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Biometric investigation on *Gobio gobio* subspecies from Turkey

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A b s t r a c t . To this day five *Gobio gobio* subspecies in northern, western and central Anatolia, in Turkey have been classified. Some subspecies were described based on 2-4 specimens by B a t t a l g i l (1942, 1944), L a d i g e s (1960), B ă n ă r e s c u & N a l b a n t (1973), B ă n ă r e s c u (1992), B ă n ă r e s c u (1999). In this study, *Gobio gobio* specimens from the type localities of various running waters and lakes of north, northwest and central Anatolia were collected and ANOVA (analysis of variance), cluster analysis and canonical discriminant analysis were applied to fifty variables (eight meristic and forty-two metric characters derived from thirty-four measured or counted variables) to show the main differences between them. From these statistical analyses, *Gobio gobio* specimens were placed in one of three groups: G1 Beyşehir and Akşehir Lake; G2 Sakarya River Basin, Gerede and Melendiz Stream; G3 İnsuyu Stream, southwards from Tuz Lake. Measurements Standard length/Head height (SL/hH), Head length/Head height (C/hH), Standard length/Head length (SL/C), Predorsal distance/Postdorsal distance (pD/poD), Standard length/Postdorsal distance (SL/poD) and Standard length/ Predorsal distance (SL/pD) were important characteristics for distinguishing the populations of *Gobio gobio*.

Key words: *Gobio gobio* subspecies, ANOVA, canonical discriminant analysis, cluster analysis

Introduction

The formation of a series of subspecies of *Gobio gobio* (Linnaeus, 1758) in Central Anatolia and even of a closely related endemic species (*Gobio hettitorum* Ladiges, 1960) indicates that these elements have been in Anatolia for a long period (K o s s w i g 1955). For Anatolia, two species of the genus *Gobio*, *G. hettitorum* from Göldere, Karaman, central Anatolia (L a d i g e s 1960) and *G. gobio* from north, northwest and central Anatolia, and five subspecies of the species *Gobio gobio*, *G. gobio obtusirostris* Valenciennes, 1844 (from Kızılırmak and Sakarya Drainage, North Anatolia), *G. g. microlepidotus* Battalgil, 1942 (restricted to Lake Beyşehir, central Anatolia, B a t t a l g i l (1942)), *G. g. intermedius* Battalgil, 1944 (restricted to Lake Eber and Akşehir, central Anatolia, B a t t a l g i l (1944)), *G. g. gymnostethus* Ladiges, 1960 (restricted to Kızılçay, Melendiz-Niğde, central Anatolia) and *G. g. insuyanus* Ladiges, 1960 (restricted to Cihanbeyli, southwards from Tuz Lake, central Anatolia (L a d i g e s 1960)) were listed. The known data about these subspecies have remained unchanged until now. The aim of the present study was to clarify the differences between these *Gobio gobio* populations inhabiting central Anatolia by using ANOVA, discriminant analysis and hierarchical cluster analysis. B ă n ă r e s c u (1992), expressed the view that the subspecies from the isolated lake drainage in Central Anatolia are well marked; however we found that Beyşehir and Akşehir populations were grouped as 1 (G1), Sakarya, Gerede, Melendiz populations were similar and grouped as 2 (G2), and İnsuyu was grouped as 3 (G3) according to the more morphological characters, large numbers of specimens and statistical analysis.

Material and Methods

Fish were collected by electrofishing; 60 specimens from Sakarya River, 30 specimens from Gerede, 26 specimens from Melendiz, 11 specimens from Akşehir Lake, 27 specimens from Beyşehir Lake and 41 specimens from İnsuyu stream (Fig. 1). Thirty four morphometric characters (measured according to Bănărescu & Nalbant 1973) and eight meristic characters have been taken into account. A total of 50 variables (8 of them discrete and 42 continous-derived from the morphometric characters) of 195 individuals were analysed. The list of these variables and their main summary statistics are given in Table 1.

To identify whether there were any statistically significant differences between these populations for each characteristic, a one-way analysis of variance (ANOVA) was performed. In cases where ANOVA showed significant differences, SCHEFFE-test of post hoc comparison was applied to 50 variables (Manly 1986).

To determine which variables were the most distinguishing for the analysed populations the canonical discriminant functions analysis, the stepwise procedure for the selection of the important variables, was applied (Jobson 1991, Johnson & Wichern 2002). In the last stage, hierarchical cluster analysis was applied to demonstrate the joining order of the populations.

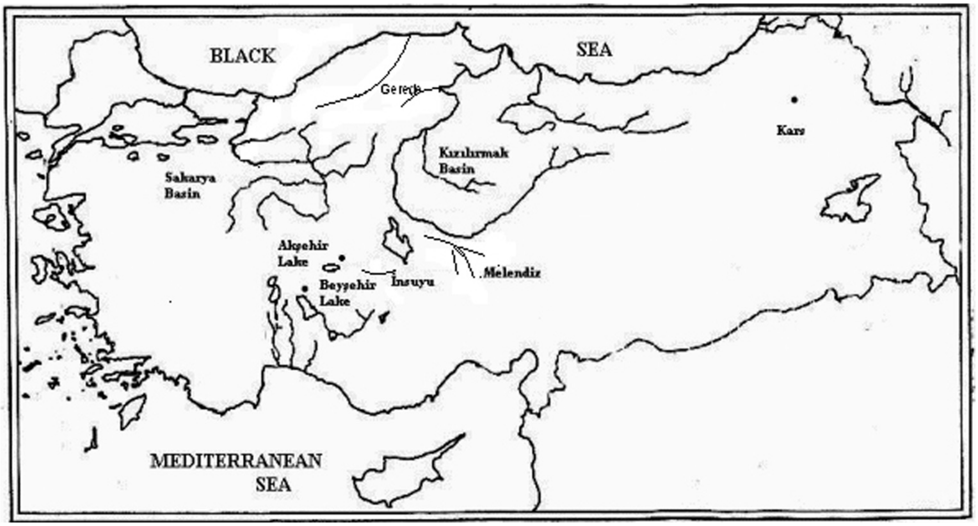

Fig. 1. Map of Turkey and the study area.

Results and Discussion

From the comparison of the specimens inhabiting Sakarya River (Eskişehir), Gerede, Melendiz, Akşehir Lake, Beyşehir Lake and İnsuyu Stream it was found that, except for branched rays of dorsal fin (Q1) and branched rays of ventral fin (Q4), the differences between the six groups' means of 48 variables were statistically significant at the 5% level.

From the ANOVA tests of six population means, İnsuyu is the most different population in 17 (35.4%) characteristics. It shows that, although Beyşehir Lake in 14 (29.2%), Akşehir Lake in four, Sakarya River (Eskişehir) in five, Melendiz in six and Gerede in two cases have the most different characteristics, İnsuyu stream and Beyşehir Lake both have extremely different populations. After the examination of the variables means of the six populations it has been decided that the *Gobio gobio* specimens collected from Sakarya, Melendiz and Gerede were approximately same especially due to the values of the SL/uM, SL/lM, SL/r, SL/pD, SL/poD, SL/pV, SL/P-V, SL/V-A, SL/pA , SL/lCp, C/r, o/io, o/r, o/poO, hB/lCp, A(Branched rays of anal fin), L.lat., L.trans.1 and L.trans.2.characteristics.

However, the individuals from Akşehir and Beyşehir Lake were similar because of the values of SL/o, SL/lA, SL/poD, SL/P-V, SL/V-A, C/hH, hB/hCp, C/io, C/r, o/io, o/r, o/poO, uM/ci, lM/ci, P-V/V-A, L.lat. , L.trans.1 and L.trans.2 characteristics. İnsuyu stream had separate populations among them (Table 2). Then in the second step of the statistical analysis canonical discriminant analysis was applied to 50 characteristics (meristic and metric) of six populations, to show the similarity or dissimilarity of these groups. Further by using the stepwise variable selection method SL/hH, SL/uM, SL/r, SL/poD, SL/hD, SL/hA, SL/pD, SL/poD, SL/pA, hB/hCp, lm/ci, the following were chosen as significant variables: Branched rays of anal fin (Q2), Branched rays of pectoral fin (Q3),Number of scales on line lateral (Q5), Number of scales between line lateral-dorsal fin (Q6) and Gill rankers on the first arch (Q7). According to the extracted (five significant) discriminant functions and their group centroids, the correct classification rate of the analysis was 93.8% (12 of the 195 observation were misclassified). From the five significant discriminant functions, coefficient scores of the 195 observations of six populations are given in Fig. 2. According to five extracted discriminant functions :

- One of the Beysehir group observation was misclassified into the Aksehir group due to the similar values of the characters SL/poD, hB/hCp, lM/ci, L.lat. and L.trans.1.

- Two of the Sakarya group observations were misclassified into the Gerede group, two of the Melendiz group observatios were misclassified into the Gerede group, five of the Gerede group observations were misclassified into the Sakarya group and two of them into the Melendiz group due to similar values of the characters SL/uM, SL/pD, SL/pA and branched rays of anal fin.

Because of the high misclassification rate given above, ANOVA tests were applied again for three groups (Akşehir-Beyşehir, Sakarya-Gerede-Melendiz, İnsuyu) and it was found that except for SL/hB(X5), SL/ci(X11), SL/lA(X15), branched rays of dorsal fin (Q1) and branched rays of ventral fin (Q4), the differences between the three group means of 45 variables were statistically significant at the 5% level. According to ANOVA results:

G1 differed from G2 in characteristics X6 (SL/hCp), X7 (SL/o), X9 (SL/r), X14 (SL/hA), X17 (SL/lP), X18 (SL/pD), X19 (SL/poD), X20 (SL/pV), X21 (SL/poV), X22 (SL/P-V), X23 (SL/V-A), X28 (hB/hCp), X29 (C/o), X31 (C/r), X34 (o/io), X35 (o/r), X39 (hB/lCp), X40 (pV(poV), X41 (pD/poD), X42 (P-V/V-A), Q5 (L. lat), Q6 (L.trans. 1), Q7 (L. trans. 2), Q8 (Gr).

G1 differed from G3 in characteristics X1 (SL/C), X2 (SL/hH), X3 (SL/uM), X4 (SL/lM), X6 (SL/hCp), X7 (SL/o), X8 (SL/io), X9 (SL/r), X10 (SL/poO), X12 (SL/hD), X13 (SL/lD), X16 (SL/lV), X17 (SL/lP), X18 (SL/pD), X19 (SL/poD), X20 (SL/pV), X21 (SL/poV), X22 (SL/P-V), X23 (SL/V-A), X24 (SL/pA), X25 (SL/lCp), X26 (C/hH), X27 (um/lM), X28 (hB/hCp), X29 (C/o), X30 (C/io), X31 (C/r), X34 (o/io), X35 (o/r), X36 (o/poO), X37 (uM/ci), X38 (lM/ci), X39 (hB/lCp), X40 (pV(poV), X41 (pD/poD), X42 (P-V/V-A), Q2 (A),Q3 (P), Q5 (L. lat), Q6 (L.trans. 1), Q7 (L. trans. 2).

G2 differed from G3 in characteristics X1 (SL/C), X2 (SL/hH), X3 (SL/uM), X4 (SL/lM), X6 (SL/hCp), X8 (SL/io), X9 (SL/r), X10 (SL/poO), X12 (SL/hD), X14 (SL/hA), X16 (SL/lV),

Table 1. List of the variables used in analyses.

Var	Sym.	Description	Min	Max	Mean	S.D.
X1	SL/C	Standard length/Head length	3.13	4.01	3.588	.1632
X2	SL/hH	Standard length/Head height	4.72	7.23	5.821	.4645
X3	SL/uM	Standard length/Length of upper jaw	11.0	17.67	14.147	1.4074
X4	SL/lM	Standard length/Length of lower jaw	13.75	21.71	16.901	1.4721
X5	SL/hB	Standard length/Body height	3.50	6.01	4.549	.3997
X6	SL/hCp	Standard length/Height of caudal peduncle	8.17	13.62	9.836	.8956
X7	SL/o	Standard length/Longitudinal eye diameter	12.71	21.25	17.015	1.5750
X8	SL/io	Standard length/Interorbital distance	9.18	16.00	12.909	1.0091
X9	SL/r	Standard length/Preorbital length	7.91	11.18	8.996	.6080
X10	SL/poO	Standard length/Postorbital length	6.21	9.26	7.666	.4767
X11	SL/ci	Standard length/Barbel length	8.75	18.18	12.770	1.6296
X12	SL/hD	Standard length/Height of dorsal fin	3.62	5.29	4.266	.2587
X13	SL/lD	Standard length/Length of dorsal fin	4.00	10.00	7.006	.5877
X14	SL/hA	Standard length/Height of anal fin	4.81	6.75	5.621	.4283
X15	SL/lA	Standard length/Length of anal fin	8.64	15.38	11.268	1.1033
X16	SL/lV	Standard length/Length of ventral fin	5.00	7.41	5.944	.4101
X17	SL/lP	Standard length/Length of pectoral fin	4.14	6.79	5.010	.4473
X18	SL/pD	Standard length/Predorsal distance	1.96	2.48	2.187	.0883
X19	SL/poD	Standard length/Postdorsal distance	2.28	3.35	2.733	.1792
X20	SL/pV	Standard length/Preventral distance	1.43	2.37	2.044	.0999
X21	SL/poV	Standard length/Postventral distance	1.92	2.54	2.252	.1063
X22	SL/P-V	Standard length/Pectoventral distance	3.89	7.35	5.026	.5685
X23	SL/V-A	Standard length/Ventral-Anal distance	4.59	7.45	5.750	.5243
X24	SL/pA	Standard length/Preanal distance	1.34	1.56	1.454	.0396
X25	SL/lCp	Standard length/Length of caudal peduncle	9.38	19.50	12.64	1.8051
X26	C/hH	Head length/Head height	1.38	1.97	1.622	.1033
X27	uM/lM	Length of upper jaw/Length of lower jaw	1.03	1.41	1.198	.0733
X28	hB/hCp	Body height/ Height of caudal peduncle	1.68	2.87	2.171	.2119
X29	C/o	Head length/Longitunal eye diameter	3.75	5.98	4.744	.4118
X31	C/r	Head length/Preorbital length	2.22	3.00	2.507	.1383
X32	C/poO	Head length/Postorbital length	1.92	2.45	2.137	.1041
X33	C/ci	Head length/Barbel length	2.49	5.06	3.563	.4598
X34	o/io	Longitudinal eye diameter/Interorbital dist.	.49	1.18	.764	.0875
X35	o/r	Longitudinal eye diameter /Preorbital length	.38	.78	.533	.0651
X36	o/poO	Longitudinal eye diameter /Postorbital length	.35	.59	.454	.0465
X37	uM/ci	Length of upper jaw /Barbel length	.64	1.35	.911	.1459
X38	lM/ci	Length of lower jaw /Barbel length	.56	1.11	.759	.1084
X39	hB/lCp	Body height/ Length of Caudal peduncle	.36	.85	.602	.0934
X40	pV/poV	Preventral distance/Postventral distance	.85	1.62	1.105	.0918
X41	pD/poD	Predorsal distance/Postdorsal distance	.99	1.65	1.252	.1093
X42	P-V/V-A	Pectoventral distance /Ventral-Anal distance	.68	1.64	1.157	.1584
Q1	D	Branched rays of dorsal fin	6.00	7.00	6.994	.0716
Q2	A	Branched rays of anal fin	5.00	7.00	6.164	.4232
Q3	P	Branched rays of pectoral fin	11.00	17.00	13.842	.9880
Q4	V	Branched rays of ventral fin	5.00	8.00	6.933	.3057
Q5	L.lat.	Number of scales on line lateral	39.00	55.00	42.148	2.2689
Q6	L.trans.1	Transversal scales (upper part)	4.50	8.50	6.359	1.0658

Q7	L.trans.2	Transversal scales (lower part)	3.50	7.50	5.025	.7716
Q8	Gr	Gill rakers on the first arch	7.00	13.00	10.923	1.3467

Table 2. Summary statistics and the results of analyses (six and three groups cases).

Six groups			Three groups		
Var	Sig.	M.D.S.	Sig.	Different Species	M.D.S.
X1	0.000	I	0.000	G1-G3;G2-G3	G3
X2	0.000	M	0.000	G1-G3;G2-G3	G3
X3	0.000	I	0.000	G1-G3;G2-G3	G3
X4	0.000	I	0.000	G1-G3;G2-G3	G3
X5	0.000	M	0.192	--------	---
X6	0.000	B	0.000	G1-G2;G1-G3;G2-G3	G1
X7	0.000	M	0.000	G1-G2;G1-G3	G1
X8	0.000	I	0.000	G1-G3;G2-G3	G3
X9	0.000	B	0.000	G1-G2;G1-G3;G2-G3	G3
X10	0.000	M	0.000	G1-G3;G2-G3	G3
X11	0.000	M	0.144	--------	---
X12	0.000	I	0.000	G1-G3;G2-G3	G3
X13	0.000	A	0.011	G1-G3	G1
X14	0.000	G	0.000	G1-G2;G2-G3	G2
X15	0.000	G	0.055	-------	----
X16	0.000	I	0.000	G1-G3;G2-G3	G3
X17	0.000	B	0.001	G1-G2;G1-G3	G1
X18	0.000	B	0.000	G1-G2;G1-G3;G2-G3	G1
X19	0.000	I	0.000	G1-G2;G1-G3;G2-G3	G3
X20	0.000	B	0.000	G1-G2;G1-G3;G2-G3	G1
X21	0.000	B	0.000	G1-G2;G1-G3;G2-G3	G1
X22	0.000	B	0.000	G1-G2;G1-G3	G1
X23	0.000	A	0.000	G1-G2;G1-G3	G1
X24	0.000	B	0.000	G1-G3;G2-G3	G3
X25	0.000	B	0.000	G1-G3;G2-G3	G3
X26	0.000	I	0.000	G1-G3;G2-G3	G3
X27	0.020	B	0.004	G1-G3;G2-G3	G3
X28	0.000	M	0.000	G1-G2;G1-G3;G2-G3	G1
X29	0.000	I	0.000	G1-G2;G1-G3;G2-G3	G3
X30	0.000	I	0.000	G1-G3;G2-G3	G3
X31	0.000	B	0.000	G1-G2;G1-G3	G1
X32	0.000	S	0.000	G2-G3	G2
X33	0.001	A	0.005	G2-G3	G2
X34	0.000	I	0.000	G1-G2;G1-G3;G2-G3	G3
X35	0.000	B	0.000	G1-G2;G1-G3;G2-G3	G1
X36	0.000	I	0.000	G1-G3;G2-G3	G3
X37	0.000	I	0.000	G1-G3;G2-G3	G3
X38	0.000	I	0.000	G1-G3;G2-G3	G3
X39	0.000	I	0.000	G1-G2;G1-G3;G2-G3	G3
X40	0.000	B	0.000	G1-G2;G1-G3;G2-G3	G1
X41	0.000	I	0.000	G1-G2;G1-G3;G2-G3	G3
X42	0.000	B	0.000	G1-G2;G1-G3	G1

Q1	0.590	----	0.153	------	----
Q2	0.000	I	0.000	G1-G3;G2-G3	G3
Q3	0.000	A	0.000	G1-G3;G2-G3	G3
Q4	0.159	----	0.430	--------	-----
Q5	0.000	S	0.000	G1-G2;G1-G3;G2-G3	G1
Q6	0.000	S	0.000	G1-G2;G1-G3;G2-G3	G2
Q7	0.000	S	0.000	G1-G2;G1-G3;G2-G3	G2
Q8	0.000	S	0.000	G1-G2;G2-G3	G2

Var: Variable, Sig.: Significance, M.D.S.: Most Different Species, S: Sakarya, A: Akşehir, B: Beyşehir, M: Melendiz, G: Gerede, I: İnsuyu, G1 (A-B), G2 (S-G-M), G3 (I).

Table 3. Canonical discriminant functions coefficients.

	Standardized functions			Unstandardized functions	
Var.	Fun.1	Fun.2	Effect(%)	Fun.1	Fun.2
X1	4.182	3.284	16.029	26.712	20.975
X2	-5.773	-5.256	23.369	-14.686	-13.372
X3	.481	.249	1.623	.479	.248
X14	-.355	-.120	1.088	-.905	-.306
X16	-.021	-.473	.865	-.056	-1.250
X17	.105	.439	.995	.242	1.012
X18	-1.172	2.445	7.112	-14.657	30.566
X19	.992	-3.499	8.476	6.613	-23.314
X22	-.118	.277	.769	-.239	.562
X26	5.335	4.578	21.116	58.491	50.190
X28	.015	.403	.729	.078	2.152
X41	-1.598	3.924	10.711	-18.351	45.059
Q2	-.468	-.152	1.423	-1.531	-.496
Q3	-.051	-.324	.684	-.055	-.349
Q5	-.263	.336	1.230	-.171	.219
Q6	-.693	.603	2.757	-1.166	1.015
Q7	240	-.237	1.003	.384	-.380
Constant				-46.893	-151.219

Table 4. Functions at group centroids.

	Function	Function
REGION	1	2
1.00	-1.134	4.211
2.00	1.770	-.680
3.00	-3.958	-1.979

Unstandardized canonical discriminant functions evaluated at group means

X18 (SL/pD), X19 (SL/poD), X20 (SL/pV), X21 (SL/poV), X24 (SL/pA), X25 (SL/lCp), X26 (C/hH), X27 (um/lM), X28 (hB/hCp), X29 (C/o), X30 (C/io), X32 (C/poO), X33 (C/ci), X34 (o/io), X35 (o/r), X36 (o/poO), X37 (uM/ci), X38 (lM/ci), X39 (hB/lCp), X40 (pV(poV), X41 (pD/poD), X41 (pD/poD), Q2 (A),Q3 (P), Q5 (L. lat), Q6 (L.trans. 1), Q7 (L. trans. 2), Q8 (Gr).

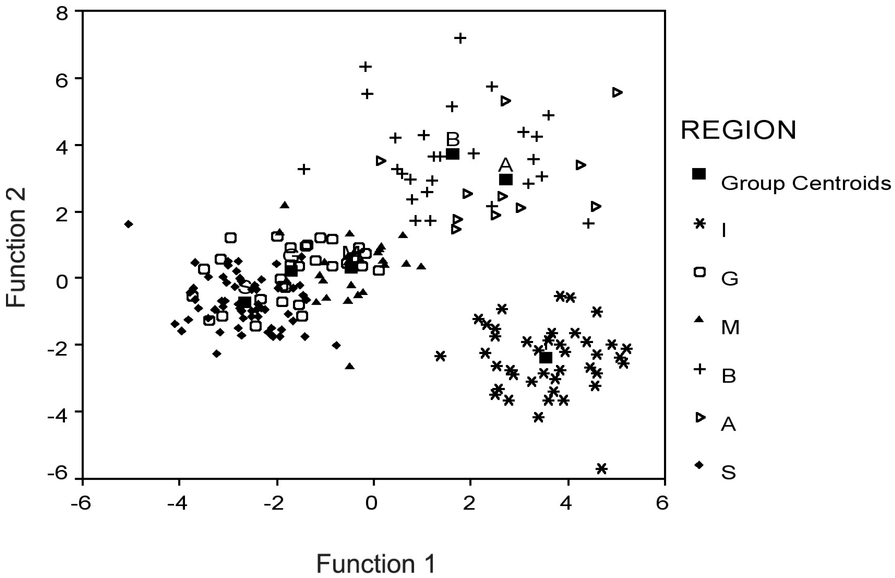

Fig. 2. Canonical discriminant functions scores of the observations (nine group case).

Also from Table 2, Akşehir-Beyşehir (G1) is the most different population in 15 (33,3%) characters such as SL/hCp (X6), SL/o (X7), SL/lD (X13), SL/lP (X17), SL/pD (X18), Sl/pV (X20), SL/poV (X21), SL/P-V (X22), SL/V-A (X23), hB/hCp (X28), C/r (X31), o/r (X35), pV/poV (X40), P-V/V-A (X42) and number of scales on line lateral (Q5).

İnsuyu (G3) is the most different population in 24 (53.3%) characters such as Sl/C (X1), Sl/hH (X2), Sl/uM (X3), SL/lM (X4), SL/io (X8), SL/r (X9), SL/poO (X10), SL/hD (X12), SL/lv (X16), SL/poD (X19), SL/pA (X24), SL/Icp (X25), C/hH (X26), uM/lM (X27), C/o (X29), C/io (X30), o/io (X34), o/poO (X36), uM/ci (X37), lM/ci (X38), hB/lCp (X39), pD/poD (X41), branched rays of anal fin(Q2) and branched rays of pectoral fin (Q3).

Finally Sakarya-Gerede-Melendiz (G2) is the most different population in 6 (13.3%) characters such as SL/hA (X14), C/poO (X32), C/ci (X33), transversal scales (upper part) (Q6), transversal scales (lower part) (Q7) and gill rakers on the first arch (Q8).

According to the above reason, canonical discriminant analysis was applied again for three groups case and two significant discriminant functions were derived. While the first one explained 54.3% of the variance and the second explained 45.7%. The list of the seventeen chosen variables and the standardized and unstandardized coefficients of the variables in two functions are given in Table 3.

The unstandardized coefficients used to allocate observations (according to their score values) to one of the existing groups in the data set, and standardized coefficients used to evaluate the weights of the variables in discrimination were analyzed. From the unstandardized coefficients (Table 3), the values of functions at group centroids of three populations were calculated (Table 4).

Canonical discriminant function scores, calculated from the same equations (unstandardized function coefficients) are given in Fig. 3. According to the extracted discriminant functions and their group centroids, the correct classification rate of the analysis was 100%.

Although the Central Anatolia lake drainage system is accepted as an isolated lake system, there is a connection between some of these lakes and running waters by the chasms and subterranean waters. Although according to the ANOVA tests there are significant differences

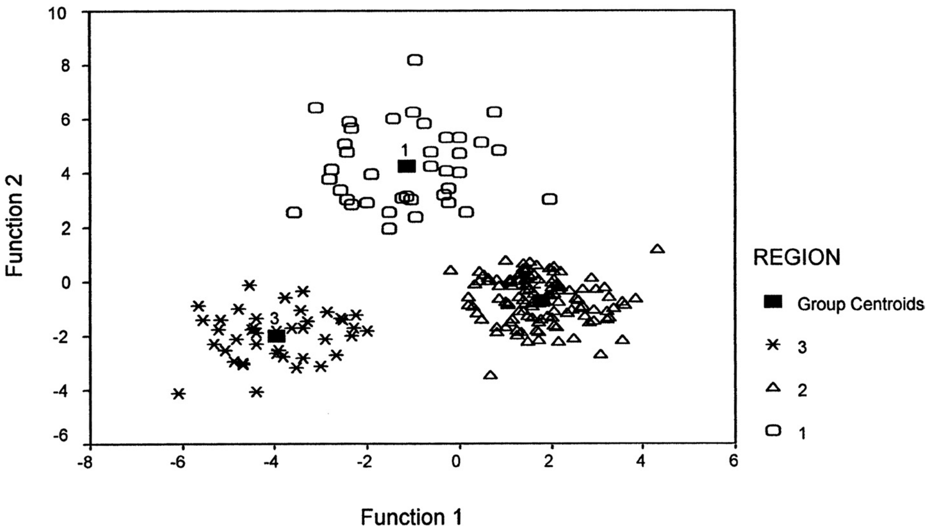

Fig. 3. Canonical discriminant functions scores of the observations (four group case).

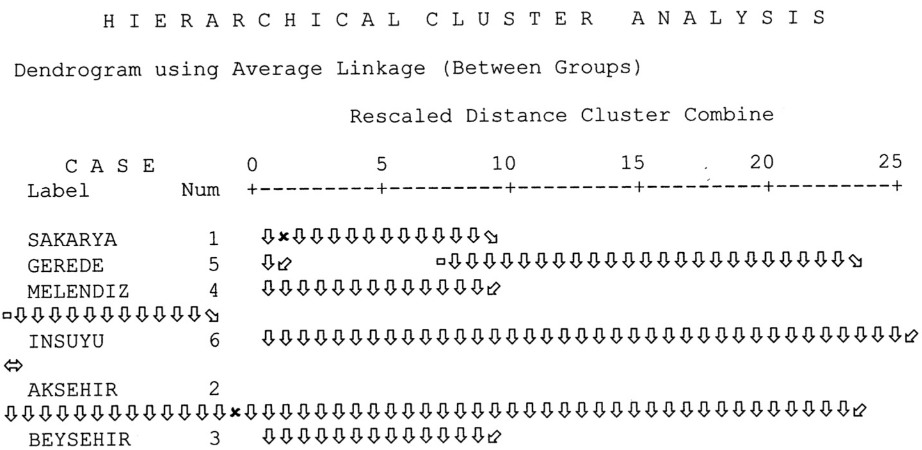

Fig. 4. Dendrogram of hierarchical cluster analysis.

between the populations, the discriminant analysis revealed that the observations of the specimens from Sakarya-Gerede-Melendiz and specimens from Akşehir-Beyşehir lakes are very similar. According to B ă n ă r e s c u (1992), *G. g. gymnostethus* occurs in Niğde, Kızılçay and the description of this subspecies was based on only four specimens and scales on the lateral line. In our study, we collected this subspecies from Melendiz, Niğde and found that this group is very close to Sakarya group. Geographically, Melendiz Stream is connected with the Kızılırmak River Basin and there are no exact geographic boundaries. Likewise, the Akşehir population is included in the Beyşehir population for the same reason given above. Geographically, there may be some connection between Lake Akşehir and Beyşehir by chasms.

It can also be seen from the results of the analyses (ANOVA tests and discriminant analysis) and the dendrogram of hierarchical cluster analysis (Fig.4), that the İnsuyu Stream stream is the most different population both in terms of meristic and metric characteristics. The

Insuyu Stream is a spring water and this stream is isolated and does not reach any river and lake drainage system.

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