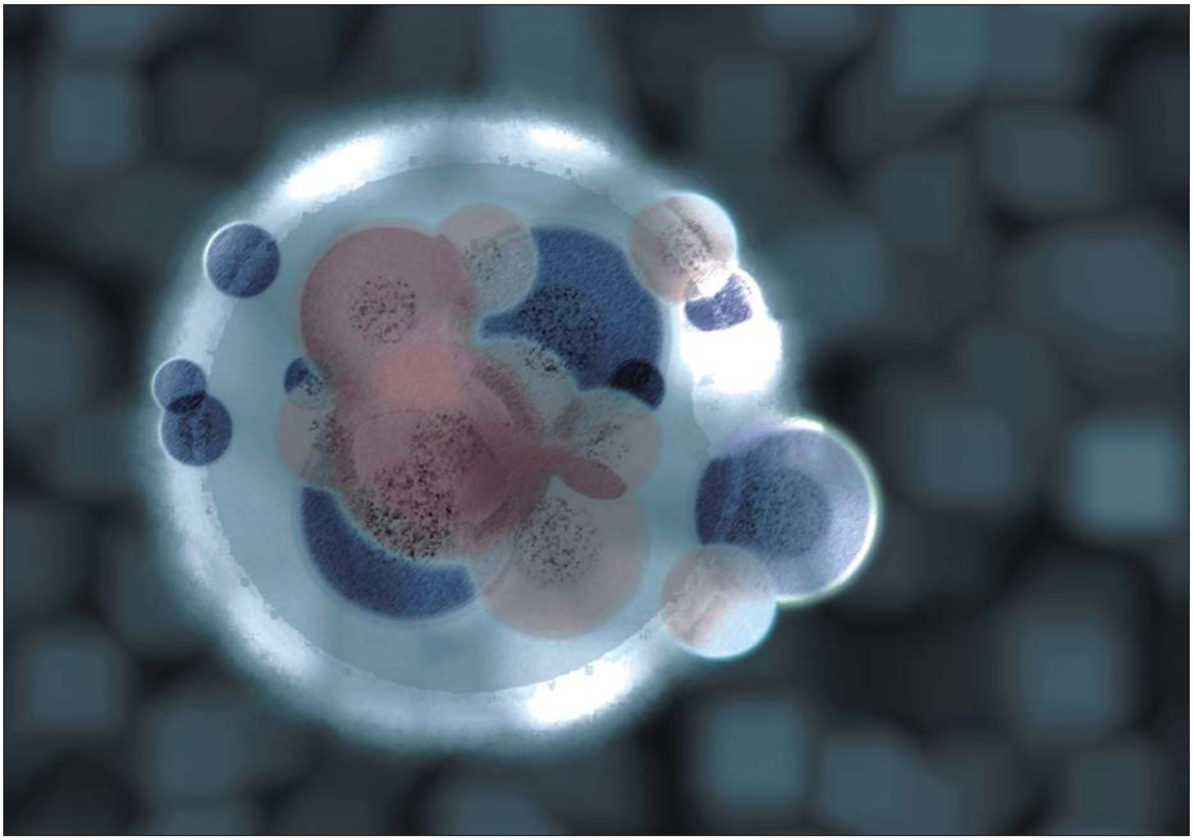

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Morphometrics and Meristics of the Three Epinepheline Species: *Cephalopholis argus* (Bloch and Schneider, 1801), *Cephalopholis miniata* (Forsskal, 1775) and *Variola louti* (Forsskal, 1775) from the Red Sea, Egypt

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Abstract: In the present investigation, the morphometrics and meristics characteristics of *Cephalopholis argus, Cephalopholis miniata* and *Variola louti* were studied. The type of allometry of the morphometric traditional as well as truss characters in terms of size and shape were determined. The morphometric indices exhibited a great variability in their behavior among the three Epinepheline species studied and in turn different mode of growth of such species. However the only indices to be size-free are PRVFL/SL, DEVOFL/SL, DEDCFL/SL, VDOL/HL, VEAOFL/HL, AEVCFL/HL and AEDCFL/HL for the three Epinepheline species considered. The clustering of the allometric growth was considered as a taxonomic tool in fishes. The inter-and intra-specific relationship between the three Epinepheline species were also evaluated on further patterns of size and shape using standard DFA and cluster analysis. Moreover, the gill raker patterns were found to be valid for discrimination with no relationship between the gill raker counts and the size of the three Epinepheline species studied. The pectoral and dorsal fin ray counts exhibited little intra-and inter-specific variations. In conclusion, the geometric morphometrics and meristics are valid in identification of Epinepheline species as fishery stock units in addition to their validity as a taxonomic tool.

Key words: Morphometrics, meristics, epinephalinae, multivariate analysis, Red sea

INTRODUCTION

Intra-and inter-specific patterns of variations in fishes can be obviously evaluated in terms of concept of size and shape (Mekkawy and Mahmoud, 1992a, b; Hajjej *et al*., 2011). Such concept is considered as a basic step in study of biometric variations in species especially in geometric terms (Jolicoeur and Mosimann, 1960; Bookstein, 1991; Akhter *et al*., 2003). The relative contribution of size and shape to the overall pattern of racial, geographic and inter-specific variations in species has long been investigated Gunawickrama (2007) and Hajjej *et al*. (2011). Such concept was found to be valid in identification of fish stock from a fisheries point of view (Cadrin, 2000; Monet *et al*., 2006). The traditional and geometric morphometric measurements are considered in univariate (allometric growth) and multivariate senses (Mekkawy, 1990) reflecting different patterns of size and shape variations. Analysis of these variations isolates specific morphometric indices and variants which have taxonomic potentials and discriminating powers away of the environmental and geographical influences.

The meristic characters were also found to be valid in race and species identification and in turn in stock identification for fishery purposes (Mekkawy, 1991, 1997; Turan, 2004). However, the situation for some species of the marine fishes including *Epinephelus, Lethrinus*, *Siganus* and *Lutjanus* species was different since the meristic characters especially vertebral counts are less variables and hence of no taxonomic importance (Mekkawy *et al*., 2002).

According to the aforementioned highlight, the present aimed at studying the morphometrics and meristics of the three Epinepheline species, *Cephalopholis argus,* (Bloch and Schneider, 1801), *Cephalopholis miniata* (Forsskal, 1775) and *Variola louti* (Forsskal, 1775) to illustrate intra-and inter-specific variations and to determine their validity in fish stock unit identification. So, the following question arises, could one consider the three Epinepheline species as one stock unit in fisheries management?

MATERIALS AND METHODS

Morphometrics: A total of 723 specimens of the three Epinepheline species (242 specimens of *C. argus,* 180-375 mm in Standard Length (SL), 254 specimens of *C. miniata,* 160-320 mm in SL and 227 of *V. louti,* 170-360 mm in SL)

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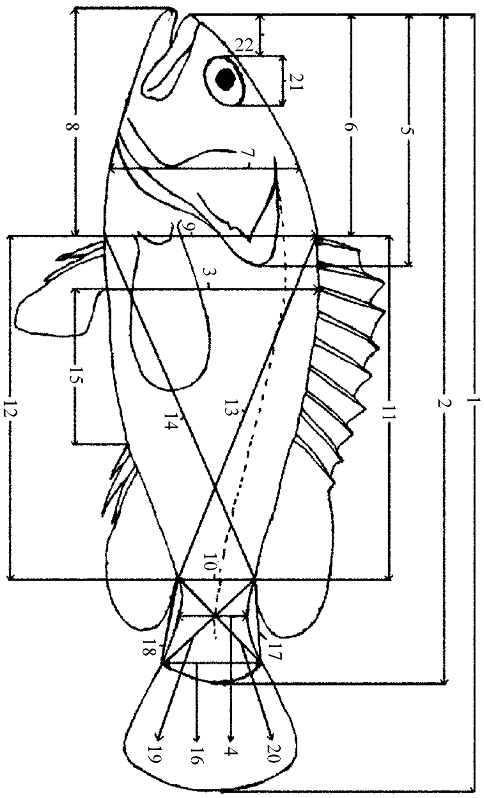

Fig. 1: Schematic illustration of measurements taken on the body of the three Epinepheline species from the Red Sea, Quseir, Egypt. 1: Total length (TL), 2: Standard length (SL), 3: Body depth (BD), 4: Caudal peduncle depth (CPD), 5: Head length (HL), 6: Predorsal fin length (PRDFL), 7: Head depth (HD), 8: Preventral fin length (PRVFL), 9: Distance between ventral and dorsal fins origin (VDOL), 10: Distance between anal and dorsal fin ends (ADFEL), 11: Dorsal fin base length (DFBL), 12: Distance between the ventral fin origin and the end of anal fin (VOAEFL), 13: Distance between the first spine of the dorsal fin and the end of anal fin (SpDAEFL), 14: Distance between dorsal fin end and ventral fin origin (DEVOFL), 15: Distance between ventral fin end and anal fin origin (VEAOFL), 16: Distance between dorsal and ventral caudal fin origin (DVCFL), 17: Distance between dorsal fin end and dorsal caudal fin origin (DEDCFL), 18: Distance between anal fin end and ventral caudal fin origin (AEVCFL), 19: Distance between dorsal fin end and ventral caudal fin origin (DEVCL), 20: Distance between anal fin end and dorsal caudal fin origin (AEDCFL), 21: Eye diameter (ED), 22: Snout length (SNL)

were collected from the Red Sea, at Quseir south of Hurghada by 140 Km, Egypt during the period November 2001 to October 2002. Twenty two morphometric measurements including 8 traditional measurements (1-5, 7, 21-22) and 14 truss ones (6, 8-20) were measured to the nearest mm with a divider and measuring board. These measurements are diagrammatically represented in Fig. 1.

Meristics: 11 meristic characters were counted for each fish of the three Epinepheline species considered. These counts are number of the Dorsal Fin Spines (DFS), number of the dorsal fin soft rays (DFR), number of the Pectoral Fin Rays (PFR), number of the Ventral Fin Spines (VFS), number of the Ventral Fin Rays (VFR), number of the anal spines (AFS), number of anal rays (AFR), number of Caudal Fin Rays (CFR), number of gill rakers on the ceratohypobranchial portion of the first left gill arch (ascending) (UGR), number of gill rakers on epibranchial portion of the first left gill arch (descending) (LGR) and total number of gill rakers on the first left gill arch (TGR).

Statistical analysis: The basic statistics of certain morphometric indices (relative to standard length, SL or head length, HL) and meristic characters were estimated. The allometric coefficients of the raw morphometric characters and their relationships with fish size (SL) were estimated using power function equation and linear regression model respectively. The type of allometry was evaluated by testifying the significance of the allometric coefficients (b) ($b = 1$, $b>1$ and $b<1$ for isometry, negative allometry and positive allometry respectively) that serves as a criterion for the intensity of differential increase in the morphological characters relative to a certain reference length. The distribution of meristic characters among species considered is testified by Chi-square test. In multivariate sense, morphometric and meristic discriminations between the three Epinepheline species were carried out using standard discriminant function analysis (DFA) and cluster analysis using Statistica Package Release 5 (Statsoft, 1995).

RESULTS

Morphometrics: The relationship between the morphometric characters and fish size (SL) were best described by the linear regression equations (Table 1, 2). The basic statistics of the morphometric indices (relative to SL and HL) of the three Epinepheline species considered show inter-and intra-specific variations (Table 3, 4). PRVFL/SL, DEVOFL/SL, DEDCFL/SL, VDOL/HL, VEAOFL/HL, AEVCFL/HL and AEDCFL/HL are the only indices to be size-free and so valid as a

Table 1: The relationship between some parameters of morphometric characters and standard length (SL) of *C. argus* and *C. miniata* studied from the Red Sea, Quseir, Egypt for future prediction of missing parameters (Fig. 1 for abbreviations)

The equation	R*	The equation	R*
C. argus			
BD = 70.66 + 1.98*SL	0.88	SpDAEFL = 23.25 + 1.70* SL	0.91
CPD = 52.93 + 5.86*SL	0.90	DEVOFL = 30.64 + 1.66* SL	0.93
HL = 19.70+ 2.36* SL	0.94	VEAOFL = 89.93 + 2.51* SL	0.85
PRDFL = 34.31 + 2.63* SL	0.93	DVCFL = 142.25 + 2.87* SL	0.65
HD = 40.01 + 2.37* SL	0.91	DEDCFL = 71.31 + 4.92* SL	0.88
PRVFL = 59.69 + 2.05* SL	0.88	AEVCFL = 150.53 + 3.25* SL	0.65
VDOL = 31.59 + 2.35* SL	0.94	DEVCL = 50.90 + 4.05* SL	0.86
ADFEL = 41.34 + 4.71* SL	0.89	AEDCFL = 35.98 + 3.76* SL	0.87
DFBL = 13.95 + 1.98* SL	0.91	ED = 15.62 + 18.43* SL	0.59
VOAEFL = 44.40 + 1.82* SL	0.91	SNL = 113.82 + 6.82* SL	0.77
C. miniata			
BD = 35.97+ 2.27*SL	0.88	SpDAEFL = 22.83 + 1.68* SL	0.93
CPD = 61.68 + 5.53*SL	0.86	DEVOFL = 26.97 + 1.68* SL	0.93
HL = 19.70+ 2.50* SL	0.93	VEAOFL = 62.04 + 2.84* SL	0.81
PRDFL = 13.31+ 2.87* SL	0.92	DVCFL = 81.13 + 3.67* SL	0.79
HD = 25.93 + 2.39* SL	0.92	DEDCFL = 81.29 + 4.60* SL	0.84
PRVFL = 26.42 + 2.27* SL	0.92	AEVCFL = 88.18 + 4.33* SL	0.81
VDOL = 25.12 + 2.28* SL	0.94	DEVCL = 58.58 + 3.83* SL	0.88
ADFEL = 44.78+ 4.62* SL	0.87	AEDCFL = 37.36 + 3.60* SL	0.91
DFBL = 18.80 + 1.90* SL	0.89	ED = 41.08 + 14.02* SL	0.56
VOAEFL = 33.22 + 1.90* SL	0.90	SNL = 98.92 + 6.85* SL	0.75

*Correlation is significant at the 0.01 level

Table 2: The relationship between some parameters of morphometric characters and standard length of *V. louti* studied from the Red Sea, Quseir, Egypt for future prediction of missing parameters

The equation	R*	The equation	R*
Variola louti			
BD = 46.75 + 2.27*SL	0.93	SpDAEFL = 29.20 + 1.71* SL	0.96
CPD = 61.26 + 5.26*SL	0.92	DEVOFL = 39.34 + 1.62* SL	0.94
HL = -4.15+ 2.77* SL	0.94	VEAOFL = 61.28+ 2.96* SL	0.87
PRDFL = 7.68 + 3.14* SL	0.90	DVCFL = 75.54 + 3.23* SL	0.87
HD = 18.93 + 2.64* SL	0.95	DEDCFL = 108.79 + 3.52* SL	0.78
PRVFL = 28.97 + 2.41* SL	0.94	AEVCFL = 97.33 + 3.36* SL	0.84
VDOL = 15.75 + 2.56* SL	0.91	DEVCL = 67.70 + 3.10* SL	0.92
ADFEL = 61.29 + 3.90* SL	0.90	AEDCFL = 41.07 + 3.12* SL	0.93
DFBL = 36.66 + 1.85* SL	0.91	ED = -3.57 + 17.38* SL	0.54
VOAEFL = 37.16 + 1.92* SL	0.90	SNL = 73.39 + 7.57* SL	0.75

*Correlation is significant at the 0.01 level

discriminating tool between these species. The other indices exhibited variable mode of growth with fish size among species, so could not be considered in key identification.

The patterns of variations in the morphometric characteristics of Epinepheline species were considered in terms of their mode of growth; i.e., their type of allometry. Except for DFBL of *C. argus* and HL and PRDFL of *C. miniata* and *V. louti*, all characters of the three Epinepheline species exhibited negatively allometric growth (Table 5). So, their interspecific variations in the mode and value of growth were evident.

In multivariate sense, clustering of the three Epinepheline species, based on SL-indices set, HL-indices set and both HL-indices + SL-indices set grouped *C. argus* and *C. miniata* in one cluster that is separated from *V. louti* one (Fig. 2).

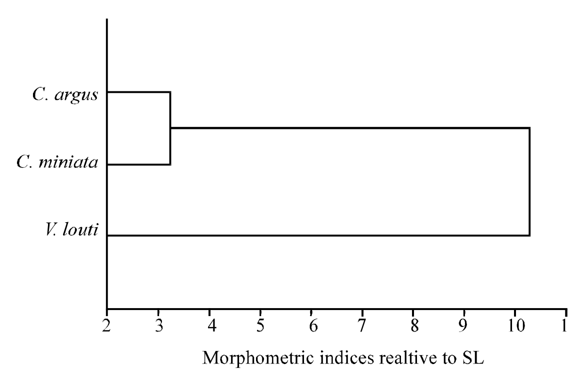

Fig. 2: Clustering of the three Epinepheline species studied from the Red Sea, Quseir, Egypt, based on their morphometric indices relative to SL, (Complete Linkage, Euclidean distances)

Table 3: The basic statistics (mean±standard error and range) of morphometric indices (relative to standard length) of the three Epinephelinae species studied from the Red Sea, Quseir, Egypt

	Species					
	C. argus		*C. miniata*		*V. louti*	
Morphometric character	Mean±SE	Range	Mean±SE	Range	Mean±SE	Range
BD	38±0.18	30-50	37±0.15**	31-47	36±0.16	30-43
CPD	14±0.06	12-18	13±0.06	11-16	14±0.07**	11-17
HL	40±0.13	28-50	40±0.11**	35-47	37±0.12**	29-41
PRDFL	33±0.12	27-42	33±0.10**	29-40	31±0.15**	27-53
HD	36±0.14**	27-44	37±0.12	31-43	35±0.12	30-39
PRVFL	38±0.19	32-73	39±0.13	33-48	36±0.13	25-42
VDOL	38±0.12	32-46	39±0.11	35-46	37±0.16**	23-45
ADFEL	18±0.08*	15-23	18±0.07	14-20	19±0.11**	15-32
DFBL	48±0.18**	41-58	49±0.17**	40-55	46±0.22	38-68
VOAEFL	46±0.19	34-63	45±0.17*	36-53	44±0.21	37-63
SpDAEFL	54±0.21**	36-74	54±0.16	44-60	51±0.17	45-58
DEVOFL	54±0.19	37-65	53±0.16	46-60	52±0.21	38-58
VEAOFL	27±0.16	20-34	26±0.14**	16-35	25±0.15	15-31
DVCFL	17±0.16*	7-21	18±0.11	10-23	21±0.15*	13-25
DEDCFL	15±0.08	13-21	14±0.08	11-17	16±0.15	11-29
AEVCFL	14±0.14	7-19	15±0.09	8-19	18±0.15**	8-25
DEVCL	20±0.10**	15-25	20±0.09	13-23	23±0.13**	17-29
AEDCFL	23±0.11**	19-28	23±0.09	20-27	27±0.12	19-31
ED	5±0.04**	4-8	6±0.04**	5-9	6±0.05**	4-11
SNL	9±0.07	6-12	9±0.06	5-11	9±0.07**	7-17
Range of correlation coefficient	(-0.74)-(0.08)		(-0.74)-(0.12)		(-0.79)-(0.34)	
N	242		254		227	

**Correlation with SL is significant at the 0.01 level. *Correlation with SL is significant at the 0.05 level

Table 4: The basic statistics (Mean±standard error and range) of morphometric indices (relative to head length) of the three Epinephelinae species studied from the Red Sea, Quseir, Egypt

	Species					
	C. argus		*C. miniata*		*V. louti*	
Morphometric character	Mean±SE	Range	Mean±SE	Range	Mean±SE	Range
BD	96±0.49**	78-129	95±0.41**	78-129	97±0.46**	75-115
CPD	35±0.17**	29-47	34±0.16**	25-41	39±0.21**	30-47
PRDFL	84±0.28**	74-122	83±0.22**	75-111	84±0.48**	75-147
HD	92±0.34**	75-109	95±0.35**	78-111	95±0.47	75-129
PRVFL	97±0.50**	82-176	99±0.35**	84-122	99±0.46*	65-129
VDOL	96±0.44	80-141	99±0.40	86-122	100±0.57	60-129
ADFEL	46±0.23**	36-68	44±0.20**	33-53	52±0.33	38-88
DFBL	122±0.43**	100-147	123±0.42**	105-141	125±0.61**	94-188
VOAEFL	117±0.60*	96-176	115±0.51	89-144	120±0.71	95-176
SpDAEFL	137±0.53**	92-182	136±0.45**	110-153	140±0.56**	113-179
DEVOFL	136±0.61**	89-194	133±0.49**	114-167	141±0.60**	100-167
VEAOFL	69±0.49	52-109	66±0.39	39-89	69±0.43	40-89
DVCFL	44±0.44**	17-71	45±0.29	23-56	58±0.46	33-86
DEDCFL	38±0.22	30-54	36±0.20**	25-44	43±0.45	31-83
AEVCFL	36±0.37	17-53	37±0.24	18-50	48±0.46	22-79
DEVCL	51±0.30*	36-76	50±0.24	32-61	63±0.44	43-100
AEDCFL	59±0.34	42-91	59±0.26	44-68	72±0.39	50-88
ED	13±0.10**	10-21	15±0.10**	12-22	16±0.13**	12-29
SNL	22±0.17**	17-31	22±0.15	13-28	25±0.20**	19-43
Range of correlation coefficient	(-0.18)-(0.62)		(-0.34)-(0.62)		(-0.35)-(0.35)	
N	242		254		227	

**Correlation with HL is significant at the 0.01 level, *Correlation with HL is significant at the 0.05 level

The morphometric characteristics (raw-set, SL-indices set, HL-indices set and HL-indices + SL-indices sets) of the three Epinephelinae species were subjected to standard Discriminant Function Analysis (DFA). The inter-specific variations in terms of patterns of size and shape were evident on CVI and CVII. Such variations are due to SL versus HL, ED/SL versus HL/SL, AEDCFL/HL versus VDOL/HL and SpDAEFL/HL versus DVCFL/HL on CVI. Variations on CVII are due to HD versus DEVCL, ED/SL versus DEVCL/SL, ED/HL versus DEVCL/HL and VDOL/SL versus VDOL/HL. The pattern of variations reflected by CVI and CVII exhibited to a partial

Table 5: The allometric coefficient and their standard errors (b±SE) of certain morphometric characters of the three Epinepheline species studied from the Red Sea, Quseir, Egypt, derived by the power function equation

	C. argus		*C. miniata*		*V. louti*	
Morphometric character	b±SE	a	b±SE	a	b±SE	a
BD	0.78±0.03-	-0.14	0.87±0.03-	-0.37	0.84±0.02-	-0.26
CPD	0.84±0.03-	0.11	0.76±0.03-	0.20	0.75±0.02-	0.21
HL	0.94±0.02-	-0.64	0.99±0.02*	-0.87	1.01±0.02*	-0.86
PRDFL	0.90±0.02-	-0.38	0.98±0.03*	-0.64	0.96±0.03*	-0.55
HD	0.88±0.03-	-0.37	0.91±0.02-	-0.49	0.93±0.02-	-0.53
PRVFL	0.83±0.03-	-0.28	0.89±0.02-	-0.48	0.89±0.02-	-0.41
VDOL	0.90±0.02-	-0.48	0.89±0.02-	-0.46	0.91±0.03-	-0.49
ADFEL	0.86±0.03-	-0.01	0.80±0.03-	0.07	0.72±0.02-	0.16
DFBL	0.97±0.03*	-0.94	0.93±0.03-	-0.77	0.84±0.03-	-0.41
VOAEFL	0.85±0.03-	-0.43	0.86±0.03-	-0.47	0.84±0.03-	-0.40
SpDAEFL	0.91±0.03-	-0.78	0.90±0.02-	-0.72	0.86±0.02-	-0.55
DEVOFL	0.89±0.02-	-0.69	0.87±0.02-	-0.61	0.82±0.02-	-0.41
VEAOFL	0.71±0.03-	0.11	0.71±0.03-	0.10	0.73±0.03-	0.08
DVCFL	0.41±0.04-	0.56	0.61±0.03-	0.32	0.61±0.03-	0.30
DEDCFL	0.75±0.03-	0.20	0.68±0.03-	0.28	0.58±0.03-	0.39
AEVCFL	0.38±0.03-	0.61	0.61±0.03-	0.37	0.50±0.03-	0.45
DEVCL	0.81±0.03-	0.03	0.73±0.03-	0.14	0.69±0.02-	0.16
AEDCFL	0.87±0.03-	-0.15	0.81±0.02-	-0.04	0.79±0.02-	-0.04
ED	0.92±0.08-	0.32	0.81±0.08-	0.37	0.98±0.10-	0.22
SNL	0.61±0.03-	0.47	0.59±0.03-	0.48	0.67±0.04-	0.39
Number	242		254		227	

(-) = Negative allometric growth, i.e. b =1 at 5% significance level, (*) = Isometric growth, i.e., b =1 at 5% significance level

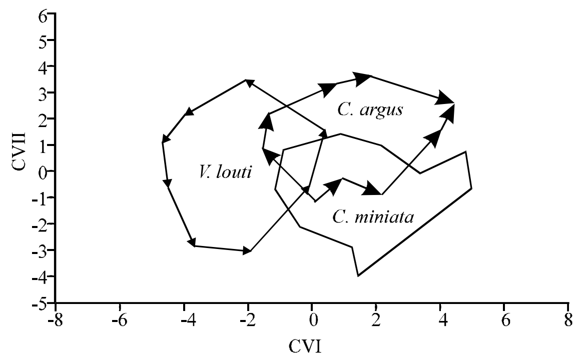

Fig. 3: Plots of canonical variates scores of the three Epinepheline species studied from the Red Sea, Quseir, Egypt, of the morphometric indices relative to SL

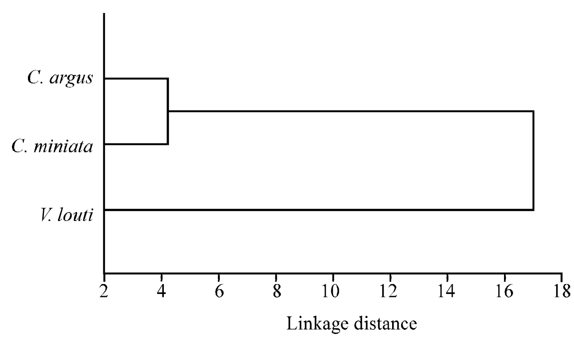

Fig. 4: Clustering of the three Epinepheline species studied from the Red Sea, Quseir, Egypt, based on the morphometric of SL-indices set, (MahalanobisD2 matrix)

discrimination between the three Epinepheline species. *C. argus* and *C. miniata* form one group while *V. louti* forms a separate another one (Fig. 3) based on the SL-indices set.

Cluster analysis based on Mahalanobis D2 (Fig. 4) exhibited similar patterns of variations for raw-set, SL-indices set, HL-indices set and HL-indices + SL-indices set. *C. argus* and *C. miniata* are grouped in one cluster and *V. louti* forms another cluster.

Meristics: Except for gill rakers, the meristic characters of the three Epinepheline species studied were markedly more conservative than their morphometrics. The pelvic Epinepheline species under investigation. Table 6 shows (II + 10) and the anal fin (III + 9) were constant in the three the frequencies and basic statistics of gill raker counts of the three Epinepheline species studied. The Inter-and intra-specific variations in gill raker counts were evident (χ^2 >111.6, Table 6).

Table 7 shows march 18, 2011 the frequencies and basic statistics of certain meristic characters of the three Epinepheline species studied. According to Chi-square test, Interspecific variations were evident. The total, precaudal and caudal, vertebral counts of the three Epinepheline species studied were constant within and between species (24 = 10 + 14).

Table 6: The total, lower and upper gill raker counts of the three Epinepheline species from the Red Sea, Quseir, Egypt

	Total gill raker											
Species	14	15	16	17	18	19	20	21	22	23	24	Mean±SD
C. argus	-	-	-	-	61	60	24	46	14	13	24	20.11±1.9
C. miniata	8	28	47	63	49	40	13	6	-	-	-	17.26±1.59
V. louti	23	22	81	74	25	2	-	-	-	-	-	16.27±1.13
$\chi^2 = 468.2$, $p<0.05$ df = 20												

	Upper gill raker								
Species	5	6	7	8	9	10	11	χ^2	df	Mean±SD
C. argus	-	-	-	93	65	46	38			9.12±1.09
C. miniata	23	93	55	83	-	-	-	618.38	12	6.78±1.01
V. louti	62	103	62	-	-	-	-	$p<0.05$		6±0.74

	Lower gill raker						
Species	9	10	11	12	13	χ^2	df	Mean±SD
C. argus	-	103	73	31	35			10.99 ±1.07
C. miniata	55	69	93	28	9	111.6	8	10.48±1.06
V. louti	47	85	81	14	-	$p<0.05$		10.27±0.86

Table 7: The dorsal soft rays and pectoral fin rays counts of the three Epinepheline species from the Red Sea, Quseir, Egypt

		Dorsal fin rays						Pectoral fin rays			
Species	N	14	15	16	17	18	X±SD	15	16	17	X±SD
C. argus	242	-	9	93	124	16	16.61±0.67	33	140	69	16.15±0.63
C. miniata	254	-	127	111	16	-	15.56±0.61	39	131	84	16.18±0.67
V. louti	227	66	141	17	3	-	14.81±0.62	57	149	21	15.84±0.57
χ^2 (DF)		536.5 (8) $p<0.05$						45.3 (4) $p<0.05$			

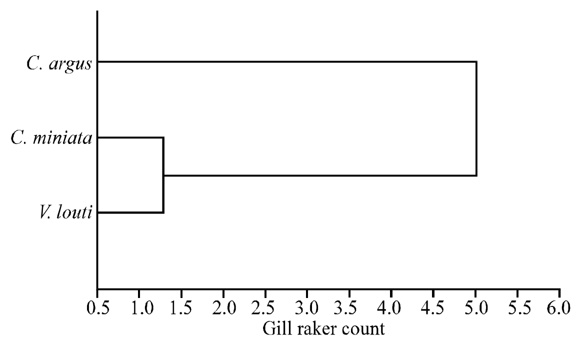

Fig. 5: Clustering of the three Epinepheline species studied from the Red Sea, Quseir, Egypt, based on their gill raker counts (Complete Linkage, Euclidian distances)

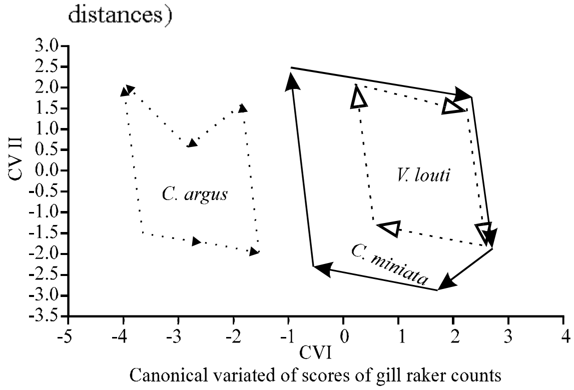

Fig. 6: Plots of canonical variates scores of the three Epinepheline species studied from the Red Sea, Quseir, Egypt, of gill raker counts

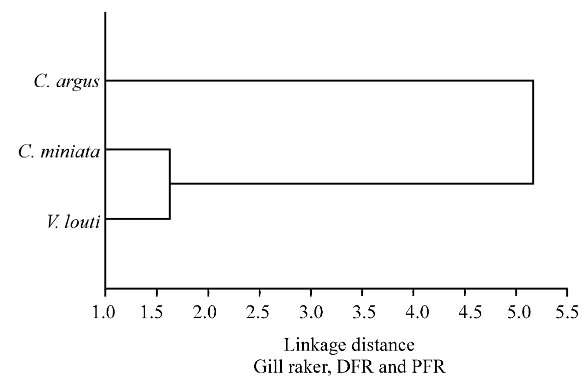

Fig. 7: Clustering of the three Epinepheline species studied from the Red Sea, Quseir, Egypt, based on their gill raker, dorsal soft rays (DFR) and pectoral fin rays (PFR) counts (Complete Linkage, Euclidian distances)

Cluster analysis of gill raker counts shows that *C. argus* forms one cluster whereas, *C. miniata* and *V. louti* forms another cluster (Fig. 5). The discriminant function analysis confirm these inter-specific relationships on the canonical variates CVI and CVII of the gill raker counts (Fig. 6). The cluster analysis of gill raker, Dorsal Soft Rays (DFR) and Pectoral Fin Rays (PFR) counts shows that *C. argus* forms one cluster whereas, *C. miniata* and *V. louti* form another cluster (Fig. 7).

DISCUSSION

The biometric analysis, including meristic and morphometric characters, has been adopted by many authors to identify and relate different fish races and/or populations (Khalil *et al*., 1984; Mekkawy, 1995; Mekkawy *et al*., 2002; Turan, 2004; Ali and McNoon, 2010). This trend in biometric analysis reflects its validity in stock identification in different fisheries of the world. The present findings confirmed the validity of this biometric approach.

The value of allometric coefficient was found to be of taxonomic interest (Gould, 1966). Moreover, the type of allometry was used to study intra- and inter-specific variations in some fish species (Haug and Fevolden, 1986; Meyer, 1990; Mekkawy *et al*., 2002). The present work confirms this statement and emphasizes on the taxonomic significance of allometric criterion in revealing inter-and intra-specific variations of morphometric characters of the three Epinepheline species considered.

Morphometric indices of traditional characters were used for identification of fish races and species by many investigators including, Khalil *et al*. (1983), Libosvarsky (1982), Mekkawy and Mahmoud (1992a, b), Khan *et al*. (2002), Myers *et al*. (2004), Cadrin (2005), Cheng *et al*. (2005) and Palacios-Salgado and Ramirez-Valdez (2011). Moreover, Morphological characters have been commonly used in fisheries biology to measure discreteness and relationships among various taxonomic categories (Turan, 1999).

Although such indices were frequently used by fish taxonomists, they were subjected to different criticisms since they were found to vary according to individual factors such as size and sex (Dodson, 1976; Khalil *et al*., 1983; Mekkawy, 1995). Humphries *et al*. (1981) pointed out that a bridge is needed between traditional quantitative methods and the geometrical analysis of shape. The latter and Strauss and Bookstein (1982) emphasized on the use of a geometric protocol for character selection, the truss network of morphometric characters which enforces systematic coverage of the form and which exhaustively and redundantly archives the landmark configuration. Mekkawy *et al*. (2002), Cheng *et al*. (2005) and Hossain *et al*. (2010) reported a similar emphasis on the validity of geometric protocol in taxonomy. This was on contrary to the findings of Mekkawy (1995) working on the biometry of some *Tilapiine* species. The latter author referred to the traditional characters to be more reliable than the truss ones for some fish species. In the present investigation, the indices of the truss morphometric characters in combination with traditional ones, were valid and appropriate in identification of the three Epinepheline species (*C. argus, C. miniata* and *V. louti*) using individual size-free characters or all characters in a multivariate sense. The multivariate analysis of some morphometric indices were found to be valid for discrimination between the three Epinepheline species studied and those of Mekkawy *et al*. (2002) (Table 8, Fig. 8a-c).

The relationship between the fish size and the total gill raker counts was interesting for many investigators. Such a relationship was found to be curvilinear in *Alestes neures* and *Alestes baremose* (Khalil *et al*., 1983), *Labeo niloticus* (Khalil *et al*., 1984) and linear in *Labeo horie, Labeo forskalii, Clarias gariepinus, Bagrus bayad* and *Bagrus docmac* (Mahmoud, 1991; Mekkawy, 1997). By contrast, King (1985) for *Clupea harengus*, Mekkawy (1991) for *Chrysicthys auratus*, Mekkawy *et al*. (2002) for *Epinephelus* species and the present authors for *C. argus, C. miniata* and *V. louti* found no relationship between the total gill raker count and fish size.

Several other trends of gill raker counts were reported by fish taxonomists. Total, epibranchial (upper) and ceratobranchial (lower) gill raker counts of the first left gill arch were used by Copeman (1977) for the differentiation between three populations of *Osmerus mordaz;* the total gill raker count was the most diagnostic feature for such differentiation. Only the total gill raker count of the first right gill arch was considered by Collares-Pereira (1979) for the differentiation between two species of the genus *Rutilus*. Eepibranchial, ceratobranchial and total gill raker counts of the left gill arch were found to be diagnostic for the differentiation between four *Tilapiine* species by Mekkawy (1995). In the present study, the total gill raker count was the most reliable features for the differentiation between *Cephalopholis argus, Cephalopholis miniata* and *Variola louti* in univariate and multivariate senses. The gill raker counts were also valid in discriminate between these Epinepheline species and four species of *Epinephelus* studied by Mekkawy *et al*. (2002) (Table 9, Fig. 12 and 13). All variable patterns of morphometric variations referred to the fact that *Epinephelus* species are clearly separated from those of *Cephalopholis* and *Variola* and the latter genera are closely related.

In the present investigation, except for the dorsal and pectoral fin rays, pelvic and anal fins spines and rays were found to be constant on the generic level. Mekkawy *et al*. (2002) reported similar conclusions for some *Epinephelus* species. The pectoral and dorsal fin rays in combination with the gill raker counts were helpful in discrimination between the Epinepheline species of genera *Cephalopholis*, *Variola* and *Epinephelus* (Table 10, Fig. 14) with emphasis on the aforementioned fact.

Table 8: The basic statistics (mean ± SD and range) of morphometric indices (relative to SL and HL) of the Epinepheline species based on raw data of the present work and that of Mekkawy *et al.* (2002) from the Red Sea, Egypt

Morpho- metric characters	*C. argus* X±SD(range)	*C. miniata* X±SD(range)	*V. louti* X±SD(range)	*E. fasciatus* X±SD(range)	*E. summana* X±SD(range)	*E.polyphekadion* X±SD(range)	*E. chlorostigma* X±SD(range)
BD/HL	95.73±7.65	94.75±6.47	96.85±6.93	84.5±5.59	80.24±8.30	82.5±6.24	83.25±5.44
	(77.78-129.41)	(77.78-128.57)	(75-115)	(72.73-100)	(65.52-100)	(68.57-105)	(70.97-95.65)
CPD/HL	35.08±2.66	33.85±2.55	38.53±3.19	27.66±3.90	26.09±2.61	28.15±2.92	31.14±3.63
	(28.57-47.06)	(25-41.18)	(30-47.06)	(20-48.89)	(17.14-35.56)	(14.94-36)	(20.69-56.36)
PRDFL/HL	84.40±4.32	83.31±3.47	84.23±7.18	99.19±3.74	100.54±4.84	100.65±3.66	99.93±2.33
	(74.07-122.35)	(75-111.11)	(75-147.06)	(76.19-116.67)	(62.96-111.11)	(91.67-125)	(94.29-111.11)
PRVFL/HL	97.28±7.72	99.36±5.6	99.34±6.96	95.38±6.95	93.54±8.78	93.54±6.03	94.55±6.44
	(82.14-176.19)	(84.21-122.22)	(65-128.57)	(76.19-120.37)	(55.56-111.11)	(77.78-115)	(67.5-110)
VDOL/HL	95.67±6.77	99.21±6.31	99.75±8.65	84.08±5.84	79.77±7.06	82.25±6.82	83.11±5.84
	(80.46-141.18)	(85.71-122.22)	(60-128.57)	(63.16-100)	(66.67-100)	(70-110)	(64.42-95.45)
ADFAL/HL	45.95±3.6	44.43±3.17	52.00±4.93	40.45±4.82	37.41±2.69	40.38±5.72	45.69±3.71
	(36.36-68.24)	(33.33-52.94)	(37.5-87.5)	(31.11-80.95)	(31.58-50)	(34.4-68.75)	(31.73-55)
SNL/HL	22.08±2.57	21.56±2.4	25.15±3.02	22.39±2.19	20.49±1.78	21.08±2.24	24.1±2.21
	(17-30.77)	(13.33-28)	(18.75-42.86)	(16.15-28.42)	(16.19-25)	(15.38-26.4)	(16.36-30)
BD/SL	37.78±2.85	37.44±2.44	35.59±2.36	37.56±6.98	35.76±2.1	36.03±5.12	34.4±5.41
	(30-50)	(30.61-47.37)	(30-43.4)	(30.56-89.47)	(30-46.3)	(31.71-84)	(28.16-85)
CPD/SL	13.84±0.95	13.38±0.9911.1	14.16±1.1111.3	12.27±2.47	11.68±1.32	12.34±2.12	12.9±2.59
	(11.54-17.5)	1-16)	6-16.98)	(8.8-29.41)	(8.14-16.84)	(5.28-27.2)	(8.46-32)
HL/SL	39.53±2.01	39.57±1.79	36.81±1.88	44.47±7.23	44.89±3.89	43.75±4.96	41.41±6.39
	(28.33-50)	(34.62-47.06)	(29.17-41.18)	(36-94.12)	(35.29-51.92)	(35.37-80)	(35.71-100)
PRDFL/SL	33.33±1.9	32.94±1.59	30.95±2.28	44.15±7.88	45.02±3.3	44.07±6.23	41.37±6.42
	(27.2-42.31)	(29.17-40)	(26.67-52.63)	(32.65-100)	(32.69-51.85)	(36.2-100)	(35.68-100)
PRVFL/SL	38.40±2.99	39.26±2.01	36.48±1.98	42.32±7.19	41.72±2.58	40.85±5.45	39.08±6.46
	(32-72.55)	(33.33-47.62)	(25-41.51)	(32.65-94.12)	(28.85-49.06)	(35.29-92)	(26.21-100)
VDOL/SL	37.73±1.87	39.18±1.8	36.61±2.37	37.34±6.72	35.59±2.05	35.91±5.41	34.34±5.48
	(32-45.83)	(34.78-45.83)	(22.64-45.24)	(28.57-88.24)	(31.37-48.08)	(31.82-88)	(24.81-85)
ADFAL/S	18.13±1.21	17.56±1.19	19.10±1.65	17.99±3.71	16.76±1.58	17.57±2.55	18.88±3.00
L	(14.81-23.08)	(14-20.41)	(15-31.82)	(12-41.18)	(12.55-23.68)	(14-36)	(12.22-45)
SNL/SL	8.72±1.04	8.52±0.91	9.24±1.11	9.94±1.79	9.18±0.95	9.2±1.44	9.95±1.64
	(6-12.08)	(5.45-10.91)	(6.82-16.67)	(6.77-23.16)	(6.98-11.32)	(7.14-20.8)	(7.2-24)
No.	242	254	227	163	124	110	101

Table 9: Gill-raker-based comparison between Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus, E. summana, E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt

	Total gill raker counts															
Species	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Mean±SD
C. argus	-	-	-	-	61	60	24	46	14	13	24	-	-	-	-	20.11± 1.9
C. miniata	8	28	47	63	49	40	13	6	-	-	-	-	-	-	-	17.26 ±1.59
V. louti	23	22	81	74	25	2	-	-	-	-	-	-	-	-	-	16.27 ± 1.13
E. fasciatus	-	-	-	-	-	-	5	12	51	50	9	-	-	-	-	22.36±0.89
E. summana	-	-	-	-	-	-	-	-	3	26	26	30	-	-	-	23.98±0.89
E. polyphekadion	-	-	-	-	-	-	-	-	-	10	39	29	8	-	-	24.41±0.82
E. chlorostigma	-	-	-	-	-	-	-	-	-	-	-	23	41	6	7	25.96±0.87
$\chi^2 = 2508$																
df = 84																

	Upper gill raker counts									
Species	5	6	7	8	9	10	11	χ^2	df	N	Mean±SD
C. argus	-	-	-	93	65	46	38	1248.9	36	242	9.12 ± 1.09
C. miniata	23	93	55	83	-	-	-			254	6.78± 1.01
V. louti	62	103	62	-	-	-	-			227	6 ± 0.74
E. fasciatus	11	51	65	-	-	-	-			127	6.25±0.65
E. summana	-	-	-	47	38	-	-			85	8.45±0.50
E. polyphekadion	-	1	5	33	47	-	-			86	8.46±0.66
E. chlorostigma	-	-	2	59	6	10	-			77	8.31±0.73

	Lower gill raker counts												
Species	9	10	11	12	13	14	15	16	17	18	19	χ^2	df	Mean±SD
C. argus	-	103	73	31	35	-	-	-	-	-	-	2176.4	60	10.99±1.07
C. miniata	55	69	93	28	9	-	-	-	-	-	-			10.48±1.06
V. louti	47	85	81	14	-	-	-	-	-	-	-			10.27±0.86
E. fasciatus	-	-	-	-	-	-	24	87	16	-	-			15.9±0.56
E. summana	-	-	-	-	-	9	26	48	2	-	-			15.51±0.72
E. polyphekadion	-	-	-	-	-	-	20	50	15	1	-			15.97±0.68
E. chlorostigma	-	-	-	-	-	-	-	1	28	47	1			16.62±0.54

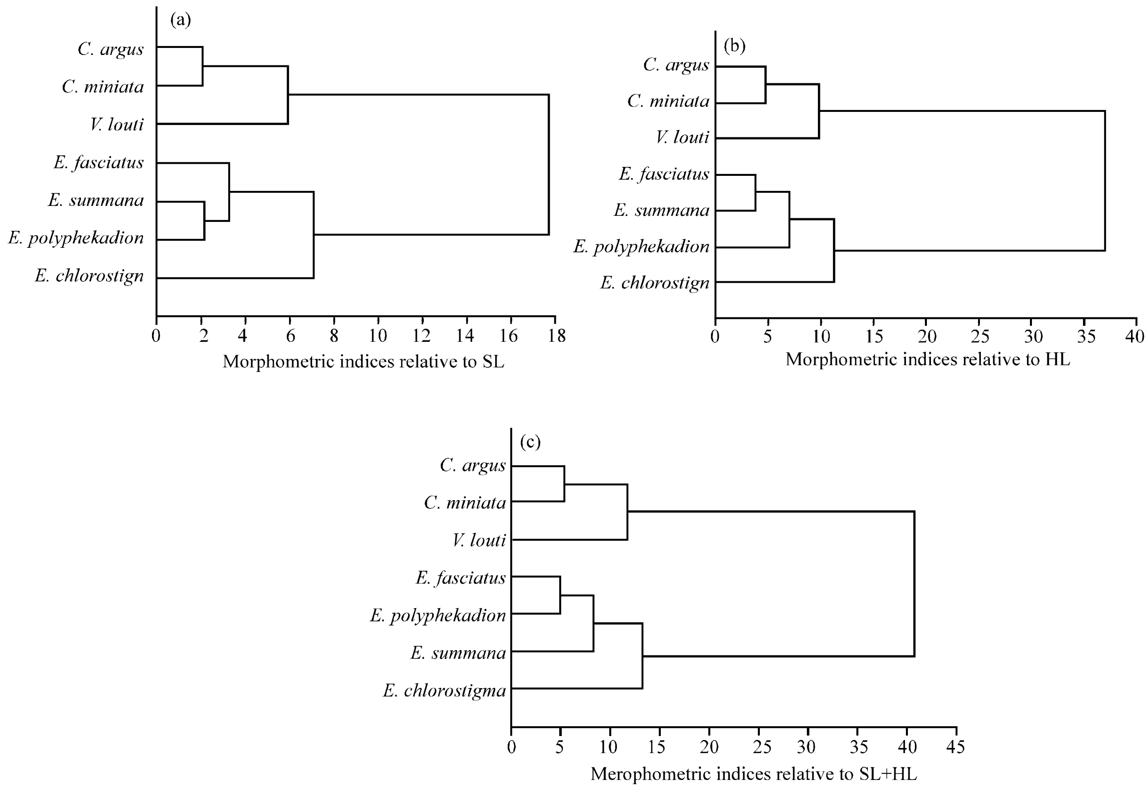

Fig. 8: Clustering of the Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus, E. summana*, *E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt, based on their morphometric indices relative to (a) SL, (b) HL and (c) HL+SL indices (Complete Linkage, Euclidean distances)

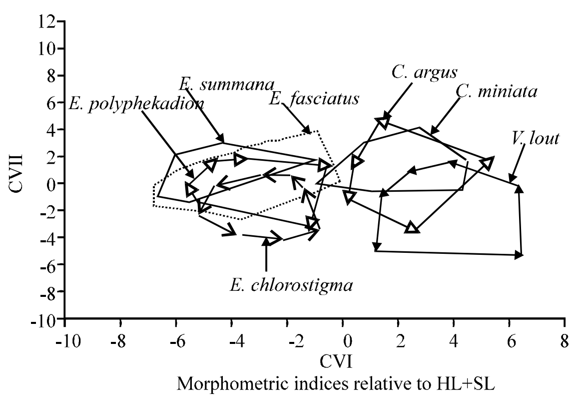

Fig. 9: Plots of canonical variates scores of the Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus, E. summana*, *E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt, of the morphometric indices relative to HL+SL

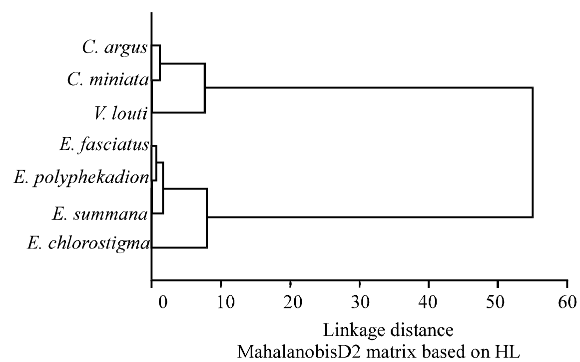

Fig. 10: Clustering of the Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus, E. summana*, *E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt, based on the morphometric of HL-indices set, (MahalanobisD2 matrix)

Generally, the meristic characters of the present work can be compared with those reported by other authors reflecting variability (Table 11).

Table 10: Fin-rays-based comparison between Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus*, *E. summana*, *E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt

Meristic character		Dorsal fin rays						Pectoral fin rays				
Species	N	14	15	16	17	18	X±SD	15	16	17	18	X±SD
C. argus	242		9	93	124	16	16.61±0.67	33	140	69		16.15±0.63
C. miniata	254		127	111	16		15.56±0.61	39	131	84		16.18±0.67
V. louti	227	66	141	17	3		14.81±0.62	57	149	21		15.84±0.57
E. fasciatus	139		2	53	81	3	16.61±0.56		10	108	21	17.08±0.47
E. summana	97	2	25	70			15.70±0.50	32	54	11		15.78±0.63
E. polyphekadion	88	3	85				14.97±0.18	35	50	3		15.64±0.55
E. chlorostigma	64				19	45	17.70±0.46		22	38	4	16.72±0.58
χ^2 (DF)		1487.2 (24)						469.1 (18)				

Table 11: The meristic characters of the present work compared with those of different authors

	Gill raker		Dorsal fin		Anal fin		Pectoral fin	Pelvic fin			
Species	Lower	Upper	Spines	Rays	Spines	Rays	Rays	Spines	Rays	Area	Source
C. argus	17-19	9-11	IX	15-17	III	9	16-18	II	10	Indo- pacific	Heemstra and Randall. (1993)
C.miniata	14-16	7-9	IX	14-16	III	8-9	17-18	II	10		
V. louti	15-18	7-10	IX	13-14	III	8	16-19	II	10		
C. argus	10-13	8-11	IX	15-18	III	9-10	15-17	II	10	Egyptians waters red sea	Present study
C. miniata	9-13	5-8	IX	15-17	III	9-10	15-17	II	10		
V. louti	9-12	5-7	IX	14-17	III	8-10	15-17	II	10		

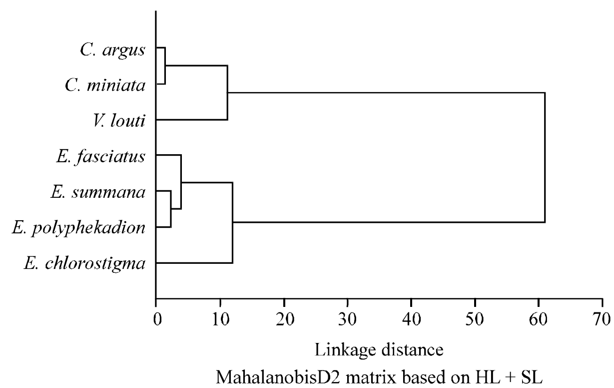

Fig. 11: Clustering of the Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus, E. summana, E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt, based on the morphometric of HL-indices set + SL-indices set, (MahalanobisD2 matrix)

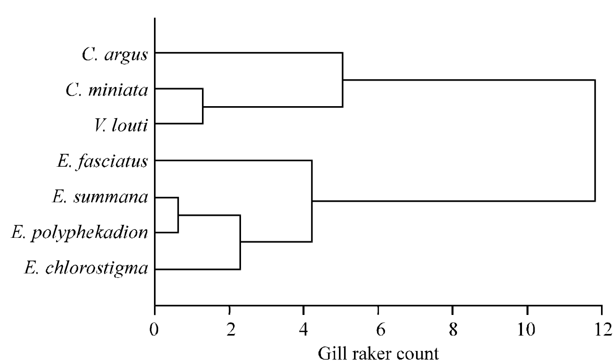

Fig. 12: Clustering of the Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus, E. summana, E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt, based on their gill raker counts, (Complete Linkage, Euclidean distances)

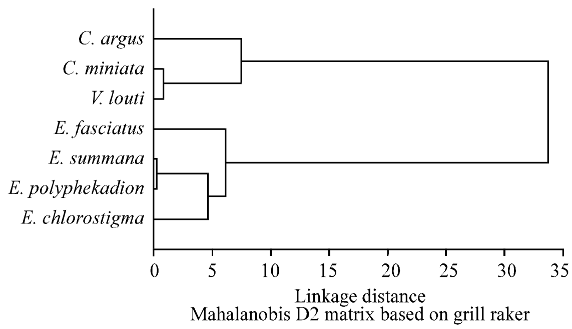

Fig. 13: Clustering of the Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus, E. summana, E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt, based on their gill raker counts, (MahalanobisD2 matrix)

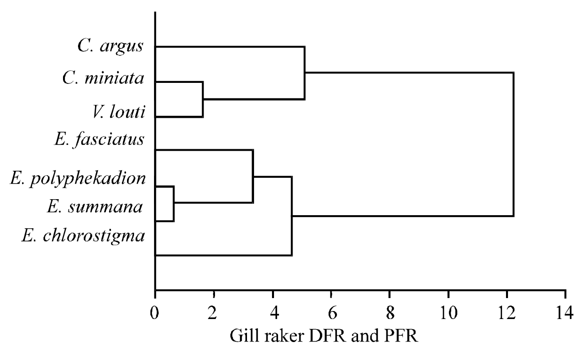

Fig. 14: Clustering of the Epinepheline species of the present work (*C. argus*, *C. miniata* and *V. louti*) and of those of Mekkawy *et al.* (2002) (*Epinephelus fasciatus, E. summana, E. polyphekadion* and *E. chlorostigma*) from the Red Sea, Egypt, based on their gill raker, dorsal soft rays (DFR) and pectoral fin rays

CONCLUSION

Size-free meristics and morphometric characters are valid tools to identify species, genera and fish stock units. The present findings referred to different patterns of intra- and interspecific relationships between Epinepheline species and hence different fisheries management strategies. The most related species could be treated as one stock unit.

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