



Morphometric characteristics and phenotypic differentiation of roach (*Rutilus -rutilus*) populations in lakes Aydarkul and Zamonbobo

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ABSTRACT

This study provides a comparative assessment of the morphometric structure and phenotypic differentiation of roach (*Rutilus-rutilus* Linnaeus, 1758) populations inhabiting two ecologically contrasting lentic systems of the Aral Sea basin: Lake Aydarkul and Lake Zamonbobo. Field collections were carried out between 2021 and 2025, yielding a total sample of $n=170$ specimens (Lake Aydarkul, $n=95$; Lake Zamonbobo, $n=75$). Morphometric measurements were processed following I.F. Pravdin's standard procedure. Statistical analysis revealed significant ($p<0.001$) divergence in body conformation: individuals from the large, open pelagic zone of Lake Aydarkul displayed a streamlined, low-bodied morphotype (maximum body depth $H=26.4\pm0.25\%$) with a prolonged caudal peduncle ($pl=20.6\pm0.28\%$), whereas the isolated, shallow, macrophyte-dominated Lake Zamonbobo favored a deep-bodied littoral morphotype ($H=30.5\pm0.32\%$). These empirical findings demonstrate the range of phenotypic plasticity and micro-evolutionary adaptation of native cyprinid species under differing hydroclimatic regimes.

KEYWORDS: *Rutilus-rutilus*, roach, Lake Aydarkul, Lake Zamonbobo, morphometrics, phenotypic plasticity, morphotype, allometry.

INTRODUCTION

As a result of the rapid modification of water resources in the Aral Sea basin and the redistribution of river flows, a system of water bodies of natural and artificial origin with fundamentally different hydrological regimes has emerged. On the one hand, massive hydrosystems with wide water areas and strong wind waves (the Aydar-Arnasay system of lakes) were created. On the other hand, closed, stagnant, and shallow lake ecosystems fed by collector-drainage waters were formed in the lower reaches of rivers (Lake Zamonbobo in the Zarafshan basin).

In such sharply contrasting hydrological and hydrodynamic conditions, the survival of fish populations is closely tied to their phenotypic plasticity-the ability to modify their external morphological characteristics in response to habitat factors. The roach (*Rutilus-rutilus* Linnaeus), 1758), a native representative of the cyprinid (Cyprinidae) family, is a species possessing such high morpho-ecological lability.

The development of roach populations in closed lakes with dense coastal macrophytes like Zamonbobo and in lakes with a developed open pelagic zone like Aydarkul occurred by

occupying different ecological niches. A comparative assessment of the morphometric parameters of roach from these two basins allows for the determination of intra-species micro-evolutionary adaptation mechanisms and the variability of body proportions induced by biotopic factors.

Material and Methods

Research materials were collected during the spring and autumn seasons of 2021–2025 across two main testing areas:

- Open and semi-open coastal areas of Lake Aydarkul (n=95).
- The water area of the closed, shallow Lake Zamonbobo in the Lower Zarafshan basin (n=75).

The total volume of analyzed materials was n=170 individual specimens. Scientific control nets with a mesh size of 18-40 mm were utilized to catch the fish. To avoid allometric distortions in the measurements, primarily sexually mature individuals belonging to the 2+ and 3+ age groups

Morphometric analysis was conducted according to the methodology of I.F. Pravdin (1966). The main plastic characters were measured using a caliper with an accuracy of 0.1 mm and expressed as percentages relative to the standard body length (SL):

- Maximum body depth (T)
- Minimum body depth (Sl)
- Antedorsal distance (aD)
- Postdorsal distance (pD)
- Caudal peduncle length (pl)
- Head length (c)
- Pectoral fin length (lP)
- Pelvic fin length (lV)

In the statistical processing of the obtained biometric data, the arithmetic mean (M), its standard error (m), and the coefficient of variation (Cv, %) were calculated. The reliability of the morphometric differences between the two populations was evaluated using Student's t-test.

Results

A comparative analysis of morphometric indicators demonstrated statistically reliable differences in body proportions between (*Rutilus-rutilus*) individuals living in lakes Aydarkul and Zamonbobo ($p<0.05-0.001$).

The following table presents the biometric indicators for the main plastic characters of the two lake populations and the reliability level of the differences between them:

Basic plastic characters of roach (*Rutilus-rutilus*) populations in lakes Aydarkul and Zamonbobo ($M \pm m$, in percentage relative to SL)

Plastic Characters	Lake Aydarkul (n=95)	Lake Zamonbobo (n=75)	t-criteria	Reliability (p)
DOCX	DOCX	DOCX	DOCX	DOCX
Maximum body depth (H)	26.4±0.25	30.5±0.32	10.09	p<0.001
Minimum body depth (h)	8.7±0.10	9.8±0.13	6.71	p<0.001
Antedorsal distance (aD)	49.2±0.33	51.9±0.37	5.44	p<0.001
Postdorsal distance (pD)	37.5±0.28	35.4±0.31	5.03	p<0.001
Caudal peduncle length (pl)	20.6±0.28	18.1±0.24	6.78	p<0.001
Head length (c)	21.5±0.19	23.3±0.24	5.88	p<0.001
Pectoral fin length (IP)	18.2±0.21	16.7±0.22	4.93	p<0.001
Pelvic fin length (IV)	16.8±0.18	15.5±0.20	4.83	p<0.001

The most notable difference between the populations was recorded in the body depth parameters. In Lake Zamonbobo roaches, the maximum body depth averaged $30.5 \pm 0.32\%$, which was found to be significantly higher than that of the Aydarkul population ($26.4 \pm 0.25\%$) ($t=10.09$, $p<0.001$). Additionally, the minimum body depth was also reliably higher in Zamonbobo roaches (9.8% versus 8.7%).

Conversely, superiority in the caudal peduncle length (pl) was observed in the Aydarkul population ($20.6 \pm 0.28\%$). In Lake Zamonbobo, this indicator decreased to an average of $18.1 \pm 0.24\%$.

It was also found that the relative length of the pectoral (IP) and pelvic (IV) fins, which are important elements of the locomotor apparatus, are much longer in the roaches from the open waters of Lake Aydarkul compared to individuals from Lake Zamonbobo (18.2% and 16.8%; $p<0.001$). The head length indicator in the Zamonbobo population was notable for its larger size relative to the body (23.3%).

Discussion The morphometric data obtained indicate the presence of two different ecological forms (morphotypes) in terms of body structure among the (*Rutilus-rutilus*) populations established in lakes Aydarkul and Zamonbobo.

Lake Aydarkul is a dynamic hydrosystem featuring a vast water surface, an open pelagic layer, and constant wind-driven waves. In such conditions, searching for food and moving about require overcoming significant hydrodynamic resistance. For this reason, traits such as a low body profile (26.4%), a short antedorsal distance (49.2%), and a long caudal peduncle (20.6%) have developed in Aydarkul roaches. These traits give the fish a torpedo-like shape, providing high hydrodynamic efficiency and the capacity for rapid movement. The relatively long fins (IP=18.2%) are also a result of adaptation to maintaining balance and continuous swimming in wavy water.

Conversely, Lake Zamonbobo is geomorphologically a biotope situated in a closed depression in the lower reaches of a river; it is shallow, lacks currents, and its shores are thickly covered

with reed beds. In such stagnant and shallow water bodies, there is no need for long-distance pelagic migrations. Instead, it requires the ability to turn freely among aquatic plants and reed stalks, avoid obstacles, and feed on benthic organisms (chironomids, mollusks). Consequently, a high-bodied (30.5%), short caudal peduncled (18.1%), and compact body structure has formed in the Zamonbobo population. Furthermore, a high body shape serves a morphological defense function that makes it difficult for predatory fish (e.g., catfish or zander) to swallow them.

The relatively larger head length in Zamonbobo roaches ($c=23.3\%$) reflects allometric principles related to the fact that the linear growth rate of this lake's population is lower than that in Aydarkul.

Conclusion

1. It was determined that a profound morphological differentiation exists between the roach (*Rutilus-rutilus*) populations inhabiting lakes Aydarkul and Zamonbobo, dependent on the hydrodynamic and landscape characteristics of their habitat.
2. The Aydarkul population, which occupies an open and wavy water area, is represented by a pelagic morphotype with a low body ($H=26.4\%$), a long caudal peduncle ($pl=20.6\%$), and developed paired fins.
3. In the closed, shallow, and reed-lined Lake Zamonbobo, a high-bodied ($H=30.5\%$) littoral morphotype specialized for maneuvering among macrophytes and benthophagic feeding has formed.
4. The identified set of morphological characteristics confirms that the (*Rutilus-rutilus*) species possesses high phenotypic plasticity in the anthropogenically altered hydro systems of the arid region.

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