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The geographic isolation impact on evolution of some morpho-physiological features in the brown trout (*Salmo trutta fario* Linnaeus)

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Abstract. The researches made by our team have in view the bio-morphometric study of some brown trout populations. We aimed, on the one hand, to see the geographic and reproductive isolation impact and, on the other hand to highlight the environmental factors' influence on morphological features in this species. The researches have in view three aquatic basins, known as sanctuaries of the brown trout, respectively Someş, Criş and Arieş. For the morphometric study were taken in calculus 14 body dimensions, which allow to analyze on scientific basis the intra-specific variability degree, to which we add also the estimation of some meristic features (number of red or black spots). All data were statistically processed using modern methods thereby the interpretation errors to be more reduced. The results are presented in tables included in our paper.
Key words: brown trout, geographic isolation, morpho-physiological features.

Tartalom. Jelenlevő dolgozatunk, bemutatja kutatómunkánk eredmenyeit, a sebespisztráng bio-morfológiai jellemvonásaira vonatkozoan. Kutatásaink célkitűzése, egyrészt, a földrajzi és szaporodási elzártság befolyása, másrészt pedig a környezeti salyátoságok befolyása a sebespisztráng morfológiai jellemvonásaira. Kutatásainkat három vízrendszerben hajtottuk végre, melyek közismertek a sebespisztráng előhelyeként, névileg ezek a következők: Szamos, Körös és Aranyos. Morfológiai kutatásaink 14 testméret vizsgálására alapoztak, melyek segitségével meghatározhattuk az intra-specifikus változékonyság arányát. Másrészt pedig, megfigyelés alá vetettünk nehány merisztikus vonásokat is (piros és fekete testfoltok száma). Adatainkat, statisztika programba vezettük be, mely segítségével értékes értelmezeseket hozhattunk felméréseinkre, melyeket dolgozatunk tablázataiban szemléltetünk.
Kulcsszavak: sebespisztráng, földrajzi elzárság, morfo-fiziológiai jellemvonások.

Rezumat. Cercetările intreprinse de colectivul nostru au avut în vedere studiul biomorfometric al unor populaţii de păstrăv indigen, pentru a vedea care este impactul izolării geografice şi reproductive, pe de o parte, iar pe de altă parte pentru a evidenţia influenţa factorilor ambientali asupra însuşirilor morfologice la această specie. Cercetările au vizat trei bazine acvatice, cunoscute ca sanctuare ale păstrăvului indigen, respectiv Someş, Criş şi Arieş. Pentru studiul morfometric s-au luat în calcul 14 dimensiuni corporale, care ne-au permis să analizăm pe baze ştiinţifice gradul de variabilitate intraspecifică, la care s-au adăugat şi aprecierea unor însuşiri meristice (număr de pete roşii sau negre). Toate datele au fost prelucrate statistic pe baza metodelor moderne, astfel ca erorile de interpretare să fie cât mai reduse iar rezultatele sunt prezentate în tabelele ataşate lucrării.
Cuvinte cheie: păstrav indigen, izolare geografică, însuşiri morfo-fiziologice.

Introduction. The trout are aquatic being known and consumed from the first contact with the human and it will be sureness in his attention as the life will persist on Earth.

Although the brown trout, economically (Regost et al 2001; Benzie 2002; FAO 2009), ecologically (Moss 2002; Ferguson 2004), scientifically (Jorde & Ryman 1995; Marić et al 2004) and even esthetically, is a very valuable species, it is too less studied, but especially is too less investigated genetically, ethologically and reproductively. From various reasons, the trout populations are geographically and reproductively isolated, which, in time, leads to significant changes both as concerning the morphological and behavioral features, and also as concerning the reproductive indices (Osinov 1984; Thompson 1985; Vlaic 2007).

Pursuant to human activity, more or less controlled, the fishing fauna from mountain zones suffered a series of changes that create a dangerous pressure on biological diversity and lead to disappearing of some valuable genetic funds (Smith et al 1991; Saksena 1999).

The uncontrolled repopulations with biological material from less valuable species or genetically different ones, will lead either to the brown trout obliterating from its specific spreading area, or to genetic fund changing (FISHBASE 2009).

On the other hand, the brown trout distribution is expanded on a very large specific spreading area (Stickney 1991, 2000), with a very large variability of medial conditions and thus exist populations that significantly differ among them either by geographic isolation cause or of specific conditions from each specific spreading area (see Pictures 1-7).

A survey of the literature focused on the brown trout as concerns the variability, ecological forms, morphological, ethological and reproductive features are almost totally unknown, or occasionally refer only to general characterizations, and the interest manifested for the species preservation fails totally, existing the danger that without an appropriate protection the brown trout will disappear in short time from the mountain aquatic fauna biodiversity patrimony.

Having in view these considerations, in present work-paper we proposed to do a study concerning the intra-specific variability in brown trout basis on some morphological features and some statistic calculus, which will put into evidence the geographic and reproductive isolation impact on development and reproduction of this species.

Material and Method. In view of morphological characterization and emphasizing of differences existent among populations from three distinct zones, Someş, Criş and Arieş (Europe, Romania), basins approved in time as sanctuaries of trout (Hoitsy 2002; Bud & Vlădău 2004; Cristea 2007; Păsărin et al 2004), we attempt a bio-morphometric study on 50 individuals of brown trout captured from natural environment.

The sections from which were extracted the individuals were next ones: Someşul Rece, upstream of Răcătău, Drăgan stream, affluent of Crişul Repede and Arieşul Mic, respective Arieşul Mare.

The morphological features taken in study were next ones: standard length (l), maximal height (H), minimal height (h), head height (iC), head length (lC), distance between pectoral and ventral fins (P-V), dorsal fin length (lD), anal fin length (lA), dorsal fin height (iD), anal fin height (iA), pectoral fin length (lP), ventral fin length (lV), caudal peduncle length (lpc), distance between dorsal and caudal fins (idic), a total of 14 features.

All body measurements were reported to standard length, and the standard length, in its turn, was reported to total length, respective all values were represented by percent.

Also, we analyzed on populations and respective comparatively among them the number of red spots, above and below the lateral line, the number of black spots on operculum and the number of red spots on dorsal fin.

The data were statistically processed, and the significance degree of inter-population differences was established by the Tukey test.

Results and Discussion. After obtained results and statistical processing, comes out as first aspect the fact that the most important dimension, respective standard length, do no present significant differences because almost all individuals were selected with same length (about 15 cm), but it must be mentioned that can exist differences as concern the individuals' age, criterion that was not taken in view at taking moment, but only the biologic material uniformity as concerns the length (Table 1).

All the other sizes taken in study were reported to standard length and are interpreted further on as percent. Thus, analyzing the standard length variation, we can observe the existence of some close values among populations derived from Someş, and from the other two basins, with insignificant differences among them.

Another morphological feature especially important that competes for the format index calculation, respective the maximal height, gives us values close among the three populations, fact that confirms that is a feature with high heritability coefficient and can be heavily influenced by the environment conditions (Table 2).

Following further on the minimal height values, we observe that among the three population exist differences, but the most significant ones are registered only in trout derived from Criş and respectively those ones derived from Arieş (9.19%, given to 9.969% from standard length). These differences reveal that caudal peduncle is better developed in the trout from Arieş, comparatively to that one derived from Criş or that one from Someş (Table 3).

As concerns the head length, from the three populations the highest value is in trout derived from Arieş (22.86%), and the smallest one in population from Criş, with only 21.73% from standard length, differences being reduced and insignificant or few significant among populations (Table 4).

If we analyze the values that concern the distance between pectoral and ventral fins, important feature for body proportions' characterization, we observe that differences among populations are in general reduced, with values more significant between populations from Someşul Rece and Criş, and less significant between those ones derived from Someş and Arieş, respective insignificant between populations from Criş and Arieş (Table 5).

The dorsal fin length differentiates the populations in an interval comprised between 11.74% in population from din Criş and 15.98% in that one derived from Arieş, the differences being very significant between the two populations, but insignificant among trout from Someşul Rece and respective those ones from Criş (Table 6).

If we analyze the dorsal fin height, we observe that the variability is very high, the differences among populations being in all cases very significant, from values more reduced of 8.6977% in trout from Criş and until a maxim value of 16.45% in trout population derived from Arieş (Table 7).

Another feature followed in the three populations was the anal fin length, in which also exists variability but less pronounced comparatively with anterior feature, but in all cases is significant and insured (Table 8).

The anal fin height is also non-uniform among population, with values situated between 11.46% in population derived from Criş and with a maximal value of 14.10% in trout population derived from Arieş, insignificant differences being only between trout populations derived from Someşul Rece and those ones from Arieş, of only 0.640 (Table 9).

As concerns the differences existent among the three populations, in case we report to pectoral fin length we can observe that in all cases exist significant differences and therefore a high variability, with maxim value registered between population from Criş (10.98% from length) and that one derived from Arieş (20.02% from length) (Table 10).

The ventral fin length is, comparatively to other morphological dimensions, more uniform in the three populations, the differences being at values under 2%, but significant among populations derived from Someş and Criş, Criş and Arieş (Table 11).

The last morphometric feature taken in study was the caudal peduncle length that as comes out from Table 12 data presents significant differences among trout populations derived from Someş and Criş, Someş and Arieş, and insignificant ones between populations from Criş and Arieş.

Beside morphological dimensions followed on populations and among populations, we have in view also other aspects that we consider important as concerns the impact of breeding conditions from respective specific spreading area on the brown trout exterior.

Table 1

Comparative values of brown trout populations depending on standard length (l)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	93.39	92.53	92.35	A – C	0.8600	3.241	NS p>0,05
Standard deviation	1.4587	0.782	1.7281	A – D	1.040	3.813	NS p>0,05
Standard error of average	0.2978	0.1706	0.3965	C - D	0.180	0.640	NS p>0,05

Table 2

Comparative values of brown trout populations depending on maximal height (H)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	23.315	23.499	23.517	A – C	- 0.1840	0.6762	NS p>0,05
Standard deviation	0.52345	1.1185	1.9631	A – D	- 0.2020	0.7224	NS p>0,05
Standard error of average	0.1068	0.2441	0.4504	C - D	- 0.018	0.0624	NS p>0,05

Table 3

Comparative values of brown trout populations depending on minimal height (h)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	9.43	9.19	9.969	A – C	0.2400	1.8300	NS p>0,05
Standard deviation	0.4454	0.423	0.600	A – D	- 0.539	4.000	NS p>0,05
Standard error of average	0.0909	0.0923	0.1378	C - D	- 0.779	5.606	** p<0,01

Table 4

Comparative values of brown trout populations depending on head length (lC)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	23.32	21.73	22.86	A – C	- 0.1840	4.352	* p>0,05
Standard deviation	0.6164	1.2817	3.1598	A – D	- 0.2020	1.225	NS p>0,05
Standard error of average	0.1258	0.2792	0.7249	C - D	- 0.018	2.919	NS p>0,05

Table 5

Comparative values of brown trout populations depending on distance between pectoral and ventral fins (P-V)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	32.15	34.22	34.21	A – C	- 2.070	4.980	** p>0,05
Standard deviation	1.7516	0.9377	3.4267	A – D	- 2.060	4.822	* p>0,05
Standard error of average	0.3575	0.2046	0.7861	C - D	0.0100	0.0227	NS p>0,05

Table 6

Comparative values of brown trout populations depending on dorsal fin length (ID)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	12.76	11.74	15.98	A – C	1.020	3.131	NS p>0,05
Standard deviation	0.49024	2.1245	1.0671	A – D	- 3.220	9.616	*** p<0,001
Standard error of average	0.1001	0.4636	0.2448	C - D	- 4.240	12.281	*** p<0,001

Table 7

Comparative values of brown trout populations depending on dorsal fin height (iD)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	13.27	8.6977	16.45	A – C	4.572	13.163	*** p<0,001
Standard deviation	1.1093	1.2870	2.01198	A – D	- 3.180	8.908	*** p<0,001
Standard error of average	0.2264	0.2808	0.4616	C - D	- 7.752	21.062	*** p<0,001

Table 8

Comparative values of brown trout populations depending on anal fin length (lA)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	9.57	8.39	10.63	A – C	1.180	7.136	*** p<0,001
Standard deviation	0.6263	0.8873	0.6951	A – D	- 1.060	6.237	*** p<0,001
Standard error of average	0.1278	0.1936	0.1595	C - D	- 2.240	12.784	*** p<0,001

Table 9

Comparative values of brown trout populations depending on anal fin height (iA)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	13.46	11.46	14.10	A – C	2.000	6.267	*** p<0,001
Standard deviation	0.8619	0.9705	1.7099	A – D	- 0.6400	1.951	NS p>0,05
Standard error of average	0.1759	0.2118	0.3923	C - D	- 2.640	7.807	*** p<0,001

Table 10

Comparative values of brown trout populations depending on pectoral fin length (lP)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	16.81	10.98	20.02	A – C	5.830	23.147	*** p<0,001
Standard deviation	0.81001	0.9916	1.8328	A – D	- 3.210	12.401	*** p<0,001
Standard error of average	0.1653	0.2164	0.4205	C - D	- 9.040	33.872	*** p<0,001

Table 11

Comparative values of brown trout populations depending on ventral fin length (lV)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	12.89	11.7	13.57	A – C	1.190	6.206	*** p<0,001
Standard deviation	0.4392	1.0054	0.3309	A – D	- 0.6800	3.451	NS p>0,05
Standard error of average	0.08965	0.2902	0.0722	C - D	- 1.870	9.204	*** p<0,001

Table 12

Comparative values of brown trout populations depending on caudal peduncle length (lpc)

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	19.56	17.5	16.4	A – C	2.060	7.608	*** p<0,001
Standard deviation	0.7575	0.8833	1.751	A – D	3.160	11.356	*** p<0,001
Standard error of average	0.1546	0.1928	0.4017	C - D	1.100	3.834	NS p>0,05

Analyzing the brown trout color that is a genetic feature good enough consolidate, we observe that exists however a relatively high variability (see Pictures 1-7). Thus, we observed when refer to head color and respective of body dorsal side, that is dark, green-olive in population from Someşul Rece zone and green dark-brown in populations from Arieş and Criş. We mention that in trout population that derives from Criş basin we can observe on lateral and inferior sides a brown-greenish color with metallic reflections, distinct to white-yellowish color to brown in the population from Arieş.

As have observed also other specialists in domain, the physical-chemical features of aquatic basins are significant conditions of the brown trout color (Kottelat & Whitten 1996; Crivelli et al 2000). Also, we observed that individuals collected from the section covered on long portions by forest have a more dark pigmentation comparatively with trout individuals collected from zones more uncovered, more shiny, which have more light the pigmentation, even they proceed from the same water course.

Our researches in time also put into evidence the fact that under influence of different chemical, physical and biological factors, the brown trout was significantly influenced also as concerns the dynamics of prolification increasing, pigmentation etc (Decei 2001; Bud 2007ab).

Having in view these elements, further on we center on emphasizing of red spots number and distribution on body surface and on dorsal fin level, as well the black spots number on the operculum and pre-operculum surface, features that we consider important and insignificant influenced by the environmental factors.

The red spots were counted from the both sides of body and were processed per total body and not per separate sides. The statistical analysis has in view the average, standard deviation and standard error, with help of statistic software GraphPad InStat. The inter-population differences were established by variance analysis ANOVA post-hoc, the Tukey test, the data being presented in next tables.

As result of researches effected in the three populations we observed the next more significant situations. Thus, in population that proceeds from Someşul Rece basin, the distribution of red spots sheared with yellow-brown color stripe is irregular, their majority being on anterior body half and with a diameter comprised between 0.2 and 0.4 cm. As results from data presented in Table 13, the number of red spots is net superior in population proceeded Someşul Rece, 70.5, given to the two populations where these do no surpass 48.8 and respective 45.6 spots.

In case of number of red spots located along lateral line, we observe that their number varies from a population to another one, but in reduced limits, the differences being significant only between populations derived from Someş and Criş: 21.25, given to 15.60 (Table 14).

If we analyze the number of red spots located above lateral line, we observe that the differences are significant between population from Someş, in which the number reaches to 23.38, and the most few can be observed in population derived from Criş, with only 9.6 red spots (Table 15).

In case of red spots located under lateral line, we observe that these have more high density, comparatively with region situated above lateral line, varying between a maximal value of 25.88 spots in trout derived from Someşul Rece and a minimal one of 16.4 spots in that one derived from Arieş, differences being significant between extremes and insignificant between populations from Criş and Arieş (Table 16).

Following the number of red spots from the dorsal fin surface, we must precise that we can determine this aspect only in two populations, because in individuals derived from Criş the dorsal fins were either broken or incomplete, either very fragile and can not be correctly identified these spots. As result, we can compare only the other two populations, establishing that there are significant differences between them, as comes out from data of Table 17.

A last aspect that we have in view was to put into evidence the possible differences existent in the three populations as concerns the number of black spots from the operculum surface (Table 18).

Table 13

Variability of total number of red spots on body surface in brown trout depending on provenance

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	70.5	45.6	48.8	A – C	24.900	10.810	*** p<0,001
Standard deviation	12.524	6.693	13.560	A – D	21.700	9.167	*** p<0,001
Standard error of average	2.556	3.111	1.461	C - D	3.200	1.311	NS p>0,05

Table 14

Variability of total number of red spots along lateral line in brown trout depending on provenance

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	21.25	15.60	18.93	A – C	5.650	6.879	*** p<0,001
Standard deviation	3.4948	5.1769	3.6148	A – D	2.320	2.748	NS p>0,05
Standard error of average	0.7134	1.130	0.8293	C - D	- 3.330	3.826	NS p>0,05

Table 15

Variability of total number of red spots located above lateral line in brown trout depending on provenance

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	23.38	9.6	13.47	A – C	13.780	10.715	*** p<0,001
Standard deviation	8.568	1.6733	6.4793	A – D	9.910	7.498	*** p<0,001
Standard error of average	1.749	0.3651	1.486	C - D	- 3.870	2.840	NS p>0,05

Table 16

Differences registered as concern the total number of red spots located under lateral line

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	25.88	18.8	16.4	A – C	7.080	6.004	*** p<0,001
Standard deviation	6.7705	4.1473	6.8536	A – D	9.480	7.823	*** p<0,001
Standard error of average	1.382	0.905	1.572	C - D	2.400	1.921	NS p>0,05

Table 17

Variability of total red spot number on dorsal fin surface in brown trout depending on provenance

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	7.25	0	4.53	A – C	0	0	0
Standard deviation	2.3755	0	2.8752	A – D	2.720	4.596	*** p<0,001
Standard error of average	0.4849	0	0.6596	C - D	0	0	0

Table 18

Variability of black spot number on operculum surface in brown trout depending on provenance

Specification	Someşul Rece (A)	Criş (C)	Arieş (D)	Difference among populations			
				Between	*Difference among averages*	*q*	*p value*
Average	5.38	4.40	4.13	A – C	0.9800	2.171	NS p>0,05
Standard deviation	1.3025	1.6733	2.3258	A – D	1.250	2.695	NS p>0,05
Standard error of average	0.2659	0.3651	0.5336	C - D	0.2700	0.5645	NS p>0,05

From the data of this table comes out that exist differences, but reduced and insignificant, situated between 5.38 in trout derived from Someşul Rece and a minimal one of 4.13 black spots in population from Criş.

After the effected researches and obtained results come out few conclusions presented further on.

Conclusions and recommendations. The analysis of the three populations taken in study permit us to establish that they differ significantly in very many features, that mean a pronounced intra-specific variability as result of geographic isolation, but also of the influence exerted by physical, chemical and biological features of aquatic environment.

The stocking actions into some mountain water courses, with embryonic spawns, alevins, sapling or even adult trout, bring from other zones from our country or abroad, have the role to contribute to a mixture of populations, which leads to significant differences also between the brown trout populations.

The main features of trout populations, which difference them, are also the result of contact fail between geographic zone and genetic identity.

Our researches confirm also the fact that our brown trout, arrived in a new aquatic environment, changes some of features depending on new conditions that confirms the plasticity of this species.

From all followed features, that one who presented the highest variability was the color, the three populations differing by colors typical for each zone. Beside body color appear significant differences as concern the red or black spots from different body regions.

After statistic calculus were put into evidence significant differences among populations, both in general and on body segments, determined by reproductive isolation or by appearance of some new genes by more or less controlled stocking.

On different mountain river sectors, by debit decreasing, tree vegetation cutting, water temperature increasing, pollution, construction of some barrages, courses deviation the brown trout has been totally extinct on some zones, or it is still present in certain extremely short water streams.

The distribution of red spots is non-uniform and different from an individual to another one, from a population to another one, a certain order being kept only along lateral line.

The most conspicuous color was met in population derived from Someşul Rece and more colorless in the other two populations.

The shearing around the red spots, so evident in trout populations derived from Someş and Criş is very pale or fails in population derived from Arieş.

Each trout population, depending on derivation, has beside basis features common for all populations taken in study also some specific ones, forming local varieties or ecotypes, as result of some local medial pressures or some external interventions effected by human.

The study approached by our team aims to be also a signal for the genetic integrity conservation of brown trout populations from Transylvania.

Stocking fish in mountain water streams needs much more discernment and it should be done with genetically pure material in order to avoid uncontrolled hybridization or creation of pressures that could replace the brown trout from its specific spreading area.

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Picture 1. Brown trout captured by sport fishing

Picture 2. Brown trout in cold season

Picture 3. Brown trout in no-forestry zones

Picture 4. Brown trout in reproduction period

Picture 5. Brown trout in forestry zone

Picture 6. Brown trout in deep water

Picture 7. Brown trout near barrage

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