

Morphometric characters of the whitefish ludoga (*Coregonus lavaretus ludoga*) in connection with the lake Issyk-Kul ecological and geographical conditions and its introduction

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Abstract. This article considers the influence of ecological and geographical conditions in the sequent whitefish ludoga (*Coregonus lavaretus ludoga*) relocation from Lake Ladoga to Lake Sevan and then from Lake Sevan to Lake Issyk-Kul. Morphometric studies of whitefish ludoga from Lake Issyk-Kul and a comparative analysis with similar data of this fish species of Lake Ladoga and Lake Sevan were carried out, taking into account the ecological and geographical condition of these lakes. In the course of our research, we found that the morphometric characters of whitefish ludoga during the introduction from Lake Ladoga to Lake Sevan and then to Lake Issyk-Kul changed due to the ecological and geographical conditions of these lakes. We have identified changes that occurred sequentially when moving from the plain region lake (Ladoga) to the mountain lake (Sevan) and to the mountain lake with brackish water (Issyk-Kul). These changes were mainly in the quantitative increase of some morphological parameters of these fish, such as raker counts on first branchial arch; scale counts on the lateral line; snout length and lower jaw length; predorsal distance and caudal peduncle length; head depth. In addition, there are changes characteristic of the Issyk-Kul fish, it is an increase in body depth and the dorsal fin height.

1 Introduction

Whitefish (*Coregonus*) are ray-finned fish, Salmon family. This genus contains about 68 species. All of these species differ morphologically. These signs vary depending on the ecological conditions of their habitat.

Whitefish are fish species that have valuable tastiness, so they are often used to populate water bodies where they were not found before.

Whitefish belong to semidiadromous fish; they lived in the seas and run to spawn in rivers, but given their valuable eatability, they began to be bred in lakes. Therefore, at

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present many natural water bodies are populated with this fish. Whitefish easily adapt to new conditions and in the adaptation, they change their morphological properties. Therefore, they have a great variety of these signs depending on environmental conditions [1].

According to the researchers, whitefish are extremely polymorphic species and morphologically easily change depending on their habitat, even within one water body whitefish can be represented by several forms, which are manifested by differences in raker counts, morphological features of the snout, body (high body or humpbacked, or stretched out and elongated forms); by the morphological features of fins, etc. [2].

The whitefish ludoga (*Coregonus lavaretus ludoga*) is a subspecies of the common whitefish (*Coregonus lavaretus*). For this subspecies, the indicator of the lower mouth is characteristic, although this mouth position can change from the typical lower to almost the final one. The snout tip area is well expressed and its height is less than its width, their fins are dark, even black; the raker counts vary even among the subspecies of whitefish ludoga and is associated with the food type. The whitefish size also depends on the habitat and their feeding [3].

Ilmast N.V. (1999) notes that when studying different ecological forms of whitefish, the raker counts are important, since this trait is inherited and depends less on their living environments [4].

From the complex of signs that form the shape of the body, the AO body length, postdorsal distance, antedorsal distance, head length, eye diameter is usually distinguished.

Lake Issyk-Kul began to be populated with whitefish in 1966 [5]. The ecological conditions of this lake were favorable for this fish, as salmon require clean water with high oxygen, in addition, they are cold water fishes. The history of the whitefish introduction into Issyk-Kul had a consistent character: the whitefish ludoga (*Coregonus lavaretus ludoga*) was brought to Lake Issyk-Kul in the 1960s from Lake Sevan. And in turn, it was populated in Lake Sevan from Lake Ladoga in the 20-30s of the last century [6]. The ecological conditions of Lake Sevan, compared with Issyk-Kul, differ in that Issyk-Kul is larger in area, deeper and its water is brackish. Thus, whitefish had to adapt to new habitat conditions twice.

According to M.N. Alpiev and S. S. Lysenko, in Lake Issyk-Kul, whitefish ludoga (*Coregonus lavaretus ludoga*) formed two forms depending on the growth rate — fast growing and stunted [5].

In our previous studies [7], we compared the morphological features of the Issyk-Kul whitefish with the Sevan whitefish [8, 9], that is, the morphological characteristics of the whitefishes of the time when they were first introduced into Lake Issyk-Kul. We have identified changes in the mouth area, fin area, and body size.

Many papers have been devoted to morphometric characters of whitefish, and researchers conduct comparative studies even in water bodies of the same region and even in the same lake near different shores.

Pravdin (1966) gives the following recommendations in determining the morphological characteristics of the whitefish — the necessary and important action is the measurement of body length, then the measurement of the upper jawbone, the measurement of the snout area, then such measures as the scale counts in the lateral line, the count of gill stamens and gill rays and the number of vertebrae. Measurements of the whitefish head and gill apparatus are also important [10].

Whitefish are particularly valuable commercial and endemic fish [11] and many researchers note the importance of studying their ecological and morphological properties. This fish is listed in the Red List in many regions, which shows how important it is to preserve this fish species. And this requires knowledge and understanding of the conditions for its preservation.

In addition, as noted by E. A. Borovikova and A.A. Makhrov (2013) due to plasticity and the ability to distant hybridization for taxonomists, whitefish have a certain interest and even a problem, and in this regard, research in this area has a certain value [12].

The purpose of the study: to study the morphological properties of whitefish ludoga living in Lake Issyk-Kul in connection with the ecological and geographical features of this lake. To analyze morphometric changes during the double introduction of whitefish ludoga from Lake Ladoga to Lake Sevan and from Lake Sevan to Lake Issyk-Kul.

Research objectives:

- to give ecological and geographical characteristics of Lake Ladoga, Lakes Sevan and Issyk-Kul;
- to determine the main morphometric characters of the whitefish ludoga (*Coregonus lavaretus ludoga*) of Lake Issyk-Kul and to identify changes during their introduction.
- to analyze these data for whitefish ludoga (*Coregonus lavaretus ludoga*) with a double introduction.

2 Materials and methods

The material for the study was freshly caught ludoga whitefish (*Coregonus lavaretus ludoga*) from Lake Issyk-Kul (11 individuals) and on the same day the studies were conducted.

Scales, calipers, a tape measure, scissors, and a scalpel were used in the study.

Morphometric studies were carried out according to the methods accepted in ichthyology according to Pravdin (1966).

The morphometric characters carried out during the study were as follows: Q, g — fish weight, l_{smit} , cm — body length from the snout top to the end of the caudal fin middle rays; ll_1 — scale counts in the lateral line; D_1 — number of rays in the dorsal fin; A — number of rays in the anal fin; sp.br. — stamen counts on the first gill arch. The following indicators are expressed in % l_{smit} ; ll_1 — scale counts in lateral line; prO — snout length; O — eye horizontal diameter; Oop — post-orbital length; lc — head length; l_{max} — maxillary bone length; h_{max} — maxillary bone height; l_{md} — mandible length; hc — head height at the occiput; io — forehead (interorbital space) width; H — greatest body depth; h — smallest body dept; aD — antedorsal distance; lpc_2 — caudal peduncle length; aV — anteventral distance; hD_1 — the greatest first dorsal fin height; ID_1 — length of first dorsal base; lA — length of anal base; hA — height of anal fin; lP — length of pectoral fin; lV — length of pelvic fin; PV — distance between bases of pectoral and pelvic fins; VA — distance between bases of pelvic and anal fins.

Mathematical and statistical processing was carried out by comparing the indicators of whitefish ludoga (*Coregonus lavaretus ludoga*) from Lake Issyk-Kul with those of whitefish from Lake Sevan and Lake Ladoga.

Comparative measures of morphometric measurements of whitefish during their introduction from Lake Ladoga to Lake Sevan and then to Lake Issyk-Kul were compared with limnological parameters of these lakes [6, 13].

3 Results

Table 1. Natural and geographical conditions and limnological parameters of 3 lakes studied by us.

No.	Indicators	Lakes		
		Issyk-Kul	Ladoga	Sevan
1	Absolute altitude above sea level, m	1607.8 m	4.84 m.	1898 m.

2	Catchment area, km	1738 km ³	838 km ³	36.088 km ³
3	Lake area, km ²	6236 km ²	17.87 thousand km ²	1240 km ²
4	Average depth, m	1898 m	46.9 m.	41.3 m
5	Maximum depth, m	702 m	233 m.	98,7 m.
6	Transparency, m	20 m and 47 m in winter	2-2.5 m and in the center reaches 4.5 m.	4,5 m.
7	Mineralization, mg/l	5,8—5,9 ‰	56	
8	pH of water in the lake	8,5-8,8	7,2–7,6	8,7
9	Plankton in lake	111 species	378 species	
10	Bentos		385 species	
11	Water brackishness	5,8‰	0,06‰	-
12	Species of fish in the lake, how many	20 species	58 species	30 species
13	Water temperature in summer months	+18°C to +23°C	+14°C to +21.4°C	+15°C to +20°C

Table 2. The results of morphometric studies of the whitefish ludoga (*Coregonus lavaretus ludoga*) of Lake Issyk-Kul.

Sign Character	Whitefish of Lake Issyk-Kul, 2020			Whitefish of Lake Sevan, (Mailyan, 1954)		Whitefish ludoga of Lake Ladoga (Pravdin I.F. 1954.)	
	Whitefish weighing 500 up to 800 g			M	m	M	M
<i>Q. g</i>	577.2	84.8	11	-	-	540	-
<i>l_{smit.} cm</i>	34.9	1.82	11	38.3	0.48	40	-
<i>ll₁</i>	89.3	3.5	11	83.3	0.59		-
<i>sp.br.</i>	30.0	2.9	11	26.6	0.25	23.47	-
	% <i>l_{smit.}</i>						
<i>prO</i>	5.4	0.61	11	5.3	0.06	5.11	-
<i>O</i>	3.7	0.21	11	4.0	0.02	3.80	-
<i>Oop</i>	9.8	0.55	11	9.8	0.07	9.24	-
<i>lc</i>	18.6	0.86	11	18.7	0.10	18.54	-
<i>hc</i>	15.9	1.17	11	-	-	13.26	-
<i>l_{max}</i>	5.4	0.58	11	5.4	0.05	5.24	-
<i>l_{md}</i>	7.4	0.57	11	7.0	0.06	6.39	-
<i>H</i>	25.6	1.36	11	25.9	0.18	22.02	-
<i>aD</i>	46.5	2.65	11	44.9	0.20	43.34	-
<i>lpc₂</i>	17.7	0.79	11	13.4	0.11	12.78	-
<i>hD₁</i>	15.2	0.73	11	13.4	0.08	13.48	-
<i>lD₁</i>	11.9	0.85	11			11.14	-
<i>h</i>	7.7	0.34	11			6.51	-

Data on % <i>ls</i>							
<i>prO</i>	10.3	0.57	11	27.0	0.23	38.04	
<i>O</i>	6.9	0.41	11	21.4	0.16	28.24	
<i>Oop</i>	18.4	1.02	11	56.0	0.26		
<i>l_{max}</i>	10.0	1.10	11	28.1	0.16	41.10	
<i>l_{md}</i>	14.0	1.11	11	38.5	0.20	48.04	
<i>hc</i>	30.2	1.81	11				
<i>H</i>	48.1	2.71	11			48.46	

4 Discussion

Fish are very important in human nutrition. Fishing and fish farming have always been one of the branches of human activity. People have always sought to improve the species composition of fish in the wild. Recently, special attention has been paid to fish introduction. Once in other ecological and geographic environments, the fish change so much that in some cases researchers even suggest introducing the name of new species. It is not always possible to agree with this, so research work on the morphometric indicators of fish during their introduction is of great theoretical importance.

We have established that the whitefish ludoga (*Coregonus lavaretus ludoga*) was brought to Lake Issyk-Kul from Lake Sevan in 1966 [5]. In turn, the whitefish ludoga (*Coregonus lavaretus ludoga*) was brought to Lake Sevan from Lake Ladoga [6]. The ecological and geographical conditions of these 3 regions and the limnological parameters of these 3 lakes are different. Comparing the ecological, geographical, and limnological parameters of the three lakes in which the relocation of the whitefish ludoga (*Coregonus lavaretus ludoga*) took place, we can see that Lake Ladoga is located in a flat; Lakes Sevan and Issyk-Kul are mountain lakes, but Sevan is slightly higher, although not much higher compared to Lake Issyk-Kul. In terms of area and depth, Lake Issyk-Kul surpasses Lake Sevan, Issyk-Kul area is 5 times larger and its depth is 7 times compared to Lake Sevan. The water in Issyk-Kul is cleaner; its transparency is 4.4 times higher. The species diversity of fish in Lake Sevan is greater compared to Lake Issyk-Kul, but less compared to Lake Ladoga. Lake Ladoga is larger in area than Lake Issyk-Kul (2.9 times), but shallower in depth (3 times). The water in Lake Issyk-Kul is brackish unlike the other two lakes. The water temperature in Issyk-Kul in the summer months ranges from +18°C to +23°C, in Lake Sevan —15.0°C to 22.0°C, and in Lake Ladoga — 14.5°C to 21.4°C [14, 15].

From these data, we can see that all three lakes are different and this affects the fish life processes which leads to changes in fish morphometric parameters.

Adapting to the new conditions, the migratory fish changed and this can be found when studying their morphometric parameters.

To identify the such changes, we have conducted studies of whitefish ludoga from Lake Issyk-Kul at the present time and a comparative analysis of these parameters with similar parameters of whitefish from Lake Sevan [8, 9] and Lake Ladoga [10].

Comparing the changes that occurred during the whitefish ludoga relocation from one lake to another and then to the third ones can be explained by their ecological and geographical condition.

We have established a proportional, that is, the indicators of fish from Lakes Ladoga, Sevan, and Issyk-Kul increase in the raker counts on first branchial arch; the scale counts on the lateral line; the snout length and the lower jaw length; the predorsal distance and the caudal peduncle length; the head depth of whitefish ludoga is higher compared to fish from Lake Ladoga (Mailyan does not have ID_1 and h).

These changes occurred as a result of the fact that the fish first got from the environment of the flat area of Lake Ladoga in the mountainous conditions which are characterized by atmospheric pressure, radiation levels, and higher continental climate typical of mountainous terrain. As a result, fish have to put more effort into their biological functions, namely feeding and movement.

The whitefish ludoga (*Coregonus lavaretus ludoga*) of Lake Issyk-Kul has larger weight compared to the ones of the fish of Ladoga and Lake Sevan, but the length is smaller. We explain this by the fact that the fish we studied were identified during the spawning period and were mostly gravid.

The fish of Lake Sevan are smaller in size than the fish of Lake Ladoga, and in Issyk-Kul they are smaller than one in Lake Sevan. This is due to the fact that the Issyk-Kul

and Sevan lakes are higher above sea level, and the water in Issyk-Kul is also brackish. These two ecological signs contributed to a decrease in the size of fish in Lake Issyk-Kul.

In addition, the body depth and the dorsal fin height of the whitefish of Lake Issyk-Kul is higher. This, we believe, is due to the fact that the water here is brackish.

Thus, we can see that the changes in the morphometric indicators of whitefish ludoga (*Coregonus lavaretus ludoga*) are caused by the fact that the Issyk-Kul and Sevan are high-altitude lakes. But there are also changes that are related to the fact that Lake Issyk-Kul has brackish water which increases the resistance to fish movement.

5 Conclusion

Whitefish ludoga (*Coregonus lavaretus ludoga*) came to Issyk-Kul after two relocations from Lake Ladoga to Lake Sevan and from Lake Sevan to Lake Issyk-Kul. The conditions of these three lakes differ in ecological and geographical conditions: altitude above sea level, m; lake area, km²; average depth, m; maximum depth, m; transparency, mineralization, pH, brackishness of water; species of fish inhabiting lakes. The changes occurred at the level of morphometric parameters: a) successive changes that occurred during the first relocation, and then during the second one: increase in the raker counts on first branchial arch, the scale counts on the lateral line, the snout length and the lower jaw length, the predorsal distance and the caudal peduncle length, the head depth; b) changes that occurred during the second migration, that is, when moving to Lake Issyk-Kul: the body depth and the dorsal fin height.

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