

Morphometric Measurements and Meristic Counts of the Fish *Alestes baremoze* From the River Nile and its Tributaries, Sudan

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Abstract

Morphometric indices are used for identification of fish to the species level. In this study ratios indices, morphometric measurements and meristic counts were used to compare and differentiate *Alestes baremoze* that is collected from different areas of River Nile; Atbara River (Khashm El Girba), Blue Nile (Sinnar) and the main course of River Nile (Kreima). Examination of morphological characters in 267 samples showed statistical significant difference ($P= 0.000$) between groups. Discriminant functions calculated from the 13 selected variables and the variables that mostly influenced the separation of *A. baremoze* from the three sites were: Head length (HL), Pre-pelvic length (PPL), Pectoral fin length (PFL), Pre-anal length (PAL), Pre-pectoral length (PPCL), Caudal-peduncle depth (CPD), Anal-fin base length (AFBL) and Anal fin ray (AFR) in function 1 and Body width (BW), Lateral line scale (LLS), Scales above lateral line (SALL), Inter orbital distance (IOD) in function 2. The scatter plot of the Canonical discriminant function (CDF) showed an overlap between the populations from Khashm El Girba and Sinnar and with few specimens from Kreima population. The Chi-square was highly significant, indicating population with definite differences between the three populations from the three sites ($\chi^2=5.991$, $df=26$, $p=0.000$). Thus, hierarchical cluster analysis of morphometric measurements and meristic counts shows the present of closely relationship between the two populations of *Alestes baremoze* from Khashm El Girba and Sinnar.

Keywords: Morphometric measurements; Meristic counts; *Alestes baremoze*; Fish classification

الصفات المورفومترية والقياسات العددية لأسماك الكوارة البلدي من نهر النيل وروافده، السودان

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مستخلص الدراسة

تستخدم المؤشرات المورفومترية للصفات التقليدية لمعرفة أنواع و أجناس السمك. أجريت هذه الدراسة لمقارنة سمك الكوارة البلدي من نهر عطبرة (خشم القرية)، النيل الأزرق (سنار) و نهر النيل (كريمة) باستخدام مؤشر النسبة للصفات المورفومترية والقياسات العددية في 267 عينة. أوضح تحليل التباين أحادي الإتجاه وجود فروقات عالية المعنوية ($P=0.000$) بين غالبية قياسات الصفات المورفومترية و كذلك التحليل التمييزي بين سمك الكوارة من المناطق الثلاثة. التحليل التمييزي حُسب من المتغيرات الثلاث عشر التي تم إختيارها. المتغيرات التي أوضحت الفروقات بين أسماك الكوارة من المناطق الثلاث في الغالب هي: طول الرأس، طول ما قبل الزعنفة الحوضية، طول الزعنفة الصدرية، طول ما قبل الزعنفة الذيلية، طول ما قبل الزعنفة الصدرية، عمق السويقة الذيلية، طول قاعدة الزعنفة الذيلية وأشعة الزعنفة الشرجية في الوظيفة (1) وعرض الجسم، عدد قشور الخط الجانبي، عدد القشور أعلى الخط الجانبي والمسافة بين المدارية في الوظيفة (2). رسم مخطط الإنتشار للتحليل التمييزي أوضح تداخلاً بين مجتمعات خشم القرية ومجتمعات سنار مع بعض من التداخل مع كريمة. إختبار تربيع كاي ($\chi^2=5.991$, $df=26$, $p=0.000$) أشار إلى الإختلافات الهامة جداً بين المجتمعات في المواقع الثلاثة. وهكذا، التحليل العنقودي للصفات المورفومترية والقياسات العددية أوضح وجود علاقات وثيقة الصلة بين مجتمعات الكوارة من خشم القرية وسنار. الكلمات المفتاحية: الصفات المورفومترية، القياسات العددية، الكوارة البلدي، تصنيف الأسماك.

1. Introduction:

The Nilotic fauna is rich and diverse in fish species, with over 300 species falling at least into 54 genera (Hammerton, 1972). This diversity is related to diversification of the habitat of the Nile system itself (natural and man-made lakes, falls, cataracts, swamps, canalization systems etc). In some instances, deliberate introduction of exogenous species into parts of the Nile system or canalization system contributes to diversity of fish species (Abu Gideiriet *al.*, 2008).

The Alestidae was first proposed as a family separate from the Characidae by Géry (1977). Calcagnotto *et al.*, (2005) hypothesized that the Alestidae is a monophyletic group in agreement with Buckup (1998).

Systematic studies on Alestidae have lagged behind in comparison with their neotropical characiform counterparts (Stiassny and Schaefer, 2005; Paugy and Schaefer, 2007). The relationships among genera within the family remain largely unstudied and comprehensive morphological evidence is unavailable for purposes of establishing unambiguous diagnoses for the vast majority of the included genera (Paugy and Schaefer, 2007).

The first systematic account of freshwater fishes of the Sudan was given by Boulenger (1907). The subsequent work of Sandon (1950), Abu Gideiri (1984) and Bailey (1994) was based on Boulenger's work. After the work of Boulenger (1907) few additions of species were made including *Synodontiskhartoumiensis* by Abu Gideiri (1967), *Labeomeroensis* by Mortitz, T (2007) and *Paradistchodusdimidiatus* by Radimet *al.* (2016). The last species caught in Kosti, appeared as first record for the whole Nile river

system. The recent list of freshwater fishes of the Sudan available online at Fishbase.org, first created by Jen (2003) and modified by Elijah, (2004) was of low reliability for inclusion of marine species, giving wrong genus or species names or inclusion of species not recorded in Sudan (Abu Gideiriet al., 2008). The fish taxonomy of genera and species given by the earlier mentioned authorities was largely based on descriptive notes of the morphological characters.

The study aims to examine the differences between populations of *Alestes* specie collected from River Nile and its tributaries in Sudan using ratio indices, morphometric measurements and meristic counts.

1. Materials and methods:

1.1. Study sites:

Alestes baremoze samples were collected from three sites at River Nile: River Atbara (Khashm El Girba), Blue Nile (Sinnar) and River Nile (Kreima). The three sites characterize by having different climatic conditions (Figure 1).

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Figure1: Location map showing the sampling areas (1= Khashm El Girba, 2=Sinnar, 3=Kreima). Source: [www. Google](http://www.Google), Wednesday,

2.2. Fish sampling:

Fish samples were randomly collected by gill nets of mesh size 2x2 and 3x3 cm. Target fish species (Plate 1-3) which were not available at time of collection were purchased from the fish landing sites from the operating fisher at Khashm El Girba in February 2013, Sinnar in March 2013 and Kreima in April 2013. A total of 267 samples were collected (67 from Khashm El Girba, 100 from Sinnar and 100 from Kreima).



Plate 1: *Alestes baremoze* from Khashm El Girba.



Plate 2: *Alestes baremoze* from Sinnar.



Plate 3: *Alestes baremoze* from Kreima.

2.3. Morphometric measurements:

Morphological identification and morphometric measurements have been made as described by Sandon (1950), Abu Gideiri (1984), Bailey (1994) and Paugyet *al.* (2003).

2.3. Meristic Counts:

Meristic counts have been made following Barelet *al.*(1977), Sneoks (1994), Paugy *et al.* (2003) and Ebraheem (2012).

2.4. Statistical analysis:

The Statistical Package for Social Science (SPSS Version 15) was used to perform the One way analysis of variance (ANOVA) and it was used to test the variations in the measured morphological characters between all *Alestes baremoze* from the three sites, K independent sample test (Kruskal-wallis) it is the alternative statistical analysis to explained Chi-Square was did between *Alestes baremoze* from the three site, the principal component analysis and Discriminant analysis for morphometric measurements and meristic counts were done to decide which variables better differentiate among the species. The ratios of measured character were entered for analysis.

3. Results:

3.1. Morphometrics:

The results of ANOVA test which conducted for *A. baremoze* spp. within the populations showed extremely very highly statistically significant differences ($p=0.000$) between most of measured morphological characters (15 characters) and very highly significant differences ($p<0.001$) in IOD/HL, Pre-pelvic length (PPVL)/ Standard Length (SL) and Pre-dorsal length (PDL)/SL and insignificant differences ($p>0.05$) in Body depth (BD)/SL and Dorsal-adipose distance (DAD)/SL (Table 3).

Table 3. Comparison of morphometric ratio of *Alestes baremoze* from Khashm El Girba (Atbara)

Sites	Ratio	Mean±SE	Sig.	Ratio	Mean±SE	Sig.
Khashm El Girba	HW/HL	0.422±0.003	0.000	PDL/SL	0.503±0.002	0.001
Sinnar		0.416±0.003			0.497±0.001	
Kreima		0.451±0.002			0.489±0.003	
Khashm El Girba	SNL/HL	0.268±0.003	0.000	LDFL/S L	0.185±0.001	0.000
Sinnar		0.280±0.002			0.192±0.001	
Kreima		0.291±0.002			0.180±0.001	
Khashm El Girba	ED/HL	0.276±0.003	0.000	DFBL/ SL	0.089±0.001	0.000
Sinnar		0.301±0.002			0.095±0.001	
Kreima		0.304±0.002			0.089±0.001	
Khashm El Girba	IOD/HL	0.317±0.002	0.001	DAD/S L	0.264±0.001	0.367
Sinnar		0.320±0.003			0.261±0.001	
Kreima		0.329±0.002			0.260±0.002	
Khashm El Girba	HL/SL	0.195±0.001	0.000	CPL/SL	0.164±0.001	0.000
Sinnar		0.197±0.001			0.168±0.001	
Kreima		0.178±0.001			0.159±0.001	
Khashm El Girba	BD//SL	0.224±0.001	0.086	CPD/S L	0.080±0.000	0.000
Sinnar		0.229±0.002			0.081±0.001	
Kreima		0.224±0.002			0.077±0.001	
Khashm El Girba	BW/SL	0.091±0.001	0.000	AFBL/ SL	0.228±0.001	0.000
Sinnar		0.083±0.001			0.228±0.001	
Kreima		0.092±0.001			0.221±0.001	
Khashm El Girba	PPCL/SL	0.200±0.001	0.000	PVFL/S L	0.144±0.001	0.000
Sinnar		0.201±0.001			0.141±0.001	
Kreima		0.192±0.001			0.129±0.001	
Khashm El Girba	PPVL/SL	0.437±0.002	0.003	PFL/SL	0.171±0.001	0.000
Sinnar		0.430±0.001			0.170±0.001	
Kreima		0.441±0.003			0.155±0.001	
Khashm El Girba	PAL/SL	0.617±0.003	0.000	CFL/SL	0.306±0.002	0.000
Sinnar		0.616±0.002			0.303±0.002	
Kreima		0.644±0.005			0.293±0.002	

3.2. Meristics:

Kruskal-wallisof K independent sample test was done and the grouping variable in *Alestes baremoze*(Table 4) showed extremely highly significant differences ($p < 0.000$) in Dorsal fin ray (DFR), Pectoral Fin ray (PFR), LLS and Scales below lateral line (SBLL), and insignificant different ($p > 0.05$) in AFR and SALL between the three sites.

Table 4. Kruskal-wallis test based on grouping variable in *A.baremoze* from the three sites.

Statistics	DFR	AFR	PFR	PVFR	LLS	SALL	SBLL
N	267	267	267	267	267	267	267
Median	10	27	13	9	47	8.5	3.5
Range	9-11	22-30	12-15	9-10	41-54	6.5-9.5	2.5-4.5
Chi-Square	169.074	3.422	39.605	11.261	15.646	5.232	38.744
Df	2	2	2	2	2	2	2
Aymp. Sig.	0.000	0.181	0.000	0.004	0.000	0.073	0.000

3.3. Discrimination between *Alestes baremoze* from the three study sites:

Table 5 showed that two significant functions (Wilk's Lambda= 0.247, $\chi^2 = 495.696$, $df = 26$, $P = 0.000$) were derived with 91.3% and 8.7% of the total variance were explained by factor 1 and factor 2, respectively.

The two functions had a p-value ($p = 0.000$) indicating that the group centroids of the three species were highly significantly different. The canonical correlation coefficient of functions 1 and 2 was 0.895 and 0.523 and the related Chi-square=495.696 and 82.379, this indicates a low correlation between the discriminant functions and the original variables.

The Chi-square was highly significant ($p=0.000$; $df=26$ and 12) in the two functions respectively, indicating population with definite differences between the three sites.

Table 5 showed the canonical discriminant functions and standardized canonical discriminant functions respectively for the discriminant functions calculated from the 13 selected variables. Largest absolute correlation between each variable and any discriminant function was indicated by a (*) in Table 5. The variables that mostly influenced the separation of *A. baremoze* from the three sites were: HL, Pelvic fin length (PVFL), PFL, PAL, PPCL, CPD, AFBL and AFR in function 1 and BW, LLS, SALL, IOD in function 2 (Table 5).

Table 5: Canonical Discriminant Function (CDF) and Standardized Canonical Discriminant Function (SCDF) from discriminant analysis of *A. baremoze* from Khashm El Girba (Atbara River), Sinnar (Blue Nile) and Kreima (main Nile).

Character	CDF		SCDF		Loading	
	Function		Function		Function	
	1	2	1	2	1	2
HL/SL	95.289	-39.214	0.866	-0.356	0.488*	0.030
PVFL/SL	55.203	76.738	0.434	0.604	0.428*	0.363
PFL/SL	17.111	4.314	0.194	0.049	0.323*	0.148
PAL/SL	-23.451	-26.244	-0.733	-0.821	-0.216*	-0.082
PPCL/SL	-0.209	11.191	-0.002	0.113	0.198*	-0.003
CPD/SL	58.388	-37.510	0.315	-0.202	0.174*	-0.026
AFBL/SL	5.862	8.772	0.069	0.104	0.137*	0.110
AFR	-0.076	-0.057	-0.109	-0.082	-0.046*	-0.011
BW/SL	-36.853	98.708	-0.261	0.698	-0.238	0.598*
LLS	0.120	-0.247	0.231	-0.474	0.083	-0.286*
SALL	0.155	0.377	0.064	0.156	-0.029	0.210*
IOD/HL	5.813	-3.833	0.128	-0.085	-0.112	-0.146*
PPVL/SL	-17.108	37.812	-0.364	0.805	-0.102	0.126*

In cross validation, each case is classified by the functions derived from all cases other than that case. This discrimination was valid, since 85.4% of original grouped specimens and 83.5% of cross-validated ones were correctly classified (Table 6).

Table 6: Leave-one-out cross validation for *A. baremoze* specimens used in discriminant function analysis from Khashm El Girba (Atbara River), Sinnar (Blue Nile) and Kreima (main Nile) using thirteen measured characters.

	Sites		Predicted Group Membership			Total
			Khashm El Girba	Sinnar	Kreima	
Original	Khashm El Girba	Count	58	9	0	67
		%	86.6	13.4	.0	100
	Sinnar	Count	24	74	2	100
		%	24	74	2	100
	Kreima	Cont	2	2	96	100
		%	2	2	96	100
Cross-validated	Khashm El Girba	Count	55	11	1	67
		%	82.1	16.4	1.5	100
	Sinnar	Count	24	74	2	100
		%	24	74	2	100
	Kreima	Count	4	2	94	100
		%	4	2	94	100

The scatter plot of the CDF derived from measured characters of three *A. baremoze* showed an overlap between populations from Khashm E Girba and Sinnar an obvious separation for Kreima population has been noticed

(Fig. 2).

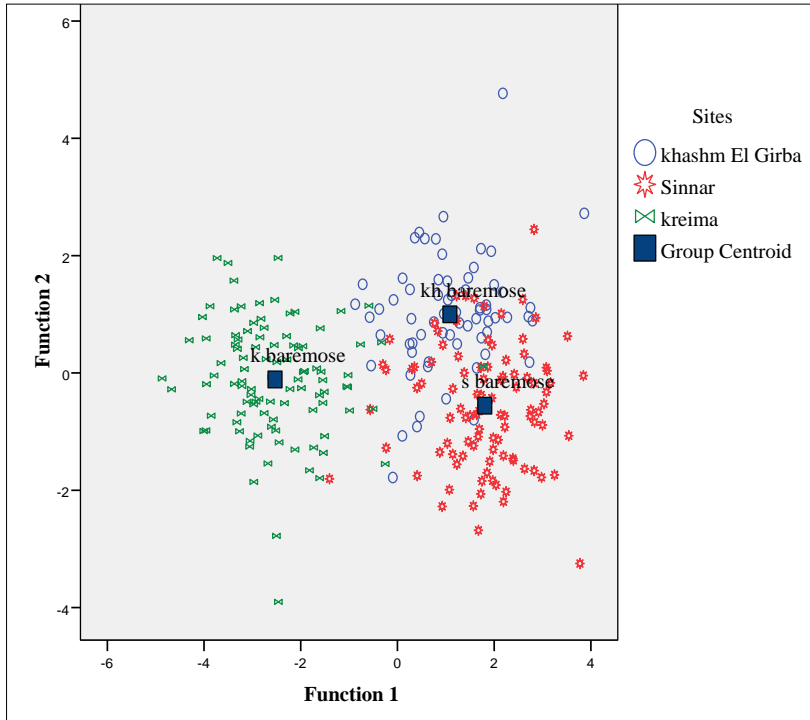


Figure 2: Scatter plot of canonical discriminant functions derived from measured characters of *A. baremoze* collected from Khashm El Girba (Atbara River), Sinnar (Blue Nile) and Kreima (main Nile).

3.4. Cluster analysis: For better understanding of the relationship of the study species from the three sites, hierarchical cluster analysis of the morphometric measurements (Figure. 3a) and meristic counts (Figure. 4a) were performed. Cluster analysis of IOD/HL, PPVL/SL and PDL/SL showed that *Alestes baremoze* from Khashm El Girba and Sinnar are more closely-related since they form one cluster whereas, *Alestes baremoze* from

Kreima forms another cluster (Figure. 3b). The, same result was obtained when AFR and SALL clustering (Figure. 4b).

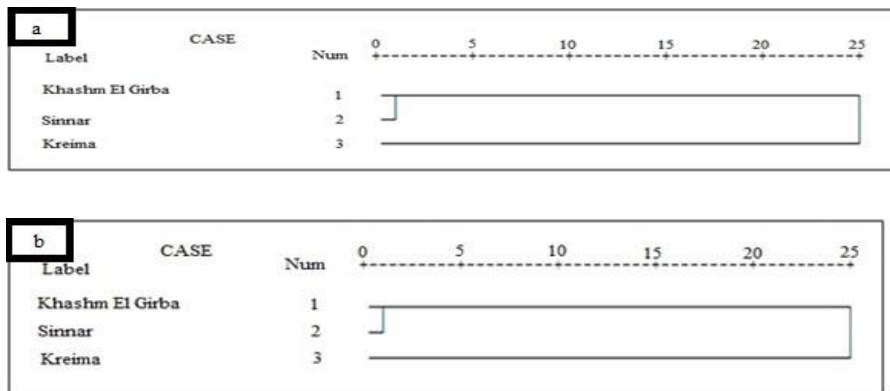


Figure 3: Dendrogram of *Alestes baremoze* from Khashm El Girba (Atbara River), Sinnar (Blue Nile) and Kreima (main Nile) using average linkage (between groups) using: (a) 22 morphometric measurements, (b) Inter orbital distance / Head length, Pre-pelvic length / Standard length and Pre-dorsal length / Standard length.

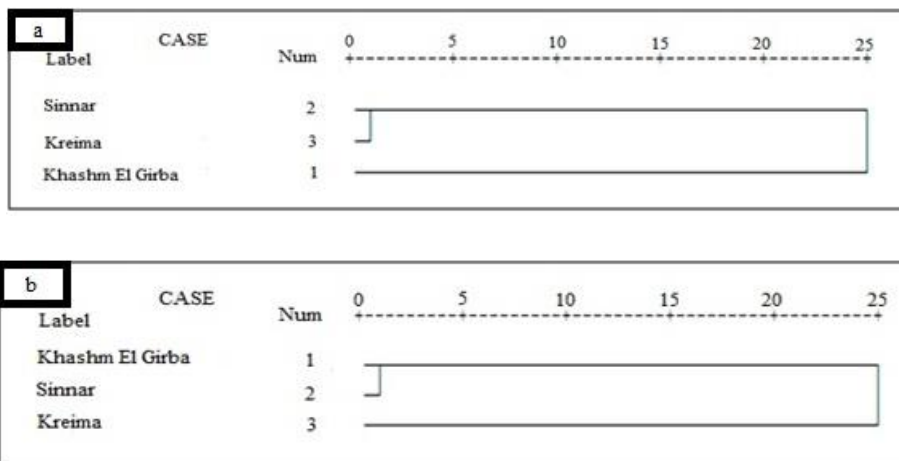


Figure 4: Dendrogram of *Alestes baremoze* from Khashm El Girba (Atbara River), Sinnar (Blue Nile) and Kreima (main Nile) using average linkage (between groups) using: (a) 7 meristic counts, (b) Anal fin ray and Scales above lateral line.

4. Discussion:

Morphometric indices of traditional characters were used for identification of fish races and species by many investigators including, Khalil et al. (1983), Libosvasky (1982), Mekkawy and Mahmoud (1992a, b), Khan et al. (2002), Myers et al. (2004), Cadrin (2005) and Cheng et al. (2005). Moreover, morphological characters have been commonly used in fisheries biology to measure discreteness and relationships among various taxonomic categories (Turan, 1999). (Mekkawy and Mohammed, 2011), all the above studies used morphological characters which used in this study and it's pointed out that they are good tool for characterization and classification of fish.

The obtained results of morphological characters of *Alestes spp.* in this study similar to previous studies reported by Sandon (1950), Abu Gideiri (1984) and Bailey (1994), such as LLS, SALL, SBLL, ARR and TL, in *A. dentex* with 44-51 LLS, 8½-9½ SALL, 3½ SBLL, 22-26 AFR and 40cm TL (Sandon, 1950), 39-50 LLS, 6½-9½ SALL, 3½ SBLL, 22 AFR and 40cm TL (Abu Gideiri, 1984), 22-26 AFR and 50cm TL (Bailey, 1994) and in this study 42-50 LLS, 7½-9½ SALL, 3½ SBLL, 20-26 AFR and 34.2cm TL, although there are some differences, they are due to the occurrence of the

time periods where these various studies were carried out.

The variables that mostly influenced the separation of *A. baremoze* from the three sites when canonical discriminant functions was used were: HL/SL, PVFL/SL, PFL/SL, PAL/SL, PPCL/SL, CPD/SL, AFBL/SL and AFR/SL in function 1 and BW/SL, LLS, SALL, IOD/HL in function 2. Which Mekkawy and Mohammed (2011) found the only indices to be size-free are (7 out of 22) PRVFL/SL, DEVOFL/SL, DEDCFL/SL, VDOL/HL, VEAOFHL/HL, AEVCFL/HL and AEDCFL/HL for the three *Epinepheline* species considered.

Cluster analysis using morphometric measurements showed that *Alestes baremoze* from Khashm El Girba and Sinnar form one cluster Whereas, *Alestes baremoze* from Kreima forms another cluster, same result conformed in the clustering of IOD/HL, PPVL/SL and PDL/SL (Fig. 4) & AFR and SALL (Fig. 5). While, scatter plot of the CDF derived from measured characters of three *A. baremoze* showed Overlap between population of Khashm E Girba and Sinnar.

5. Conclusions:

The study investigates the presence of similarity between the populations of *Alestes baremoze* from three studied sites. However, the biggest similarities are between the populations of Khashm El Girba and Sinnar more than population of Kreima in the term of the statistical analysis carried out but as in terms of the numbers and size of the fish the population of *Alestes baremoze* from Khashm El Girba has fewer and less size than the two others

sites, this may indicate that its threatened or due to the different circumstances of the environment.

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