Egypt. J. Aquat. Biol. & Fish., Vol.6, No.3:143 - 162 (2002) ISSN 1110 – 6131

OCCURRENCE OF NATURAL HYBRIDS BETWEEN NILE TILAPIA, Oreochromis niloticus (L.) AND BLUE TILAPIA *Oreochromis aureus* (Steind.) IN LAKE EDKU, EGYPT.

Shnoudy A. Bakhoum
National Institute of Oceanography and Fisheries, Alexandria, Egypt.

Key words: Cichlidae, *Oreochromis niloticus, Oreochromis aureus*, hybridization, biometrics, Lake Edku , Egypt.

ABSTRACT

The Nile tilapia (*Oreochromis niloticus*),blue tilapia, (*Oreochromis aureus*) and specimens showing intermediate external appearance to both species were sampled from Lake Edku and examined for differences in morphological characteristics to determine the natural hybrids of these species. The results of univariate analyses indicated highly significant differences of biometric characters between the hybrid groups and parental species. Multivariate analysis of meristic and morphometric values showed significant differences between all examined fish groups. The number of biometrics characters, which revealed significant differences between Nile tilapia and its hybrids, ranged from four to five out of seven meristic and twelve to fifteen out of twenty-one morphometric characters. Meanwhile, between blue tilapia and hybrids there were two to five out of seven and fourteen to sixteen out of twenty-one meristic and morphometric characters respectively. Also discriminate function analysis indicated that the biometric variables giving the most separation between the hybrid and parental species were dorsal fin spines, vertebrae number, pectoral fin length, postorbital length, head length and interorbital width. A classification to groups using the above functions derived from morphometric data yielded stronger separation than meristic counts for the examined groups. The results indicated the existence of natural hybridization between *O. niloticus* and *O. aureus* in Lake Edku.

INTRODUCTION

Tilapias play an important part in the economy of the Egyptian fisheries, since they constitute about RD 35.32 % of the total fish production of the country in 1997(GAF, 1997). In all the Egyptian brackish water Lakes, tilapia species were found with external appearance being intermediate to Nile tilapia (*Oreochromis niloticus*) and blue tilapia (*Oreochromis aureus*). Several investigators have documented the apparent case of natural hybridization between different species of tilapias (Welcomme 1964; Fryer & Iles 1972 and Agnese *et al.*1998). The hybrid nature reveals the high heterogeneity of its different traits, which are inherited from different parents, posing the question of how to recognize the hybrid and backcrossing specimens from the parental species.

The present study aimed to get evidence for the existence of natural hybridization between *O. niloticus* and *O. aureus* in Lake Edku and examine the biometrics intermediary of the hybrids to indicate the extent of morphological differences between parental species and hybrid groups.

MATERIAL AND METHODS

Lake Edku situated at about 30 km to the northern east of Alexandria, has an area of about 12,600 hectare (30,000 feddan). It lies west to Rosetta branch of the Nile, at latitude 30° 25΄ N and longitude 31° 15΄ E. It is a shallow lake connected with the Mediterranean Sea at the western side through a narrow channel (Boughaz El-Maadia). It receives considerable amounts of drainage water from Rashid, El-Bousily, Edku and El-Barzik drains (Philips, 1994).

Trammel nets were used to collect parental *Oreochromis niloticus* and *Oreochromis aureus* and their hybrids from the Lake during the period from May 1998 to December 1999. A total of 105, 91 and 345 specimens (total length ranging from 88 to 310 mm) for Nile tilapia, blue tilapia and hybrid groups respectively were randomly sampled. Parental species were determined by following descriptions of pure *O. niloticus* (Boulenger, 1915; Bishai and Khalil, 1997) and *O.aureus* (Trewaves, 1964). The biometric characters examined included twenty-one morphometric measurements (all the measurements were taken to the nearest mm.) and seven meristic counts. Morphometric measurements were standardized to the maximum value of standard length by the method outlined by Beacham and Murray (1983). This allometric regression to a standard size is a preferred method of removing size variation in characters among individuals (Reist, 1985). The meristic and size-adjusted data sets were analyzed univariately by the methods of one-way ANOVA and Kolmorov-Simirnov test (Haddon and Willis, 1995) and multivariately using discriminant function analysis for the selection of the important variables (Henault and Fortin, 1989).

RESULTS

Description of parental and hybrid specimens

Straight or slightly convex head profile, black dorsal fin edge and black caudal fin edge with seven to twelve vertical bars characterize Nile tilapia (Boulenger, 1915). Blue tilapia is distinguished by a straight head profile, pink or reddish dorsal fin edge and the caudal fin has a reddish edge but unmarked by any vertical bars (Trewaves, 1964). In the present study the hybrid specimens were differentiated morphologically to three forms: Hybrid 1 (H1) is characterized by a straight head profile, reddish dorsal fin edge and red caudal fin with one and few uncompleted vertical bars. Hybrid 2 (H2) is distinguished by a slightly convex head profile, reddish dorsal fin edge and red caudal fin with two or three complete and few uncompleted bars. Hybrid 3 (H3) is characterized by a straight head profile, black dorsal fin edges and a red caudal fin with two or three complete and few uncompleted vertical bars. Parental and hybrid specimens are shown in Fig. 1.

For determination of the differences in fish abundance between parental and hybrid specimens, the study was based on random samples of 845 specimens (189, 77, 150, 267 and 162 for *Oreochromis niloticus*, *Oreochromis aureus*, H1, H2 and H3 respectively). The results indicated that hybrid specimens greatly dominated the tilapias (*Oreochromis* spp.) catch in lake Edku. The relative numerical abundance of parental and hybrid specimens revealed that hybrid 2 ranked at the top (31.60%) followed by *O. niloticus* (22.37%), hybrid 3 (19.17%), hybrid 1 (17.75%) and *O. aureus* (9.11%).

The comparison of seven meristic counts and twenty-one morphometric characters between parental species and hybrid groups are summarized in Table 1.

i. Univariate analyses

One-way ANOVA indicated significant differences of meristic counts ($F=3.679, p<0.001$) and morphometric measurements ($F=11.955, p<0.001$) between the hybrid groups and parental species. Tukey's honest-significant difference (HSD) of merisric characters indicated that the significant difference was found only between Nile tilapia and blue tilapia ($p<0.05$). Meanwhile, morphometric characters revealed that Nilc tilapia was significantly different from others groups ($p<0.001$), blue tilapia showed significant difference from hybrids (h1, h2) ($p<0.05$) beside Nile tilapia. The difference among hybrids revealed that hybrids I and 3 (H1&H3) differed from Nile tilapia ($p<0.001$) and blue tilapia ($p<0.05$), while hybrid 2 (H2) was significantly different only in the morphometric characters from Nile tilapia ($p<0.001$).

A Kolmogorov –Smirnov test of meristic counts indicated that *O. niloticus* showed significant difference from *O. aureus* and hybrid types in all examined characters except dorsal fin rays and anal fin rays compared with *O. aureus* and dorsal fin rays with hybrids 1&2. Furthermore, significant differences of *O. niloticus* from hybrid 3 were found in dorsal fin and pectoral fin rays. Comparing blue tilapia with hybrid groups revealed that this species differed from hybrids 1&2 only in the number of anal fin rays, and from hybrid 3 in all examined characters except dorsal fin spines. On the other hand, differences among hybrids indicated that hybrid 2 showed significant difference from hybrid 1 only in scales on lateral line and differed from hybrid 3 in dorsal fine spine, pectoral fin rays, scales on lateral line and vertebrae.

Concerning morphometrics, results from Kolmogorov–Smirnov test showed significant differences between Nile tilapia and the other four fish groups in all examined characters except in pelvic base length from hybrid 2, the maximum dorsal rays height from hybrid 3 and in pelvic base length and the maximum dorsal rays height from hybrid 1. Blue tilapia differed significantly in fifteen characters from hybrids 1&3 and eleven characters from hybrid2. Comparing hybrid specimens revealed that eight of the twenty-one characters were significantly different between hybrid 1 and other hybrid groups, but highly significant differences in 18 out of 21 morphometric characters were found between hybrid 2 and hybrid 3 (Table 2).

ii. Multivariate analysis

Squared Mahalanobis distance based on morphometric values for the five fish groups revealed that only the distance between hybrid 1 and hybrid 2 was not significant. In case of using meristic and or all biometrics characters, the results revealed significant differences between all examined groups. The highest Mahalanobis distance was found between Nile tilapia and hybrid 3, whereas the smaller distances were between hybrids 1&2 (Table 3).

Stepwise discriminate function analysis of meristic and morphometric values showed significant differences between different fish groups (Table 4). This analysis indicated that four out of seven meristic counts and three out of the investigated twenty-one morphometric measurements contributed significantly to the multivariate discrimination between Nile tilapia and blue tilapia. The number of biometric characters, which revealed significant differences between the Nile tilapia and hybrids, ranged from one to three out of seven meristic and two to six out of twenty-one morphometric character, while between *O. aureus* and hybrids they were one to five out of seven and two to seven out of twenty-one meristic and morphometric characters respectively. Concerning the differences among hybrid groups, hybrid 1 showed significant difference in meristic counts from hybrid2 in the number of vertebrae and from hybrid 3 in dorsal fin spines and pectoral fin rays. The differences between hybrids 1&2 were in the number of vertebrae and dorsal fin spines, whereas the number of morphometric measurements, which revealed significant difference between hybrids ranged from three to four out of twenty-one characters (Table 5). A posteriori classification to groups using classification functions derived from the meristic characters yields separation with 79% for Nile tilapia, 34% for blue tilapia, 28% for hybrid 1, 60% for hybrid 2 and 31% for hybrid 3. When using the classification functions derived from morphometric data yielded stronger separation than meristic counts for all examined groups. The rate of correct site was 83% for Nile tilapia, and 71% for blue tilapia, 28% for hybrid1, 74% for hybrid 2 and 35% for hybrid 3. while the best discrimination for these fish groups derived from meristic and morphometric data set. The rate of correct site allocation was high for all fish groups, being 100% for Nile tilapia, 82% for blue tilapia, 48% for hybrid1, 80% for hybrid 2 and 74% for hybrid3. The coefficients for the number of vertebrae, standard length, maximum body depth, dorsal fin spines, upper jaw length, anal base length, dorsal base length, head length and head depth passing through eyes were relatively large, indicating their relative importance for discrimination (Fig.2).

DISCUSSION

The reason for the occurrence of natural hybridization is the breaking of reproductive barriers that may be physiological, behavioral or geographic. The existence of at least a partial physiological barrier to reproduction is shown by failure to obtain viable progeny in certain combinations, and by cases where hybrid progenies are fewer than those obtained from intraspecific spawning (Lovshin and Da Silva 1975). The possible role of geographic separation in speciation is obvious. It seems virtually certain that one reason for the occurrence of natural hybrids is the breaking of the geographical reproductive barrier by artificial transfer of tilapias in African Lakes (Fryer and Iles 1972). In Lake Edku, the artificial transfer of Nile tilapia by drainage water into the Lake causes a break of the geographical reproductive barrier, also both parental species have overlapping spawning periods (EL-Haweet 1991 and El-Shazly 1993), and display a similar spawning behavior (maternal brooders).

The morphometric and meristic characters of hybrids were intermediate between the parents except anal fin rays in hybrids 1&2 and maximum dorsal rays height in hybrids 1&3, which showed higher values than those of parental species. Haroun (1999) in her study on the artificial hybridization between *Oreochromis niloticus* and *Oreochromis aureus*, reported that morphological features of the hybrids were intermediate between the parents and reported that *O. niloticus* female X *O. aureus* male hybrid showed higher values in scales in lateral line, gill rakers and number of vertebrae than *O. aureus* female X *O. niloticus* male hybrid. This finding agrees with the present result when comparing hybrid 3 with both of hybrids 1&2. In addition, according to Badawy (1993), the cytogenetic and electrophoresis studies showed that *O. niloticus* from water bodies empty of *O. aureus* and *O. aureus* selected from brackish water, where *O. niloticus* is absent or rarely present, are more genetically pure. The results indicated the existence of natural hybridization between *O. niloticus* and *O. aureus* in Edku Lake. Also discriminate function analysis revealed that the best biometric characters for distinguishing between parental species and hybrids were the number of dorsal fin spines and vertebrae, pectoral fin length, postorbital length, head length and interorbital width. The extent of backcrossing and introgression resulting from natural hybridization between *O. niloticus* and *O. aureus* is difficult to be ascertained, for backcrossing or F_2 progeny cannot be individually distinguished from F_1 hybrids. Therefore, using the electrophoretic analysis in detailed experimental mating between these two species is required to resolve this problem.

REFERENCES

Agnese, J. F. ; Adepo-Gourene, B. and Pouyaud, L. (1998). Natural hybridization in tilapias. In: Genetics and Aquaculture in Africa Collection colloques et seminires. Paris: ORSTOM, 95-103.

Badawy, E. A. (1993). Biological studies on Tilapia species as a major component of the Egyptian fish farming system. Pd. D. Thesis, Fac. Sc., Zagazig Univ.

Beacham, T. D. and Murray, C. B. (1983). Sexual dimorphism in the adipose in of Pacific salmon (*Oncorhynchus*). Can. J. Fish. Aquat. Sci., *40*: 2019 - 2024.

Bishai, H. M. and Khalil, M. T. (1997). Freshwater fishes of Egypt. National Biodiversity Unit. (9): 229pp.

Boulenger, G. A. (1915). Catalogue of the freshwater fishes of Africa in the British Museum (Natural History). 526pp.

El-Haweet, A. A. K. (1991). Biological studies of some Cichlid species in Lake Borollus. M. Sc. Thesis, Fac. Sci., Alexandria Univer. Egypt.

El-Shazly, A. A. (1993). Biological studies on four cichlid fishes *Tilapia nilotica, Tilapia galilae*, *Tilapia zillii*, *Tilapia aurea* in Lake Mariut. M. Sc. Thesis, Fac. Sci., Zagazig Univ. Egypt.

Fryer, G. and Iles, T. D. (1972). The Cichlid Fishes of the Great Lakes of Africa – their Biology and Evolution. Oliver and Boyd: Edinburgh

GAFRD, (1997). General Authority for fish resources development, data on fish production in Egypt, Ministry of Agricult., Cairo 193pp.

Haddon, M. and Willis, T. J. (1995). Morphometric and meristic comparison of orange roughy (*Hoplostethus atlanticus* : Trachichthyidae) from the Puysegur Bank and Lord Howe Rise, New Zealand, and its implications for stock structure. Marine Biology, *123*: 19-27.

Haroun, M. R. (1999). Crossbreeding Egyptian races of tilapias to produce more productive hybrids. Ph. D. Thesis, Fac. of Sci., Tanta Univ., Egypt.

Henault, M. and Fortin, R. (1989). Comparison of meristic and morphometric characters among spring-and fall-spawning ecotype of Cisco (*Coregonus artedii*) in southern Quebec, Canada. Can. J. Fish. Aquat. Sci., *46*: 166 - 173.

Lovshin, L. L. and Da Silva, A. B. (1975). Culture of monosex and hybrid tilapias. Paper presented at FAO/CIFA Symposium on Aquacult. in Africa, Accra, Ghana.(CIFA/75/SR9) p. 16.

Philips, A. E. (1994). Studies on the biology of two tilapia species in Lake Edku. Ph. D. Thesis, Fac. Sci. Alexandria Univ. Egypt.

Reist, J. D. (1985). An empirical evaluation of several univariate methods that adjust for size variation in morphometric data. Can J. Zool., *63*:1429 – 1439.

Trewavas, E. (1965). *Tilapia aurea* (Steindachner) and the status of *T. nilotica exul*, *T. monodi* and *T. Lemassoni*. Pisces, Cichlidae. Isr. J. Zool., *14*:258-276.

Welcomme, R. L. (1964). Notes on the present distribution and habits of the nonendemic species of tilapia, which have been introduced into Lake Victoria. Rep. E. Afr. Fresh wat. Fish. Res. Org., *63*:36-39.

151 NATURAL HYBRIDS BETWEEN NILE TILAPIA AND BLUE TILAIA IN LAKE EDKU

Table(1): Comparison of meristic and morphometric measurements of *O. niloticus*, *O. aureus* and hybrid specimens collecteo from La… …dku .

Biometric characters	***O. niloticus***	***O. aureus***	**Hybrid (1)**
Meristic count	**Mean±SD(Range)**	**Mean±SD(Range)**	**Mean±SD(Range)**
Dorsal fin spines	16.84±0.485(16-18)	15.91±0.412(15-17)	15.97±0.324(15-17)
Dorsal fin rays	12.62±0.563(12-14)	12.57±0.620(12-13)	12.75±0.622(12-14)
Anal fin rays	9.34±0.601(9-10)	9.25±0.519(9-10)	9.54±0.695(9-11)
Pectoral fin rays	13.43±. 0.604(12-15)	13.13±0.542(12-14)	13.14±0.684(12-14)
Scales in lateral line	30.83±0.884(29-34)	29.79±1.091(28-33)	29.79±0.942(28-32)
Gill rakers	29.23±2.763(24-35)	26.45±2.822(22-33)	26.99±2.460(22-31)
Vertebrae (total)	31.73±0.903(33-30)	30.32±0.727(29-32)	30.11±0.754(29-31)
Morphometric measurement (m m)			
Total length	166.62±43.251(100-310)	116.99±15.261(96-191)	126.99±21.479(94-211)
Standard length	135.30±36.657(81-257)	92.95±11.988(77-142)	100.67±17.777(74-171)
Predorsal length	48.01±13.253(29-95)	35.46±8.558(29-66)	37.04±8.814(28-64)
Prepectoral length	46.69±12.653(28-85)	34.00±8.386(29-46)	35.86±9.593(19-60)
Preanal length	95.81±25.804(58-188)	65.20±8.815(53-92)	71.33±13.632(52-116)
Prepelvic length	53.45±13.521(32-95)	37.62±8.866(21-52)	41.46±10.481(28-64)
Maximum body depth	55.37±16.520(15-98)	34.47±8.320(27-50)	39.57±9.978(28-70)
Caudal peduncle length	20.49±9.682(9-37)	13.67±9.33(8-21)	15.50±8.718(10-27)
Caudal peduncle depth	19.81±10.728(11-34)	13.52±9.281(11-18)	14.68±8.755(10-25)
Dorsal base length	78.51±21.954(25-139)	51.05±8.195(41-72)	55.47±11.727(32-97)
Anal base length	25.76±10.254(13-48)	17.60±8.898(13-23)	20.34±9.556(13-47)
Pelvic base length	.39.47±11.451(23-72)	27.66±9.170(19-40)	31.30±8.992(15-50)
Pectoral fin length	49.26±12.112(31-83)	33.71±7.972(27-46)	38.47±8.515(25-57)
Head length	45.59±12.713(29-86)	33.08±8.157(26-47)	35.04±8.725(26-57)
Maximum head depth	49.98±15.212(28-97)	32.21±8.342(27-47)	36.08±9.330(25-60)
Head depth (passing through eyes)	29.12±10.437(15-54)	20.91±8.919(16-37)	22.84±8.634(16-36)
Interorbital width	18.39±9.960(10-39)	11.87±9.459(8-19)	12.83±9.075(7-23)
Snout length	16.13±9.475(9-32)	11.44±9.474(8-15)	12.39±8.918(8-21)
Pregill cover	30.97±10.340(19-58)	22.32±8.690(18-32)	23.71±8.558(12-37)
Upper jaw length	13.12±8.951(8-19)	10.52±9.639(8-17)	10.94±8.909(7-19)
Lower jaw length	14.09±8.806(8-19)	11.58±9.429(8-16)	11.81±8.835(8-18)
Maximum dorsal rays height	29.00±13.938(14-74)	20.51±9.439(12-24)	33.81±18.354(12-58)

Continued

Table(1): (Cont.)

Biometric characters	Hybrid (2)	Hybrid (3)
Meristic count	Mean±:SD(Range)	Mean±SD(Range)
Dorsal fin spines	16.02±.405(15-17)	16.45±0.755(15-18)
Dorsal fin rays	12.78±0.528(14-12)	12.66±0.572(14-12)
Anal fin rays	9.52±0.531(10-9)	9.53±0.540(10-8)
Pectoral fin rays	13.21±0.475(13-14)	13.50±0.503(13-14)
Scales in lateral line	29.51±1.859(28-33)	30.39±1.385(28-34)
Gill rakers	26.84±2.835(22-33)	27.69±3.170(22-35)
Vertebrae (total)	30.43±0.696(29-32)	30.72±1.083(29-33)
Morphometric measurement (m m)		
Total length	121.32±22.111(88-234)	125.63±36.528(75-241)
Standard length	96.01±18.688(69-197)	100.12±30.262(59-200)
Predorsal length	36.03±9.984(22-96)	37.11±11.277(22-64)
Prepectoral length	34.23±8.598(23-65)	36.01±11.743(21-66)
Preanal length	67.14±14.730(30-146)	70.00±20.256(42-142)
Prepelvic length	39.88±10.284(25-83)	40.13±13.299(23-77)
Maximum body depth	37.79±9.321(26-76)	39.67±15.101(20-85)
Caudal peduncle length	14.67±8.182(8-29)	15.63±9.811(8-31)
Caudal peduncle depth	14.13±7.922(9-26)	15.14±9.968(8-44)
Dorsal base length	53.62±12.180(38-120)	57.27±19.657(15-116)
Anal base length	19.20±8.019(12-37)	19.04±10.250(10-34)
Pelvic base length	31.21±7.704(20-49)	29.80±11.294(15-49)
Pectoral fin length	34.80±7.920(23-59)	36.75±12.428(18-65)
Head length	33.33±8.018(23-61)	35.37±11.294(21-64)
Maximum head depth	34.59±8.925(22-71)	36.33±13.519(21-74)
Head depth (passing through eyes)	21.08±7.982(14-42)	23.22±9.100(14-42)
Interorbital width	11.76±8.144(7-27)	13.29±9.884(7-28)
Snout length	11.56±8.092(7-25)	12.67±9.553(6-24)
Pregill cover	22.78±7.710(16-40)	23.89:9.798(13-44)
Upper jaw length	10.43±8.108(6-21)	11.12:9.435(5-19)
Lower jaw length	11.42±7.953(7-20)	12.14:9.200(7-19)
Maximum dorsal rays height	24.88±17.241(15-34)	30.55:17.218(17-34)

Table (2):Kolmogorov-Smirnov tests of meristic and morphometric measurement of *O. niloticus* (N), *O. aureus* (A) and hybrids(H1,H2,H3)collected from Lake Edku. Significance levels: * p<0.05; **p<0.01 and *** p<0.001.

Biometric characters	(N) vs. (A) Maximum Difference	(N) vs. (H1) Maximum Difference	(N) vs. (H2) Maximum Difference	(N) vs. (H3) Maximum Difference	(A) vs.(H1) Maximum Difference
Meristic count					
Dorsal fin spines	0.764**	0.770**	0.719**	0.342***	0.114
Dorsal fin rays	0.039	0.076	0.149	0.048	0.009
Anal fin rays	0.023	0.243**	0.234**	0.247**	0.259**
Pectoral fin rays	0.251**	0.235**	0.224**	0.053	0.065
Scales in lateral line	0.415***	0.441***	0.521***	0.218*	0.084
Gill rakers	0.387***	0.354***	0.366***	0.278**	0.181
Vertebrae (total)	0.598***	0.647***	0.590***	0.377***	0.108
Morphometric characters					
Standard length	0.730***	0.630***	0.746***	0.555***	-0.346***
Preanal length	0.471***	0.375***	0.446***	0.367***	-0.106
Prepelvic length	0.629***	0.347***	0.418***	0.440***	-0.360***
Predorsal length	0.375***	0.393***	0.451***	0.318***	0.075
Maximum body depth	0.821***	0.583***	0.598***	0.469***	-0.524***
Caudal peduncle length	0.600***	0.392***	0.450***	0.313***	-0.474***
Caudal peduncle depth	0.709***	0.526***	0.589***	0.473***	-0.303***
Dorsal base length	0.771***	0.677***	0.685***	0.390***	-0.183
Anal base length	0.570***	0.299***	0.312***	0.394***	-0.300***
Pelvic base length	0.518***	0.139	0.126	0.371***	-0.453***
Pectoral fin length	0.626***	0.536***	0.640***	0.481***	-0.226*
Head length	0.438***	0.432***	0.528***	0.298***	0.120
Maximum head depth	0.808***	0.593***	0.585***	0.471***	-0.461***
Head depth through eyes	0.497***	0.317***	0.531***	0.299***	-0.206*
Interorbital width	0.651***	0.517***	0.688***	0.533***	-0.148
Snout length	0.480***	0.354***	0.464***	0.239**	-0.255**
Pregill cover	0.540***	0.498***	0.616***	0.406***	-0.199*
Upper jaw length	0.400***	0.241**	0.363***	0.281***	-0.200*
Lower jaw length	0.396***	0.345***	0.395***	0.210*	0.167
Prepectoral length	0.414***	0.395***	0.530***	0.325***	0.264**
Maximumdorsal rays height	0.366***	0.084	0.476***	0.191	-0.417***

Continued

Table (2): (Cont.)

Biometric characters	(A) vs.(H2) Maximum Difference	(A) vs. (H3) Maximum Difference	(H1) vs.(H2) Maximum Difference	(H1) vs.(H3) Maximum Difference	(H2) vs.(H3) Maximum Difference
Meristic count					
Dorsal fin spines	0.144	0.048	0.089	0.427***	0.377***
Dorsal fin rays	0.058	0.421***	0.011	0.074	0.096
Anal fin rays	0.248**	-0.280**	0.056	0.02	0.022
Pectoral fin rays	0.058	-0.270**	0.051	0.271**	0.263***
Scales in lateral line	0.134	-0.247**	0.218*	0.273**	0.303***
Gill rakers	0.14	0.234*	0.07	0.181	0.152
Vertebrae (total)	0.059	0.227*	0.152	0.270**	0.213*
Morphometric characters					
Standard length	-0.256**	-0.264**	0.149	0.289***	0.259***
Preanal length	0.093	-0.123	0.098	-0.072	-0.105
Prepelvic length	-0.302***	-0.249**	-0.133	0.144	0.152
Predorsal length	0.143	-0.135	-0.091	-0.139	-0.216**
Maximum body depth	-0.566***	-0.369***	0.140	0.167	0.269***
Caudal peduncle length	-0.311***	-0.312**	0.206*	0.216*	-0.165
Caudal peduncle depth	-0.328***	-0.275**	0.096	0.180	0.211*
Dorsal base length	-0.158	-0.379***	-0.120	-0.291***	-0.294***
Anal base length	-0.356***	-0.238**	-0.165*	0.320***	0.380***
Pelvic base length	-0.462***	-0.159	-0.092	0.308***	0.350***
Pectoral fin length	-0.199*	-0.172	0.122	0.229**	-0.225**
Head length	0.157	-0.206*	0.144	-0.167	-0.269***
Maximum head depth	-0.481***	-0.347***	0.074	0.182	0.219**
Head depth through eyes	0.102	0.326***	0.238**	-0.106	-0.262***
Interorbital width	0.154	-0.179	0.179*	-0.107	-0.210*
Snout length	-0.101	-0.270*	0.190*	-0.159	-0.271***
Pregill cover	-0.175	-0.193	0.125	-0.144	-0.210*
Upper jaw length	0.077	-0.266**	0.181*	-0.156	-0.262***
Lower jaw length	0.119	-0.220*	-0.139	-0.196*	-0.241**
Prepectoral length	0.274***	0.226*	0.221**	-0.092	-0.220**
Maximum dorsal rays height	0.301***	-0.387***	0.467***	0.250**	-0.417***

Table (3): Squared Mahalanobis distances between groups of *O. niloticus*; *O. aureus* and hybrid specimens collected from Lake Edku . (Parentheses = F- values. Significance level **p<0.01.)

Meristic counts	*O. niloticus*	*O. aureus*	Hybrid (H1)
O. niloticus	0.000	8.388 (56.911)**	8.29 (60.884)**
O. aureus	8.388 (56.911)**	0.000	0.482 (3.302)**
Hybrid (H1)	8.29 (60.884)**	0.482 (3.302)**	0.000
Hybrid (H2)	7.02 (58.298)**	0.512 (3.930)**	0.239 (2.004)
Hybrid (H3)	2.776 (19.894)**	2.346 (15.695)**	1.945 (14.0683)**
Morphometric measurements			
O. niloticus	0.000	29.687(59.983)**	33.884(74.169)**
O. aureus	29.687(59.983)**	0.000	13.078(26.426)**
Hybrid (H1)	33.884(74.169)**	13.078(26.426)**	0.000
Hybrid (H2)	18.018(44.655)**	11.925(27.006)**	13.152(32.595)**
Hybrid (H3)	177.736(377.608)**	98.815(194.227)**	102.3(217.341)**
Meristic and Morphometric characters			
O. niloticus	0.000	31.9557(13.664)**	39.200(22.761)**
O. aureus	31.956(13.664)**	0.000	12.819(6.428)**
Hybrid (H1)	39.120(22.761)**	12.819(6.4281)**	0.000
Hybrid (H2)	29.082(21.034)**	8.840(5.343)**	2.119(2.041)**
Hybrid (H3)	63.410 (36.819)**	22.375(11.220)**	18.558(13.469)**

Continued

Table (3): (cont.)

Meristic counts	Hybrid (H2)	Hybrid (H3)
O. niloticus	7.02 (58.298)**	2.776 (19.894)**
O. aureus	0.512 (3.930)**	2.346 (15.695)**
Hybrid (H1)	0.239 (2.004)	1.945 (14.0683)**
Hybrid (H2)	0.000	1.575 (12.861)**
Hybrid (H3)	1.575 (12.861)**	0.000
Morphometric measurements		
O. niloticus	18.018(44.655)**	177.736(377.608)**
O. aureus	11.925(27.0060**	98.815(194.227)**
Hybrid (H1)	13.152(32.595)**	102.3(217.341)**
Hybrid (H2)	0.000	109.234(261.742)**
Hybrid (H3)	109.234(261.742)**	0.000
Meristic and Morphometric characters		
O. niloticus	29.0840(21.034)**	63.410(36.819)**
O. aureus	8.840(5.343)**	22.375(11.220)**
Hybrid (H1)	2.119(2.041)**	18.558(13.469)**
Hybrid (H2)	0.000	22.428(21.603)**
Hybrid (H3)	22.428(21.603)**	0.000

Table (4):Discriminant function analysis between groups of *O. niloticus* (N), *O. aureus* (A) and hybrid (H1, H2,H3) specimens were collected from Lake Edku.

	Morphometric measurement			Meristic count		
Species	Wilks' Lambda	F-remove	p-level	Wilks' Lambda	F-remove	p-level
N-A	0.1134	68.799	p<0.00001	0.26888	129.16	p<0.00001
N-H1	0.8674	112.89	p<0.00001	0.26173	95.437	p<0.00001
N-H2	0.09388	136.93	p<0.00001	0.33876	92.131	p<0.00001
N-H3	0.01378	743.32	p<0.00001	0.67003	13.86	p<0.00001
A-H1	0.12656	57.511	p<0.00001	0.87647	5.3837	p<0.0001
A-H2	0.12967	73.831	p<0.00001	0.8555	6.2496	p<0.00001
A-H3	0.0062	1290.7	p<0.00001	0.67927	14.559	p<0.00001
H1-H2	0.17103	60.588	p<0.00001	0.932	5.8371	p<0.001
H1-H3	0.01025	1140.9	p<0.00001	0.71974	19.665	p<0.00001
H2-H3	0.00643	1432.9	p<0.00001	0.77972	16.527	p<0.00001
All groups	0.00394	67.557	p<0.00001	0.40761	19.266	p<0.00001

Table (5): The meristic and morphometric characters investigated contributed significantly to the multivariate discrimination between groups of *O. niloticus* (N), *O. aureus* (A) and hybrids(H1,H2,H3) collected from Lake Edku. (Significance levels: * $p<0.05$; ** $p<0.01$, *** $p<0.001$.)

Meristic count	N-A	N-H1	N-H2	N-H3	A-H1
Dorsal fin spines	6.508*			6.968*	6.920*
Dorsal fin rays					
Anal fin rays		7.987**			6.898*
Pectoral fin rays	26.082***				
Scales in lateral line		9.699**			14.669***
Gill rakers	5.568*				4.612*
Vertebrae (total)	58.157***	70.030***	21.408***	18.364***	29.124***
Morphometric characters					
Standard length	28.203***	49.029***	5.321*	8.128**	
Predorsal length					
Prepectoral length			4.640*		
Preanal length				4.817*	
Prepelvic length		9.002**			
Maximum Body depth	5.567*			6.362*	6.824*
Caudal peduncle length		4.842*			10.345**
Caudal peduncle depth					5.053*
Dorsal base length					5.354*
Anal base length					
Pelvic base length		8.445*			6.274*
Pectoral fin length					
Head length				13.107***	15.097***
Maximum head depth				11.572***	
Head depth (passing through eyes)		4.763*			
Interorbital width				15.435***	
Snout length		4.609*			7.937**
Pregill cover					
Upper jaw length					
Lower jaw length	5.156*				
Maximum dorsal rays height					

Continued

Table (5): (Cont.)

Meristic count	A-H2	A-H3	H1-h2	H1-H3	H2-H3
Dorsal fin spines		8.516**		20.030***	8.272**
Dorsal fin rays					
Anal fin rays					
Pectoral fin rays		10.464**		5.424*	
Scales in lateral line	8.047**				
Gill rakers					
Vertebrae (total)		34.411***	36.378***		21.595***
Morphometric cherecters					
Standard length					
Predorsal length					
Prepectoral length		7.931**			
Preanal length					
Prepelvic length					
Maximum Body depth		7.403**			14.480***
Caudal peduncle length					
Caudal peduncle depth			4.509*	9.629**	
Dorsal base length	10.059**			10.009**	
Anal base length					21.222***
Pelvic base length					
Pectoral fin length					
Head length	10.649**				
Maximum head depth					
Head depth (passing through eyes)	73.174***			6.723*	5.371*
Interorbital width	23.997***		7.041**		
Snout length					
Pregill cover			5.201*	5.107*	
Upper jaw length	5.529*				
Lower jaw length					
Maximum dorsal rays height					

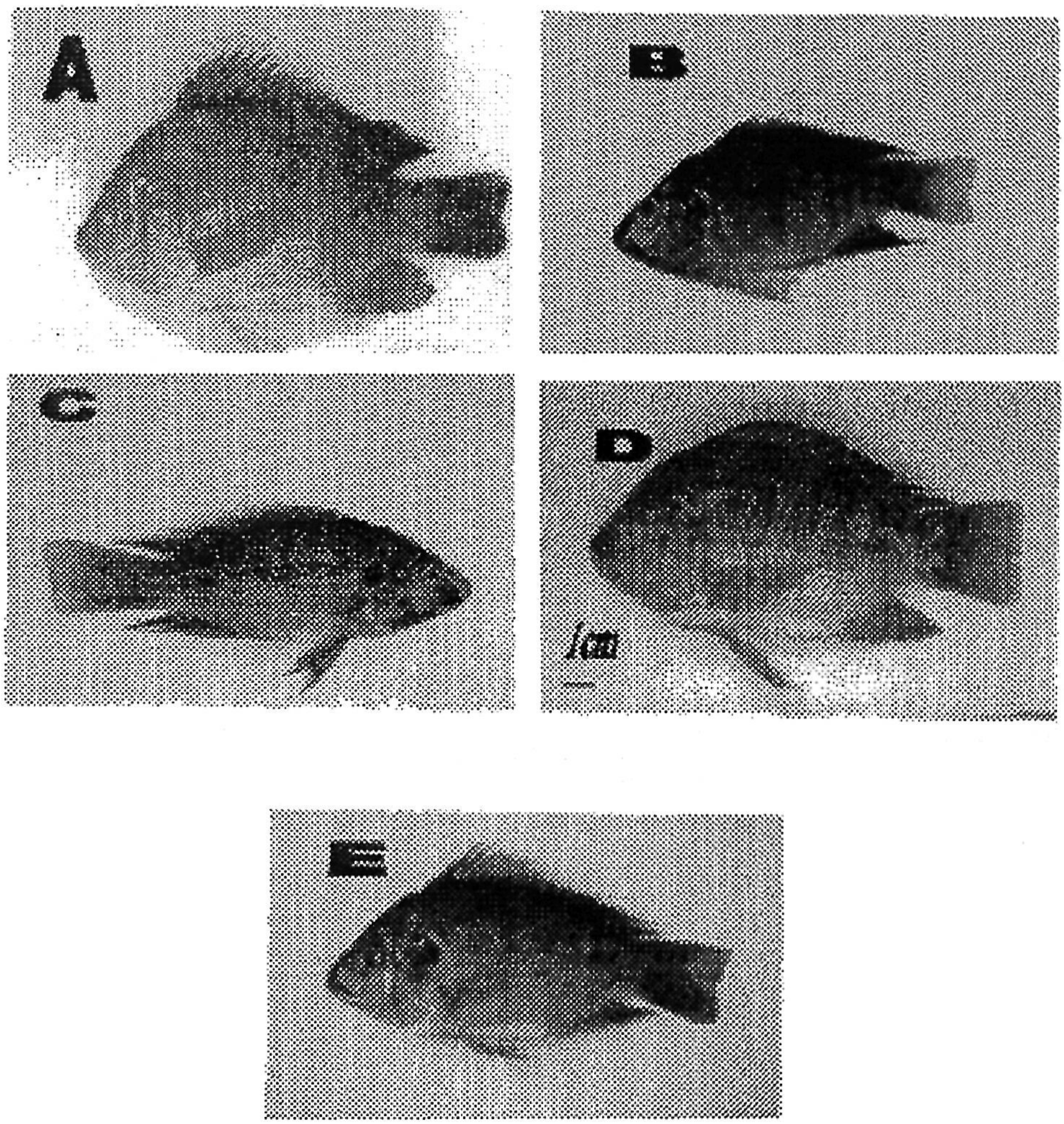

Fig.(1): Photographs of (A) Nile tilapia; (B) blue tilapia; (C) hybrid1; (D) hybrid2 and (E) hybrid3.

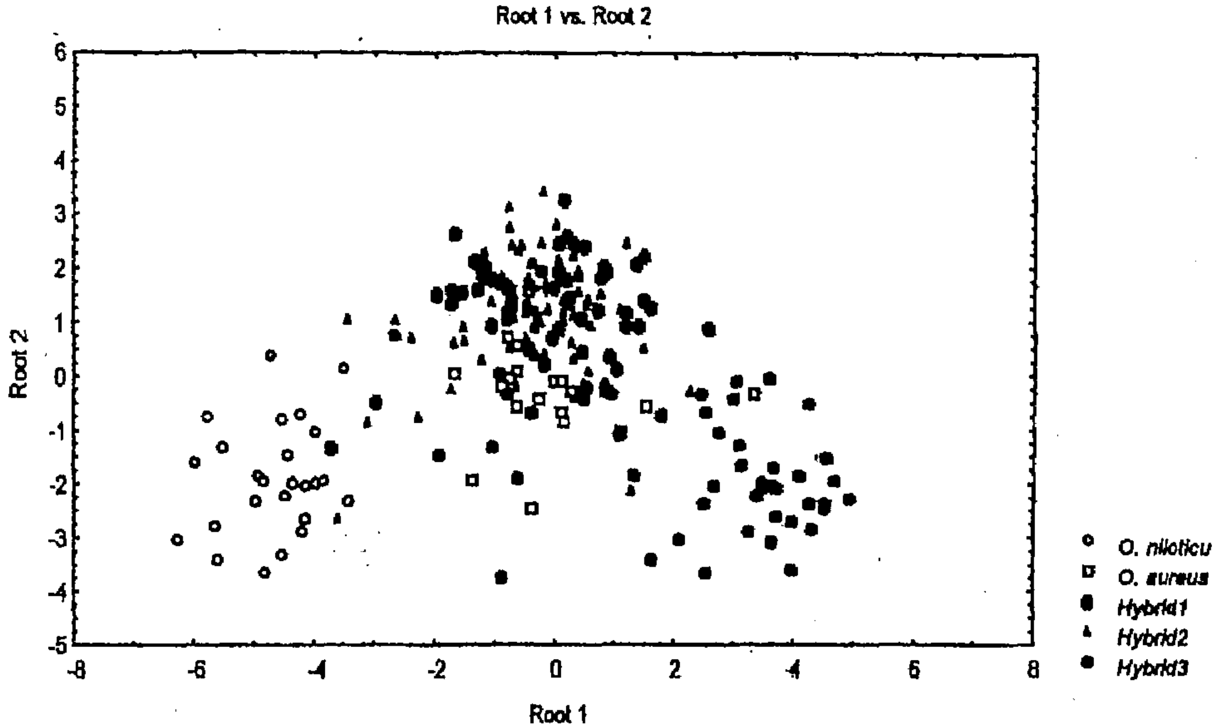

Fig.(2): Plot of the first two canonical discriminate-factor scores of meristic and morphometric characters for *O. niloticus*; *O. aureus* and hybrid specimens collected from Lake Edku.