). Thus, biometric variations are important for the descriptions of species. Morphological characters, such as body shape and meristic counts, have long been used for stocks identifications (Willig *et al.* 1986, Keenlyne *et al.* 1994 and Gürkan 2008).

According to Teugels *et al.* (2003), the genus Chromidotilapia is composed of seven species in which only *C. guntheri* (Sauvage, 1882) is present in West Africa. This species is a freshwater cichlid that has a vast distribution in West Africa Rivers. Mainly met in coastal basins from river St John in Liberia to Cross River in Nigeria/Cameroon, it is also known in the Niger and Benoué Rivers. The same author revealed that *C. guntheri* is apt to colonize riverine regions where current is not so fast and in the slack water regions with vegetation.

Trewavas (1974) has recognized two sub-species and named that found in West Africa, *Chromidotilapia guntheri* guntheri. In the same area, Paulo (1979) described Chromidotilapia bosumtwensis from Lake Bosumtwi in Ghana. These species characteristics, as presented by the author, correspond to those of *C. guntheri* and should be reviewed according to Teugels *et al.* (2003). Yet, in many Ivorian Rivers, *C. guntheri* is sometimes met with dark spots on dorsal fin. Though, this characteristic has not been noticed by authors who described this species.

The objective of this paper is to report on morphometric variability of both *C. guntheri* with dark spots on dorsal fin and those without spots on dorsal fin in Ivorian coastal rivers. As a rule, specimens originating from different areas differ from one another in morphology (Franičevič *et al.* 2005), then, in order to reduce this geographical heterogeneity, this study has been led within four neighbouring rivers located in south east of Côte d'Ivoire.

Material and Methods

Study area and sampling sites - The four small coastal rivers (Soumié, Eholié, Ehania and Noé) studied belong to the Western Guinean ichthyoregion, Eburnéo-Ghanaian sector and are located in lowland rainforest (Daget and Iltis 1965). Noé

River (05◦19' – 05◦35' N and 02◦55' – 02◦47' W) and Ehania River (05◦17' – 05◦43' N and 02◦46' – 03◦03' W) are tributaries of Tanoé River. The Soumié River (05◦23' – 05◦39' N and 03◦ 15' – 03◦29' W) is a tributary of the Bia River. Eholié River (05◦21' – 05◦36' N and 03◦10' – 02◦59' W) runs into Aby lagoon (Fig. 1) (Konan *et al.* 2006).

In each river, two sampling sites were retained: one in upstream and the other in downstream.

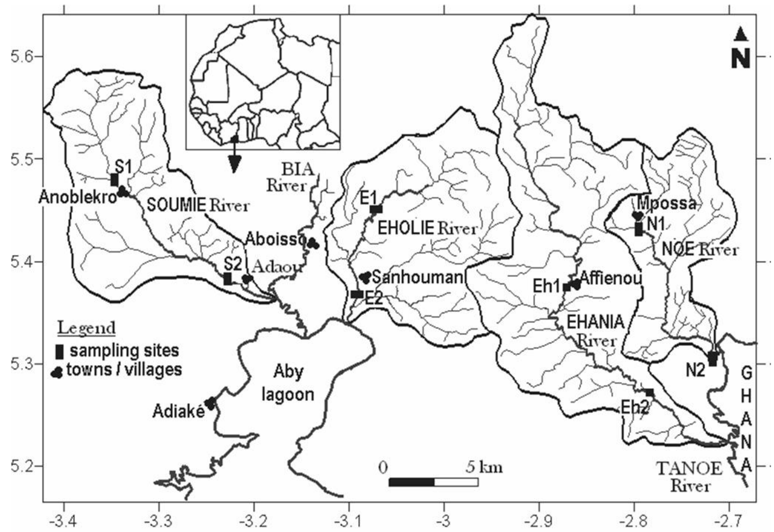

Figure 1. Map of sampling locations. Soumié River, Eholié River, Ehania River, Noé River. 1= first sampling site, 2= second sampling site (Konan *et al* .2006).

Fish sampling - The fishes were sampled during 8 sampling surveys from July 2003 to March 2005 (i.e. 4 during rainy seasons and 4 during dry seasons). The 8 sites were sampled during each survey. The sampling sites covered a river section of approximately 1.5 km in length (i.e. reach scale). This river section length was selected to cover a fair degree of habitat heterogeneity. Fishes were collected with two sets of 8 gillnets (mesh sizes 12, 15, 17, 22, 25, 30, 40 and 45 mm), allowing capture of almost all the fish longer than 50 mm total length. Fish specimens were identified according to the identification keys of Paugy *et al.* (2003). Each specimen was measured (standard length and total length) to the nearest millimetre and weighed to the nearest gram in situ. Fishes were then preserved in formalin 10% for later laboratory observations.

Laboratory work - To test the hypothesis of *Chromidotilapia guntheri* population fragmentation through the four Côte d'Ivoire south east rivers, sex of each fish was determined by external and internal inspections after obtaining the meristic counts and morphometric measurements. For each specimen, 19 morphometric and 9 meristic characters were recorded (Table I). Two hundred four (204) specimens were used for these measurements: 45 from Soumié river, 37 from Eholié River, 54 from Ehania river and 68 from Noé river.

Morphometric measurements were taken on the left side of the body (Fig. 2) using conventional orthogonal methods between the perpendicular plane and the horizontal plane on which the fish was resting, not following the curve of the body (Quilang *et al.* 2007).

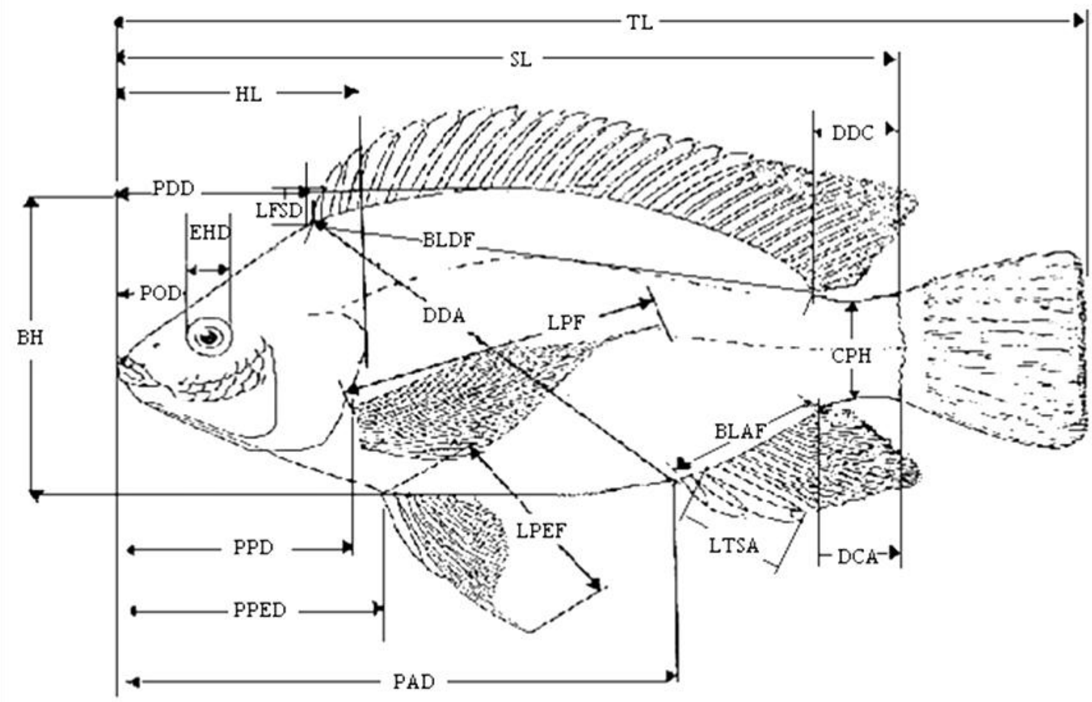

Figure 2. Morphometric measurements used in this study on *Chromidotilapia guntheri* (Teugels *et al.,* 2003, modified). See table 1 for details of acronyms.

Measurements of all characters were made to the nearest 0.01 mm using Mitutoyo-Vernier calliper (range: 0 – 300mm). A stereomicroscope was used for the meristic characters.

Data analysis - The morphological variation was analysed considering each specimen as one multivariate observation, because a univariate approach would ignore the joint effect of variables (Almeida *et al.* 2008).

Because of probable variation in size of fish from different areas, morphometric data were statistically adjusted before analyses to permit comparative analysis in terms of shape independently of size (Thorpe, 1976). The morphometric measurements were first transformed to common logarithms because linearity and normality are usually more closely approximated by logarithms than by original variables (Hair *et al.*, 1998).

Each of the 19 morphometric characters showed a significant linear relationship with standard length ($R > 0.70$; $p < 0.05$) after log-transformation (Table II).

The morphometric character is thus adjusted applying a modification of the formula given by Costa *et al.* (2003):

$$ACi = LogRCi – \beta*(LogSLi – LogMSL)$$

where ACi is the adjusted logarithmic character measurement of specimen i, RCi is the unadjusted character (raw measurement) of specimen i, β is the common within-group or overall linear regression coefficient (slope) of that character against total length after the logarithmic transformation of both variables, SLi is the standard length of specimen i and MSL is the overall mean standard length. According to Almeida *et al.* (2008), it is advisable to determine the common within-group regression slope and not the slope of the data pooled irrespective of locality. If there is both geographic variation in the allometric character and the specimen sizes differ between samples, the regression slope computed from all the data, pooled irrespective of geographic origin, will usually differ from the within-group regression slopes and consequently will not be the most suitable for eliminating allometric influence of size (Thorpe 1976). Accordingly, a multivariate analysis of covariance (MANCOVA) approach was employed to test the homogeneity of slopes of morphometric variables - standard length relationships among rivers and sex. All the morphometric variables (excepted standard length) were used as dependant variables, river and sex as factors and standard length as the covariate. Main effect of river, sex and interactions river-sex-standard length appeared significant (Table III). Indeed, univariate analysis showed that within-group regression slopes were not homogeneous significantly ($p < 0.05$) for seven of the morphometric characters (i.e., BH, POD, BLDF, BLAF,PDD, DDA and DDC), and thus size adjustment was based on the common within-group slopes. For the other twelve variables, slopes were determined with data pooled irrespective of locality.

Table I. Morphometric and meristic characters used for analysis of *Chromidotilapia guntheri*.

	Acronyms	Characters
Morphometric measurements	*TL*	Total length
	SL	Standard length
	BH	Body height
	HL	Head length
	POD	Preorbital distance
	EHD	Eye horizontal diameter
	IOT	Interorbital thickness
	PDD	Pre-dorsal fin distance
	PAD	Pre-anal distance
	PPD	Pre-pectoral distance
	PPED	Pre-pelvic distance
	BLDF	Base length of dorsal fin
	BLAF	Base length of anal fin
	LPF	Length of pectoral fin
	LPEF	Length of pelvic fin
	CPH	Caudal peduncle height
	DDA	Distance between dorsal and anal fin
	DDC	Distance between dorsal and caudal fin
	DCA	Distance between caudal and anal fin
	LTSA	Length of the third spine of the anal fin
	LFSD	Length of the first spine of the dorsal fin
Meristic counts	*DFR*	Dorsal fin rays
	DFS	Dorsal fin spines
	AFR	Anal fin rays
	AFS	Anal fin spines
	VFS	Ventral fin spines
	VFR	Ventral fin rays
	SLL	Number of superior lateral line scales
	ILL	Number of inferior lateral line scales
	GRUL	Number of gill rakers on the upper limb of the first gill arch on the left side

Reist (1985) has proved that this adjustment effectively remove size variation and Claytor and MacCrimmon (1987) have shown that it is an appropriate procedure for objective analysis of the data when there is size overlap among the groups examined.

Analyses were performed separately for morphometric and meristic characters, since these two variables are biologically and statistically different (Quilang *et al.* 2007). Meristic characters, which are discrete variables, are known to be not normally distributed (Costa *et al.* 2003). Data were not standardized because no significant relationship ($p > 0.05$) was found between meristic characters and total length. Thus, the analyses were done on the raw data. All the statistics concerning meristic characters were then done using non-parametric tests.

Table II. Results of linear regression between logarithm values of standard length (SL) and each morphometric measurements. See table 1 for details of acronyms.

Regressions	SL : BH	SL : HL	SL : POD	SL : EHD	SL : IOT	SL : PDD	SL : PAD	SL : PPD	SL : PPED
R*	0.97	0.96	0.93	0.91	0.95	0.98	0.96	0.95	0.96

SL : BLDF	SL : BLAF	SL : LPF	SL : LPEF	SL : CPH	SL : DDA	SL : DDC	SL : DCA	SL : LTSA	SL : LFSD
0.99	0.93	0.95	0.95	0.89	0.99	0.79	0.86	0.90	0.85

*$p < 0.05$

Table III. Results of multivariate analysis of covariance that tested the effect of river, sex, standard length and interactions on raw morphometric variables. P-values in bold indicate a significant effect.

Effect	Test	Value	F	df	p
Intercept	Wilk	0.886	1.092	19	0.363
River	Wilk	0.586	1.660	57	**0.002**
SEX	Wilk	0.801	0.998	38	0.477
SL	Wilk	0.903	0.909	19	0.572
River*SEX	Wilk	0.406	1.393	114	**0.006**
River*SL	Wilk	0.586	1.665	57	**0.002**
SEX*SL	Wilk	0.802	0.989	38	0.491
River*SEX*SL	Wilk	0.407	1.392	114	**0.006**

Results

Discriminant analysis of morphometric data - The regression for canonical scores from discriminant functions 1 and 2 of discriminant analysis against standard length were not significant ($R1 = 0.087$; $F1 = 1.53$; $P = 0.218$ and $R2 = 0.034$; $F2 = 0.21$ $P = 0.645$), indicating that size effects had been effectively removed from the adjusted morphometric variables.

The forward stepwise discriminant analysis revealed that eight adjusted morphometric characters (BH, POD, DDC, BLAF, PDD, BLDF, LPF, IOT) and Beads contributed significantly to the multivariate discrimination of the four groups of fish when river was taken as classification variable (Table IV). The Wilk's partial Lambda indicated that body height (BH) and pre-orbital distance (POD) gave the highest contribution. IOT and Beads were characters that less contributed to the discrimination of groups. Variables correlated to discriminant characters were excluded by the model. Chi-square ($\chi 2$) test with successive removal of canonical functions showed that discriminant functions 1 and 2 were statistically significant (Table IV). The first canonical variable explained 99.5% of the variance. According to discriminant loadings of characters (Table IV), this function is strongly defined by body height (BH) and pre-orbital distance (POD). Means of canonical variates (Table V) showed that the first discriminant function (1) apparently provides the distinction between fish from Noé and those from the remaining sampling sites on the basis of morphometric variables. This observation was confirmed by the plot of individuals on canonical variables 1 and 2 (Fig. 4a) for the four groups. Thus, BH and POD with the highest discriminant loadings can be considered the most important morphometric characters providing distinction between fish from Noé River to those from the remaining rivers. Indeed, fish from Noé River presented the lowest (ANOVA, $p <0.001$) values of these characters compared to the other rivers (Table VI). The correct classification rates estimated, ranged from 59.45% (Eholié) to 100% (Noé) with an overall rate of 82.35% (Table VI).

All morphometric variables were then analysed through sex (male, female and immature). The stepwise discriminant analysis showed that three characters (Beads, PPD and DDA) could be used to separate fish according to the sex (Table VII). Wilk's Lambda indicated that presence or absence of beads on dorsal fin is the character that more discriminates significantly ($P < 0.001$) the sex of *C. guntheri*. Otherwise, PPD and DDA discriminant powers were considerably inferior to that of beads ($P < 0.05$). The two canonical variables were significant for discriminating the groups (Table VII) with discriminant function 1 explaining more than 91% of total variance (Table VII). The first discriminant function was highly correlated to the colour (beads) of dorsal fin (Table VII) and means of canonical variates per group showed that the first discriminant function distinguished females from males and juveniles of *C. guntheri* (Table VIII). Correct classifications were 96.61%, 77.14% and 12.5% for males, females and juveniles fish respectively. The overall classification accuracy was 83.33% (Table VIII). The separation of females from males and immature individuals was confirmed by the plot of the two canonical variates (Fig. 4b).

Figure 3. Two specimens of *Chromidotilapia guntheri. a* = specimen with beads on dorsal fin (BDF); *b* = specimen without beads on dorsal fin (NBDF)

The plot displayed two clusters very distinct. The cluster situated in the negative part of canonical function 1 showed a noticeable overlap of individuals of the three groups with high proportions of male and immature. The other cluster, composed essentially of females, is located in the positive part of the canonical variable 1. Means of canonical variates combine with cluster composition indicated that presence of beads on dorsal fin is a characteristic of *C. guntheri* female.

Discriminant analysis of meristic data - Wilk's lambda tests indicated differences in meristic characters of fish among the four rivers, but only the first discriminant function was significant and ensured this discrimination ($\chi 2 = 24.07$, df = 6, $P < 0.05$).

Table IV. Results of Wilk's partial lambda indicating discriminant power of adjusted morphometric characters for rivers and their discriminant loadings for the canonical variates (C V). The table also shows the Eigen values, the cumulative percentages of variance and results of χ^2 test of discriminant functions 1 and 2. See table 1 for details of acronyms.

Variables	Wilk's partial lambda	$F_{3,186}$	Discriminant loadings	
			CV 1	CV 2
BH	0.502***	61.346	-0.768	-0.166
POD	0.665***	31.136	-0.696	0.208
DDC	0.885***	8.055	-0.258	0.624
BLAF	0.887***	7.898	-0.335	-0.391
PDD	0.937**	4.103	0.286	-0.064
BLDF	0.933**	4.386	-0.205	0.308
LPF	0.946*	3.476	0.185	0.243
HL	0.971	1.820	0.168	0.013
Beads	0.950*	3.216	0.006	0.562
IOT	0.954*	2.962	0.162	-0.069
EHD	0.964	2.284	-0.099	-0.342
CPH	0.971	1.847	-0.052	-0.121
PPD	0.979	1.293	0.139	-0.201
LTSA	0.979	1.267	0.124	0.032
LPEF	0.980	1.210	0.045	0.131
Eigen value			**63.608**	**0.164**
Cum. % of variance			**0.995**	**0.998**
χ^2			**857.68*** **	**51.1***
df			**45**	**28**

**P < 0.05 ; **P <0.01 ; ***P < 0.001.*

Moreover, the stepwise analysis revealed that only dorsal fin rays (DFR) contributed significantly (Wilk's lambda = 0.918, F3.198 = 5.886, P < 0.001) to the multivariate discrimination of the four groups of fish. The correct classification rates (Table V) by discriminant functions estimated were 51.47%, 42.22%, 33.96% and 2.7% respectively for Noé, Soumié, Ehania and Eholié. The overall correct classification rate was 35.96%.

When meristic characters were compared among sex by discriminant analysis, the Wilk's lambda test indicated that only number of inferior lateral line scales (ILL) and dorsal fin rays (DFR) could discriminate significantly the populations of *C. guntheri* studied (Wilk's lambda = 0.96, F2.196 = 4.093 and Wilk's lambda = 0.97, F2.196 = 3.077, P < 0.05 respectively). This discriminant power was obtained through discriminant functions 1 and 2, however only the first one was significant ($\chi 2$ = 24.978, df = 10, P < 0.05). Means of canonical variables indicated that the first discriminant function distinguished immature individuals from the remaining fish (Table VIII). Indeed, the plot of the two discriminant functions (Fig. 5) showed a noticeable overlap of whole individuals. The overall classification accuracy given by the discriminant functions was 56.86% (Table VIII).

Spatial distribution and sex analyses - Beaded dorsal fin fish (BDF) and unbeaded dorsal fin fish (NBDF) were examined separately through rivers. Unbeaded dorsal fin fish (NBDF) were more numerous than BDF ones in all the rivers (Fig. 6).

When the sex is examined, it is noteworthy that almost all the BDF fishes in any river were female. Male and immature individuals were relatively scarce in BDF populations. Similarly, males predominated notably in populations of *C. guntheri* without beads on dorsal fin (NBDF). Immature fish were numerous in NBDF population than in fish with beads on dorsal fin (BDF) whatever river.

Length-class and sex analyses - In female population (Fig. 7a), beaded specimens (BDF) appeared firstly at [60 mm - 70 mm] length–class. Their proportion went increasing until standard length of 120 mm, from which all females appeared beaded. The unbeaded (NBDF) females were in high proportion only in the first two length-classes (i.e. from 60 mm to 80 mm).

With males specimens (Fig. 7b), whatever length class, there were not beaded individuals excepted [60 mm - 70 mm], [70 mm - 80 mm] and [90 mm – 100 mm] classes where it appeared only one beaded (BDF) individual per class.

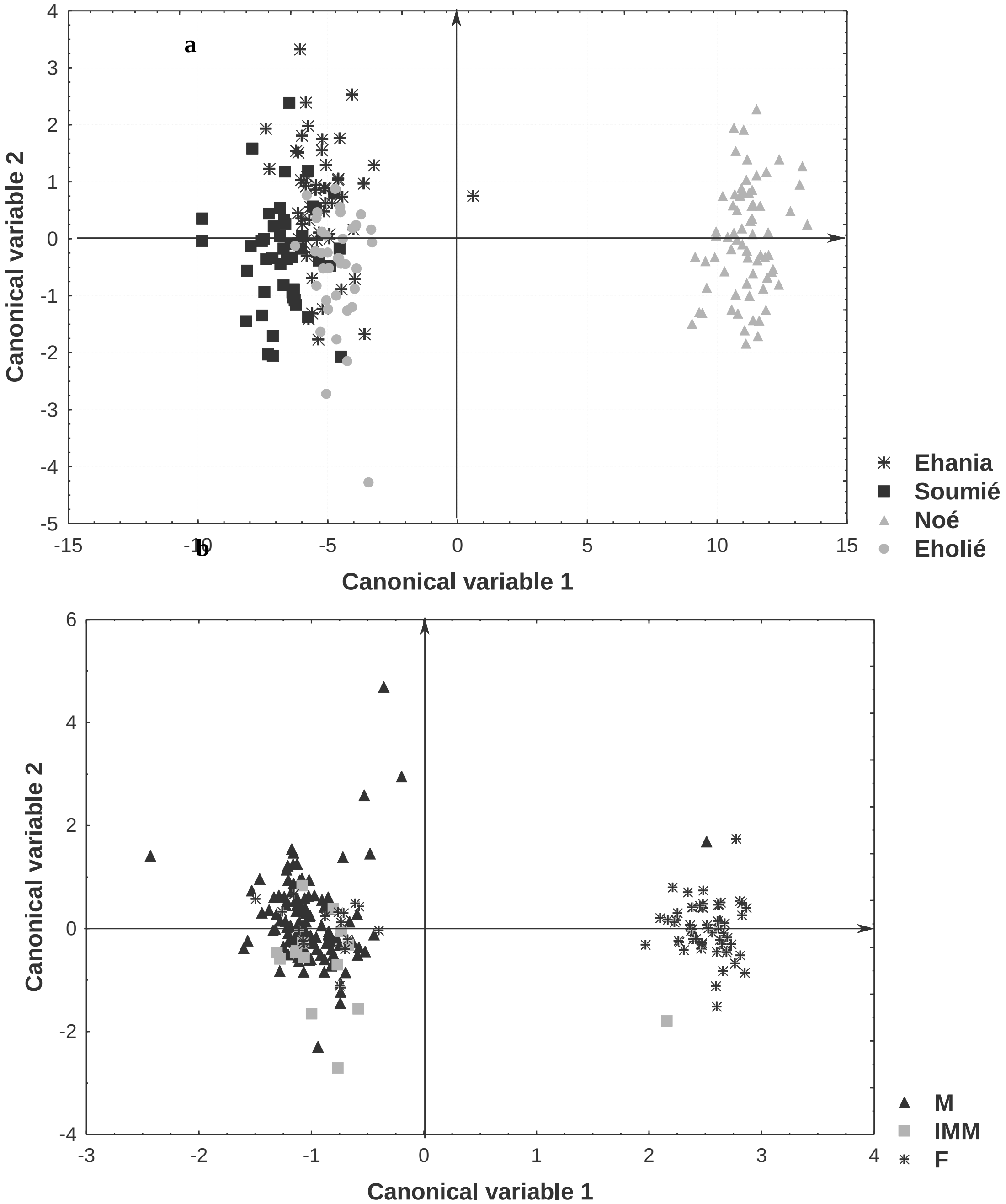

Figure 4. Plot of the discriminant scores on canonical variables 1 and 2 for the four groups (rivers) of *Chromidotilapia guntheri* (a) and according to the sex (b), based on the morphometric characters.

Table V. Means of canonical variates and percentage of classification for rivers both for adjusted morphometric and unadjusted meristic variables. Means in bold indicate rivers clearly isolated by the corresponding canonical variate.

Groups	Means of canonical variates (CV)		% of correct classification	Ehania	Soumié	Noé	Eholié
	CV 1	CV 2					
Morphometric variables							
Ehania	-5.218	0.599	77.77	42	4	0	8
Soumié	-6.712	-0.277	80.00	7	36	0	2
Noé	**11.125**	-0.007	100.00	0	0	68	0
Eholié	-4.667	-0.523	59.45	15	0	0	22
		Total	82.35	64	40	68	32
Meristic variables							
Ehania	0.422	0.073	33.962	18	7	28	0
Soumié	-0.459	0.084	42.222	1	19	25	0
Noé	-0.017	0.085	51.470	13	20	35	0
Eholié	-0.013	-0.364	2.702	9	10	17	1
		Total	35.960	41	56	105	1

Table VI. Mean ± standard deviation and p-values (derived from the analysis of variance) of each morphometric character. All morphometric variables in this table were transformed as described in the materials and methods. Number of specimens examined: Ehania (54); Noé (68); Soumié (45); Eholié (37). See table 1 for details of acronyms.

	Rivers				
Morphometric variables	Ehania	Noé	Soumié	Eholié	p- values
BH	$1.602^{a} \pm 0.033$	$1.343^{b} \pm 0.023$	$1.628^{c} \pm 0.021$	$1.601^{a} \pm 0.019$	**0.000**
POD	$1.204^{a} \pm 0.034$	$0.930^{b} \pm 0.029$	$1.223^{ac} \pm 0.058$	$1.197^{ad} \pm 0.043$	**0.000**
EHD	$0.933^{a} \pm 0.034$	$0.927^{ab} \pm 0.030$	$0.945^{ac} \pm 0.028$	$0.938^{a} \pm 0.030$	**0.022**
IOT	1.050 ± 0.030	1.051 ± 0.046	1.047 ± 0.028	1.061 ± 0.025	0.314
PPED	1.615 ± 0.023	1.595 ± 0.184	1.621 ± 0.023	1.619 ± 0.019	0.556
BLAF	$1.211^{a} \pm 0.035$	$0.965^{b} \pm 0.042$	$1.243^{c} \pm 0.040$	$1.218^{a} \pm 0.035$	**0.000**
BLDF	$1.759^{a} \pm 0.015$	$1.508^{b} \pm 0.016$	$1.779a^{c} \pm 0.020$	$1.698^{ad} \pm 0.282$	**0.000**
LPF	1.448 ± 0.028	1.449 ± 0.035	1.418 ± 0.223	1.461 ± 0.034	0.301
LPEF	1.453 ± 0.026	1.464 ± 0.041	1.420 ± 0.236	1.455 ± 0.027	0.243
CPH	1.193 ± 0.031	1.206 ± 0.061	1.205 ± 0.045	1.194 ± 0.035	0.336
DDA	1.738 ± 0.017	1.737 ± 0.016	1.698 ± 0.253	1.738 ± 0.014	0.281
DDC	$0.944^{a} \pm 0.071$	$0.682^{b} \pm 0.057$	$0.928^{ac} \pm 0.064$	$0.896^{c} \pm 0.067$	**0.000**
DCA	1.065 ± 0.055	1.060 ± 0.051	1.051 ± 0.046	1.062 ± 0.048	0.583
LTSA	1.178 ± 0.044	1.167 ± 0.034	1.176 ± 0.044	1.183 ±0.038	0.222
LFSD	0.752 ± 0.056	0.749 ± 0.076	0.735 ± 0.063	0.738 ± 0.073	0.564
Beads	0.407 ± 0.495	0.333 ± 0.476	0.191 ± 0.396	0.162 ± 0.373	0.192

Bold values in ANOVA results indicate strong variation; Mean values on a line having different superscripts differ significantly (p <0.05)

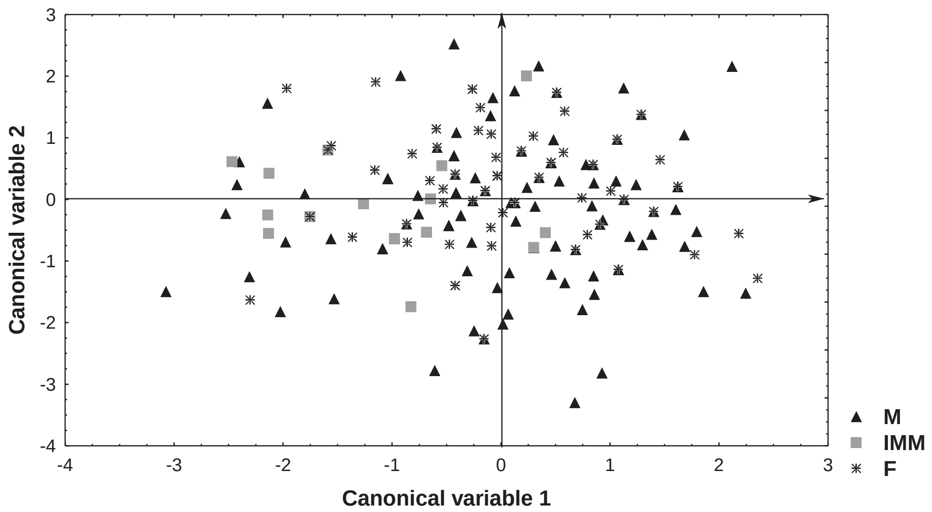

Figure 5. Plot of the discriminant scores on canonical variables 1 and 2 according to the sex, based on the meristic characters

Table VII. Results of Wilk's partial lambda indicating discriminant power of adjusted morphometric characters for sex and their discriminant loadings for the canonical variates (C V). The table also shows the Eigen values, the cumulative percentages of variance and results of χ^2 test of discriminant functions 1 and 2. See table 1 for details of acronyms.

Characters	Partial lambda	$F_{2,192}$	Discriminant loadings	
			CV 1	CV 2
Beads	0.410***	137.584	1.018	0.035
CPH	0.987	1.247	0.080	-0.359
PPD	0.950*	5.041	-0.125	-0.601
DDA	0.969*	3.054	-0.229	-0.087
BLDF	0.981	1.792	0.161	-0.180
LPF	0.974	2.519	-0.210	-0.015
PDD	0.974	2.549	-0.075	0.457
PPED	0.975	2.431	0.050	0.552
EHD	0.988	1.113	0.034	-0.312
LFSD	0.989	1.046	0.123	0.115
Eigen value			**1.612**	**0.148**
Cum. % of variance			**0.915**	**1.000**
χ^2			**215.933*** **	**27.262** **
df			**20**	**9**

**P < 0.05 ; **P <0.01 ; ***P < 0.001*

Comparison with holotype characters - A comparison of some morphometric and meristic characters of *C. guntheri* were achieved between specimens studied in this paper and the holotype (Table IX). The ranges of variation of these characters between BDF, NBDF and the holotype did not differ consistently (Chi- square test), overlapping more or less. Nevertheless, an apparent difference in preorbital distance (POD) ranges of variation expressed in ratio of standard length was observed between specimens of the current study and that of the holotype ($\chi2$ test, $P < 0.05$). Indeed, POD of specimens currently studied ranged from 11% SL to 20% SL and from 13.2% SL to 25.91% SL respectively for BDF and NBDF whereas the holotype exhibited a range of 36.7% SL to 46% SL.

Table VIII. Means of canonical variates and percentage of classification for sex both for adjusted morphometric and unadjusted meristic variables. Means in bold indicate rivers clearly isolated by the corresponding canonical variate. F = Females; M = Males; IMM = Immature or juveniles.

Groups	Means of canonical variates (CV)			% of correct classification	M	IMM	F
	CV 1	CV 2					
Morphometric variables							
M	-0.929	0.164		96.610	114	1	3
IMM	-0.772	-1.291		12.500	13	2	1
F	**1.742**	0.017		77.142	16	0	54
			Total	83.333	143	3	58
Meristic variables							
M	0.137	-0.121		89.830	106	5	7
IMM	**-1.074**	-0.100		25.000	11	4	1
F	0.014	0.231		8.571	63	1	6
			Total	56.862	180	10	14

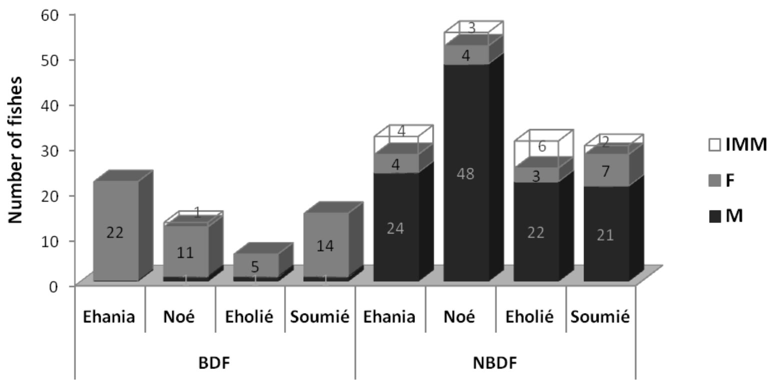

Figure 6. Spatial distribution of beaded dorsal fin fish (BDF) and unbeaded dorsal fin fish (NBDF) of *Chromidotilapia guntheri* taking in account the individuals sex. F = Female; M = Male; IMM = Immature or juvenile.

Table IX. Low-high values of a few body proportions as ratios of standard length (SL) and some meristic counts of specimens (BDF and NBDF) from the current study and those of the holotype from Teugels *et al.* (2003). The table shows also results of Chi-square test (χ^2) at P = 0.05. ns = no significant differences, s = significant differences. See table 1 for details of acronyms.

	BDF	NBDF	Holotype	χ^2 test
BH (% of SL)	37.15-45.21	36.1-46.6	36.4-45.5	ns
HL (% of SL)	34.3-41.41	36-41.8	34.6-38.2	ns
POD (% of SL)	11-20[a]	13.2-25.91[a]	36.7-46[b]	s
DFS	15-17	15-17	15-17	ns
DFR	8-12	8-12	9-12	ns
AFS	3-4	2-4	3-4	ns
AFR	5-8	5-8	6-8	ns
VFS	1	1	_	ns
VFR	5	5	_	ns
SLL	15-22	15-22	18-22	ns
ILL	7-13	7-13	9-12	ns

Values on a line having different superscripts differ significantly (p <0.05)

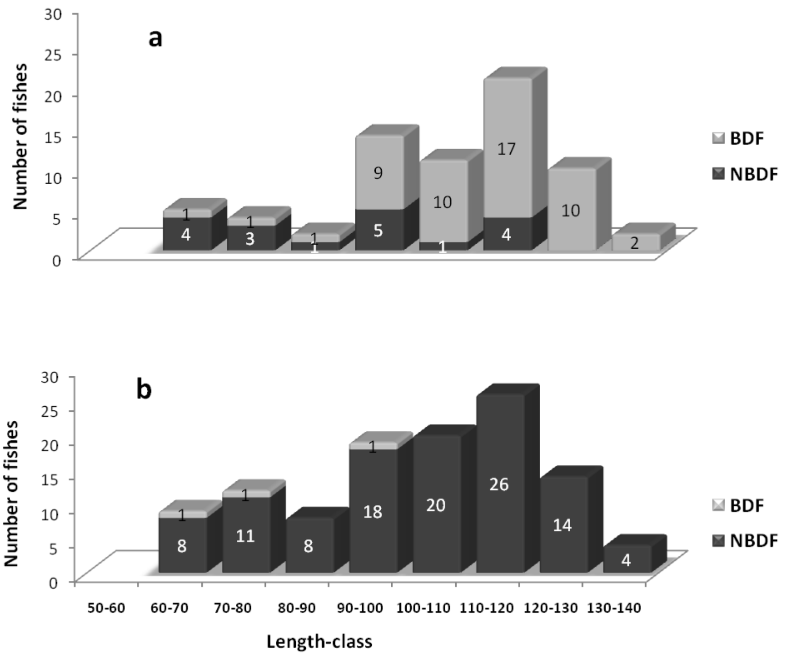

Figure 7. Proportions of NBDF and BDF fish in female (a) and male (b) populations of *Chromidotilapia guntheri* in relation to the length class.

Discussion

In this study, morphometric and meristic analyses were performed to explore an eventual fragmentation of populations of *C. guntheri* from four coastal rivers of Côte d'Ivoire.

Since the rivers Noé and Ehania are geographically closer, being both tributaries of river Tanoé, the morphological differences observed between fishes from Noé on one hand and the other rivers, Ehania included on the other hand, could be due to environmentally-induced morphological differences. Swain and Foote (1999) stated that phenotypic variation in morphological characters or meristic counts may not only be genetic but may be environmentally induced. Indeed, according to Konan *et al.* (2006), Noé encompasses the smallest catchment area, presents the shortest main-channel length with the lowest annual flow among the four rivers studied. These results are similar to the findings of Quilang *et al.* (2007) who reported that the morphological variation in silver perch *Leiopotherapon plumbeus*, was induced by differences in physico-chemical characteristics of water in three lakes of the Philipines.

The discriminant analysis according the sex showed low discriminatory power of the morphometric variables and meristic counts suggesting an absence of sexual dimorphism in this species. Only, body height and pre-pectoral distance separate mature individuals from juveniles which exhibit shortest measures of these characters. When however presence of beads on dorsal fin is added to the characters studied, the stepwise discriminant analysis throughout the sex ensure a clear separation of females from males and juveniles, the more discriminating character being fin beads. Females should be characterised by beaded dorsal fin contrary to males and juveniles which do not display dot on dorsal fin. Moreover, the spatial distribution of fish according to the dorsal fin pigmentation, jointly with the sex, confirms the previous statement that beaded dorsal fin specimens were females and fish without dots on dorsal fin were males and juveniles. The study of standard length revealed that there were no BDF specimens less than 60mm SL.

This result supports the hypothesis that BDF specimens were not born with beads on their fins. This character should be a secondary character, related to sex, age or length. Investigations taking in account sex proportions per length class showed that BDF appeared in female population when they reach 60 mm SL. All females more than 120 mm SL were BDF individuals. These results showed once more an apparent linkage between female and beaded dorsal fin specimens. The occurrence of pearls (beads) on the dorsal fin of females would be secondary sexual character.

Teugels *et al.* (2003), in the description of that species, indicated different colours between mature female and male adults. Male distinguished by presence of two bright red spots, one located in postero-ventral area of eye and other, triangular, behind opercula; also the distal margin of dorsal and upper margin of caudal fins reddish, with blue submarginal band. Female are characterized, especially in reproduction period, by broad pink, sometimes violet ventral area; upper margin of dorsal and caudal fins, black. Presence of beads on female dorsal fin was not mentioned by these authors. In this study, males found with beaded dorsal fin could be due to sex identification mistakes.

Furthermore, comparison of some morphometric and meristic characters of the studied specimens with those of the holotype as described by Teugels *et al.* (2003), showed a light difference in ranges of head length, body height and the overall meristic variates. These weak differences are explainable, according to Tiainen (1982), by the fact that morphology of a species is an adaptation to environments encountered by individuals during the annual cycle and the specific form of life. The snout length ranges expressed in ratio of SL were (11% SL - 20% SL) and (13.2% SL – 25.91% SL) respectively for BDF and NBDF specimens of *C. guntheri*. These intervals are consistently different from the range (36.7% SL – 46% SL) reported by Teugels *et al.* (2003) which seems incongruous insofar as the head length varies between 34.6% SL and 38.2% SL. Undoubtly, these ratios have been calculated in comparison to the head length instead of the standard length as mentioned by authors.

Acknowledgments

This study was funded by the partnership between the FEM/ONG (Fonds pour l'Environnement Mondial/NGO) and the CREPA-CI (Centre Regional pour l'Eau Potable et l'Assainissement à faible coût – Côte d'Ivoire) directed by Prof. T. GNAGNE. We are grateful to Drs E. N. ASSEMIAN, M. K. KONAN and M. K. KOUAMÉ (Laboratoire d'Environnement et de Biologie Aquatique, Abobo-Adjamé University, Côte d'Ivoire) for their valuable help and advice.

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Received August 2009
Accepted May 2010
Published online March 2011