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MORPHOLOGICAL IDENTIFICATION AND TAXONOMIC RELATIONSHIP OF FARMED FISH OF THE GENUS CHRYSICHTHYS

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ABSTRACT

Variation of Chrysichthys nigrodigitatus, C. maurus and C. auratus from the fish farm of Jacqueville were studied using morphometric and meristic analyses. The morphological analysis included thirty nine morphometric measurements and eight meristic counts. The Principal Component Analysis and the Discriminant function Analysis were used in order to determine morphological difference and relationship between the species of Chrysichthys. Average of coefficient of variation of morphometric was lower (CV< 30 %) for all variables within groups, except NBL and MBlL2, showing that most of the morphometric characters were not variable among three species of Chrysichthys. The specimens of C. nigrodigitatus were significantly differentiated from those of C. maurus and C. auratus. These last two species were morphologically similar. C. nigrodigitatus were distinguished from the other species by a large occipital process, a long nasal barbell. In this species, the mandible barbells and the nostrils were well separated. In addition, this species is defined by the higher number of branched anal fin rays, the number of gill raker on the epibranchial of the first gill arch and the number of gill raker on the cerato and hypo-branchial of the first gill arch. The utility of morphometric measurements for discriminating Chrysichthys species has been demonstrated but the result must be corroborated by genetic analysis.

Keywords: Morphological variation, Chrysichthys, species, multivariate analysis

1. INTRODUCTION

The species of catfish *Chrysichthys* are widely distributed in fresh and backish waters in West Africa where there are commercially important fish (Holden & Reed, 1991). In addition, the culture of the species of *Chrysichthys* is widely practiced in many countries of the West Africa and constitutes one of the largest freshwater cultivated fish. In Ivory Coast, *Chrysichthys* is highly valued food-fish and is among the wildly commercial catches fish as well as cultural fish species (Otémé, 1993; Hem *et al.*, 1994). Much of the rapid increase in aquaculture production in last decade years in Ivory Coast has come from the increasing of culturing systems of catfish *Chrysichthys*. However, in recent years, a decrease of zootechnical performance of these species has been observed. This is probably related to the misidentification of species used in aquaculture due to the confusion in this genus taxonomy (*C. nigrodigitatus* has better growth than *C. maurus*). Hence, knowledge on the identity of the species chosen for culture is an impelling necessity to eliminate mixing of species (Mariappan & Balasundaram, 1999). So, more detailed studies were needed to morphologically and genetically distinguish the species of genus *Chrysichthys* used in fish farming. In fact, there are some evidences of morphological differences among species of *Chrysichthys*.

The African catfish of genus *Chrysichthys* (Bleeker, 1862) contains more than 35 species which are not easily distinguished morphologically because of great morphological resemblance between these species, which makes their taxonomic separation very difficult (Agnèse, 1989). Risch (1986) used both morphometric and meristic characters to cluster species and subspecies of the genus *Chrysichthy* into thee valid species: *C.*

auratus, *C. maurus* and *C. nigrodigitatus*. In addition, the author declared *C. filamentosus* as a junior synonym of *C. auratus*, recognized *C. walkeri* and *C. velifer* as *C. maurus* (Valenciennes, 1839); and identified *C. furcatus* as a junior synonym of *C. nigrodigitatus*. Risch's taxonomic revision based on morphometric and meristic characters was confirmed a few years later by Agnèse (1989; 1991) and Agnèse *et al*. (1989) using morphometric and enzyme polymorphism characters; and reported that *C. auratus* and *C. filamentosus* were not clustered according to their species definition but to their geographical origin. Consequently, Agnèse (1991) confirmed that *C. auratus* and *C. filamentosus* were the same species, within which morphological differentiation between brackish and freshwater populations has occurred without any related genetic differentiation. Morphological differentiation can be principle result from two causes; genetic differences or environmental factors, or their interactions (Kara *et al*., 2011). Genetic differences and reproductive isolation between populations can lead to local adaptation, which is reflected in morphology, behaviour, physiology and life history traits (Taylor, 1991; Pakkasmaa & Piironen, 2001). Environmental factors, on the other hand, can produce phenotypic plasticity, which is the capacity of a genotype to produce different phenotypes in different environmental conditions (Scheiner, 1993). The aim of this study is to illustrate intra and inter- specific variations and to determine their validity in fish stock unit identification.

2. MATERIALS AND METHODS

2.1. Fish sample

A total of 109 specimens of the three *Chrysichthys* species were collected in February 2010 from the fish farm of Jacqueville in the Ebrié lagoon: 5°15' to 5°20'N and 4'25' to 4°30'W (Figure 1). The samples were composed by 38 specimens of *C. nigrodigitatus* (172 - 259 mm Standard Length (SL)), 40 specimens of *C. maurus* (114 – 234 mm SL), and 31 specimens of *C. auratus* (122 - 214 mm SL). All the captured fish specimens were immediately preserved in a plastic barrel containing 4% formaldehyde solution. Measurements were taken with digital callipers on the left side of the specimens and rounded to the nearest 0.05 mm in the Figure 2.

2.2. Morphometric measure

Forty-one conventional characters were measured on each specimen including the following: 1 total length (TL), 2 standard length (SL), 3 head length (HL), 4 snout length (SnL), 5 width of premaxillary toothplate (WPm T), 6 occipital process length (OPL), 7 occipital process width (OPW), 8 nasal barbel length (NBL), 9 predorsal length (DsL), 10 preadipose length (AdL), 11 prepectoral length (PtL), 12 prepelvic length (PlL), 13 preanal length (AnL), 14 distance between dorsal and adipose fins (DDsAd), 15

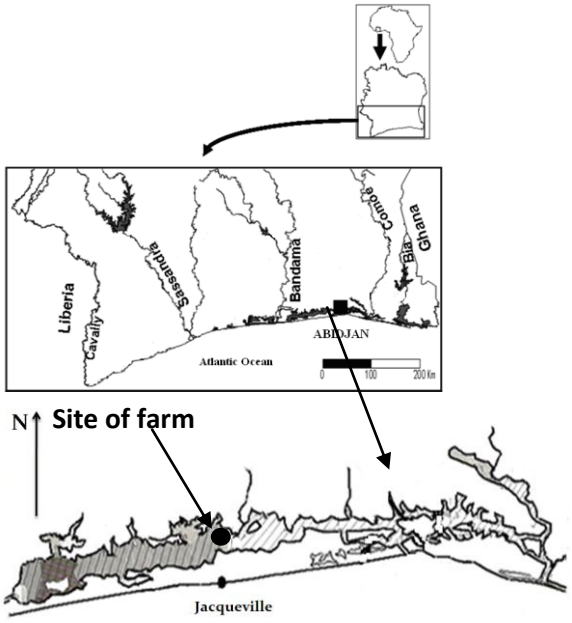

Figure 1. Geographic location of *Chrysichthys* sampling in Ebrie lagoon

dorsal fin heigth (DsH), 16 dorsal base (DsB), 17 adipose base (AdB), 18 eye diameter horizontal (ED1), 19 eye diameter vertical (ED2), 20 caudal peduncle length (CPcL), 21 pectoral height (PtH), 22 pectoral base (PtB), 23 pelvic height (PlH), 24 pelvic base (PlB), 25 anal height (AnH), 26 anal base (AnB), 27 distance pectoral/pelvic (DPtPl), 28 distance pelvic/anal (DPlAn), 29 distance pectoral/anal (DPtAn), 30 body height (BdH), 31 mandible barbell length 1 (MBlL1), 32 mandible barbell length 2 (MBlL2), 33 mandible barbell length 3 (MBlL3), 34 distance inter-orbital (DIO), 35 distance inter-nostril (DIN), 36 distance pectoral/dorsal (DPtDs), 37 distance pelvic/dorsal (DPlDs), 38 distance anal/dorsal (DAnDs), 39 distance pectoral/adipose (DPtAd), 40 distance pelvic/adipose (DPlAd), 41 distance anal/adipose (DAnAd) (Fig. 2). To minimize errors (Cakić *et al.*,

2002) reduce the allometric effect (Dumay *et al.*, 2004) and make the results more comparable (O'Reilly and Horn, 2004), each measurement data was transformed into ratio to the head length (HL) or the standard length (SL) for the measurements recorded on the fish's head or the measurements performed on the fish's body.

2.3. **Meristic study**

For meristic study, eight meristic characteristics were counted from the number of gill raker on the epibranchial of the first gill arch (RN1), gill raker on the cerato and hypo-branchial of the first gill arch (RN2), soft dorsal fin rays (NSDs), soft pectoral fin rays (NSPt), unbranched pelvic fin rays (NUPl), branched pelvic fin rays (NBrPl), unbranched anal fin rays (NUAn) and branched anal fin rays (NBrAn).

2.4. **Statistical analysis**

For each metric variable, the arithmetic mean ($\bar{X}$), the standard deviation (S.D.), and maximum and minimum values (max-min) were calculated. The coefficient of variation (CV %) was determined for each character within-groups as CV = 100 DS/$\bar{X}$ where DS is standard deviation and $\bar{X}$ is the mean of the transformed measurements of morphometric characters. One way analysis of variance (ANOVA) and Student t-test were used to test significant differences for each morphometric character among the species. The ANOVA was followed by the multiple comparison test of honest significant difference of Turkey at $p < 0.05$ level. The characters that presented significant variation between species were retained for Principal Component Analysis (PCA) and Discriminant Factorial Analysis (DFA). PCA was used to estimate morphometric variation among species and to identify variables contributing substantially to this variation. The use of the correlation matrix in PCA, allowed a direct interpretation of character loadings (≥ 0.7) and a direct comparison between species. DFA was run to test the effectiveness of the characters in predicting different species location. For this analysis, a stepwise inclusion procedure was carried out to reduce the number of characters (Jain *et al.*, 2000; Poulet *et al.*, 2005) and to identify the combinations of characters that best separated species (Hair *et al.*, 1996). The percentage of discrimination per pair of groups was estimated as the proportion of correctly classified individuals of two groups on the total classified individuals. All treatments were performed using the program STATISTICA (StatSoft, version 7.1)

3. RESULTS AND DISCUSSION

The values of the CV% for the morphometric variables were lower (between 2 and 30) for all variables. In contrast, NBL (36.39%) for *C. maurus*, NBL (38.35%) and MBL2 (35.05) for *C. auratus* showed higher variability (Table 1). The ANOVA showed that the all morphometric characters measured had highly significantly difference ($P<0.05$) between the three species except for PlL, DsB, AdB, AnB, DAnDs and DPtAd (Table 1). The Turkey post-hoc analysis revealed that HL, OPW, NBL, DsL, AdL, DsH, ED1, PtH, AnH, DPlAn, MBlL1, MBlL3 and DPlAd isolated *C. nigrodigitatus* of the two other species *C. maurus* and *C. auratus*. The specimens of *Chrysichthys nigrodigitatus* displayed the highest values of OPW, NBL, MBlL1 and MBlL3. This species was also characterized by the lowest values of HL, DsL, AdL, AnL, DsH, ED1, PtH, AnH, DPlAn and DPlAd (Table 1). On the other hand, the descriptors SnL, PtL, DPtPl, BdH, DIO, DPtDs, and DAnAd separated *C. maurus* from *C. auratus*. The specimens of *C. maurus* were characterized by low values of SnL, BdH and DAnAd, while those of *C. auratus* were characterized by the highest values of PtL, DPtPl, DIO and DPtDs. Overall, the three species were significantly different ($P<0.05$) for AnL, CPcL, PlH, MBlL2 and DIN. CPcL, MBlL2 and DIN were always lower with *C. maurus* while AnL and PlH were lower with *C. nigrodigitatus*.

Based on the Principal Component Analysis (PCA) on the 33 morphometric characters which presented significant differences between the three species nine principal components totalizing 72.51 % of the cumulative variances were calculated (Table 2). The positive and negative values indicated the shape of variation. The two first components (PC1 and PC2) which explained 41.99 % of the total variance were selected for the ordination of species. Nine variables are strongly correlated ($|r| \geq 0.7$) with PC1. The head length ($r = 0.8$), predorsal length ($r = 0.8$), the pelvic height ($r = 0.7$) and the dorsal fin height ($r = 0.7$) were positively correlated. By contrast, the length of the mandible barbell 3 ($r = -0.9$), the length of nasal barbell ($r = -0.8$), the length of the mandible barbell 2 ($r = -0.8$), the distance between nostril ($r = -0.8$), and the width of occipital process ($r = -0.7$) were

negatively correlated. PC2 was mainly defined by the pedoncule height (r = -0.7) and the distance anal/adipose (r = -0.7). The screenings of individuals along PC1 vs PC2 was showed by the Figures 3. On the plot, the population is arranged in two groups. The first group is composed by individuals of *C. nigrodigitatus* and the second group is composed by specimens of *C. maurus* and *C. auratus*. All specimens of *C. nigrodigitatus* were segregated on negative sector of PC1 while the other species *C. maurus* and *C. Auratus* were mainly located on the positive sector of the same axis. The scatterplot representing the last two species overlapped widely. *Chrysichthys nigrodigitatus* were characterized by high values of characters correlated negatively to PC1: the width of occipital process, the length of nasal barbell, the length of the mandible barbell 2, the length of the

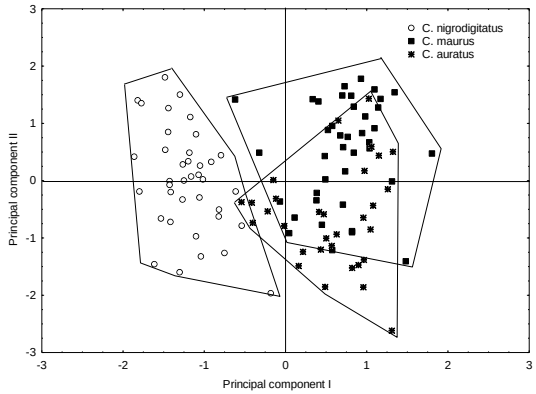

Figure 3. Scatter plot of first two principal components from the principal component analysis using metric variables for *Chrysichthys* population.

mandible barbell 3 and the distance between nostrils. In contrast, C. *maurus* and *C. auratus* were characterized by high values of characters correlated positively to PC1: the head length, predorsal length, the pelvic height and the dorsal fin height. Individuals of *C. maurus* were mostly located in the positive sector of PC2 while specimens of *C. auratus* were mainly situated in the negative part of this axis.

The stepwise discriminant analysis identified 10 descriptors that discriminated the studied species (Table 3). According to the importance of their discriminant power [wilk's lambda (λ)], there are the mandible barbell length 2 (λ= 0.71), the nasal barbell length (λ= 0.71), the body height (λ= 0.83), the dorsal fin height (λ= 0.84), the preanal length (λ= 0.87), the peduncle height (λ= 0.87), the distance inter-nostril (λ= 0.89), the width of premaxillary tooth plate (λ= 0.91) , the distance pelvic/adipose (λ= 0.92), and the snout length (λ= 0.93).

Table 3. Percentage of individuals reclassified in each group, in the validation of the discriminant analyses for the morphometric and meristic data

Species	Percentage of correction	C. nigrodigitatus	C. maurus	C. auratus
Morphometric data				
C. nigrodigitatus	100.00	38	0	0
C. maurus	85.00	0	34	6
C. auratus	80.65	0	6	25
Total	88.99	38	40	31
Meristic data				
C. nigrodigitatus	92.11	35	3	0
C. maurus	72.50	1	29	10
C. auratus	54.84	2	12	17
Total	74.31	38	44	27

The discriminant analysis confirmed 88.99 % of the classifications from the PCA (Table 4). Consequently, a reclassification of some specimens of different samples analysed were proposed. Six specimens of *C. auratus* were allocated to samples of *C maurus* and vice-versa. The predicted classification was 100 % for *C. nigrodigitatus*, 85 % for *C. maurus* and 80.65 % for *C. auratus*. The results of DFA identified the same groups as those obtained by the PCA (Figure 4). Along axis1, specimens of *C. nigrodigitatus* were clearly distinguishable from *C. maurus* and *C. auratus* that were discriminated on the axis 2 with a slight overlap. Specimens of *C maurus* were situated in the negative sector of the second axis and the specimens of *C. auratus* were situated in the positive sector of this axis.

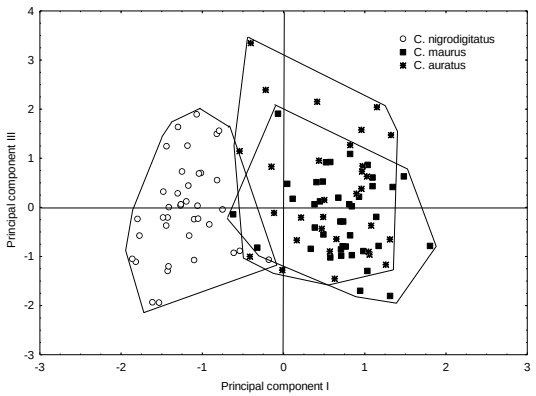

Figure 4. Scatter plot of first and third principal components from the principal component analysis using metric variables for *Chrysichthys* population.

To determine which combinations of variables discriminated *C. maurus* to *C. auratus*, they were submitted to different analyses (Student t-test, PCA and DFA). The Student t test revealed that out of the 33 characters studied, 15 varied significantly between specimens of *C. maurus* and *C. auratus*; SnL, PtL, AnL, DDsAd, CPcL, PtB, PlH, DPtPl, DPtAn, BdH, MBlL2, DIO, DIN, DPtDs and DAnAd (Table 5). The specimens of *C. auratus* exhibited the highest values for all variables. The two components (axis1 and axis 2) which explained 43.47 % of the total variance were selected for the ordination of species. The axis1 was mainly defined by CPcL (r = -0.8), DPtPl (r = - 0.7), DIN (r = -0.8) and DAnAd (r = - 0.7) and the axis 2 was strongly correlated by DPtAn (r = - 0.7). On the plot, specimens of the both species *C. maurus* and *C. auratus* were distributed with a wide overlap (Figure 5). The specimens of *C. maurus* were mostly situated in the positive sector of the PC1 while specimens of *C. auratus* were located in the negative sector of PC1. The stepwise discriminant analysis identified four discriminant descriptors: DIN (λ= 0.88), PlH (λ= 0.92), CPcL (λ= 0.93) and BdH (λ= 0.93).

Meristic characteristics such as number of soft dorsal fin rays (NSDs), unbranched pelvic fin rays (NUPl) and branched pelvic fin rays (NBrPl) were excluded from further analyses because they remained constant. Meristic data were reduced to 2 Principal Components. The axis1 (52.31 %) was strongly and negatively correlated with the number of branched anal fin rays (r = -0.8), the number of gill raker on the epibranchial of the first gill arch (r = - 0.9) and the number of gill raker on the cerato and hypo-branchial of the first gill arch (r = - 0.7). Conversely, the axis2 (16.34 %) was strongly and positively correlated to the

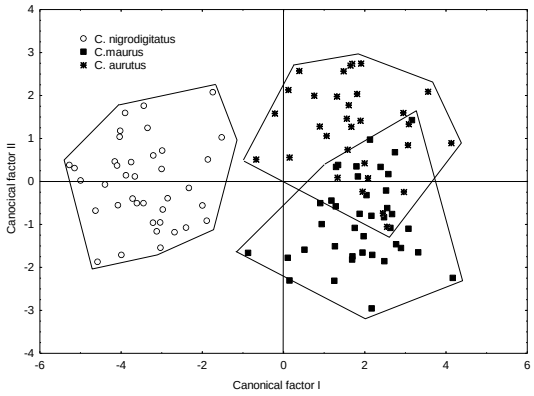

Figure 5. Scatter Plot of first two significant canonical variables from the discriminant analysis using metric variable for *Chrysichthys* population

number of unbranched anal fin rays (r = 0.7) (Table 6). According to plot graphic using by PC1 and PC2, the specimens of *C. nigrodigitatus* (group1) were mostly found in the negative sector of the PC1 and were defined by the higher number of descriptors correlated negatively to PC1. The specimens of *C. maurus* and *C. Auratus* (group 2) were mainly located in the positive sector of the PC1 (Figure 6). These specimens presented the higher number of unbranched anal fin rays and were completely overlapped.

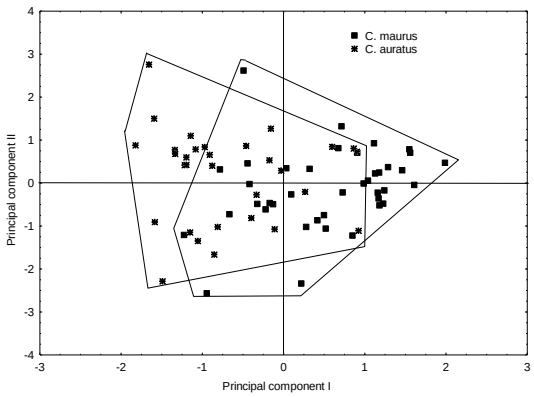

Figure 6. Scatter plot of first two principal components from the principal component analysis using metric variables for *C. maurus* and *C. auratus*

The discriminant analysis provided a matrix that confirmed 74.31 % of the classifications (Table 4). The correct classification of specimens of *C. nigrodigitatus*, *C. maurus* and *C. auratus* were 92.11, 72.5 and 54.84 % respectively. For the 40 specimens of *C. maurus*, 29 were recognized as being effectively members of this species, 10 belonging to *C. auratus* and 1 as *C. nigrodigitatus.*

In addition, 17 of the 31 specimens of *C. auratus* were correctly classified, 12 specimens of this species were attributed to *C. maurus* while only two were recognized as *C. nigrodigitatus*. By contrast, in *C. nigrodigitatus*, only 3 specimens were defined as *C. maurus*.

Some conventional morphometric and meristic characters for genus *Chrysichthys* from different populations or races of species have been recorded and analyzed previously by many investigators for species differentiation (Risch, 1986; Agnèse, 1991) or for stock identification (Adepo-Gourene *et al*., 1997; Turan, 2004). The lowest values of coefficient of variation (CV <30%) in this study indicated that minimal or very low intrapopulation variation similar to results obtained by Ferrito *et al.* (2007) in the population of *Aphanius fasciatus* they studied. In fish, the coefficients of variation within populations are usually far greater than 10 % (Carvalho, 1993). A total of 18 morphometric characters among 39 analyzed are used to differentiate *C. nigrodigitatus* of the other two specimens while only 7 variables are used to separate *C. maurus* of *C. auratus*. Our results confirmed the validity of this morphometric approach. The representation of individuals along the PC1 and PC2 identified two groups in which, one represented by specimens of *C. nigrodigitatus* and the other by specimens of both *C. maurus* and *C. auratus*. The specimens of *Chrysichthys nigrodigitatus* were distinguished from the two other species by a large occipital process, a long nasal barbell, the mandible barbells and the nostrils well separated. However, *C. auratus* differs from *C. maurus* by a large caudal peduncle, a long pelvic fins and nostrils well separated. The segregation of species was confirmed by discriminant analysis which correctly classified *C. nigrodigitatus* and showed that *C. maurus* and *C. auratus* are morphologically similar as confirmed by Hem *et al.* (1994). The authors indicated that the distinction between *C. maurus* and *C. auratus* was not always easy because, for individuals of similar size, interspecific morphological differences were minimal, while intra-specific variability can be very large. According to Agnèse (1989), the distinction of these species with *C. nigrodigitatus* was easy because of its large size and its color rather silver-gray, while it tends to yellow in *C. maurus* and *C. auratus*. The author grouped the species of the genus *Chrysichthys* into two subgenus: *Chrysichthys (Chrysichthys auratus* and *Chrysichthys maurus*) and *Melanodactylus* (*Chrysichthys nigrodigitatus* and *Chrysichthys johnelsi*). Based on discriminant function data, 88.99 % of the populations were classified into three groups using both conventional morphometric characters data, although the clustering patterns were slightly different (table 4). The classification was included *C. nigrodigitatus* (100 %), *C. maurus* (85 %) and *C. auratus* (80.65 %). This high percentage of classification (88.99 %) obtained for all groups in our study indicating that the morphometric descriptors used had an important taxonomic weight. These characters can be therefore useful for the measurement of morphometric variability between different taxa. According to Warheit (1992) the morphometric features are essential components into systematic. In Bia River, two species (*C. maurus* and *C. nigrodigitatus*) were identified by Gourène *et al.* (1995) according to morphological and anatomical criteria.

Using meristic characters, Risch (1992) characterized the tree species of *Chrysichthys* as: (1) *Chrysichthys maurus* by 8 to 10 soft rays in the pectoral fin, 3-6 simple rays and 6-10 branched rays in anal fin and 12 to 16 gill rakers on first gill arch; (2) *Chrysichthys auratus* by 7-9 soft rays in the pectoral fin, 2-6 simple rays and 6-10 branched rays in anal fin and 9 to 13 gill rakers; (3) *Chrysichthys nigrodigitatus* by 8 to 10 soft rays in the pectoral fin, 3-7 simple rays and 8-12 branched rays in anal fin, and 14 to 21 gill rakers on first gill arch. In this study, also number of soft rays in the pectoral fin, simple and branched rays in anal fin and gill rakers has been determined as different from *Chrysichthys nigrodigitatus, C. auratus and C. maurus*. The results of the present study indicate that these meristic characters were good descriptor of the body shape variation among the species of *Chrysichthys*. The meristic characters were previously used to discriminate species of *Epinephelus* (Mekkawy *et al*., 2002) and populations of *Sarotherodon melanotheron melanotheron* (Adepo-Gourene and Gourene, 2008). Our results and the previous studies indicated that the meristic characters were valid and important in species identification. The lowest values of coefficient of variation (CV <30%) in this study indicated that minimal or very low intrapopulation variation similar to results obtained by Ferrito *et al.* (2007) in the population of *Aphanius fasciatus*. According to Carvalho (1993), the coefficients of variation within fish populations are usually far greater than 10 % (Carvalho, 1993).

4. CONCLUSION

This study of morphological and meristical characters of *Chrysichthys* species from Jacqueville farm is a preliminary work in this research. The results showed that the metric and meristic characters allowed us to differentiate species of *Chrysichthys* from the fish farm of Jacqueville. *Chrysichthys nigrodigitatus* was morphologically different from *C. maurus* and *C. auratus* suggesting that the broodstock and larvae from different populations should be kept separately. Further study on genetic differentiation of individuals from different species is necessary to confirm findings of the present study. The genetic analyses would allow us to know whether *C. maurus* and *C. auratus* were separated or the same species.

5. REFERENCES

1. Adepo-Gourene, B., Teugels, G.G., Risch, L.M., Hanssens, M.M. & Agnese J.F., 1997. Morphological and genetic differentiation of 11 populations of the African catfish *Chrysichthys nigrdigifatus* (Siluroidei; Claroteidae), with consideration of their biogeography. *Canadian Journal of Zoology* 75: 102-109.
2. Adepo-Gourene, B. & Gourène, G., 2008. Différenciation morphologique des populations naturelles d'une sous-espèce de tilapia *Sarotherodon melanotheron melanotheron* Rüppell, 1852 (Teleostei ; Cichlidae) de Côte d'Ivoire. *Science & nature* 5 (1): 15-27.
3. Agnèse, J.F., 1989. Différentiation génétique de plusieurs espèces de siluriformes Ouest-africains ayant un intérêt pour la pèche et l'aquaculture. Thèse de l'université des Sciences et Techniques du Languedoc.
4. Agnèse, J.F., 1991.Taxonomic status and genetic differentiation among West African populations of the *Chrysichthys auratus* complex (Pisces, Siluriformes) based on protein electrophoresis. *Aquaculture and Fisheries Management* 22: 229-237.
5. Agnèse, J.F., Pasteur, N. & Lévêque, C., 1989. Différenciation génétique de quelques populations de *Chrysichthys nigrodigitatus* et de *C. johnelsi* (Pisces, *Bagridae*) de Côte d'Ivoire et du Mali. Revue d'Hydrobiologie Tropicale, ORSTOM, Paris, 1990: 101-105.
6. Cakic´, P., Lenhardt, M., Mic´kovic´, D., Sekulic´, N. & Budakov, L. J., 2002. Biometric analysis of *Syngnathus abaster* populations. *Journal of Fish Biology* 60: 1562–1569.
7. Carvalho, G.R., 1993. Evolutionary aspects of fish distribution: genetic variability and adaptation. *Journal of Fish Biology* 43: 53–73.
8. Dumay. O., Tari, P.S., Tomasini, J.A. & Mouillot, D., 2004. Functional groups of lagoon fish species in Languedoc-Rousillon (South of France, Mediterranean Sea). *Journal of Fish Biology* 64(4): 970-983.
9. Ferrito, V., Mannino, M.C., Pappalardo, A.M. & Tigano, C., 2007. Morphological variation among populations of *Aphanius fasciatus* Nardo, 1827 (Teleostei, Cyprinodontidae) from the Mediterranean. *Journal of Fish Biology* 70: 1-20.
10. Gourène, G., Teugels, G.G. & Thys Van Den Audenaerde, D.F.E., 1995. Manuel pratique d'identification des poissons du lac d'Ayamé (rivière bia, Côte d'Ivoire). *Archives Scientifiques* 14 (1), 41p.
11. Hair, JR., Anderson, R., Tatham, R. & Black, W., 1996. Multivariate data analysis with readings. Prentice Hall Incorporated, New Jersey.
12. Hem, S., Legendre, M., Trébaol, L., Cissé, A., Otémé, Z. & Moreau, Y., 1994. L'aquaculture lagunaire. In: *Environnement et ressources aquatiques de Côte d'Ivoire: Les milieux lagunaires*. Durand, J.R., Dufour, P., Guiral, D., Guillaume, S., Zabi, F., (Eds), ORSTOM, Tome II, Paris, 1-46 pp.
13. Holden, M. & Reed, W., 1991. West African Freshwater Fish. Longman, Singapore.
14. Jain, A.K., Duin, R.P.W. & Mao, J., 2000. Statistical pattern recognition: a review. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 22 (1): 4–37.
15. Kara, C., Alp, A. & Gürlek, M.E., 2011. Morphological Variations of the Trouts (*Salmo trutta* and *Salmo platycephalus*) in the Rivers of Ceyhan, Seyhan and Euphrates, Turkey. *Turkish Journal of Fisheries and Aquatic Sciences* 11: 77-85.
16. Mariappan, P. & Balasundaram, C., 1999. Hunting grounds for freshwater prawn seed. Science Express, The New Indian Express.
17. Mekkawy, I.A.A., Saber, S.A., Shehata, S.M.A. & Osman, A.G.M., 2002. Morphometrics and meristics of four fish species of genus Epinephelus (Family Seranidae) from the Red Sea, *Egyptian*

Bulletin of Faculty of Sciences Assiut University 31: 21-41.

18. O'Reilly, K.M. & Horn M.H., 2004. Phenotypic variation among populations of Atherinops affinis (Atherinopsidae) with insights from a geometric morphometric analysis. *Journal of Fish Biology* 64: 1117–1135.
19. Otémé Z. J., 1993. Cycle sexuel et fécondité du Mâchoiron *Chrysichthys nigrodigitatus* en lagune Ebrié, Côte d'Ivoire. *Journal Ivoirien d'Océanologie et de Limnologie* II(1): 61-67.
20. Pakkasmaa, S. & Piironen, J., 2001. Morphological differentiation among local trout (*Salmo trutta*) populations. *Biological Journal of the Linnean Society* 72: 231-239.
21. Poulet, N., Reyjol, Y., Collier, H. & Lek, S., 2005. Does fish scale morphology allow the identification of population at a local scale? A case study for rostrum dace Leuciscus leuciscus burdigalensis in river Viaur (SW France). *Aquatic Sciences* 67: 122–127.
22. Risch, L.M., 1986. Het genus Chrysichthys Bleeker, 1858 en aanverwante genera (Pisces, Siluriformes, Bagridae): een systematische, morphologische, anatomische en zogeografische studie. Katolieke Universiteit Leuven, Belgium. Ph.D.
23. Rish, L.M., 1992. *Bagridae*. In : *Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest.* Lévêque, C., Paugy, D. et Teugels, G.G. (Eds), ORSTOM, Tome II, Paris, Tervuren, 395-431 pp.
24. Scheiner, S.M., 1993. Genetics and evolution of phenotypic plasticity. *Annual Review of Ecology Systems* 24: 35-68.
25. Taylor, E.B., 1991. A review of local adaptation in Salmonidae, with particular reference to Pacific and Atlantic salmon. *Aquaculture* 98: 185-207.
26. Turan, C., 2004. Stock identification of Mediterranean horse mackerel (*Trachurus mediterraneus*) using morphometric and meristic characters. *ICES Journal of Marine Science* 61: 774-781.
27. Warheit, KI., 1992. The role of morphometrics and cladistics in the taxonomy of fossils: a paleornithological example. *Systems Biology* 41(3):345–36

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Table 1. Descriptive statistics of morphometric variables of *Chrysichthys* species. Mean ± standard deviation (S.D.), Coefficient variation (CV %), minimum and maximum values (Min - Max). Results from analysis of variance (ANOVA) testing mean differences between species.

Metric characters	*C. nigrodigitatus* (N=38)			*C. maurus* (N=40)			*C. auratus* (N=31)		
	Mean ± S.D.	CV	Range	Mean ± S.D.	CV	Range	Mean ± S.D.	CV	Range
HL	26.83 ^{a} ± 1.10	4.09	24.37 – 28.62	29.08 ^{b} ± 1.12	3.85	26.07 – 32.51	29.27 ^{b} ± 1.51	5.18	24.31 – 31.12
SnL	37.57 ^{b} ± 2.16	5.74	34.36 – 42.86	36.12 ^{a} ± 2.56	7.10	30.34 – 40.48	38.03 ^{b} ± 1.99	5.24	34.78 – 43.24
WPmT	30.50 ^{b} ± 3.98	13.06	18.69 – 38.69	25.40 ^{a} ± 5.12	20.28	17.28 – 40.91	27.68 ^{ab} ± 6.83	24.66	17.39 – 48.73
OPL	22.14 ^{b} ± 3.63	16.38	16.76 – 30.41	19.81 ^{a} ± 2.98	15.04	12.36 – 25.45	20.65 ^{ab} ± 3.00	14.53	13.51 – 29.03
OPW	13.88 ^{b} ± 1.24	26.02	19.69 – 25.46	9.83 ^{a} ± 1.35	23.99	21.96 – 28.92	10.46 ^{a} ± 0.92	26.70	22.38 – 26.90
NBL	14.15 ^{b} ± 3.45	24.36	4.19 – 20.39	7.33 ^{a} ± 2.67	36.39	2.47 – 13.11	7.05 ^{a} ± 2.70	38.35	2.38 – 13.12
DsL	35.03 ^{a} ± 1.19	3.39	14.59 –17.53	36.76 ^{b} ± 1.16	3.16	13.41 – 16.69	37.01 ^{b} ± 1.50	4.06	13.74 – 16.81
AdL	72.06 ^{a} ± 1.14	2.94	15.73 – 21.28	73.98 ^{b} ± 0.93	2.91	14.32 – 19.00	74.35 ^{b} ± 0.89	2.72	15.28 – 19.05
PtL	21.04 ^{a} ± 1.50	7.11	18.30 – 25.00	21.30 ^{a} ± 1.37	6.45	18.38 – 24.93	22.26 ^{b} ± 1.72	7.73	17.65 – 24.92
PlL	50.18 ^{a} ± 2.20	4.38	44.12 – 54.32	49.95 ^{a} ± 1.99	3.98	45.77 – 53.71	51.22 ^{a} ± 2.35	4.58	45.48 – 57.65
AnL	67.74 ^{a} ± 2.84	4.19	62.95 – 72.87	70.41 ^{b} ± 2.23	3.17	66.67 – 78.09	71.64 ^{b} ± 2.76	3.85	62.13 – 76.28
DDsAd	26.40 ^{b} ± 1.80	6.81	21.74 – 30.33	24.16 ^{a} ± 2.44	10.11	20.00 – 30.60	25.29 ^{ab} ±1.62	6.40	22.8 – 29.45
DsH	22.32 ^{a} ± 2.47	11.06	16.39 – 25.79	26.36 ^{b} ± 2.00	7.57	22.34 – 31.98	26.47 ^{b} ± 2.42	9.14	20.76 – 30.54
DsB	11.65 ^{a} ± 1.02	8.73	9.42 – 14.63	11.42 ^{a} ± 1.59	13.9	8.33 – 15.65	11.72 ^{a} ± 1.43	12.22	8.84 – 14.67
AdB	7.85 ^{a} ± 0.86	10.96	5.96 – 9.77	7.38 ^{a} ± 1.05	14.24	5.54 – 9.16	7.79 ^{a} ± 1.02	13.13	5.83 – 9.74
ED1	23.55 ^{a} ± 2.67	22.71	18.8 – 29.14	26.7 ^{b} ± 3.44	12.87	16.39 – 33.71	26.89 ^{b} ± 2.97	11.03	21.00 – 32.97
ED2	14.03 ^{a} ± 2.44	26.38	9.02 – 18.52	15.78 ^{b} ± 2.56	16.21	9.84 – 23.75	14.75 ^{ab} ± 2.58	17.46	9.09 – 21.74
CPcL	8.16 ^{b} ± 0.64	7.89	6.20 – 9.27	7.72 ^{a} ± 0.79	10.20	6.19 – 9.48	8.72 ^{c} ± 0.90	10.27	6.67 – 10.22
PtH	16.24 ^{a} ± 2.03	12.38	12.30 – 21.96	18.03 ^{b} ± 2.39	13.26	13.25 – 22.72	18.64 ^{b} ± 2.81	15.07	13.06 – 22.6
PtB	5.12 ^{b} ± 0.74	14.54	3.54 – 6.84	4.45 ^{a} ± 0.66	14.90	3.46 – 6.22	4.88 ^{ab} ± 0.84	17.26	2.83 – 6.56
PlH	14.71 ^{a} ± 1.08	7.32	12.00 – 16.49	16.07 ^{b} ± 0.89	5.56	14.40 – 18.36	16.71 ^{b} ± 1.52	9.12	13.54 – 19.86
PlB	3.57 ^{b} ± 0.34	3.66	2.86 – 4.33	3.12 ^{a} ± 0.56	18.09	1.83 – 4.23	3.35 ^{ab} ± 0.48	14.33	2.16 – 4.22
AnH	18.09 ^{a} ± 1.01	5.56	15.68 – 19.59	19.3 ^{b} ± 1.48	7.64	16.34 – 22.96	19.64 ^{b} ± 1.21	6.14	17.38 – 22.04
AnB	10.85 ^{a} ± 0.99	9.15	9.13 – 12.61	10.49 ^{a} ± 1.40	13.38	7.69 – 14.00	10.91 ^{a} ± 1.53	14.02	7.17 – 13.48
DPtPl	27.45 ^{b} ± 1.91	6.97	23.92 – 31.95	24.72 ^{a} ± 2.42	9.81	20.09 – 29.41	26.21 ^{b} ± 2.20	8.39	21.59 – 31.54

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DPlAn	15.81 [a] ± 1.68	10.62	13.03 – 19.35	17.83 [b] ± 1.72	9.6	13.6.00 – 20.74	18.00 [b] ± 1.70	9.44	14.86 – 22.30
DPtAn	45.86 [a] ± 2.20	4.79	41.60 – 50.93	46.72 [ab] ± 2.82	6.03	40.77 – 54.60	47.83 [b] ± 2.69	5.61	41.42 – 52.74
BdH	17.63 [b] ± 1.94	11.01	13.75 – 21.96	15.94 [a] ± 1.44	9.01	13.68 – 19.95	17.54 [b] ± 2.10	11.99	12.14 – 21.47
MBlL1	82.96 [b] ± 9.58	11.55	60.63 – 103.03	76.26 [a] ± 8.23	10.79	60.23 – 93.37	74.42 [a] ± 9.74	13.08	56.43 – 96.08
MBlL2	13.12 [c] ± 1.93	14.74	8.39 – 16.05	6.49 [a] ± 1.90	29.3	2.70 – 11.30	7.93 [b] ± 2.78	**35.05**	2.90 – 17.09
MBlL3	21.80 [b] ± 2.15	9.85	16.17 – 25.26	12.60 [a] ± 3.27	25.93	7.58 – 21.82	14.22 [a] ± 4.12	28.93	8.70 – 28.00
DIO	21.05 [b] ± 1.97	9.38	18.07 – 26.16	18.76 [a] ± 2.70	14.37	14.29 – 27.27	20.41 [b] ± 3.16	15.49	12.05 – 25.49
DIN	13.80 [c] ± 2.02	14.63	6.84 – 18.85	8.76 [a] ± 1.62	18.51	5.33 – 12.50	10.80 [b] ±2.15	19.91	6.52 – 14.36
DPtDs	30.54 [a] ± 1.26	4.13	28.19 – 32.99	31.02 [a] ± 1.82	5.87	27.15 – 34.28	32.15 [b] ± 2.06	6.39	28.46 – 36.64
DPlDs	17.24 [b] ± 1.60	9.26	13.71 – 21.87	16.23 [a] ± 1.50	9.22	13.65 – 19.35	16.82 [ab] ± 1.95	11.58	12.22 – 21.77
DAnDs	28.67 [a] ± 1.73	6.03	22.96 – 31.96	28.04 [a] ± 2.10	7.5	20.28 – 32.51	29.2 [a] ± 2.02	6.93	23.68 – 33.03
DPtAd	54.09 [a] ± 2.22	4.11	48.39 – 60.47	53.55 [a] ± 2.67	4.98	46.44 – 58.22	54.62 [a] ± 1.88	3.44	49.98 – 57.82
DPlAd	25.82 [a] ± 1.91 [a]	7.41	21.86 – 29.90	27.64 [b] ± 1.74	6.31	23.94 – 31.20	27.14 [b] ± 1.51	5.56	24.44 – 30.03
DAnAd	15.58 [b] ± 1.18	7.57	13.57 – 17.94	14.47 [a] ± 1.13	7.82	11.76 – 17.00	15.45 [b] ± 1.49	9.64	12.92 – 18.93

[a, b, c] letters in the same row show differences among species ($p<0.05$). Head length (HL); snout length (SnL); width of premaxillary toothplate (WPmT); occipital process length (OPL); occipital process width (OPW); nasal barbel length (NBL); predorsal length (DsL); preadipose length (AdL); prepectoral length (PtL); prepelvic length (PlL); preanal length (AnL); distance between dorsal and adipose fins (DDsAd); dorsal fin heigth (DsH); dorsal base (DsB); adipose base (AdB); eye diameter horizontal (ED1); eye diameter vertical (ED2); caudal peduncle length (CPcL); pectoral height (PtH); pectoral base (PtB); pelvic height (PlH); pelvic base (PlB); anal height (AnH); anal base (AnB); distance pectoral/pelvic (DPtPl); distance pelvic/anal (DPlAn); distance pectoral/anal (DPtAn); body height (BdH); mandible barbell length 1 (MBlL1); mandible barbell length 2 (MBlL2); mandible barbell length 3 (MBlL3); distance inter-orbital (DIO); distance inter-nostril (DIN); distance pectoral/dorsal (DPtDs); distance pelvic/dorsal (DPlDs); distance anal/dorsal (DAnDs); distance pectoral/adipose (DPtAd); distance pelvic/adipose (DPlAd); distance anal/adipose (DAnAd)

Table 2. Factor scores, eigenvalues and proportions of the variance expressed by the axes of the principal components analysis of metric variables.

Variables	Axis1	Axis2	Axis3	Axis4	Axis5	Axis6	Axis7	Axis8	Axis9
HL	0.8	-0.3	0.3	-0.0	0.0	0.2	0.2	0.0	-0.1
SnL	-0.2	-0.4	0.2	-0.0	0.1	-0.3	-0.5	0.2	-0.2
WPmT	-0.5	-0.3	0.4	0.1	0.3	0.4	0.2	-0.1	-0.0
OPL	-0.4	-0.3	-0.4	0.1	0.1	0.2	-0.3	-0.0	0.1
OPW	-0.7	-0.3	-0.2	0.2	0.1	0.1	-0.1	0.2	-0.2
NBL	-0.8	-0.1	-0.1	-0.0	0.2	-0.0	-0.1	-0.0	0.1
DsL	0.8	-0.4	0.1	0.1	-0.1	-0.1	-0.1	0.1	-0.0
AdL	0.5	-0.5	0.5	0.2	-0.3	0.2	0.0	-0.0	-0.1
PtL	0.2	-0.5	0.5	0.2	-0.3	0.2	0.0	-0.0	-0.1
AnL	0.6	-0.5	-0.1	-0.2	0.3	0.1	0.1	0.0	0.1
DDsAd	-0.4	-0.4	-0.0	-0.1	-0.1	0.3	-0.5	- 0.1	-0.0
DsH	0.7	-0.1	0.0	0.4	0.0	-0.0	-0.0	0.0	0.1
CPcL	-0.1	-0.7	0.2	-0.0	-0.1	-0.1	0.2	-0.1	-0.2
ED1	0.4	-0.2	-0.4	0.5	0.0	0.2	0.0	-0.3	-0.3
ED2	0.3	-0.1	-0.6	0.3	-0.0	0.2	0.2	-0.2	-0.1
PtH	0.4	-0.3	0.1	0.5	-0.2	-0.2	-0.2	-0.4	0.2
PtB	-0.4	-0.5	-0.2	0.0	0.2	-0.0	0.1	0.3	-0.3
PlH	0.6	-0.3	0.3	0.2	0.1	-0.2	-0.2	0.1	0.2
PlB	-0.4	-0.4	0.0	0.2	-0.2	-0.3	0.2	0.2	-0.3
AnH	0.5	-0.3	0.2	0.2	0.1	0.4	0.0	0.4	0.1
DPtPl	-0.4	-0.6	-0.0	0.0	0.4	-0.1	-0.1	-0.3	0.0
DPlAn	0.6	-0.3	-0.2	-0.1	0.3	0.0	0.4	0.1	0.1
DPtAn	0.3	-0.5	-0.2	-0.3	0.5	-0.3	0.1	-0.2	-0.0
BdH	-0.2	-0.6	-0.2	-0.3	-0.5	-0.1	-0.1	0.2	-0.0
MBlL1	-0.4	0.1	-0.4	0.4	-0.1	-0.1	-0.3	0.2	0.3
MBlL2	-0.8	-0.2	0.2	0.0	0.0	0.1	0.1	-0.0	0.1
MBlL3	-0.9	-0.2	0.2	0.0	0.1	0.2	0.1	-0.1	0.1
DIO	-0.4	-0.4	0.1	0.4	0.0	-0.1	0.1	0.3	0.3
DIN	-0.8	-0.3	0.2	0.2	0.0	0.1	0.1	-0.0	0.2
DPtDs	0.3	-0.6	-0.3	0.1	0.1	-0.2	0.0	0.1	-0.2
DPlDs	-0.2	-0.6	-0.2	-0.3	-0.5	0.2	0.1	-0.1	0.1
DAnAd	-0.2	-0.7	0.0	-0.2	-0.3	-0.2	0.2	-0.2	0.2
DPlAd	0.5	-0.3	-0.3	-0.2	-0.2	0.3	-0.0	0.2	0.2
Eigenvalues	8.76	5.09	2.14	1.74	1.56	1.35	1.22	1.05	1.02
Variance explained (%)	26.55	41.99	48.46	53.73	58.46	62.55	66.25	69.43	72.51

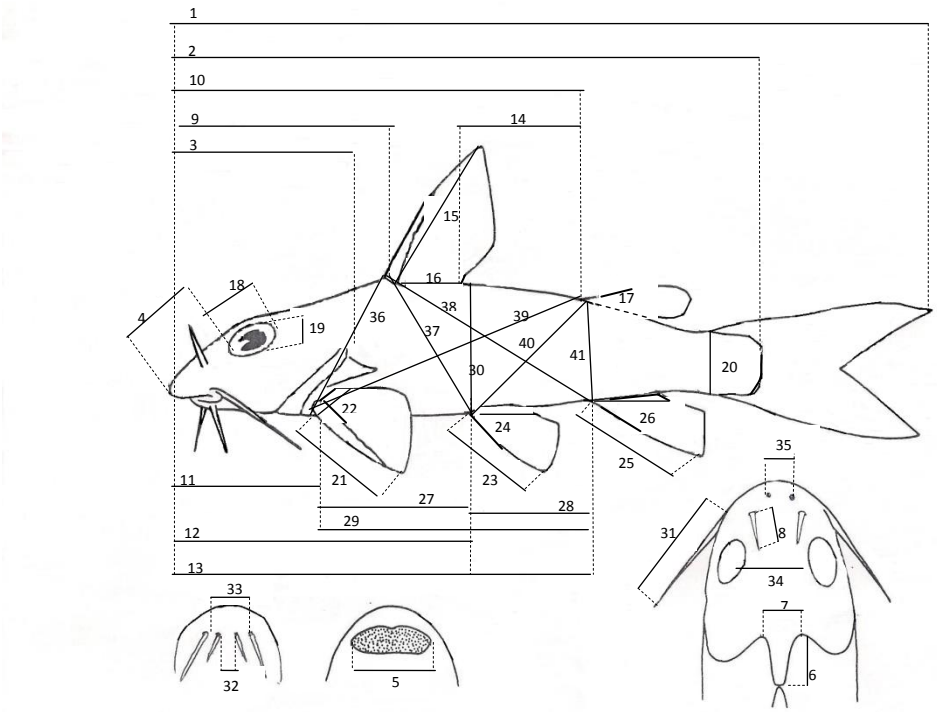

Figure 2. Metrics measurements taken from the individuals of the three species of *Chrysichthys*