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COMPARATIVE ANALYSIS OF THE MORPHOLOGICAL CHARACTERISTICS OF ISKANDARIA KUSCHAKEWITSCHI (HERZENSTEIN, 1890) POPULATIONS OCCURRING IN THE QAMCHIQSOY AND OLTARIQSOY RIVERS

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ABSTRACT

In this study, a comparative analysis of the morphometric characteristics of *Iskandaria kuschakewitschi* (Herzenstein, 1890) populations distributed in the Qamchiqsoy and Oltariqsoy rivers of the Fergana Valley was carried out. The study was conducted on the basis of samples collected during 2024–2026, and more than 30 morphometric characters were measured according to standard methodology and evaluated using biostatistical methods. According to the results of Student's t-test, statistically reliable differences at the 1% significance level were identified in 21 out of the 35 studied morphometric characters, while no significant differences were observed in the remaining 14 characters. The greatest differences were recorded in body length, head length, body depth, fin lengths, and caudal peduncle parameters. In the Oltariqsoy population, the high values of

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the coefficient of variation are explained by the ecological variability of the environment, whereas the Qamchiqsoy population is characterized by a relatively stable morphological structure. The obtained results indicate the presence of morphological differentiation between the populations and confirm the important role of hydrological factors in its formation.

Keywords: Iskandaria kuschakewitschi, morphometry, population differentiation, Qamchiqsoy, Oltiariqsoy, Nemacheilidae, hydrological factors, variation

Аннотация

В данной работе проведён сравнительный анализ морфометрических признаков популяций *Iskandaria kuschakewitschi* (Herzenstein, 1890), обитающих в реках Кемчиксай и Алтыарыксай Ферганской долины. Исследование основано на материалах, собранных в 2024–2026 гг., при этом было измерено более 30 морфометрических признаков с использованием стандартных методик и проведён их биостатистический анализ. По результатам критерия Стьюдента установлено, что из 35 изученных признаков в 21 случае выявлены статистически значимые различия на уровне значимости 1%, тогда как по 14 признакам достоверных различий не обнаружено. Наиболее выраженные различия отмечены по общей длине тела, длине головы, высоте тела, длинам плавников и параметрам хвостового стебля. Популяция Алтыарыксай характеризуется более высокими значениями коэффициента вариации, что связано с большей изменчивостью экологических условий, тогда как популяция Кемчиксай отличается относительной морфологической стабильностью. Полученные результаты свидетельствуют о наличии морфологической дифференциации популяций, обусловленной гидрологическими и экологическими факторами.

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Ключевые слова: *Iskandaria kuschakewitschi*, морфометрия, популяционная дифференциация, коэффициент вариации, критерий Стьюдента, *Nemacheilidae*

INTRODUCTION

Morphological studies are currently considered one of the most widely used and economically effective phenotypic description methods for identifying different fish populations. Morphometric analyses, which take into account size and shape variation, make it possible to successfully distinguish many local fish populations [1]. In addition, morphometric studies are also widely used in aquaculture research and have yielded good results in assessing fish health [2], determining biomass [3], and differentiating populations [4]. At the same time, morphometric studies are also important in determining the relative importance of the origin of local populations and habitat conditions in shaping general body morphology. Therefore, the study of variation in morphological characters is also important in explaining the patterns of phenotypic and genetic differentiation observed in fish populations [5].

Iskandaria kuschakewitschi (Herzenstein, 1890) is a fish inhabiting mountain and lowland rivers and is commonly known as the “Kushakevich loach.” It constitutes an important natural fish resource in the river ecosystems of the Fergana Valley. This fish belongs to the family *Nemacheilidae* and the genus *Iskandaria*, and is considered an endemic species of the Fergana Valley. In the river systems of Uzbekistan, only two species of this genus occur: *Iskandaria kuschakewitschi* (Herzenstein, 1890) and *Iskandaria pardalis* (Turdakov, 1941) [6]. These fishes are small in size, inhabit fast-flowing mountain rivers and streams, and usually lead a hidden way of life, living under stones or concealed in muddy bottoms [7]. Researchers have reported the occurrence of *Iskandaria pardalis* (Tajik loach) in the To‘palang and Sherabod rivers of Surkhandarya [8]. *I. kuschakewitschi* has been recorded in the upper Syr Darya, in the Naryn and Qoradaryo rivers, and

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outside the valley in the Chirchik and Ohangaron rivers, as well as in tributaries of the Syr Darya basin flowing through the territory of Tajikistan [9], [10]. Its presence has also been recorded in small rivers and artificial canals within the valley [11]. At present, the range of this species appears to be expanding, and its adaptation to new hydrological conditions has been observed [12].

Although *Iskandaria kuschakewitschi* is considered a widespread species, its populations are observed to be declining in many areas. At present, the disappearance of native fish species is associated with human activities such as water withdrawal for irrigation, direct extermination, introduction of invasive species, water pollution, and changes in hydrological regime [13], [22], [23]. In particular, benthic fishes of the family Nemacheilidae, including *I. kuschakewitschi*, are usually highly specialized for fast-flowing river sections rich in oxygen and with rocky substrates [14], [15], and changes in such ecological conditions restrict their habitat and lead to a reduction in population numbers. These ecological characteristics also provide the basis for considering them sensitive bioindicator species in relation to water quality and hydrological conditions.

Geographical isolation and hydrological separation between water bodies lead to the formation of genetic and phenotypic differentiation in freshwater fishes, especially in benthic representatives of Nemacheilidae. Representatives of this family usually have low dispersal ability, and fragmentation of river systems together with differences in ecological conditions intensifies the emergence of morphological and genetic differences between populations [14], [16], [17]. The high level of regional phylogenetic differentiation among Nemacheilidae is also considered to be related to the long-term geographical isolation of this group [18]. At the same time, in geographically isolated small populations with limited exchange with neighboring populations, genetic drift and bottleneck events become stronger, leading to increased genetic and phenotypic differentiation [19]. Morphometric differences among local populations within a species are important

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in evaluating population structure and identifying local populations [16]. In some cases, morphometric variation also corresponds to differences in genetic composition [20]. For this reason, the aim of the present study was to identify *Iskandaria kuschakewitschi* populations from two rivers of the Fergana Valley on the basis of morphometric measurements, relying on the concepts of shape and size. The results of the study are important for understanding the ecological adaptation mechanisms of this species, evaluating the degree of population differentiation, and scientifically managing regional aquatic biological resources.

Materials and Methods

Samples of *Iskandaria kuschakewitschi* were collected from the Qamchiqsoy and Oltiariqsoy rivers using cast nets and local traps. Samples for body measurements were collected from each habitat during the period from September 2024 to February 2026. In field conditions, the samples were fixed in 5–10% formalin solution. After 3 days, the fixed fishes were transferred to 75% ethanol for permanent preservation.

In laboratory conditions, morphometric measurements of the fish were taken from the left side using an electronic caliper with an accuracy of 0.01 mm, according to the methodology proposed by Kottelat and Freyhof (2007) [15]. The characteristics of variation in morphometric characters of the fish and interpopulation differences were analyzed using the methods described by G. Lakin (1990) [21]. Percentage limits of the coefficient of variation were determined in assessing morphological variation on the basis of morphometric indicators. Differences between populations were evaluated using Student's t-test.

The abbreviations used in the article are as follows: TL — total length; SL — standard length; HL — head length; BDD — body depth at the origin of the dorsal fin; BWD — body width at the origin of the dorsal fin; PRD — predorsal length; psd — postdorsal length; PRV — preventral length; PRA — preanal length; pran

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— preanus length; DFL — dorsal fin length; DFBL — dorsal fin base length; AFL — anal fin length; AFBL — anal fin base length; PFL — pectoral fin length; VFL — pelvic fin length; CFL — caudal fin length; CPL — caudal peduncle length; CPD — caudal peduncle depth; CPW — caudal peduncle width; PVD — distance between pectoral and pelvic fins; VAD — distance between pelvic and anal fins; anad — distance between the anal opening and anal fin; HDN — head depth measured from the nape region; HDE — head depth measured from the eye region; hmw — maximum head width; SNL — snout length; ED — eye diameter; IOW — interorbital width; POL — postorbital length; MW — mouth width; MBL — upper barbel length; IRBL — inner rostral barbel length; ORBL — outer rostral barbel length; D — dorsal fin; A — anal fin; P — pectoral fin; V — pelvic fin; min — minimum value; max — maximum value; M — arithmetic mean; m — standard error of the arithmetic mean; SD — standard deviation; CV — coefficient of variation; T — distribution in Student's test; Tf — empirical value obtained in Student's test; Tst — critical value in Student's test.

RESULTS AND DISCUSSION

Statistical analyses of the morphometric characters of *Iskandaria kuschakewitschi* collected from the Qamchiqsoy (n = 15) and Oltiariqsoy (n = 19) rivers were carried out (Table 1). According to the analyses, the total length of specimens from the Qamchiqsoy population ranged from 63.09 to 88.28 mm, averaging 73.30 ± 1.68 mm, while the standard length ranged from 52.88 to 75.15 mm, averaging 62.25 ± 1.46 mm. In the Oltiariqsoy population, the total length of fish specimens ranged from 42.91 to 108.44 mm, averaging 66.66 ± 8.49 mm.

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Table 1. Morphometric characteristics of *Iskandaria kuschakewitschi* populations from the Qamchiqsoy and Oltiariqsoy rivers.

	Qamchiqsoy population (n=15)					Oltiariqsoy population (n=19)					t-test
	Min	Max	M±m	CD	V	Min	Max	M±m	CD	V	
TL	63,09	88,28	73,30±1,68	7,32	10,0	42,91	108,44	66,66±8,49	18,98	28,5	tf>tst
SL	52,88	75,15	62,25±1,46	6,38	10,3	35,07	92,41	55,30±7,33	16,39	29,6	tf>tst
SL%											
HL	17,18	20,32	18,85±0,18	0,77	4,1	20,17	24,07	21,91±1,37	1,19	5,4	tf>tst
BDD	9,43	14,20	11,79±0,32	1,40	11,9	3,08	17,62	14,73±0,42	3,06	20,8	tf>tst
BWD	7,53	11,99	10,03±0,28	1,23	12,3	12,13	15,21	13,34±0,81	0,94	7,1	tf>tst
PRL	46,96	53,03	50,23±0,39	1,72	3,4	49,78	52,91	51,64±0,68	0,95	1,8	tφ>tst
PDL	35,51	41,80	38,01±0,42	1,82	4,8	31,79	38,79	34,94±0,59	1,81	5,2	tφ>tst
PVL	47,66	51,91	49,81±0,33	1,42	2,9	48,83	52,90	51,49±0,36	1,15	2,2	tφ>tst
PAL	67,12	74,21	71,92±0,48	2,08	2,9	68,21	74,88	2,14±0,4	1,52	2,1	Tf<tst
PAnL	65,93	70,78	68,26±0,39	1,72	2,5	65,73	73,64	69,54±0,28	1,53	2,2	tφ>tst
DFL	11,74	15,43	13,59±0,22	0,98	7,2	12,46	17,52	14,27±0,34	1,31	9,2	tφ>tst
DFBL	9,97	11,84	11,04±0,13	0,56	5,0	10,09	12,68	11,42±0,28	0,81	7,1	Tf<tst
AFL	10,95	13,51	12,46±0,21	0,90	7,2	10,32	13,56	12,22±0,51	0,89	7,3	Tf<tst
AFBL	5,57	8,06	6,96±0,18	0,78	11,2	6,41	8,56	7,28±0,20	0,63	8,7	Tf<tst
PFL	11,82	13,29	12,62±0,11	0,50	3,9	12,98	16,47	14,76±0,23	0,76	5,1	tφ>tst
VFL	10,64	12,48	11,72±0,12	0,51	4,4	11,84	14,14	13,05±0,44	0,63	4,9	tφ>tst
CFL	15,44	20,15	18,21±0,31	1,34	7,3	18,48	23,98	21,27±0,55	1,45	6,8	tφ>tst
CPL	18,09	21,96	20,17±0,26	1,15	5,7	16,53	20,11	18,18±0,21	1,14	6,3	tφ>tst
CPD	5,56	7,19	6,51±0,10	0,43	6,6	5,79	7,64	6,60±2,42	0,46	6,9	Tf<tst
CPW	2,55	4,44	3,60±0,12	0,51	14,1	3,01	5,29	3,81±1,40	0,52	13,6	Tf<tst
PVD	28,31	33,16	30,80±0,34	1,50	4,9	28,48	32,33	30,88±3,31	0,99	3,2	Tf<tst
PAD	20,98	24,30	22,45±0,24	1,03	4,6	18,30	23,55	20,20±1,70	1,22	6,0	tφ>tst
VAD	2,22	4,59	3,36±0,16	0,70	4,1	0,97	2,60	1,93±0,95	0,47	24,2	tφ>tst
CPL/C PD	2,73	3,32	3,10±0,04	0,18	0,04	2,20	3,36	2,77±0,15	0,33	11,8	Tf<tst
HL%											
HD	45,75	56,02	50,63±0,83	3,60	20,9	31,75	57,11	50,92±0,94	5,42	10,6	Tf<tst
HD(E)	40,52	47,51	43,50±1,01	2,18	7,1	40,77	52,59	46,55±1,60	3,13	6,7	tφ>tst

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HW(E)	55,05	69,72	63,41±0,55	4,39	5,0	37,99	72,20	62,40±1,58	7,41	11,9	Tf<tst
SNL	35,82	45,79	41,02±0,55	2,39	6,9	28,87	46,93	40,90±1,09	3,79	9,3	
ED	12,28	20,29	16,76±0,47	2,05	5,8	10,61	18,56	14,42±0,98	2,11	14,7	tφ>tst
IOW	10,31	17,97	14,39±0,46	2,01	12,2	8,41	16,13	13,12±0,15	2,09	16,0	Tf<tst
POL	36,53	45,48	40,69±0,46	2,01	14,0	29,27	44,83	36,65±1,60	3,58	9,8	tφ>tst
MW	21,82	28,65	25,18±0,53	2,33	4,9	19,72	32,72	23,55±0,94	3,53	15,0	tφ>tst
MBL	15,84	23,44	19,86±0,52	2,27	9,2	16,59	27,80	22,47±0,95	2,43	10,8	tφ>tst
IRBL	11,10	23,70	17,71±0,81	3,54	11,4	12,30	21,11	17,26±1,70	2,19	12,7	Tf<tst
ORBL	16,87	23,79	20,63±0,52	2,27	20,0	15,89	23,11	20,56±0,15	2,15	10,5	Tf<tst

The percentage ratios of body parts relative to standard length (SL) and head length (HL) were determined for the *Iskandaria kuschakewitschi* populations collected from these rivers. In the Qamchiqsoy population ($n = 15$), the mean value of head length constituted $18.85 \pm 0.18\%$ of standard length, and this was recorded as a relatively stable indicator ($V = 4.1\%$). Body depth (BDD) was $11.79 \pm 0.32\%$, and the degree of variability was found to be moderate ($V = 11.9\%$). Predorsal length (PRL) at $50.23 \pm 0.39\%$ was greater than postdorsal length (38.01 ± 0.42), indicating the presence of a stable morphological ratio in body segmentation. The distance to the pelvic fin (PVL) and the dorsal-fin-related measurement were close to each other, indicating that fin placement is balanced. Among the fins, the caudal fin (CFL) was the longest ($18.21 \pm 0.31\%$), exceeding the other fins (DFL $13.59 \pm 0.22\%$; AFL $12.46 \pm 0.21\%$; PFL $12.62 \pm 0.11\%$; VFL $11.72 \pm 0.12\%$). Caudal peduncle length (CPL) was $20.17 \pm 0.26\%$ and depth (CPD) was $6.51 \pm 0.10\%$, and their ratio ($CPL/CPD = 3.10 \pm 0.04$) showed low variability. The distance between the pelvic and anal fins ($PAD = 22.45 \pm 0.24\%$) was smaller than the distance between the pectoral and pelvic fins ($PVD = 30.80 \pm 0.34\%$). In head morphology, eye diameter ($ED = 16.76 \pm 0.47\%$) and snout length ($SNL = 41.02 \pm 0.55\%$) were characterized by moderate variability. In the Oltiariqsoy population ($n = 19$), head length constituted $21.91 \pm 1.37\%$ of SL, and a higher value than in Qamchiqsoy was recorded. Body depth ($BDD = 14.73 \pm 0.42\%$) was high, and the degree of variability was also high ($V = 20.8\%$),

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indicating that morphological variation is stronger in this population. Predorsal length (PRL = $51.64 \pm 0.68\%$) was again greater than postdorsal length (PDL = $34.94 \pm 0.59\%$), showing that the general morphological pattern was maintained. In fin proportions as well, the caudal fin was dominant (CFL = $21.27 \pm 0.55\%$), while the remaining fins were relatively smaller (DFL = $14.27 \pm 0.34\%$; AFL = $12.22 \pm 0.51\%$; PFL = $14.76 \pm 0.23\%$; VFL = $13.05 \pm 0.44\%$). Although caudal peduncle length (CPL = $18.18 \pm 0.21\%$) and depth (CPD = $6.60 \pm 0.46\%$) were close to those of Qamchiqsoy, their variability was slightly higher. The difference between the pelvic–anal distance (PAD = $20.20 \pm 1.70\%$) and the pectoral–pelvic distance (PVD = $30.88 \pm 3.31\%$) was also maintained. In head morphological characters, eye diameter (ED = $14.42 \pm 0.98\%$) and interorbital width (IOW = $13.12 \pm 0.15\%$) were characterized by relatively high variability. Some traits, such as VAD (V = 24.2%), showed very high variability, indicating strong differentiation within the population.

At the same time, interpopulation differences based on the morphometric characters of *Iskandaria kuschakewitschi* specimens were evaluated using Student's t-test according to the methodology recommended by G. Lakin (1990). The analyses showed that, for the greater part of the morphometric characters, the condition $T_f > T_{st}$ was observed, that is, statistically reliable differences were present for most characters between the Qamchiqsoy and Oltiariqsoy populations. In particular, significant differences were identified in total length (TL), standard length (SL), head length (HL), body depth (BDD), body width (BWD), predorsal (PRL) and postdorsal (PDL) lengths, preventral length (PVL), as well as the lengths of the dorsal, anal, pectoral, and pelvic fins (DFL, AFL, PFL, VFL), and in caudal fin and caudal peduncle parameters (CFL, CPL). In addition, distances between fins (PAD, VAD) and head-related characters, including eye diameter (ED), postorbital length (POL), mouth width (MW), and barbel lengths (MBL), also demonstrated reliable differences between the populations. For some morphometric characters, however, the result $T_{st} > T_f$ was recorded, indicating

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that these characters are relatively stable and conservative between the populations. Nevertheless, because the main part of the characters showed divergence, it was concluded that the degree of morphological differentiation between the two populations is high.

In conclusion, it can be stated that the formation of these differences is primarily related to the hydrological and ecological conditions of the rivers. The Qamchiqsoy River is characterized by a relatively fast current and a stable hydrological regime, whereas in the Oltiariqsoy River, flow variability, seasonal fluctuations in discharge, and anthropogenic influences are more strongly expressed. Under such conditions, adaptive changes occur in body shape and body size of the fish. In populations inhabiting fast-flowing environments, the body is more elongated and adapted to the current, whereas in relatively slow-flowing and variable environments, the body tends to become deeper and wider. Geographic and hydrological isolation between the rivers restricts gene flow and leads to the separate development of each population. As a result, significant differences in morphological characters are formed over a long period. The results of the coefficient of variation also confirm this conclusion. In the Oltiariqsoy population, the higher degree of variability in many characters can be explained by habitat heterogeneity and the strong influence of ecological factors. In the Qamchiqsoy population, by contrast, moderate or low variability was observed in most characters, indicating the relative stability of the environment. The high level of identified morphometric differences suggests that, in addition to phenotypic differentiation, there may also be genetic differentiation between these populations. Therefore, it is considered appropriate to carry out molecular-genetic analyses in future studies in order to investigate these populations more deeply. Thus, the obtained results show that the processes of morphological differentiation are actively occurring in *Iskandaria kuschakewitschi* populations, and this serves as an important scientific basis for evaluating the ecological adaptability and population structure of the species.

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