



A Morphometric Study on Two Groups of Brown Trout (*Salmo trutta*) Population, 1758 in Northern Region of Albania

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Authors' contributions

This work was carried out in collaboration between both authors. Author EV designed the study, performed the statistical analysis. Author AH wrote the protocol and wrote the first draft of the manuscript. Authors EV and AH managed the analyses of the study. Author EV managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

This study was carried out to determine morphological differences between two brown trout (*Salmo trutta Fario*) populations of two Alpine rivers in Northern Albania: Cem River and Valbona River. Fifty five single individuals of brown trout were collected from two different rivers samples included two different age groups: (2)-year-old fish, and (3)-year-old fish; and compared their morphology in order to assess intra- variation in morphometric characteristics. Nine morphometric characteristics (total length of the fish, body height, head length, head height, snout length, eye diameter, pectoral fin length, anterodorsal length, and anteroanal length) were analyzed using PCA, and the best descriptive features of populations were determined. Among the morphometric characteristics, seven factors accounted for about 80% of variation within individuals of the two populations including, head length, eye diameter, pectoral fin length, head height. The trout populations of Cem River were easily differentiated from the ones of Valbona River according to their anterodorsal length, head height and length, and pectoral fin length. The most

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visible differences of the measured characteristics of the two populations were head height and pectoral fin length. It is suggested that the observed differences in the body shapes reflect the adaptation of the population in their native environmental condition of their habitats.

Keywords: *Salmo trutta*; morphometric characteristics; brown trout; population.

1. INTRODUCTION

The Brown Trout is a Salmon type species that is also consider an anadromous freshwater fish that reproduces in river water [1]. Studies of this type of fish have an extreme importance not only in evolution matters but also in ecology provide further information about their behaviour, their conservation, water resource management and stock assessment [2]. Unfortunately, in the recent years natural populations of brown trout have been threatened due to a constant increase of an anthropogenic impact on them, mining, over-fishing, poaching, destruction of natural spawning areas [3,4]. Brown trout is significantly widespread in parts of Europe and in Albania [5]. They are present in Valbona River and Cem River in Northern region of Albania. During the last century, there have been many studies conducted on the morphology and phenotypes of this fish in the Balkans [6,7].

On this studies it was found a high level of endemism among Balkan trout population [8,9]. The early studies reported a considerable variation of external morphology [10,11], giving rise to many taxonomic units [12].

Several *Salmo* taxa have been reported to inhabit Albanian rivers and its neighboring countries 'drainages such as Fyrom and Grecece [13,14].

Examples include *S. fariooides*, proposed by [11] and *S. ohridanus*, *S. letnica*, *S. letnicalumi*, *S. trutta*, *S. macrostigma*, *S. peristericus*, *S. marmoratus* and *S. montenegrinus*. There is a scarce data regarding the existence of the brown trout in Albania and it mostly originates from a Fish Species inventory performed there in the 1950s, [15]. Some of that data is narrowed to only certain areas [16] such as Lake Ohrid, [14,17] and Shkumbini River [18].

Rakaj and Filloko [19] extended and brought up to date the work of [15] on Albanian ichthyofauna. [19] described the trout found in following Albanian river system; Shala, Valbona Ohrid-Drin-Shkodra. [20] as well studied the trout

populating the lakes of Shkodra and Ohrid. It has been reported that trout exists within the rivers Bistrice [19], Cemite [19], Mati [21] and Shkumbini [18]. There have been very few genetic tests performed in trout populations coming from Albanian waters. These tests were restricted in Ohrid Lake, and Prespa Lake, [22,23]. The following study was conducted to determine suitable and Valbona River.

2. MATERIALS AND METHODS

River Cem and river Valbona are both situated in Northern Alps of Albania. Valbona River has its springs at the slopes of Jezercia Mountain. Valbona River is a tributary of Drini River, which drains into Adriatic Sea and precipitates along the craggy riverside of 50.6 kilometres. Cem River is a river that flows through Albania and Montenegro. It originates in Kelmend, Municipality of Malesia e Madhe, Albania for almost 64.7 kilometers, [24]. 55 individuals of *Salmo trutta* were collected from two different sampling sites. 30 individuals from Cem River and 25 individuals Valbona River Albania. The specimens were collected during the Summer season from local fishermen in 2012 and 2015. We studied two groups (2+) and (3+) ages, 9 morphometric characteristics of fish were measured with calipers (± 0.0 cm), with specimen taken from the left side of the fish.

The measured characteristics were reflections of baby forms. The size, placement of the fins, as well the eye position and they were chosen to represent those of ecological importance according to the methodology of [25-27].

The characteristics were the following: Total length of body (TL), body height (BH) front of the dorsal fin, head height (HL) from snout tip to the operculum edge, head height (HH) at the operculum edge, eye diameter (ED) measured horizontally, pectoral fin length (PF), anterodorsal length (AD) from the snout tip to the base of the dorsal first fin ray, and anteroanal length (AA) from the snout tip to the base of the anal first fin ray.

Table 1. Correlations between size-adjusted morphological variables in the 2+ and 3+ age groups of the four studied species

Variables	SL	ED	AD	HH	BH	AA	PF	HL	TL
River Cem 2+									
SL	1								
ED	0.13	1							
AD	0.53	0.23	1						
HH	0.84	0.09	0.76	1					
BH	0.39	0.17	0.66	0.63	1				
AA	0.02	0.67	0.43	0.11	0.32	1			
PF	0.45	0.33	0.81	0.79	0.57	0.41	1		
HL	0.25	0.37	0.59	0.53	0.43	0.34	0.82	1	
TL	0.09	0.58	0.12	0.15	0.12	0.2	0.18	-0.27	1
River Cem 3+									
SL	1								
ED	0.25	1							
AD	0.53	0.11	1						
HH	0.08	0.53	-0.08	1					
BH	0.06	0.42	0.05	0.19	1				
AA	0.43	0.53	0.01	-0.03	0.31	1			
PF	-0.01	0.65	-0.41	0.78	0.28	0.32	1		
HL	0.39	0.59	0.04	0.43	0.18	0.46	0.65	1	
TL	0.13	0.76	-0.07	0.69	0.30	0.33	0.76	0.61	1
River Valbona 2 +									
SL	1								
ED	-0.19	1							
AD	0.01	0.37	1						
HH	-0.73	0.79	0.40	1					
BH	0.19	-1.00	-0.36	-0.79	1				
AA	-0.36	0.99	0.39	0.89	-0.98	1			
PF									
HL	0.52	-0.94	-0.40	-0.95	0.93	-0.98		1	
TL	0.73	-0.59	0.29	-0.75	0.59	-0.67		0.72	1
Valbona River 3+									
SL	1								
ED	0.34	1							
AD	0.58	0.49	1						
HH	0.37	0.39	0.56	1					
BH	0.66	0.76	0.73	0.73	1				
AA	0.02	0.34	0.25	0.13	0.38	1			
PF	0.71	0.72	0.85	0.68	0.93	0.22	1		
HL	0.32	0.59	0.60	0.61	0.67	0.43	0.59	1	
TL	0.34	0.28	0.41	0.86	0.56	-0.02	0.51	0.29	1

(correlations are truncated to three digits; TL = total length of the fish, BH = body height, HL = head length, SL = snout length, ED = eye diameter, PF = pectoral fin length, AD = anterodorsal length, and AA = anteroanal length)

Principal components analysis (PCA) [28] was used to reduce the dimensionality of data and, to transform interdependent variables into significant and independent components. This statistical method has been extensively described elsewhere [29]. The analysis was therefore conducted on the correlation matrix.

Because of differences in size (TL), we found it reasonable to use size adjusted values in data analyses. Thus, the first step in analyzing is to calculate linear regressions against TL of the fish for all the other measured characteristics [27].

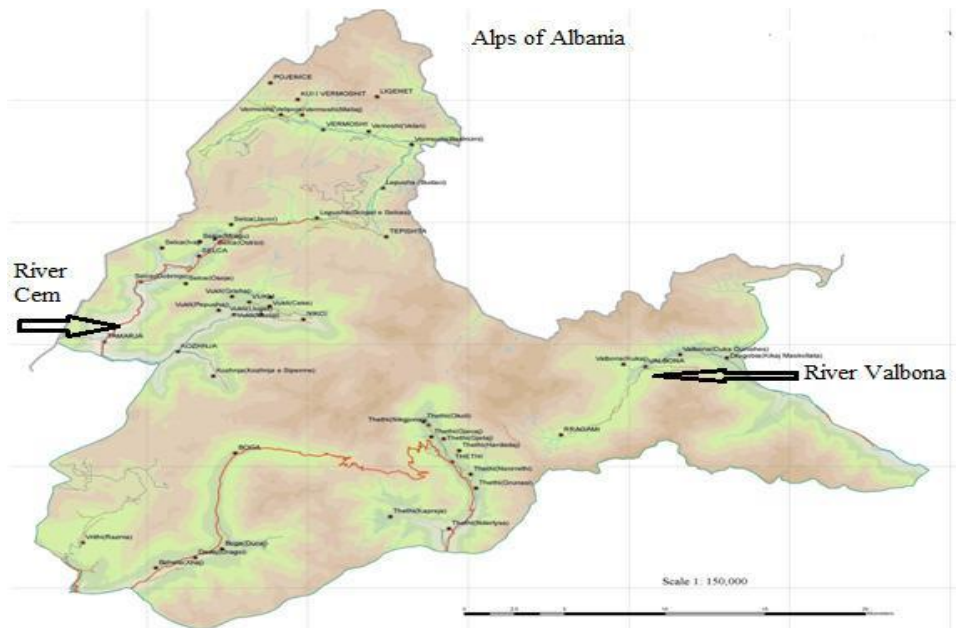


Fig. 1. Location of sampling sites for wild brown trout populations including River Cem and River Valbona in Northern Region of Albania

3. RESULTS AND DISCUSSION

The PCA allowed to the morphological analysis of the brown trout fish population in 2 stations to be taken into account simultaneously aiming to visualize the difference in population structure. We considered as principal component the Eigen values higher than 1.00 of importance. According to this criteria 7 components still remained, explaining about 80% of the variation of the original size-adjusted body morphology variables. Descriptive data for the morphometric character and range minimum - maximum mean, standard deviation of each morphometric characteristic are shown in (Table 2).

Three principal components (Table 3) were extracted from the 9 morphometric characteristics.

The component loadings (Table 3) were also very high for most of the variables accounted for by the first principal component, which described 47.2% of the variance within the samples. The second and third principal component accounted for 13.6% and 10.6% of the total variance respectively.

PCA was component from the correlation matrix using regression residuals as the initial variables.

The PCA loadings are listed together with the variable correlations (r) with the component scores, the highest of the component loadings are indicated in bold digits. The first component was composed mainly of the head and body heights, anterodorsal length, snout length, as well as the pectoral fin length interpret PC1 pooling characteristics associated with the swimming ability of the fish. The second component consisted of the antero anal of feeding and swimming. The third component does not have the highest loadings.

The second age of population in Valbona river have the same total length but they differ in body height and head height.

Jolicoeur and Mosimann [30] demonstrated that any component having all coefficients of the same sign was indicative of size variation, whereas any component having both positive and negative coefficients was indicative of shape variation.

Data from individual fish from Cem river are plotted (Axis 1 vs. Axis 2) in Fig. 2, the individuals of the Valbona River are 98% and are represented in negative axis. That indicates that they don't show a shape variation.

Table 2. A summary of morphometric characteristics measured in centimetres (to the nearest 0.01 cm) for two samples of Brown trout

Station Parameters	River Cem 30 n				River Valbona 25 n			
	Min	Max	Mean	S. D	Min	Max	Mean	S.D
Snout length	2	4.5	2.89	0.62	2	3.2	2.6	0.32
Eye diameter	0.5	0.9	0.69	0.09	0.5	0.7	0.56	0.06
Anterodorsal length	5	10	7.38	1.08	2.9	8.9	6.59	1.53
Head height	3	9	4.77	1.85	2	3.8	2.81	0.49
Body height	0.5	8	5.37	2.26	2.6	5.1	3.51	0.74
Anteroanal.	3.5	16	11.4	3.18	4.5	16	11.26	2.23
Pectoralfin length	2.5	7	4.2	1.63	2.4	3.5	2.77	0.39
Head length	2.5	8	4.43	1.11	2.1	4	3.06	0.62
Total length	16	24	18.9	2.21	17	25	19.48	2.58

Table 3. Principal component analysis for both age groups

Component	pca1	R	pca2	R	pca3	R
Snout length	0.40	0.63	0.05	0.23	0.26	0.51
Eye diameter	0.57	0.75	0.01	0.06	0.06	-0.24
Anterodorsal length	0.35	0.60	0.11	0.33	0.31	0.55
Head height	0.62	0.79	0.25	-0.49	0.03	0.16
Body height	0.54	0.73	0.01	-0.05	0.01	-0.04
Antero anal.	0.22	0.46	0.31	0.5	0.23	-0.48
Pectoral fin length	0.67	0.82	0.17	-0.4	0.06	-0.24
Head length	0.74	0.85	0.02	-0.11	0.02	-0.12
Total length	0.16	0.46	0.33	0.57	0.01	-0.09
Eigen values	4.26	1.23	0.96			
Variance (%)	47.3	13.6	10.6			
Cumulative % variance	47.3	60.9	71.6			

The standardized residuals were calculated and used in Analysis of Variance (ANOVA) to test for differences between ages for each measurement. All variables used in the analyses met the homogeneity of variances assumptions of regression and ANOVA. The null hypothesis is that all consistent variances of the results were considered statistically not significant at $P < 0.001$. The null hypothesis that all variances are consistent. The significant differences for morphometric characteristics were shown on completion of the MANOVA test, both on nominal taxa.

Wilks' test (Rao's approximation):

H0: The variable or the interaction of the corresponding column has no significant effect on the dependent variables.

Ha: The variable or the interaction of the corresponding column has a significant effect on the dependent variables.

As the computed p-value is lower than the significance level $\alpha = 0.05$, one should reject

the null Hypothesis H0, and accept the alternative hypothesis Ha.

The rivers Cem and Valbona have a rich ecosystems of flora and fauna [31,32]. In the last decades, the natural populations of brown trout is increasing [33]. Our studies were focused on freshwater baby salmon species and their morphometric characteristics such as; difference between the two age groups, which are due to the body shape variation when tested with ANOVA and multivariate analysis.

Table 4. Results of Wilks test for the 2 populations of the wild brown trout

	Tot pop
Lambda	0.47
F (Observed values)	5.6
DF1	9
DF2	45
F (Observed values)	2.09
p-value	0.001

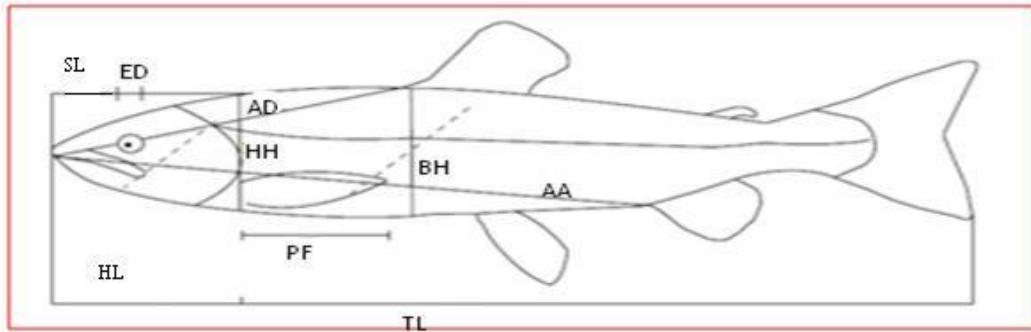


Fig. 2. The measurements taken from the salmonids

TL = total length of the fish, BH = body height, HL = head length, HH = head height, SL = snout length, ED = eyediameter, PF = pectoral fin length, AD = anterodorsal length, and AA = anteroanallength

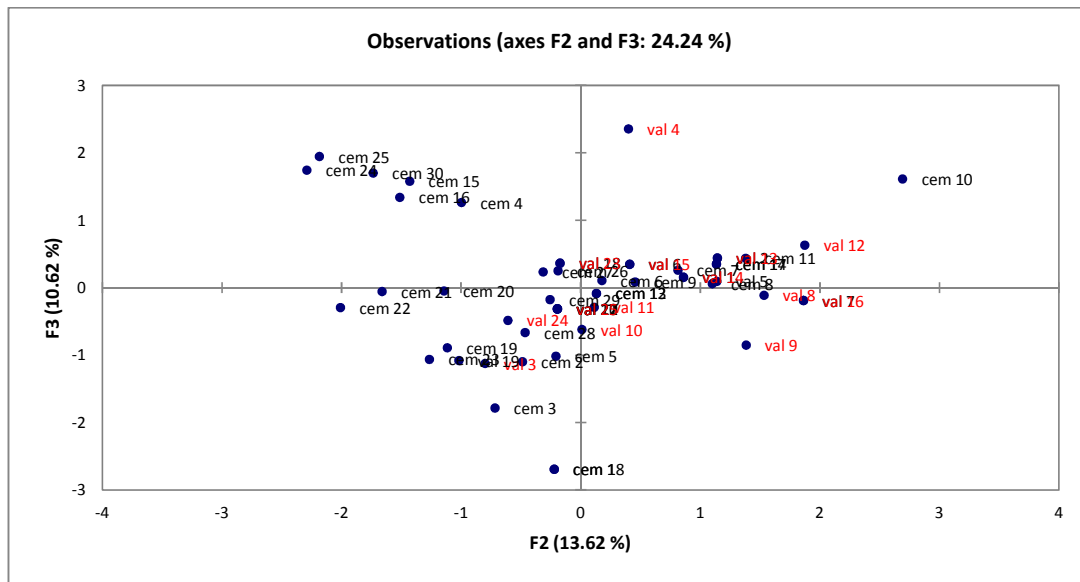


Fig. 3. Principal component analysis of untransformed morphometric data from samples taken from Cem River (n=30) and Valbona River (n=25). The scatter plot shows individual fish scores for axis 1 vs. axis 2

According to these findings, the total body length for both populations was insignificant, the population of the River Cem distinguished from the population of the Valbona rivers in the anterodorsal length, head height, pectoral fin length and head length.

With multivariate statistics PCA we could identify the characteristics that best defined the studied species. The PC1 analysis was mainly subjected of the pectoral length, head length, head height fin size, and large eyes. Those characteristics reflected the swimming ability of the fish. The eye diameter reflected the light

conditions of where the fish is living [27]. A bigger body improved swimming performance [34], it is advantageous in navigating through structurally complex habitats [35]. Long pectoral fins are related to slow and precise movements [36], and large fins are also effective in maintaining stable position in the river [37]. Brown trout live in shallow rivers, where water is clear. [38] suggested that the eye size may as well be related to feeding behaviour. The head morphology also reflects a species feeding habits [39]. The causes of morphological differences between populations are often quite difficult to explain [40].

4. CONCLUSIONS

The present study showed that each sampling site represents an independent population.

We believe that our study gives new and valuable information about the morphometric characteristics between different populations of the salmonids species.

The results can be interesting for management and conservation programs of this valuable endangered species in this region. A detailed study involving the molecular genetics and environmental aspects may further confirm the present findings unambiguously. However, in order to have better conservational policy, further studies are recommended to determine other possible populations of this species in other regions of Albania.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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