
**E-ISSN: 2347-5129**
**P-ISSN: 2394-0506**
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2019; 7(5): 573-579

www.fisheriesjournal.com
Received: 24-07-2019
Accepted: 28-08-2019

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# Morphological characterization of *Mormyrus rume* populations from Sassandra, Bandama and Comoé rivers in Côte d'Ivoire

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**Abstract**
Three populations of *Mormyrus rume*, from Prikro, Bouaflé and Guessabo (Côte d'Ivoire), fished in the Comoé, Bandama and Sassandra rivers, respectively, were morphologically assessed. A total of 93 specimens were collected from commercial fishing. Six meristic and 18 metric characters were evaluated, then subjected to statistical analysis. The analysis of variance showed that out of the 24 characters, 17 variables including 12 metrics and 5 meristics varied significantly ($p \leq 0.05$). Among the 17 characters, only 9 variables proved to be highly differential in order to segregate the studied populations. Ascending linear discriminant analysis confirms 78.44% correct classification of individuals within the three stations. The factorial discriminant analysis and the hierarchical clustering analysis showed the existence of two morphologically distinct groups consisting, on the one hand, of individuals from Prikro and on the other hand of those from Bouaflé and Guéssabo.

**Keywords:** *Mormyrus rume*, morphological characterization, metric and meristic characters

## 1. Introduction
*Mormyrus rume* is an endemic fish species of sub-Saharan Africa. According to [1], it is a species of little importance quantitatively in fisheries but still particularly appreciated for consumption. It is one of the species of Mormyridae's family which shows good growth in the natural environment and therefore has a good potential for aquaculture. This species can grow up to 900 mm long (standard length). In Côte d'Ivoire, this species is present in many rivers. However, several studies attested that the ichthyofauna of Côte d'Ivoire river system is at great risk [2]. According to [3], *Mormyrus rume* has a high vulnerability around 63%. Hence it's necessary to point to studies for a sustainable management of this ichthyological resource in order to preserve the ecological balance of hydrosystems. According to [4] any management and conservation practice must be based on prior knowledge of existing natural variation, in order to preserve any adaptive variation that may be present. In Côte d'Ivoire, although this species is known from large rivers, studies dealing with the morphological variability are not available. However, morphological studies carried out on this species probably concerned the taxonomic status (fauna of freshwater and brackish freshwater fish of West Africa volume 1 [5] and the practical manual of fish identification from Ayamé Lake [6] The purpose of this study is to estimate the morphological heterogeneity of three *Mormyrus rume* populations from Sassandra, Bandama and Comoé rivers (Côte d'Ivoire) using metric and meristic characters.

## 2. Material and Methods
### 2.1 Sampling sites
Located between the equator and the tropic of cancer, precisely between latitudes 4°30'and 10°30' North and longitudes 8°30 and 2°30 West, Côte d'Ivoire covers an area of 322,462 km$^2$. The country's river system includes four major rivers, including Cavally, Bandama, Sassandra and Comoé (Figure 1).

- Sassandra river with a length of 650 km has its source in the region of Beyla in Guinea, where it's called Feroudougouba [7]. Farming (cocoa, coffee, rubber and oil palm), industrial activities and the Buyo dam construction [8] have modified the ecological and environmental characteristics of this river.

- Bandama River has two main tributaries, White Bandama and Red Bandama also called Marahoué. They both take their sources in the Boundiali region. The Bandama has a length of 1,050 km [7]. We find around the basin, rubber, textile, wood, agro-food and mining industries.
- Comoé River has its source in the region of Banfora (Upper Volta). With a length of 1,160 km, it is the longest river in Côte d'Ivoire [7]. In this basin, the overexploitation of fish species by the abusive and uncontrolled fishing, the agricultural effluents, the rejection of the garbage [9] constitute the essential threats.

### 2.2 Sample collection
A total 93 specimens were collected including, 31 from Prikro (Comoé river), 32 from Bouaflé (Bandama river) and 30 from Guéssabo (Sassandra river). All specimens were collected from a commercial fishing from december 2018 to may 2019. They were fished by gillnets.

### 2.3 Morphological analysis
#### 2.3.1 Metric characters
Each individual was labelled with a specific code for identification. A digital camera (Sony, Japan) was used for capturing digital images. Morphometric variations among populations were assessed through geometric methods [10]. Eighteen morphometric variables were selected as inter landmark distances for *Mormyrus rume* based on the homologous anatomical landmarks as shown in Figure 2. The selection of these morphometric characteristics was based on their diagnostic importance in the identification key for African tilapia species produced by [11] and morphological studies from the Mormyridae family [12, 13].

Measurements were based on a truss network protocol [14]. The derivation of truss distances from the digital images of specimens was done using a combination of three software platforms: tpsutil, tpsdig [15, 16] and PAlentologial Statistics [17]. The first two characters (TL and SL) were measured using an ichthyometer.

To reduce effects of allometry due to age and size differences between individuals, morphometric data have been standardized according to the methods of [18, 19, 20]. All measurements were expressed in percentage of the standard length for measurements made on the fish's body (HL %LS, pAD %SL, pPD %SL, pPeD %SL, AL%SL, LDF %SL, LPF %SL, ACD %SL, CPH %SL, pAD %SL, TL %SL, LPeF %SL, HB %SL, pPeD %SL) and the percentage of head length for measurements made on the head (ptOD %HL, OD %HL pOD %HL) [21, 22, 23].

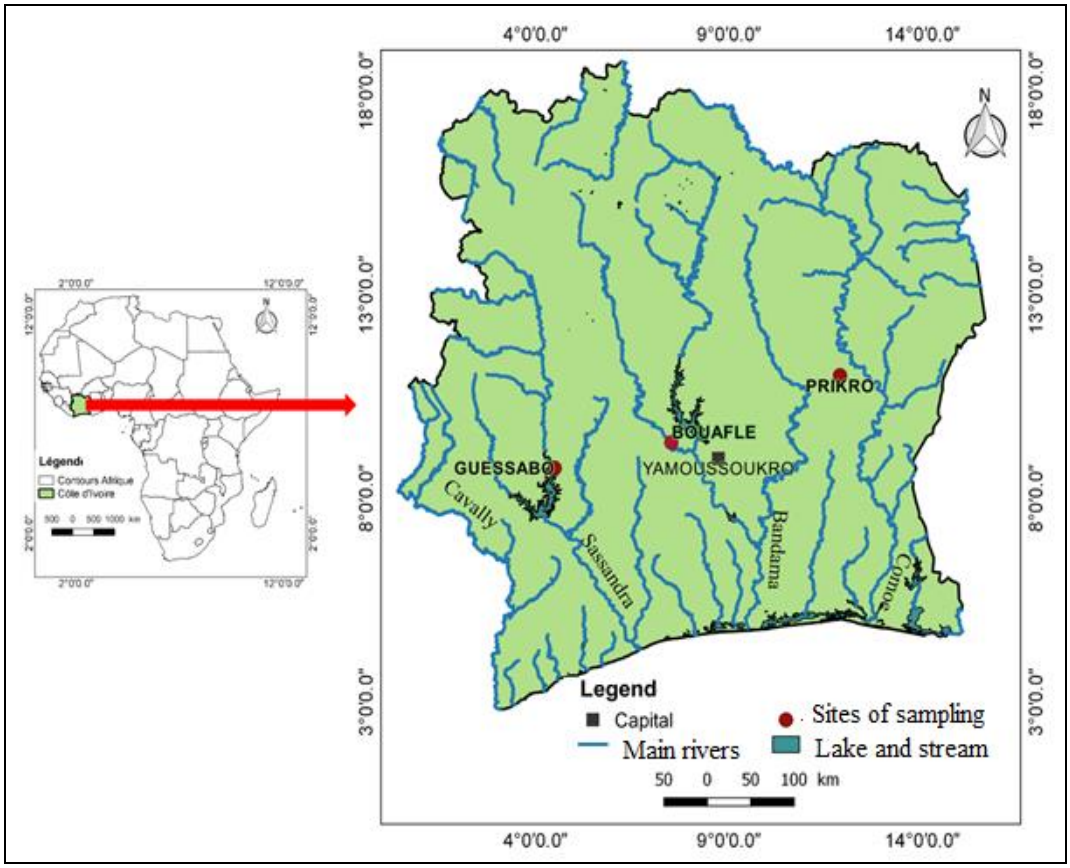


**Fig 1:** Map of Côte d'Ivoire showing sampling sites of *Mormyrus rume* specimens.

#### 2.3.2 Meristics characters
In each specimen, six meristic traits have been counted which are the number of pectoral fin rays (PFR), number of dorsal fin rays (DFR), number of pelvic fin rays (PeFR), number of anal fin rays (AFR), number of teeth to the upper jaw (TuJ) and the number of teeth to the lower jaw (TlJ).

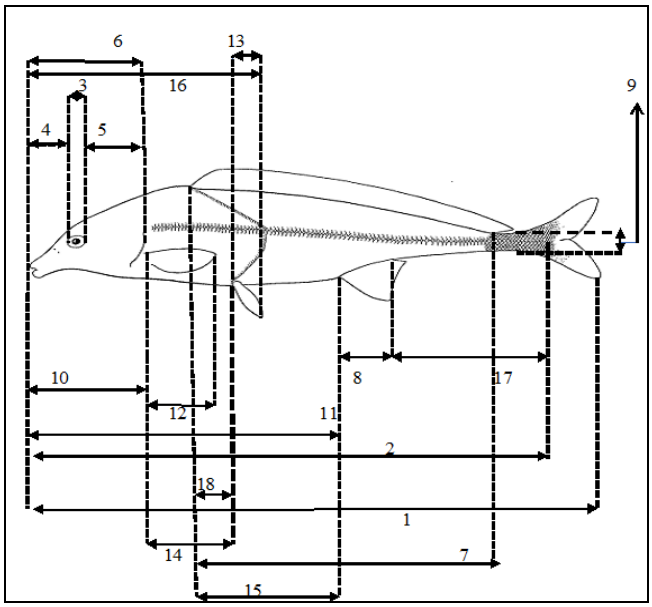


**Fig 2:** Measurements made on specimens of *Mormyrus rume* [13]: **1**- Total length (TL), **2**- Standard length (SL), **3**- orbital diameter (OD), **4**- pre-orbital distance (pOD), **5**- postorbital distance (ptOD), **6**- Head length (HL), **7**- dorsal fin base length (LDF), **8**- anal fin base length (AL)**, 9**- caudal peduncle height (CPH), **10**- prepectoral distance (pPD), **11**- pre-anal distance (pAD), **12**- pectoral fin length (LPF), **13**- pelvic fin length (LPeF), **14**- pectoral-pelvic distance (pPeD), **15**- dorsal-anal distance (DAD), **16**- Prepelvic distance (pPeD), **17**- caudal-anal distance (ACD) and **18**-height of the body (HB).

### 2.4 Data analysis

The standard length (SL) and the head length (HL) have not been taken into account as they were used for adjustments of measurements respectively related to the body and the head [24]. The descriptive statistics have been used to determine the morphological variations in each population [25]. For this analysis, the mean and coefficient of variation were calculated. The coefficient of variation (CV) was calculated using the following formula: % CV = (standard deviation / mean) × 100 [26]. The CV was used to evaluate the variations of a trait within populations. When %CV ≤ 10%, the population is very homogeneous; %CV> 10% the population is heterogeneous.

ANOVA was performed to highlight the parameters that express variability between different populations. The coefficient of linear correlation of Bravais-Pearson between variables has been calculated.

Multivariate statistics performed included Principal Component Analysis (PCA), Discriminant Factor Analysis (DFA) and Hierarchical Clustering Analysis (HCA). PCA was used to differentiate populations and identify the morphometric variables which contributed the most to their separation. These variables, integrated in a second time to discriminant analyzes, allowed to highlight the most efficient ones, to illustrate the differences and similarities between constituted groups and to optimize existing variabilities between them. Hierarchical Clustering analysis (HCA) was undertaken to assess morphological similarity between populations [27]. All these treatments were performed using Past (PAlaeontological Statistics) 2.05 [17].

## 3. Results

### 3.1 Morphological characterization of populations

Table 1 shows some statistical parameters such as ANOVA probabilities, the mean and the coefficient of variation (% CV) of the different metric and meristic descriptors of the *Mormyrus rume* specimens analyzed. The results of the one-way ANOVA test show that there is a significant difference ($p \leq 0.05$) between the samples of the different rivers for 12 of the 17 metric variables. Meristic characters, with the exception of the number of pectoral fin rays (PFR), and the five other descriptors showed a significant difference between three populations ($p \leq 0.05$). For variables that varied significantly, metric variables such as pre-orbital distance (% CV≥13), postorbital distance (CV ≥ 10.01) and anal fin base length (CV≥11.39) have different values high CV (≥10%) in all populations. Concerning meristic variables that have significantly varied, none of the parameter give any CV ≥ 10% within the populations. However, the teeth number in the upper (TuJ) and in the lower jaw (TlJ) give values greater than the coefficient of variation (%CV≥10%) in Bouaflé and Guessabo populations. By comparing the means of the parameters within the three populations, the lowest values of the metric descriptors such as the pre-orbital distance (pOD; 34.61), the pre-anal distance (pAD; 58.27), the prepelvic distance (DpPe; 37.78) and prepectoral distance (pPD; 17.20) were obtained with Prikro specimens. In the same locality, the parameters such as the postorbital distance (ptOD; 65.66) and the anal-caudal distance (ACD; 34.90) presented the highest mean values. As for the meristic characters, the averages of the different variables appear very similar within the three populations.

### 3.2 Morphological differentiation

#### 3.2.1 Differentiation of populations by PCA

Principal component analysis (PCA) was applied to the correlation matrix obtained from the 17 morphometric and meristic variables that varied significantly among the three populations. Only the axis expressing an eigen- value greater than or equal to 1 are retained. Table 2 displays eigen- values and percentages of variation for each of the six selected axis. The first axis accounts for 21.16% of the total variation. The cumulative contribution of the four others axis (57.43%) is more than half of the main components. In the analysis of ordination, only axis 1 and 2 which express the greatest variability (36.34%) were considered. Correlations of the different variables to the first two axis are shown in figures 3 and 4. The threshold for a variable to be highly correlated to the axis is fixed at -0.70 or 0.70 according to its orientation on the factorial axis. Considering the six axes, only the two first are those which allow the discrimination of populations. These two axes are strongly correlated with 4 metric variables. The first axis is strongly and positively correlated with the anal-caudal distance (ACD) and strongly and negatively correlated with the prepectoral distance (pPD). The second axis, is strongly and positively correlated with the prepectoral distance (pPD) and strongly and negatively correlated with the dorsal-anal distance (DAD). As far as the meristic characters are concerned, they do not exhibit a strong correlation on the Factorial axis. The PCA obtained does not make it possible to separate the different populations studied. However, some individuals of the three populations tend to move from the origin of the mark to the negative and positive coordinates of the factorial axis 1. Characters negatively and positively correlated with this axis seem to influence the orientation of these specimens in this ordination (Fig.5). Characters negatively correlated to this axis appear to influence the orientation of these specimens in the ordination (Figure 6).

**Table 1:** Descriptive data and probabilities of ANOVA of meristic and metric characters of *Mormyrus rume* from three populations of Côte d'Ivoire.

| Characters | | Bouaflé | | | Prikro | | | Guessabo | | | *p*-value | Significativity of *P* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | N | Mean | %CV | N | Mean | %CV | N | Mean | %CV | | |
| Meristics | TuJ | 32 | 6.38 | 16.11 | 31 | 7.13 | 8.67 | 30 | 6.06 | 16.01 | 0.0001 | *** |
| | TlJ | 32 | 9.72 | 13.78 | 31 | 9.23 | 9.16 | 30 | 10.40 | 12.19 | 0.009 | ** |
| | DFR | 32 | 78.97 | 5.86 | 31 | 80.26 | 4.38 | 30 | 82.5 | 4.72 | 0.003 | ** |
| | PeFR | 32 | 11.88 | 1.03 | 31 | 11.90 | 1.52 | 30 | 11.90 | 1.01 | 0.015 | * |
| | AFR | 32 | 16.81 | 4.64 | 31 | 16.77 | 4.54 | 30 | 17.43 | 6.06 | 0.0005 | *** |
| | PFR | 32 | 11.18 | 12.11 | 31 | 11.61 | 14.18 | 30 | 12.90 | 10.64 | 0.65 | ns |
| Metrics | pOD | 32 | 41.75 | 22 | 31 | 34.61 | 13 | 30 | 57.66 | 18.6 | 0.0001 | *** |
| | TL | 32 | 118.7 | 4.01 | 31 | 113.6 | 1.81 | 30 | 112.0 | 1.88 | 0.001 | *** |
| | pAD | 32 | 63.83 | 2.54 | 31 | 58.27 | 5.52 | 30 | 64.54 | 6.39 | 0.0001 | *** |
| | pPeD | 32 | 40.86 | 6.38 | 31 | 37.78 | 4.99 | 30 | 40.51 | 7.34 | 0.008 | ** |
| | pPD | 32 | 20.20 | 10.72 | 31 | 17.20 | 9.17 | 30 | 20.70 | 20.38 | 0 .04 | * |
| | OD | 32 | 13.64 | 35.08 | 31 | 10.02 | 26.54 | 30 | 9.24 | 41.36 | 0.32 | ns |
| | ptOD | 32 | 52.11 | 10.01 | 31 | 65.66 | 13.44 | 30 | 46.54 | 11.71 | 0.005 | ** |
| | LDF | 32 | 55.03 | 7.45 | 31 | 57 | 5.14 | 30 | 56.61 | 7.87 | 0 .06 | ns |
| | DAD | 32 | 59.51 | 5.04 | 31 | 62.04 | 3.55 | 30 | 59.77 | 12.77 | 0.004 | ** |
| | CPH | 32 | 4.83 | 16.78 | 31 | 4.93 | 5.25 | 30 | 5.11 | 9.33 | 0.06 | ns |
| | AL | 32 | 8.97 | 11.39 | 31 | 8.66 | 11.76 | 30 | 9.44 | 18.56 | 0.0002 | *** |
| | LPeF | 32 | 20.15 | 14.13 | 31 | 16.48 | 13.66 | 30 | 19 .84 | 11.51 | 0.12 | ns |
| | pPeD | 32 | 21.31 | 7.24 | 31 | 20.93 | 7.14 | 30 | 22.78 | 26.03 | 0.06 | ns |
| | LPF | 32 | 15.98 | 7.57 | 31 | 22.19 | 14.66 | 30 | 23.29 | 27.57 | 0.0001 | *** |
| | HB | 32 | 24.06 | 7.84 | 31 | 22.19 | 6.55 | 30 | 23.29 | 29.91 | 0.0007 | *** |
| | ACD | 32 | 27.92 | 6.58 | 31 | 34.90 | 5.03 | 30 | 28.08 | 9.84 | 0.001 | *** |

**Table 2:** Contribution of factorial axis of PCA

| | Axis 1 | Axis 2 | Axis 3 | Axis 4 | Axis 5 | Axis 6 |
|---|---|---|---|---|---|---|
| eigen- value | 3.59 | 2.58 | 1.91 | 1.67 | 1.39 | 1.18 |
| (%) Variability | 21.16 | 15.18 | 11.26 | 9.83 | 8.15 | 6.92 |

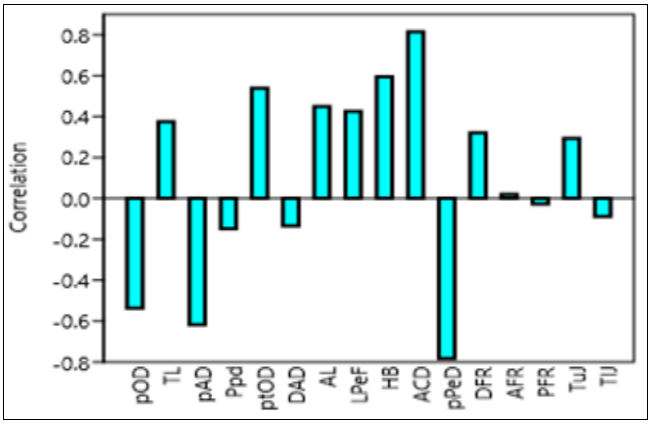


**Fig 3:** Factorial weights of metric and meristic variables on axis 1 of the PCA

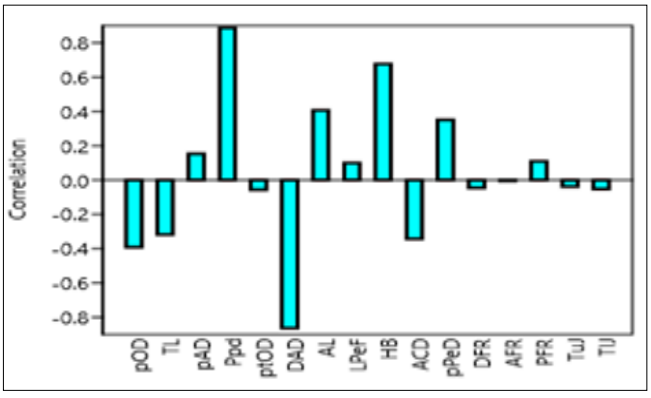


**Fig 4:** Factorial weights of metric and meristic variables on axis 2 of the PCA

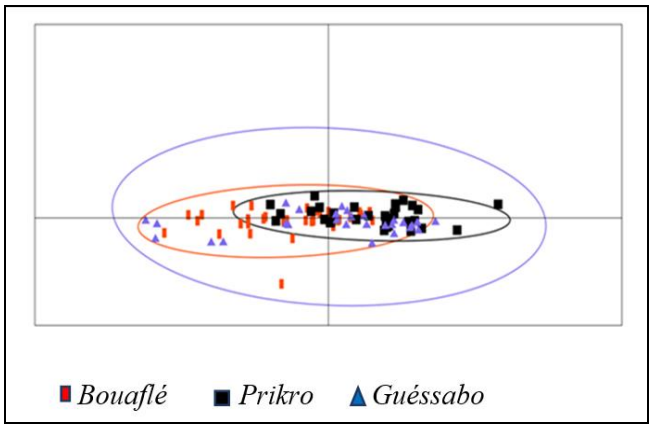


**Fig 5:** Distribution of Mormyrus rume specimens by PCA

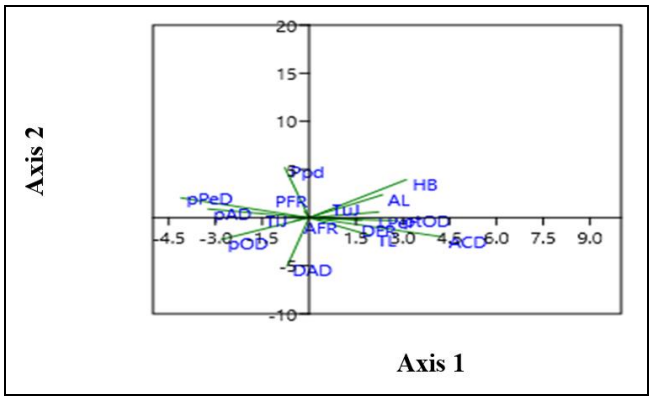


**Fig 6:** Distribution of metric and meristic variables by PCA.

### 3.1.2.2 Discriminant factorial analysis of specimens

The discriminant analysis correctly classified 73 out of 93 specimens (78.44%) (Table 3). The level of correct classification was 83.87%, 78.13% and 73.33% respectively for Prikro. Bouaflé and Guessabo. The correct classification analysis proposes a reclassification of some specimens from their first group to news one. In the Bouaflé site firstly

containing 32 individuals, seven specimens are reclassified in the Guessabo population. Out of a total of 31 individuals from the Prikro lot, 3 specimens are reclassified in the Bouaflé lot and 2 in the Guessabo lot. Five specimens are reclassified in Bouaflé and 3 in the Prikro population, out of 30 individuals from the Guessabo lot.

In addition, the Wilk lambda test reveals that 9 out of 16 descriptors used for this analysis (Table 4) allow segregation of populations. These traits are the postorbital distance (ptOD), dorso-anal distance (DAD), pelvic fin length (PeFL), anal-caudal distance (ACD), body height (BH), preanal distance (pAD), teeth in the upper jaw (TuJ) and lower (TlJ). Among these 9 descriptors, only the anal-caudal distance strongly contributes to the discrimination of the populations studied. The discriminant factor analysis presents three clusters, and isolate individuals from Prikro from those of Bouaflé and Guessabo (Figure 7). These last two clusters overlap.

**Table 3:** Individuals classification from the discriminant factorial analysis of metrics and meristics characters in *Mormyrus rume* populations from three locations in Côte d'Ivoire.

| | %Correct | Bouaflé | Prikro | Guessabo | Total |
|---|---|---|---|---|---|
| Bouaflé | 78.13 | 25 | 0 | 7 | 32 |
| Prikro | 83.87 | 3 | 26 | 2 | 31 |
| Guessabo | 73.33 | 5 | 3 | 22 | 30 |
| Total | 78.44 | 34 | 30 | 29 | 93 |

**Table 4:** Discriminatory power of metric and meristic characters retained by stepwise discriminant analysis; the probability values in bold are significant.

| Variable | Lambda | F | *p*-value |
|---|---|---|---|
| pOD | 0.974 | 2.384 | 0.126 |
| TL | 0.961 | 3.705 | 0.057 |
| pAD | 0.917 | 8.286 | 0.005 |
| pPeD | 0.951 | 4.692 | 0.033 |
| pPD | 0.965 | 3.305 | 0.072 |
| ptOD | 0.942 | 5.574 | 0.020 |
| DAD | 0.946 | 5.148 | 0.026 |
| AFL | 0.964 | 3.373 | 0.070 |
| LPeF | 0.883 | 12.012 | 0.001 |
| HB | 0.923 | 7.622 | 0.007 |
| DAC | 0.733 | 33.067 | < 0.0001 |
| DFR | 0.998 | 0.197 | 0.658 |
| AFR | 0.969 | 2.930 | 0.090 |
| PFR | 0.985 | 1.363 | 0.246 |
| TuJ | 0.890 | 11.232 | 0.001 |
| TlJ | 0.948 | 5.007 | 0.028 |

### 3.1.2.3 Morphological similarity between populations

The Hierarchical Classification Analysis (HCA) deduced from the Euclidean distances makes it possible to distinguish more clearly two large groups of populations (Figure 8). In the positive part of axis 1 is located the group that constitutes the isolated Prikro population. The second group is represented by Guessabo and Bouaflé populations. The repartition observed is similar to that obtained by the discriminant analysis.

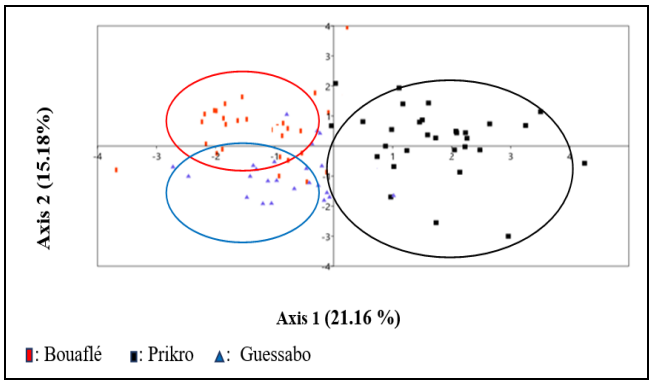


**Fig 7:** Scatterplot of first 2 significant canonical variables from the discriminant analysis of the metrics and meristics variables measured on individuals of *Mormyrus rume* from 3 locations in Côte d'Ivoire.

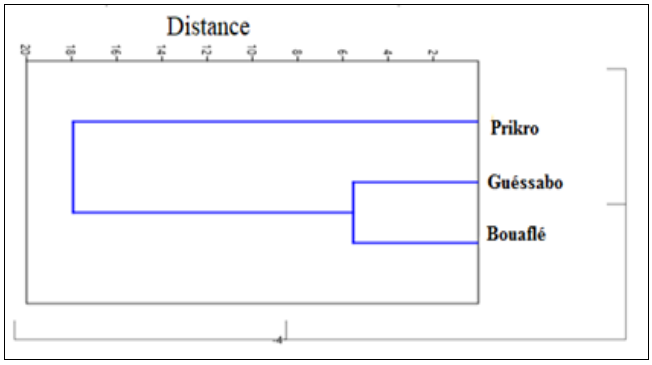


**Fig 8:** Dendrogram showing morphological proximities between *Mormyrus rume* populations from three locations in Côte d'Ivoire.

### 3.2 Discussion

Analysis of the morphological variability of 93 *Mormyrus rume* specimens from three large basins in Côte d'Ivoire (Sassandra, Bandama and Comoé) revealed the existence of morphological variations between the specimens of these coastal basins. The ANOVA results showed that 5 meristic and 12 metric characters vary from one population to another at a threshold of 5%. These descriptors could therefore be considered as key ecological traits related to the habitats of these fish populations (Konan, 2015) [28]. Morphological characters can show great plasticity in response to different environmental conditions such as food abundance and temperature (Allendorf & Phelps 1988, Swain *et al*., 1991, Wimberger 1992) [29, 30, 31]. The phenotypic plasticity of this fish species is very high. They adapt quickly by changing their physiology and behavior face to environmental changes that ultimately change their morphology [32]. The calculated coefficient of variation also showed morphological heterogeneity within populations from certain metric characters that were significant. Over all populations, metric variables such as the pre-orbital distance (DpO, % CV≥13), the postorbital distance (DptO, CV≥ 10.01) and the length of the fin base annal (LA; CV≥11.39) give CV values > 10% in each population. In general, it is the parameters related to the head that presented the high values of coefficient of variation. These same results were obtained by [33] who showed that the morphological divergence was notably related to the variables of the head.

In addition, this morphological variation observed in the variables related to the head would also be due to the diet of this fish species. In fact, *Mormyrus rume* is an insectivorous burrowing fish that searches for its prey. This way of capturing these prey could have an influence on the morphology of the characters related to the head. According to studies by [34] on the diet of the main fish species of the eastern archipelago of Lake Chad, Oligochaetes are practically not consumed by the other species, only *Mormyrus rume*, a burrowing fish with a long snout, sometimes capture them. [35] also argued that morphological variation of the head may be related to dietary behavior or exploitation of different ecological niches with different types of prey.

Regarding the significant meristic parameters, no single character gave coefficients of variation greater than 10% over the populations. In addition, the averages of the different meristic variables appear very similar among the three populations. These results revealed that the meristic characters are very stable. According to Konan, 2009 [36] meristic descriptors are discrete and fixed at the last stage of development.

Discriminant factorial and hierarchical classification analyzes elucidated the best the results of the PCA. These analyzes showed the probable existence of two subpopulations coexisting in the three localities. These two subpopulations consisted of specimens of the Comoé River (Prikro) and specimens of the Sassandra (Guéssabo) and Bandama (Bouaflé) rivers. Moreover, the analysis of the means of the metric variables revealed that the lowest values of the pre-orbital distance (pOD; 34.61), the pre-anal distance (pAD; 58.27), the prepelvic distance (pPeD; 78) and the prepectoral distance (pPD; 17.20) and the highest postorbital distance (ptOD; 65.66) and the anal-caudal distance (ACD, 34.90) were obtained in specimens from the Comoé River (Prikro). These parameters make it possible to specifically characterize the specimens representing the individuals of this river.

This morphological dissimilarity between the specimens of the Comoé River and those of the Bandama (Bouaflé) and Sassandra (Guessabo) rivers may be due to the fact that this population would present ecological and environmental factors different from the two localities. From a geographical point of view, the Prikro site is very far from the other two sites. This result suggests weak or even absent gene exchanges between this population and the other two. However, the two other geographically close populations (Bouaflé and Guéssabo) seem to have morphological affinities that tend to bring them closer. But, on the other hand, the great similarity that the two populations present retains them in this set.

## 4. Conclusion

The study of the morphological variability of *Mormyrus rume* specimens showed a great morphological variability of this species in three large basins of Côte d'Ivoire (Bandama, Sassandra and Comoé). It is also apparent from this study that the Comoé population has morphological characteristics distinct from those of Bandama and Sassandra. The population of Sassandra and Bandama are morphologically very close.

This work revealed also some new innovative descriptors which are the number of rays with the pectoral fin rays (PFR) and the number of pelvic fin rays (PeFR) complementing other meristic descriptors commonly used for the taxonomy of this species. The results of univariate and multivariate analysis provided congruent evidence for the existence of significant intraspecific morphological heterogeneity in *Mormyrus rume* in the different rivers studied. The huge morphological variation observed is associated with the environmental conditions from the point of view of geographic isolation, and therefore new comparisons of the environmental characteristics of these large basins would be of interest. The results of this study are useful as basic information on the population of *Mormyrus rume* as well as for aquaculture. Because of this, the probability of the presence of two morphologically discrete stocks of *Mormyrus rume* must be verified by the application of molecular and genetic labeling methods. It seems necessary to extend this study to the entire geographical distribution of this species in Côte d'Ivoire in order to remove confusion on the different stocks which do exit and more investigations on the impacts of environmental factors are necessary for the conservation and for the safeguarding of this very vulnerable species.

## 5. References


1. Benech V. Contribution à la connaissance de la reproduction de quelques espèces d'intérêt halieutique dans le delta central du Niger. Atelier d'études des pêches artisanales. ORSTOM/IER, Bamako (Mali), 1990, 17.
2. Teugels GG, Lévèque C, Paugy D, Traoré K. Etat des connaissances sur la faune ichtyologique des bassins côtiers de Côte d'Ivoire et de l'Ouest du Ghana. Hydrologie Tropicale. 1988; 21(3):221-237.
3. IUCN. Red list of threatened species. International Union for the Conservation of Nature (IUCN). Version 2014.3. www.iucnredlist.org. Accessed 02 February, 2019.
4. Suneetha KB. Morphological heterogeneity and population differentiation in the green chromid *Etroplus suratensis* (Pisces: Cichlidae) in Sri Lanka. Ruhuna Journal of Science. 2007; 2:70-81.
5. Lévêque C, Paugy D, Teugels GG. Faune des poissons d'eaux douces et saumâtres d'Afrique de l'Ouest. Tome1. Editions de L'orstom, Paris (France), 1990, 384.
6. Gourène G, Teugels GG, Thys van den Audenaerde DFE. Manuel pratique d'identification des poissons du lac d'Ayamé (Rivière Bia, Côte d'Ivoire). Archives scientifiques Centre de recherches Océanographiques. 1995; 14(1):1-41.
7. Girard G, Sircoulon J, Toucheboeuf P. Aperçu sur les régimes hydrologiques. *In*: Le milieu naturel de la Côte d'Ivoire. Mémoire Orstom, 50, Paris (France), 1971, 109-155.
8. Kouamé KA, Yao SS, Gooré Bi G, Kouamélan EP, N'Douba V, Kouassi NJ. Influential environmental gradients and patterns of fish assemblages. In: A West African basin. Hydrobiologia. 2008; 603:159-69.
9. Charles -Dominique E. Quelle connaissance pour quel développement des pêches artisanales? Une base de connaissance (ontologie CRM CIDOC) pour l'Afrique de l'Ouest. Rapport XXIV$^{ème}$ journées du Développement de l'Association Tiers-Monde. Economie de la connaissance et développement, Saint Louis (Sénégal), 2008, 10.
10. Zelditch ML, Swiderski DL, Sheets DH, Fink WL. Geometric morphometrics for biologist: A primer, 2004, http:/www.sciencedirect.com/science/book/9780127784601/
11. Trewavas E. Tilapiine fishes of the genera *Sarotherodon*, *Oreochromis* and Danakilia. British Museum (Natural

History), London, 1983, 583.
12. Kramer. A morphological study on species of African *Mormyrus* (Teleostei: Mormyridae) and their electric organ discharges. African Journal of Aquatic Science. 2013; 38(1):1-19.
13. Sullivan JP, Lavoué S, Hopkins CD. *Cryptomyrus*: a new genus of Mormyridae (teleostei, Osteoglossomorpha) with two new species from Gabon, West-Central Africa. Zookey. 2016; 561:117-150.
14. Bookstein FL, Chernoff B, Elder RL, Humphries JrJM, Smith GR, Strauss RE. Morphometrics in Evolutionary Biology: the Geometry of Size and Shape Change, with Examples from Fishes Academy of Natural Sciences of Philadelphia, Philadelphia. Danakilia. British Museum (Natural History), London, 1985, 583.
15. Rohlf FJ. TpsDig Version 1.4. Department of Ecology and Evolution. State University of New York at Stony Brook, New York, 2004. http://life.bio.sunysb.edu/morph/index.html/
16. Rohlf FJ. TpsDig, Digitize Landmarks and Outlines, Version 2.05. Stony Brook, NY: Department of Ecology and Evolution, State University of New York, 2006.
17. Hammer O, Harper DA, Ryan PD. Paleontological Statistics Software Package for Education and Analysis. Paleontological Electronica. 2001; 4:1-9.
18. Kraïem MM. Systématique, Biogéographie et Bio-écologie de *Barbus callensis* Valenciennes, 1842, (Poissons, Cyprinidae) de Tunisie. Thèse de Doctorat, faculté des Sciences, Université de Tunis (Tunisie), 1994, 229.
19. Adite A, Winemillier KO. Trophic ecology and ecomorphology offish assemblages in coastallakes of Benin, West Africa. Ecoscience. 1997; 4:6-23.
20. Dumay O, Tari PS, Tomasini JA, Mouillot D. Functional groups of lagoon fish species in Languedoc-Rousillon (South of France, Mediterranean Sea). Journal of Fish Biology. 2004; 64(4):970-983.
21. Mayr E. Populations species and evolution. An abridgment of animal species and evolution. The Belknap Press of Harvard University Press, Cambridge, 1970, 453.
22. Thys van den Audenaerde DFE. Bijdrage toteen systematishe bibliographische monographie van het genus Tilapia (Pisces: Cichlidae). PhD. Thesis, Rijksuniversiteit Gent., Belgium, 1970, 26.
23. Teugels GG. A systematic revision of African species of the genus *Clarias* (Pisces, Clariidae). Annales du musée royal de l'Afrique Centrale: Sciences Zoologiques, 1986, 247, 199.
24. Turki O, M'Hetli M, Chriki A, Kraïem MM. Caractérisation et variation phénotypique et biologique des deux sexes du Sandre *Sander lucioperca* (l.1758) (teleosteen, *percidae*) dans la retenue de barrage de nebhana (tunisie centrale). Bulletin de l'institut National des sciences et technologies de la Mer Salammbô. 2009; 36:75-85.
25. Tshibwabwa SM. Systématique des espèces africaines du genre *Labeo* (Teleostei, *Cyprinidae*) dans les régions ichtyogéographiques de Basse-Guinée et Congo. Thèse de doctorat. Facultés Universitaires Notre-Dame de la Paix, Faculté des Sciences, Bruxelles (Belgique), 1997, 530.
26. Zarr JH. Biostatistical Analysis. 4eme Edition. Prentice-Hall, Englewood Cliffs, New Jersey, 1999, 662.
27. Ferrito V, Mannino MC, Pappalardo AM, Tigano C. Morphological variation among populations of Aphanius fasciatus Nardo, 1827 (Teleostei, Cyprinodontidae) from the Mediterranean. Journal of Fish Biology. 2007; 70:1-20.
28. Konan KT. Systématique des poissons de la famille des mugilidae du lac fahé et des hydrosystèmes lagunaires de côte d'ivoire. Thèse de Doctorat, UFR des Sciences et Gestion de l'Environnement, Université Nangui-Abrogua (Abidjan, Côte d'Ivoire), 2015, 150.
29. Kaldhi Asma, Chargui W, Charkroun-Marzouk. Biométrie et éthologie alimentaire de deux Sparidae *Oblada melanura* (Linnaeus, 1758) et *Lithognathus mormyrus* (Linnaeus, 1758) du Golfe de Tunis. Bulletin de l'institut National des sciences et technologies de la Mer Salammbô. 2016; 43:1-8.
30. Allendorf FW, Phelps SR. Loss of genetic variation in hatchery stock of cutthroat trout. Transactions of the American Fisheries Society. 1988; 109:537-543.
31. Swain DP, Riddell B, Murray C. Morphological differences between hatchery and wild populations of Coho salmon (*Oncorhynchus kisutch*): environmental versus genetic origin. Canadian Journal Fish of Aquatic Science. 1991; 48:1783-1791.
32. Wimberger PH. Plasticity of fish body shape the effects of diet, development, family and age in two species of *Geophagus* (Pisces, Cichlidae). Bioogy Journal of Limnology Society. 1992; 45:197-218.
33. Stearns SC. A natural experiment in life-history evolution: field data on the introduction of mosquito fish (*Gambusia affinis*) to Hawaii. Evolution. 1983; 37:601-617.
34. Palma J, Andrade JP. Morphological study of Diplodus sargus, *Diplodus puntazzo*, and *Lithognathus mormyrus* (Sparidae) in the Eastern Atlantic and Mediterranean Sea. Fisheries Research. 2002; 57:1-8.
35. Lauzanne L. Regimes alimentaires des principales espèces de poissons de l'archipel oriental du lac Tchad. Cah, O.R.S.T.O.M., série hydrobiologie, 1974, 12.
36. Hyndes GA, Platell ME, Potter IC. Relationships between diet and body size mouth morphology, habitat and movement of six sillaginid species in coastal waters: implications for resource partitioning. Journal of Marine Biology. 1997; 128(4):585-598.
37. Konan KM. Diversité morphologique et génétique des crevettes des genres *Atya* Leach, 1816 et *Macrobrachium* Bate, 1868 de Côte d'Ivoire. Thèse pour l'obtention du grade de Docteur de Sciences et Gestion de l'Environnement de l'Université d'Abobo-Adjamé, 2009, 190.