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Research Article

Morphometrics and Meristic of *Oreochromis Niloticus*, *Sarotherdon Galilaeus* and *Coptodon Zilli* (Cichlidae) from Kosti, Sudan

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Abstract: Discriminant analysis using 19 morphometric measurements provided good separation between Oreochromis niloticus, Sarotherdon galilaeus and Coptodon zilli from Kosti area. The analysis selected lachrymal depth, head width, caudal peduncle depth, prepectoral distance and premaxillary pedical length as significant discriminant measures. Wilks lambda test indicated that the group centroids were extremely significantly different in functions1and 2, and clearly separated the three spp. Out of 12 meristic counts, the dorsal fin spine, dorsal fin rays, lateral scale, transverse line scale, anal and pectoral soft rays gave up to 80% correct separation.
Keywords: Morphometrics, meristic discrimination, tilapias Kosti, Sudan.

INTRODUCTION

Tilapia is the common name for about 77 Cichlid fish species in tropical Africa inhabiting a variety of freshwater habitats. They have been of major importance in commercial and artisan fishery and are gaining importance in aquaculture [1]. Thus their characterization is necessary for aquaculture.

Fish systematic relied mainly on morphology in placing different species into their proper genera [2]. Recent classification based on molecular approaches is only confirmatory [3]. The classification of Cichlids based on brooding habits [4] and colour patterns [5] is very strong discriminant tool. Early taxonomic work on freshwater of the Sudan was based on description notes and ratio indices [6, 7]. Morphometric was used by El Sayed [8] on *Eutropus niloticus*; Idris and Mahmoud [9] on *Labeo niloticus*; Saborido-Rey and Nedreaa [10] on the deeper red fish *Sebastes mentella* and Silva [11] on *Sardina bilchardus* for description and characterization.

The study aimed to utilize morphometric measurements and meristic counts to characterize *Oreochromis niloticus*, *Sarotherdon galilaeus* and *Coptodon zilli* from Kosti area (White Nile).

MATERIAL AND METHODS

Oreochromis niloticus, *S. galilaeus* and *C. zilli* used in this study were identified following Abu Gideiri [6] and Bailey [7]. Live specimens used in meristic counts (Table-1) and morphometric measurements (Table-2) were randomly collected from the commercial fisheries from Kosti.

Table-1: Description of meristic counts and their abbreviations

Description	Code
Number of dorsal fin spines.	DFS
Number of dorsal fin rays.	DFR
Longitudinal line scale: No. of scales on upper lateral line plus those on the lower lateral line.	LLS
Transverse line scales: No. of scale starting from the dorsal fin origin towards the upper lateral line divide by No. of scales starting from the anal fin origin to the upper lateral line.	TLS
Number of anal fin spines.	AFS
Number of anal fin rays.	AFR

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Number of pectoral fin rays.	PeFR
Number of scales on the check.	CS
Lateral line scale: No. of scales on the upper lateral line divided by those on the lower lateral line.	LAT scale
Number of pelvic fin spines	PFS
Number of pelvic fin rays.	PFR
Number of scales on the pelvic fin.	PFS

The posterior part of fins was examined carefully for the any thin small fin rays.

Morphometric measurements were taken from each fish using a measuring board, a tape and a verneir caliper. Measurements (Table-2) followed Barel *et al.*, [12]; Mahmoud and Hassan [13].

Table-2: Morphometric measurements

Description	**Code**
Total Length: the distance from the rostral tip of the upper jaw to the tip of the dorsal lobe of the caudal fin.	TL
Standard Length: from the nostral lip of the upper jaw to the midpoint of the origin of the caudal fin.	SL
Head Length: from the rostral lip of the upper jaw to the most posterior point of the gill cover margin.	HL
Eye diameter: maximum eye length from the most anterior point to the most posterior point of the orbit.	ED
Head width: with the opercula in a normally a ducted position.	HW
Snout Length: from the rostral tip of the upper jaw to the nostral point of the bony border of the orbit.	SNL
Premaxillary Pedical Length: from the nostril tip of the upper jaw to the tip of the ascending process of premaxilla.	PPL
Caudal peduncle length: distance between the vertical line through the caudal point of the anal fin insertion and that through the caudal border of the hypurals.	CPL
Anal fin base length: distance between the most rostral and the most caudal point to the anal fin base.	AFBL
Lachrymal depth: from the rostral corner of the bony orbit to the rostral corner of the lachrumal.	LAD
Cheek depth: from the ventral point of the bony margin of the orbit to the dorsal corner of the lower jaw.	CD
Caudal peduncle depth: minimum depth of caudal peduncle.	CPD
Body Depth : maximum depth of the body in front of the pelvic fin, starting from the dorsal fin base in a vertical plain	BD
Inter Orbital Width (IOW): minimum width of the dorsal margin of the bony orbits.	IOW
Prepectoral distance: from the rostral tip of the upper jaw to the most rostral point of the pectoral fin base.	PPD
Preanal distance: from the rostral tip of the upper jaw to the most rostral point of the anal fine base.	PAD
Predorsal distance: from the rostral tip of the upper jaw to the most rostral point of the dorsal fin base.	PDD
Prepelvic distance: from the rostral tip of the upper jaw to the most rostral point of the pelvic fin base.	PPD
Dorsal fin base: distance between the most rostral to the most caudal point of the dorsal fin base.	DFB

Discriminant analysis and Wilks lambda test were used to quantify and compare the validity of 19 morphometric measurements and 12 meristic measurements in separation between *O. niloticus*, *S. galilaeus* and *C. zilli* from Kosti area

RESULTS

Discriminant analysis using 19 morphometric measurements provided good separation between *Tilapia* spp. from Kosti area (Fig-1).

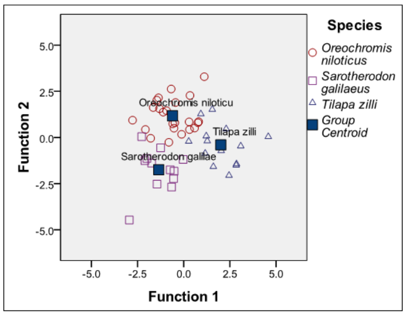

Fig-1: Scatter plot of Canonical discriminant function of 19 morphometric characters of tilapia species

This separation was based on Canonical Discriminant Functions (CDF) and Standardized Canonical Discriminant Functions (SCDF) that enabled calculation of the variable variance and consequently compare directly the relative contribution of each variable (morphometric or meristic character) into each factor (Function 1 and 2) Table-1. The p-value of Wilks Lambda test (Table-1) indicated extremely highly significant (p=0.000) value for function 1 and highly significant (p=0.005) value for function 2.

Factor 1 explains 56.1% of the total variance in the 19 morphometric measurement, leaving only 43.9% to be explained by factor 2. The most influential morphometric character in factor 1 were LAD, CHD, HW, CPD, SNL, HL, PRP, W, ED, AFB, and PAD, while in factors 2 were PRD, PP, BD, SL, IOW, DFB, PRV. Factor 1 was useful in separating *C. zilli* from *O. niloticus* and *S. galilaeus*, while factor 2 was better in separating *O. niloticus* from *S. galilaeus* and *C. zilli*.

Table-1: CDF and SCDF analysis of *O. niloticus* from *S. galilaeus* and *C. zilli*

Factor	19 – morphometric				Loading	
	CDF		SDF		Function	
	1	2	1	2	1	2
LAD	26.145	1.245	0.775	0.037	0.509*	0.188
CHD	4.453	14.413	0.202	0.653	0.413*	0.080
HW	-70.611	5.272	-0.836	0.062	-0.308*	0.002
CPD	5.219	-16.328	0.325	-1.016	0.203*	-0.189
SNL	1.825	-8.073	0.092	-0.407	0.178*	-0.034
HL	54.495	-34.734	0.569	-0.363	0.129*	0.092
PRP	5.764	-44.624	0.091	-0.703	-0.121*	-0.014
TL	-0.308	0.447	-0.094	0.360	-0.107*	0.016
AFB	-7.264	5.112	-0.416	0.293	0.084*	0.039
PAD	2.911	5.000	0.084	0.144	-0.074*	-0.023
ED	0.936	0.418	0.049	0.022	0.021*	0.010
PRD	-39.127	67.499	-0.458	0.790	-0.196	0.340*
PPL	3.933	19.709	0.147	0.738	0.219	0.324*
BD	1.189	-23.989	0.023	-0.470	0.005	-0.167*
SL	14.917	17.254	0.251	0.290	-0.060	0.150*
CPL	-1.869	9.614	-0.112	0.575	0.110	0.129*
IOW	-1.980	1.454	-0.089	0.066	-0.038	-0.126*
DFB	34.506	-51.896	-0.497	-0.747	0.253	-0.112*
PRV	-6.048	23.143	-0.094	0.360	-0.001	-0.102*

Significance of function 1 and function 2 based on Wilks lambda				
Function	Wilks lambda	Chi-Square	Df	Significance
1	0.118	81.017	38	0.000
2	.373	37.474	18	0.005

This discrimination was based on differences in signs (+ or -) shown in Table-2.

Table-2: Canonical discriminant function evaluated at group means (Group Centroids) used to different Tilapia species

Species	Functions	
	1	**2**
Oreochromis niloticus	- 1.187	0.867
Sarotherodon galilaeus	- 0.366	-2.213
Coptodon zilli	2.114	0.440

Classification based on the 19 morphometric showed 60.9%, 50% and 60% correct classification for *O. niloticus*, *S. galilaeus* and *C. zilli*, respectively at an average of 58% (Table-3). The table showed that 95.8% of grouped and 58.0% of cross-validated cases was correctly classified.

Table-3: Leave-one-out cross validation for *O. niloticus*, *S. galilaeus* and *C. zilli* by discriminant analysis using 19 morphometric characters

Aspect		Species	Predicted group Membership			Total
			O. niloticus	***S. galilaeus***	***C. zilli***	
Original	Count	*O. niloticus*	22	0.0	1	23
		S. galilaeus	0.0	12	0.0	12
		C. zilli	0.0	0.0	15	15
	%	*O. niloticus*	95,7	0.0	4.3	100
		S. galilaeus	0.0	100	0.0	100
		C. zilli	0.0	0.0	100	100
Cross- validated	Count	*O. niloticus*	14	4	5	23
		S. galilaeus	4	6	2	12
		C. zilli	3	3	9	15
	%	*O. niloticus*	60.9	17.4	21.7	100
		S. galilaeus	33.3	50	16.7	100
		C. zilli	20	20	60	100

Meristic Counts

Wilks lambda test (p=0.000) indicated that the group centroids were extremely significantly different in function1and resulted in clear separation of *O. niloticus* from the *S. galilaes* and *C. zilli* (Table-4). With respect to Function 2 its value p=0.03 significantly separated *S. galilaeus* group from the other two species.

Table-4: Group Centroids of *Tilapia* spp from Kosti, separated by Canonical Discriminant Function

Species	Function	
	1	2
Oreochromis niloticus	1.882	-0.302
Sarotherodon galilaeus	-0.046	0.978
Coptodon zilli	-2.849	-0.319

The CDF and SCDF analysis of the 9 meristic counts (Table-5) showed that 93.5% and 6.5% of the total variance were explained by factor 1and factor 2, respectively. With 4 meristic counts gave 100%, 75% and 73.3% correct classification for *O. niloticus*, *S. galilaeus* and *T. zilli*, respectively with an average value of 80%

Table-5: CDF and SCDF from discriminant analysis of *O. niloticus, S. galilaeus* and *C. zilli* in Kosti using meristic counts

Factor	12 – meristic count				4 – meristic count				Loading
	CDF		SCDF		CDF		SCDF		
	1	2	1	2	1	2	1	2	
DFS	2.82	-0.24	1.01	-0.09	2.63	-0.47	0.94	-0.10	0.85*
DFR	0.53	0.99	0.22	0.41	0.64	0.56	0.23	0.41	0.31*
LLS	-0.07	-0.19	-0.16	-0.44	-0.06	-.20	-0.13	-0.47	0.29*
TLS	0.59	1.38	0.20	0.47	0.40	1.98	0.14	0.53	-0.28*
AFR	0.99	2.49	0.39	0.98					0.3
PeFR	0.43	-1.76	0.13	-0.54					0.17
CS	0.18	-0.10	0.15	-0.08					0.04
LAT scale	-13.34	8.94	-0.41	0.27					-0.04
PFS	0.16	-0.15	0.10	-0.09					0.06
Significance of function 1 and 2 based on Wilks lambda									
Function	Wilks lambda	Chi-square	Df	Significant					
1	0.142	86.816	12	0.000					
2	0.757	12.407	5	0.03					

The influential meristic counts in factor 1 were DFS, DFR, LLS and TLS, and in factor 2 those were PeFR and AFR were (Figs 2 and 3).

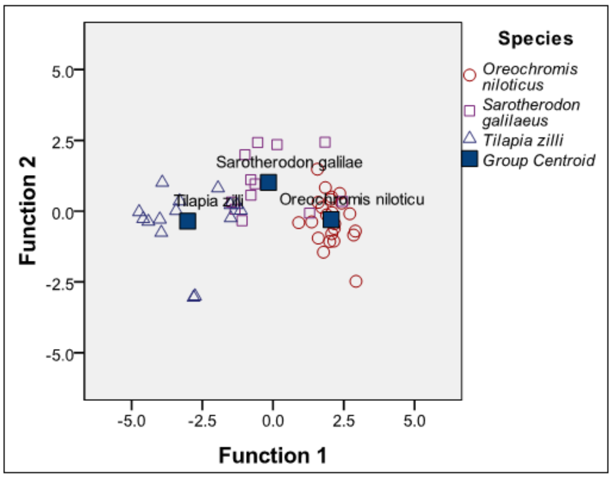

Fig-2: Scatter plot of Canonical discriminant function of 9 meristic counts on *Tilapia* spp

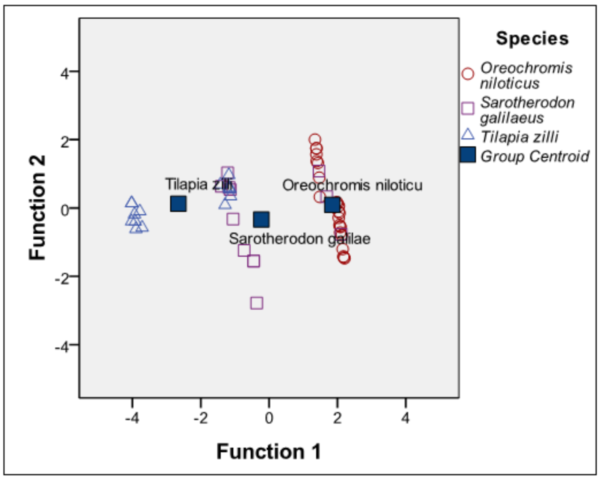

Fig-3: Scatter plot of CDF of 4 meristic counts on tilapia spp

Re-classification based on 12 meristic counts selected 9 counts which showed 100%, 83.3% and 80% correct classification for *O. niloticus*, *S. galilaeus* and *C. zilli* (Table-6). The table showed that 88% of grouped and 76% of cross-validated cases was correctly classified.

Table-6: Leave-one-out cross validation for *O. niloticus*, *S. galilaeus* and *C. zilli* by discriminant analysis using 9 meristic counts

Aspect		Species	Predicted group Membership			Total
			O. niloticus	***S. galilaeus***	***C. zilli***	
Original	Count	*O. niloticus*	22	1	0.0	23
		S. galilaeus	2	10	0.0	12
		C. zilli	0.0	3	12	15
	%	*O. niloticus*	95.7	4.3	0.0	100
		S. galilaeus	16.7	83.3	0.0	100
		C. zilli	0.0	20	80	100
Cross-validated	Count	*O. niloticus*	22	1	0.0	23
		S. galilaeus	3	6	3	12
		C. zilli	0,0	5	10	15
	%	*O. niloticus*	95.7	4.3	0.0	100
		S. galilaeus	25	50	25	100
		C. zilli	00	33.3	66.7	100

Re-classification based on 12 meristic counts selected 6 counts which showed 100%, 75% and 73.3% correct classification for *O. niloticus*, *S. galilaeus* and *C. zilli*, respectively. The table showed that 86% of grouped and 80% of cross-validated cases was correctly classified.

Table-7: Leave-one-out cross validation for *O. niloticus*, *S. galilaeus* and *C. zilli* by discriminant analysis using 6 meristic counts

Aspect		Species	Predicted group Membership			Total
			O. niloticus	***S. galilaeus***	***C. zilli***	
Original	Count	*O. niloticus*	23	0.0	0.0	23
		S. galilaeus	3	9	0.0	12
		C. zilli	0.0	4	11	15
	%	*O. niloticus*	100	0.0	0.0	100
		S. galilaeus	25	75	0.0	100
		C. zilli	0.0	26.7	73.3	100
Cross- validated	Count	*O. niloticus*	23	0.0	0.0	23
		S. galilaeus	3	7	2	12
		C. zilli	0,0	5	10	15
	%	*O. niloticus*	100	0.0	0.0	100
		S. galilaeus	25	58.3	16.7	100
		C. zilli	0.0	33.3	66.7	100

DISCUSSIONS

The morphological characters of *O. niloticus, S. galilaeus* and *C. zilli* collected from Kosti (White Nile), showed typical characteristics to those reported by Abu Gideiri [6] and Bailey [7]. Trewavas [4] based her Cichlid classification on variation on dentition, bony structures and general body morphology. Due to characters overlap and inter population variation and small differences among species; Mwanja *et al*., [3] are of the opinion that RAPD markers are superior in species identification. The current data based on 19 morphometric measurements and 12 meristic counts was subject to discriminant analysis to outline parameters that are truly important in separating the groups in each location and each species from the different locations. Discriminant analysis applied to samples of the three species successfully separated them based on 5 morphometric characters (LAD, HW, CPD, RDD and PPD). The present work confirmed the validity of the analysis applied by Murta [14] on *Trachuvus irachurus*; Pinheiro *et al*., [15] on *Solea lascaris*; Silva [11] on *S. bilchardus*; Saborido and Nedreaas [10] on *Sebastes mentella*; Vidalis [16] on *Spicara smaris* and Pollar *et al*., [17] on *Tor tambroides*. El-Serafy *et al*., [18] morphometric data showed striking similarities and overlapping among tilapia spp., making it impossible to differentiate those species on basis of morphometrics. El-Serafy *et al*., [18] found that meristic counts are more precise in differentiating *O. niloticus, O. aureus, S. galilaeus* and *T. zilli* from each other. They reported that the lateral line scales differed significantly between these four spp., while the number of rays in the dorsal and anal fins differed significantly ($p<0.05$) between *S. galilaeus* and *T. zilli*.

Gad Kareem [19] compared morphometric characters of *O. niloticus* from Sinnar and Al Sabloga, but made no effort to discriminate these measurements to pinpoint the appropriate characters to be measured. Salih [20] studied the taxonomy of *O. niloticus, S. galilaeus* and *C. zilli* from Khartoum area using16 morphometric and 4 meristic characters in addition to molecular characters. Her analysis of morphometric data was based on ratio indices and the meristic counts were given as descriptive data and no discriminant and canonical analysis data was provided. Therefore, the comparison between her findings and the current work is only possible through classical description.

With respect to species the separating 4 characters were valid (PPD, BD, TL and PAD) for *O. niloticus*; 4 (TL, BD, CPL and SL) for *S. galilaeus* and 10 (PPD, BD, TL, PAD, DFS, DFR, LLS, TRA scale, AFR and PeFR) for *C. zilli.*

The discriminant characters (DFS, DFR, LLS, TRA scale, AFR and PeFR) selected by canonical discriminant analysis gave good separation accounting up to 80% classification.

These findings are in agreement with Bailey [21] on flat fish populations; Saborido *et al*., [10] on *S. mentella* and Palma et *al*., [22] on Diplodus sargus, *Diplodus punntazo* and *Lithognathus mornurus* who found discriminant analysis a successful tool to discriminate fish species and/or populations.

According to Mwanja *et al*., [3]; Williams *et al*., [23, 24] any discrepancy in morphometric measurements and meristic counts suggest application of molecular techniques like DNA fingerprinting [25] or RAPD [26].

The description of these similarity coefficients is not simple, especially when more than one character is involved in the same cluster. Thus, *O. niloticus* and *S. galilaeus* are found to have a similarity coefficient of 82.6%, whereas it is 70% between *O. niloticus* and *C. zilli* and is 66.67% between *S. galilaeus* and *C. zilli*. The genetic similarity between *O. niloticus* and *S. galilaeus* was higher compared with that between *O. niloticus* and *C. zilli*. *S. galilaeus* and *C. zilli* showed low similarity compared with that of *O. niloticus***.**

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