

## Morphological differences among the *Garra variabilis* populations (Cyprinidae) in Tigris River system of South East Turkey

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### Abstract

In this study, by examining the character of the morphometric and meristic characters of *Garra variabilis* samples which is obtained from different locality in Tigris River, morphometric characters which are transformed, subjected to discriminant analysis and depending on grouping model, number of discriminant functions and according to importance of these in terms of explaining total variance, morphological variance among populations are determined. Success rate of classifying the groups according to the discriminant analysis of meristic characters of *G. variabilis* individuals appeared as 49.3 %. Kulp and Kayser Stream from the locality groups, showed similar dispersion. It is determined that there is high variation between the locality groups belonging the samples of *G. variabilis* according to the morphometric and meristic characters.

**Keywords:** *G. variabilis*, Tigris River, Morphological, Discriminant analysis, Cyprinidae.

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## Introduction

Meristic and morphometric characters are strong means to measure and distinguish interstock relations. (Ihsen and ark., 1981 ; Melvin ve ark., 1992). First researchers used descriptive and univariate analysis on each meristic and morphometric character but these don't give always efficient result.

Measurement of morphological characters applied widely to the systematics and classes of the fishes. Morphometric variation is used to determine the hybrid ones and differentiate the similar ones (Carlson and Ark., 1985). Morphological characters and geographical change's samples can be effected from phylogenesis and current ecological environments. (Thorpe, 1987)

Most of morphological characters of a fish is directly about physical characteristics of an environment. Therefore, local change of the morphology can be affected from environmental changes. Interspecific comparisons reveal that some variables that express body and fin shapes can be associated with their environments and water speed for the importance of swimming. (Nikolski, 1933; Gatz, 1979; Scarnecchia, 1988)

A fish's environment in which it has survived has significant effect on phenotype of the fish. Factors such as water temperature, salinity, swimming trainings, existence of food and ingredient of food in different developmental periods can modify external morphology of a fish. To understand the integrated character of

phenotypic plasticity, necessitates the study of the extent of the environment of the earlier times on phenotype of the later life periods.

Phenotypic plasticity that responds speed of water is commonly known by the morphologic characters of the individuals. Graylings of river origin usually have shorter pectoral fins and caudal pedicle in high water flow, yet middle of the body is extended in high flow in accordance with low flow. Because of this, in high and low flows, the differences that are observed in caudal pedicle fields and middle of the body of river fishes can indicate different swimming desires in different flow forms. Morphometric variation is used to determine the hybrid fish species and differentiate the similar ones. (Carlson and Ark., 1985) Morphological characters and geographical change's samples can be effected from phylogenesis and current ecological environments. (Thorpe, 1987)

Many freshwater fish species were categorized by populations that are in geographically different locations such as lakes, rivers, streams and rocky ponds. In this various habitats, significantly common biologic adaptations were developed in different behavioral characters, morphology and physiology. (Weigensberg and Roff 1996, Hoffmann, 2000) Geographic isolation can end up with the development of separate morphologic characters between fish populations. Because environment, selection and genetics' interactive effects on

individual organisms may cause morphometric differences for a specific specie. (Cadrin, 2000) Several natural process may result in phenotypical differences between populations. Differences can be adaptive, coming from different selection pressures which are moving on transferable characters. (Merila and Crnokrak, 2001)

It is inevitable for any specie that demonstrates a wide distribution to show some genetic variations with different ecological conditions of the river system in which they live in. On Tigris River system, there are some barrages constructed for irrigation and electricity. These barrages bring forth isolated fragments in the river basin. Therefore, between the distributed *G. variabilis* (Heckel, 1843) specie's samples on Tigris River system, which were caught from 4 different localities that are disconnected or far from each other, morphometric and meristic variations were tried to determine by discriminant analysis.

### Materials and methods

*G. variabilis* samples were obtained from 4 different localities (Devegeçidi Barrage, Göksu Stream, Savur Stream and Tigris River) by using extension bunt, cover net and electro-shocker. Samplings were made between

September 2007 and April 2008. Fish samples were brought to laboratory inside 5-6 % formaldehyde. Determined samples were preserved in 70 % alcohol. In order to determine the morphological characters of the fish samples, measurements of morphometric characters and counting of meristic characters were made.

26 morphological variance which are about morphometric characters are measured by sensitive 0.01 mm electronic compass and in this measurement Truss network method (Schaefer, 1991 ; Turan and ark, 2004; Tzeng, 2004; Çakmak and Alp, 2010; Bilici, 2015) has been used (Fig. 1). About countable meristic characters, totally 13 different variances have been used: numbers of dorsal opined fin (DFRS-A) Dorsal Furcated Fin Ray (DFRS-B), Ventral Spined Fin Ray (VFRS-A), Ventral Frucrated Fin's Ray (VFRS-B), Anal Opined Fin Ray (AFRS-A), Anal Branched Fin Ray (AFRS-B), Pectoral Fin in Left Spined Ray (PFRSA-L), Pectoral Fin in Left Furcated Ray (PFRSB-L), Pectoral Fin in Right Spined Ray (PFRSA-R), Pectoral Fin in Right Furcated Ray (PFRSB-R), Number of Gill Arch Spine (GRS), Lateral Line in Left Number of Scale (LLS-L) and Lateral Line in Right Number of Scale (LLS-R).



**Figure 1: Demonstration of morphometric characters on *G. variabilis*.**

In order to determine morphologic variations between *G. variabilis* populations; by calculating all the morphometric characters to standard length (SL), we tried to eliminate variations that are derived from length. Transformed morphometric characters are subjected to discriminant analysis and according to grouping model, discriminant function numbers and morphologic variation between populations with respect to their importance of explaining total variation are determined. Features that provide the classifications and their effective functions were determined. In two dimensions; based on two different discriminant functions, the place of discriminant functions are determined. The features of classification and their influential functions are determined with stepwise analysis. With the help of canonical discriminant function, the limit maps of the groups in a two dimensional platform are created. Among the distinguished groups, the place of group medium (group centers)

is detected (Turan and ark., 2004; Çakmak and Alp, 2010). Similar applications about discriminant analysis are also applied for countable meristic characters. Morphometric and meristic variations between *G. variabilis* populations are shown on plot charts. Furthermore, morphometric differences between populations are analyzed with variation analysis and F test.

### Results

In order to investigate morphologic differences of *G. variabilis* populations in Tigris River; 17 individuals from Devegeçidi Barrage, 8 from Göksu, 29 from Savur Stream and 21 from Tigris River, in total 75 *G. variabilis* individuals are analyzed. The standard heights of the samples are between 80 - 140 cm and the height difference between populations is seen statistically insignificant ( $p>0.05$ ). The standard height belonging to populations and morphometric characters that arecalculated as the percentage of standard height are given in Table 1. In

terms of morphometric characters of *G. variabilis*, between SL/SNL, SL/OHD, SL/OVD, SL/UJL, SL/LJL, SL/POHL, SL/PFL, SL/BD, SL/BW, SL/PDFL, SL/PEFL, SL/BDA, SL/AFL, SL/CPL, SL/LD, SL/LUCFL, SL/LMCFR, SL/LLCFL, UJL/LJL, BD/BDA and LUCFL/LLCFL variations, differences were seen significant. ( $p < 0.05$ )

From 9 of morphometric characters : SL/LJL, SL/HL, SL/PDFL, SL/PPEFL, SL/LMCFL, SL/LLCFL, OVD/OHD, HL/HD, PFL/PEFL were more determinant to reveal the variations. This variation is originated from all 3 locality groups.

From 9 of morphometric characters, especially 5 of them : SL/OHD, SL/LJL, SL/PFL, SL/BD, SL/PPEFL were more determinant to reveal the variations. In addition to this; between other variations, no differences were found. ( $p > 0.05$ )

From 13 countable meristic characters belonging to populations, 2 of them were different from the others among populations (Table 2). The mentioned difference is based on GRS, L.L.S.(R) characteristics ( $p < 0.05$ ). In addition to this, no differences were found between other variations. This difference is more significant in Savur Stream locality.

According to the result of discriminant analysis which is applied to the transformed morphometric

characters that are obtained from 75 *G. variabilis* individuals belonging 4 different populations, 3 discriminant function corresponded to 100 % of total variation. Hence 3 function was considered and 1. separation group generates 82.8 % (Canonical Correlation = 0.916) of total variation, 2. Separation group generates 9.4 % (Canonical Correlation = 0.574) of total variation and 3. Separation group generates 7.8 % (Canonical Correlation = 0.574) of the rest variation. Canonical discriminant

In the discriminant analysis, for the 1<sup>st</sup> function (DF1), L. L.S.(R), L.L.S.(L), DFSRB for 2nd function (DF2). (Table 3) Grouping graph that is formed by using DF1 and DF2 scores belonging meristic characters, is shown in Fig. 2b. According to grouping graph; in terms of meristic characters, Tigris River and Kayser Stream localities are different than Kulp Stream localities at the least.

Grouping graph of DF1, DF2 and DF3 scores which is obtained by using discriminant analysis of morphometric characters is given in Fig. 2a. When the grouping graph is analyzed, the individuals belonging Savur and Göksu Streams seem to have different group from other population and each other. The success of discriminant analysis is 86.7 % in terms of morphometric separation of populations.

**Table 1: Morphometric characters of different *G. variabilis* populations in Tigris River.**

Morfometrik Characters	Devegeçidi Barrage (n=17)	Göksu Stream (n=8)	Savur Stream (n=29)	Tigris River (n=21)
SL	1.2104	1.2352	1.2556	1.2424
SNL	9.8878	9.1336	9.2016	9.3517
OHD	25.6910	20.2337	20.9471	24.1687
OVD	25.8290	21.7829	22.1990	23.9625
UJL	18.2857	14.5200	16.7781	16.8033
LJL	9.2036	7.2281	8.7860	8.6803
HL	4.5347	4.4325	4.3318	4.2949
HD	7.4910	7.1947	7.0817	6.8044
POHL	11.5893	11.6073	10.6363	10.0845
PFL	5.9162	5.0856	4.0065	5.7543
BD	4.4124	4.2327	3.9574	3.8336
BW	8.0289	7.6907	7.6382	7.2539
DFL	5.4864	4.9444	4.7837	5.2205
PDFL	2.0214	1.9458	1.9940	1.9754
PEFL	5.9177	5.2577	5.1698	5.5100
PPEFL	1.8717	1.8633	1.8421	1.7776
DPA	4.3513	4.1773	4.1568	4.2609
BDA	5.5010	5.6026	5.4945	5.3076
AFL	6.3984	5.7577	5.5965	6.2553
CPL	5.8270	6.0048	6.0344	5.9121
LD	7.1003	6.9162	6.8297	6.4601
LUCFL	4.6930	4.2290	4.1066	4.4337
LMCFR	7.4080	6.2347	6.1734	6.7027
LLCFL	4.8061	4.3111	4.1074	4.9464

**Table 2: Meristic characters of different *G. variabilis* populations in Tigris River.**

Meristik Characters	Devegeçidi Barrage	Göksu Stream	Savur Stream	Tigris River
DFSR-A	2.0±0.00 (min-max)	2.0±0.00 (min-max)	2.0±0.00 (min-max)	2.0±0.0 (min-max)
DFSR-B	7.0±0.00 (min-max)	7.0±0.00 (min-max)	7.0±0.00 (min-max)	7.0±0.00 (min-max)
VFRS-A	1.00±0.00 (min-max)	1.00±0.00 (min-max)	1.00±0.00 (min-max)	1.00±0.00 (min-max)
VFRS-B	8.00±0.00 (min-max)	8.00±0.00 (min-max)	8.00±0.00 (min-max)	8.00±0.00 (min-max)
AFRS-A	2.00±0.00 (min-max)	2.00±0.00 (min-max)	2.00±0.00 (min-max)	2.00±0.00 (min-max)
AFRS-B	5.00±0.00 (min-max)	5.00±0.00 (min-max)	5.00±0.00 (min-max)	5.00±0.00 (min-max)
PFRSA-L	1.00±0.00 (min-max)	1.00±0.00 (min-max)	1.00±0.00 (min-max)	1.00±0.00 (min-max)
PFRSB-L	12.00±0.00 (min-max)	12.00±0.00 (min-max)	12.00±0.00 (min-max)	12.00±0.00 (min-max)
PFRSA-R	1.00±0.00 (min-max)	1.00±0.00 (min-max)	1.00±0.00 (min-max)	1.00±0.00 (min-max)
PFRSB-R	12.00±0.00 (min-max)	12.00±0.00 (min-max)	12.00±0.00 (min-max)	12.00±0.00 (min-max)
GRS	30.71±1.829 (min-max)	31.50±1.195 (min-max)	29.76±1.215 (min-max)	29.71±0.912 (min-max)
LLS-L	35.29±1.649 (min-max)	35.38±1.685 (min-max)	34.24±1.455 (min-max)	34.81±1.887 (min-max)
LLS-R	35.18±1.590 (min-max)	35.63±1.598 (min-max)	33.86±1.481 (min-max)	35.38±1.431 (min-max)

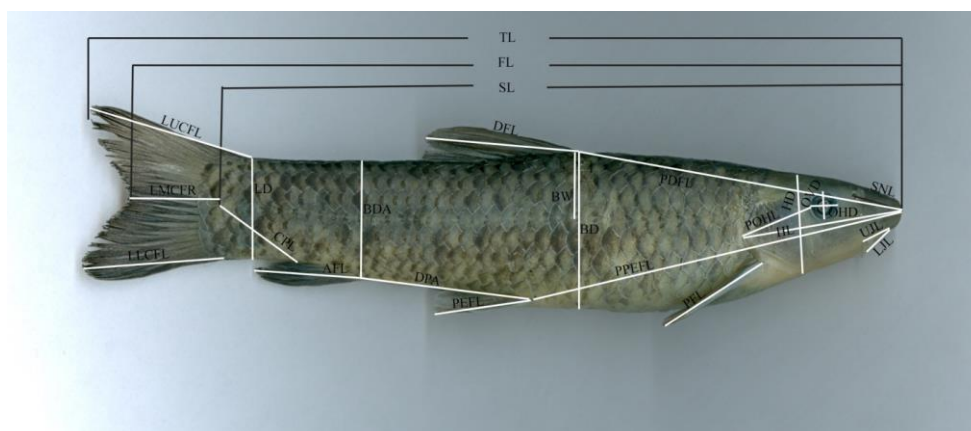


Figure 1-a : Morphometric measurements that is worked on *G. variabilis*.

TL : Total Length 2. FL : Fork Length, 3. SL : Standard Length 4. SNL : Snout Length 5. OHD : Horizontal Ocular Diam 6. OVD : Vertical Ocular Diam 7. USL : Upper Lip Length 8. L JL : Lower lip Length 9. HL : Head Length 10. HD : Head Height 11. POHL : Post Ocular Head Length 12. PFL : Pectoral Fin Length 13. BD : Body Height 14. BW : Body Width 15. DFL : Dorsal Fin Length 16. PDFL : Predorsal Length 17. Pelvic Fin Length 18. PPEFL : Prepelvic Length. 19. DPA : Distance Between Pelvic and Anal Fin 20. BDA Body Height In Anal Level 21. Anal Fin Length 22. CPL : Caudal Pedunculus Length 23. LD : Body Height in Caudal Pudunculus Area 24. LUCFL : Upper Lab Length of Caudal Fin 25. LMCFR : Caudal Fin's Fork's Length 26. LLCFL : Length of Lower Lab of Caudal Fin.

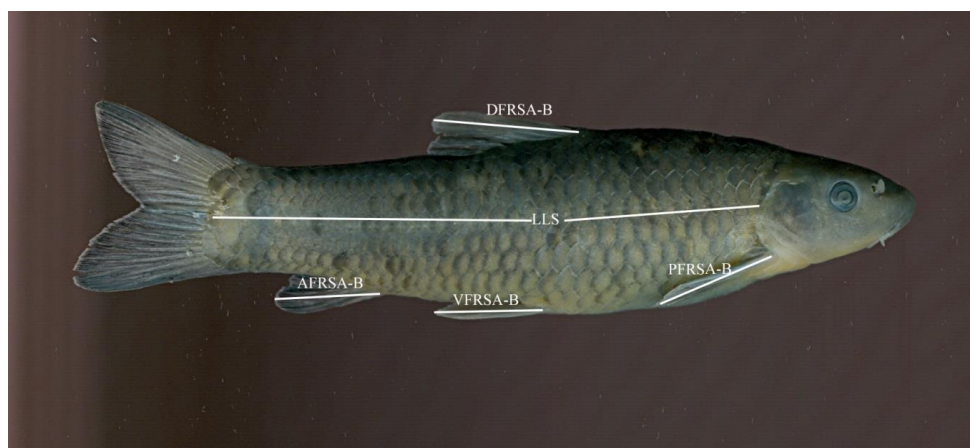


Figure 1-b : Meristic characters worked on *G. variabilis*.

DFRS(A) : Dorsal Ray Score (spine), DFRS(A) : Dorsal Ray Score (branched), VFRS(A): Ventral Ray Score (spine), VFRS(B) : Ventral Ray Score (branched), AFRS(A) : Anal Ray Score (Spine), AFRS(B) : Anal Ray Score (Branched), PFRSA(L) : Pectoral Ray Score (Left part branched), PFRSA(R) : Pectoral Ray Score (Right Part Spine), PFRSB(R) : Pectoral Ray Score (Right Part Branched), GRS : Spine Score of Gill Arch, L.L.S.(L) : Lateral Line Score (Left Part), L.L.S.(R) : Lateral Line Score (Right part).

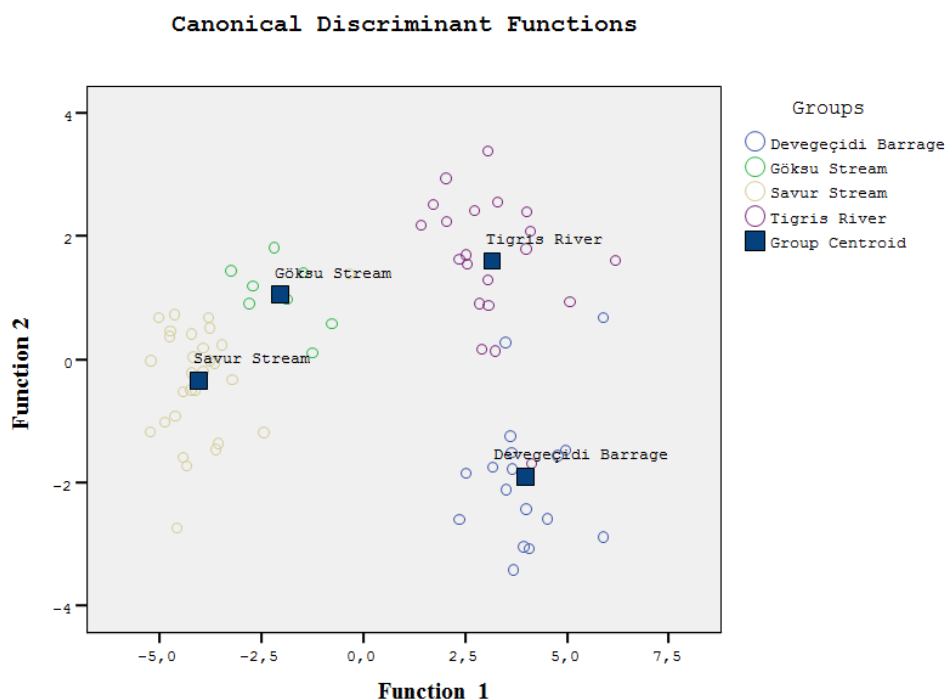


Figure 2-a: Distribution of locality groups according to the morphometric variations of *G. variabilis* specie.

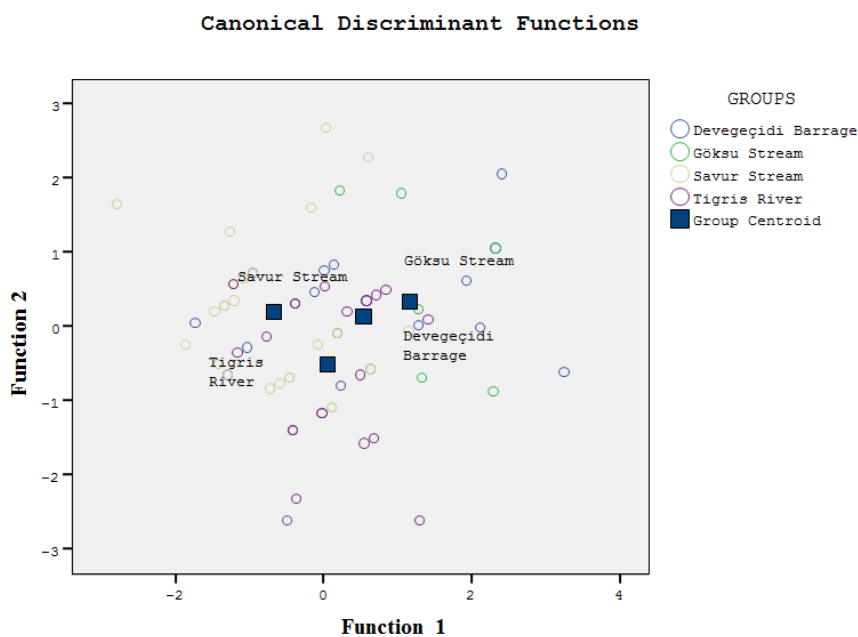


Figure 2- b: The difference between populations and graphing charts of function 1 and function 2 scores found as a result of discriminant analysis.

- a) Discriminant analysis results belonging to morphometric characters
- b) Discriminant analysis results belonging to meristic scores.



In the analysis which is done according to the meristic characters belonging to *G. variabilis* (Heckel, 1843) samples brought from 4 different localities, success rate of separating locality groups in terms of meristic characters is 49.3 %.

As a result of countable meristic characters belonging to *G. variabilis* individual's subjection to discriminant analysis ; since two discriminant functions correspond 100 % of total variation, two functions are considered. The first of them (Discriminant function 1, DF1) forms 78 % of total variation (Canonical Correlation = 0.529) and the second function forms 8.62 % (Canonical Correlation = 0.314) of total variation.

In the discriminant analysis, GRS was important for 1<sup>st</sup> function (DF1) and L. L.S.(R) for 2<sup>nd</sup> function (DF2). (Table 4) Grouping graph that is formed by using DF1 and DF2 scores belonging meristic characters, is shown in Fig. 2b. According to grouping graph ; locality groups of Savur stream are different at the least than the other groups.

In the Fig. 1-a:

In the separation analysis that is made according to the morphometric features of 75 *G. variabilis* samples which are brought from 4 different localities, the separation success of localities group in terms of morphometric features is 86.7 %.

In the evaluation results of separation analysis; while 13 of the 17 samples brought from Devegeçidi Barrage stayed in its own group, 1 of

them stayed in Göksu Stream and 3 of them stayed in Tigris River group. Possibility of the samples brought from Devegeçidi Barrage to be in its own group in terms of studied characters is 76.5 %,  $p = 0.765$ .

While 7 of 8 samples brought from Göksu Stream stayed in its own group, the one transferred to Savur Stream. Possibility of the samples brought from Göksu Stream to be in its own group in terms of studied characters is 87.5 %,  $p = 0.875$ .

While 17 of the 21 samples brought from Tigris stayed in its own group, 4 of them stayed in Devegeçidi Barrage group. Possibility of the samples brought from Tigris River to be in its own group in terms of studied characters is 81 %,  $p = 0.810$ .

28 of 29 samples brought from Savur Stream stayed in its own group and the one stayed in Tigris River group. Possibility of the samples brought from Savur Stream to be in its own group in terms of studied characters is 96.6 %,  $p = 0.966$ .

In the Fig. 1-b:

In the separation analysis made according to some meristic characters of 75 *G. variabilis* samples brought from 4 different localities, success rate of separating localities groups in terms of meristic characters is 49.3 %.

In the evaluation results of discriminant analysis; while 4 of 17 samples brought from Devegeçidi Barrage stays in its own group, 4 of them transferred to Göksu Stream, 7 of them transferred to Savur Stream and 2 of them transferred to Tigris River

group. Possibility of the samples brought from Devegeçidi Barrage to be in its own group in terms of studied characters is 23.5 %,  $p = 0.235$ .

From 8 samples brought from Göksu Stream, 1 of them stays in its own group, 4 of them transferred to Devegeçidi Barrage, 2 of them transferred to Savur Stream and 1 of them transferred to Tigris River group. The possibility of the samples brought from Göksu Stream to be in its own group in terms of studied samples is 12.5 %,  $p = 0.125$ .

From 29 samples brought from Savur Stream ; 23 of them stays in its own group, 2 of them stays in Devegeçidi Barrage group and 4 of them stays in Tigris River group. The possibility of the samples brought from Savur Stream to be in its own group in terms of studied samples is 79.3 %,  $p = 0.793$ .

From the 21 samples brought from Tigris River, 9 of them stays in its own group, 5 of them stays in Tigris river group, 7 of them stays in Savur Stream group. The possibility of the samples brought from Tigris River to be in its own group in terms of studied samples is 42.9%,  $p = 0.429$ .

In conclusion, according to the discriminant analysis of *G. variabilis* individuals belonging to 4 different localities in Tigris River ; in terms of meristic characters, all of the groups show similar distribution and they are not separated clearly. In terms of morphometric characters, they seem to be different to a large extent and most

of the samples of locality groups seem to stay in their own group.

While Devegeçidi Barrage and Tigris River show similar distribution, Savur Stream and Göksu Stream seem to show more similar distribution, we can say that habitat characters of Savur Stream and Göksu Stream groups resemble each other. Even they show very closer distribution, Devegeçidi Barrage and Tigris River group distributions were far from each other in distribution graphs. To have such a result, it seems that Devegeçidi Barrage locality groups were isolated because of Göksu Stream sets.

Especially in terms of morphometric characters ; in discriminant graph, while groups show distribution in their own groups, Savur and Göksu Stream locality groups are closer than the other two groups. It is considered that for the two locality groups stream characters (flow regime, structure bed, structurevalley, vegetation around the physical characters of the water and so on) to be similar, brings out such a result. Despite being very close geographically, Devegeçidi Barrage and Tigris River locality groups are isolated. However they stay close in terms of location in distribution graph.

Morphometric variations have more variation percentage than meristic characters. It seems that morphometric characters which reveals the difference, are in the head part and parts close to head. For the studied specie sample, having body form of the swimming fish species shows that this specie is always moving actively in the water and for

that reason they seem to be more sensitive against the different environmental conditions. In different environmental conditions, it is considered that this specie shows morphometric adaptation well enough.

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