



Growth patterns of common carp (*Cyprinus carpio*) in inland waterbodies of Uzbekistan

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Manuscript history

Received 3 September 2026 | Accepted 27 September 2026 | Published online 1 October 2026

Citation

Namozov S, Sobirov J, Atamuratova M, Sobirov B, Kamilov B, Mustafayeva Z, Dekhkonova D, Muratova D, Sagindikova N (2027) Growth patterns of common carp (*Cyprinus carpio*) in inland waterbodies of Uzbekistan. Journal of Fisheries 15(1): 151205. DOI: 10.17017/j.fish.1495

Abstract

Reservoirs and lakes in Uzbekistan support important populations of common carp (*Cyprinus carpio*), yet standardized comparisons of growth and body condition across contrasting water bodies remain scarce. We analyzed length–weight relationships (LWRs) and condition factors of common carp from six lakes and reservoirs of the Aral Sea Basin (Zamonbobov, Karakir, Tudakul, Charvak, Eastern Arnasay, and Tuzkon) using 234 fish (39 per water body) obtained from commercial set-gillnet catches during a common summer sampling window in 2025. Population-specific LWRs showed high statistical fit within the observed size ranges ($r^2 = 0.911–0.993$), and estimated b values ranged from 2.667 to 3.086. Robust HC3 inference confirmed significant negative allometry only in Karakir and Tuzkon. Diagnostic tests for condition-factor comparisons indicated non-normal residuals and heterogeneous variances; therefore, Welch’s ANOVA with Games–Howell post hoc comparisons was used for primary inference. Fulton’s condition factor (K) differed significantly among water bodies, whereas the relative condition factor (K_r) did not. Because samples were gear-selected commercial catches, size ranges differed among sites, and environmental drivers were not measured directly, these spatial differences are interpreted as baseline biometric patterns rather than causal evidence of habitat effects or stock status. The results provide standardized regional parameters that can support future, more explicitly designed monitoring of common carp populations in Uzbekistan.

Keywords: condition factors; *Cyprinus carpio*; fish population health; length-weight relationship, Uzbekistan

1 | INTRODUCTION

The common carp, *Cyprinus carpio* Linnaeus, 1758 (Cyprinidae) is one of the most widespread and economically important freshwater fish species worldwide. Its natural

distribution covers river basins of Eastern Europe and Asia, extending from the Danube and Black Sea region to the Amur basin and the Pacific coast (Berg 1949). In Central Asia, the species historically inhabited floodplain lakes

and channels of the Amu Darya and Syr Darya rivers, as well as coastal areas of the Aral Sea, where it preferred weakly flowing, warm water habitats with soft bottom substrates. Since the mid-20th century, common carp has been widely introduced into reservoirs, canals, ponds, and artificial lakes, and its acclimatization in Uzbekistan was an integral part of national fisheries development programs (Luzanskaya 1965; Kamilov 1973). As a result, the species currently occurs in almost all types of water bodies in the country, including collector–drainage lakes.

Common carp is also an important species in global aquaculture and in the fisheries sector of Uzbekistan (FAO 2022, 2026; Fisheries Scientific Research Institute 2024). Its economic importance increases the value of reliable regional biometric baselines that can be compared among inland water bodies and used to guide the design of future monitoring. Accordingly, the present study focuses on standardized biological indicators rather than on detailed production statistics.

In addition to its economic importance, common carp can influence aquatic food webs and benthic processes through its feeding activity (Weber and Brown 2013; Rahman 2015; Todd *et al.* 2024). Inland water bodies of Uzbekistan range from cold mountain reservoirs to brackish and saline lowland lakes and therefore provide a useful setting for comparing population-level biometric patterns. However, the environmental variables that could explain such differences were not measured concurrently in the present study; consequently, habitat-related explanations are treated as hypotheses rather than tested causal mechanisms.

Length–weight relationships (LWRs) and condition factors are widely used to describe fish growth form and body condition and to compare samples among water bodies (Bagenal and Tesch 1978; Muchlisin *et al.* 2010; Gupta *et al.* 2011; Dutta *et al.* 2021). In Uzbekistan, available studies are concentrated on individual water bodies, riverine native fishes, or single-population assessments, and multi-population comparisons of common carp under a common sampling period and analytical workflow remain limited (Sheraliyev *et al.* 2022; Azamov *et al.* 2024; Karimov *et al.* 2024, 2025; Namozov *et al.* 2025; Rozimov *et al.* 2025a, 2025b, 2026; Sobirov *et al.* 2025). The methodological gap addressed here is therefore not geographic coverage alone, but the direct comparison of six populations using population-specific LWRs with confidence intervals and formal tests against $b = 3$, together with two complementary condition indices and among-population statistical tests.

The present study investigates growth form and body condition of common carp from six lakes and reservoirs of Uzbekistan: Zamonbobo, Karakir, Tudakul, Charvak, Eastern Arnasay, and Tuzkon. Specifically, we (i) estimate population-specific LWR parameters and test whether b differs from 3, (ii) quantify relative condition

(K_n) and Fulton’s condition factor (K) and compare these indices among populations, and (iii) evaluate how differences in sampled size range and the use of commercial set-gillnet catches constrain interpretation. Because environmental covariates, fishing mortality, stock biomass, recruitment, and age structure were not measured directly, the study is intended as a descriptive and comparative biometric baseline rather than a causal habitat analysis or full stock assessment.

2 | METHODOLOGY

2.1 Study area and sampling

Field sampling was conducted between 28 July and 22 August 2025 (Table 1; Figure 1), so all six water bodies were sampled within the same summer period, although not on the same date. A total of 234 common carp individuals were included, with 39 individuals from each water body. Specimens originated from commercial set-gillnet catches. At each site, one sampling event was conducted using a set-gillnet 100 m in length and 2 m in height, with mesh sizes ranging from 16 to 50 mm. The net was set at approximately 17:00 and checked at approximately 06:00 the following morning, corresponding to an overnight soaking duration of about 13 h. Consequently, the samples were gear-selected rather than random population samples, and the analyses characterize the fish represented in the sampled catches rather than population abundance or catch per unit effort. After capture, individuals were anesthetized with MS-222. Total length and weight were measured from fresh specimens before fixation, as described below. The specimens were then fixed in 10% formalin for one week and transferred to 70% ethanol for long-term preservation.

TABLE 1 Sampling sites, dates, and coordinates for *Cyprinus carpio* from six lakes/reservoirs in Uzbekistan.

Sampling site	Sampling date (dd.mm.yy)	Coordinates
Zamonbobo Lake	22/08/2025	39°43′51.8″N 63°34′45.1″E
Karakir Lake	20/08/2025	40°24′10.5″N 63°17′53.1″E
Tudakul Lake	10/08/2025	39°52′09.0″N 64°48′47.0″E
Charvak Reservoir	28/07/2025	41°38′44.9″N 70°02′22.9″E
Eastern Arnasay Lake	16/08/2025	40°51′18.9″N 67°44′36.5″E
Tuzkon Lake	18/08/2025	40°41′03.2″N 67°20′48.7″E

2.2 Length-weight relationship

Species identification was based on Berg (1949) and

Salikhov *et al.* (2001). Before formalin fixation, total length (TL) was measured to the nearest 0.1 cm using a digital caliper, and each specimen was weighed to the nearest 0.01 g to obtain total weight (W). Thus, all TL and W values used for the length–weight relationship and condition-factor analyses were obtained from fresh specimens prior to preservation. Each fish contributed one TL–W observation. The analytical framework followed standard LWR procedures and is reproduced here in full for reproducibility, with Rozimov *et al.* (2025b) used as a methodological reference. LWRs were calculated using the allometric power function:

$$W = a \times TL^b$$

where W is total weight (g), TL is total length (cm), *a* is the intercept (scaling coefficient), and *b* is the allometric exponent. For each population, the relationship was linearized by logarithmic transformation and fitted by ordinary

least-squares regression (Ricker 1973; Borges *et al.* 2003; Andreu-Soler *et al.* 2006; Froese 2006; Veiga *et al.* 2009):

$$\log(W) = \log(a) + b$$

For each population, *a* and *b*, their 95% confidence intervals (CI), and the coefficient of determination (*r*²) were estimated from the log-transformed ordinary least-squares model. Departure from isometry was tested as *H*₀: *b* = 3. Because residual diagnostics indicated departures from normality and/or homoscedasticity in some population-specific regressions, inferential tests for *b* were based on heteroscedasticity-consistent HC3 standard errors. A significant *b* > 3 was interpreted as positive allometry and a significant *b* < 3 as negative allometry; when *b* did not differ significantly from 3, growth was treated as not statistically distinguishable from isometry (Sparre and Venema 1998; Froese 2006).



FIGURE 1 Sampling map of six studied populations of *Cyprinus carpio* in Uzbekistan. The orange-colored points represent sampled lakes/reservoirs.

2.3 Condition factors

Body condition was assessed for each individual using the relative condition factor (*K_r*) and Fulton's condition factor (*K*) following Fulton (1904) and Le Cren (1951).

$$K_r = W / (a TL^b)$$

K_r expresses the ratio between an individual's observed weight and the weight predicted for its length by the population-specific LWR; thus *K_r* = 1 indicates that ob-

served and model-predicted weights are equal.

$$K = 100 W / TL^3$$

Fulton's condition factor was calculated directly from observed weight and length as $K = 100 W / TL^3$ (with W in g and TL in cm). K assumes cubic (isometric) scaling, it can change systematically with fish length when b differs from 3; therefore, direct comparisons of K among samples with different size distributions require caution and were interpreted together with b , K_n , and the observed TL ranges (Froese 2006).

K_n and K provide complementary but different information. K_n standardizes an individual's weight relative to the population-specific LWR and is therefore expected to be centered near 1 when the same fitted relationship is used to calculate predicted weight. Consequently, K_n values close to 1 are not, by themselves, evidence that environmental or physiological condition is identical among populations. Fulton's K describes mass relative to cubic length but is more sensitive to size structure when growth is non-isometric. Minimum, maximum, mean, and standard deviation (SD) were calculated for both indices in each population.

2.4 Data analysis

Individual fish were treated as the statistical units (total $n = 234$; $n = 39$ per population), and population was included as a fixed factor with six levels. For population-specific length–weight regressions, residual normality was assessed using the Shapiro–Wilk test and homoscedasticity using the Breusch–Pagan test, supplemented by Q–Q and residual-versus-fitted plots. The null hypothesis $H_0: b = 3$ was evaluated using heteroscedasticity-consistent HC3 standard errors; conventional ordinary least-squares estimates were retained for a , b , and r^2 . For comparisons of relative condition factor (K_n) and Fulton's condition factor (K) among populations, normality of model residuals was

assessed using the Shapiro–Wilk test and homogeneity of variances using median-centered Levene's test. Because these assumptions were not satisfied for either condition index, Welch's one-way ANOVA was used as the primary omnibus test, followed by Games–Howell tests for pairwise comparisons. All statistical analyses and visualizations were performed using R v.4.3.2 (R Core Team 2023) and Microsoft Excel 2021.

3 | RESULTS

3.1 Sampling and morphometric features

A total of 234 common carp were analyzed, with 39 individuals from each of the six water bodies. The samples covered markedly different total-length (TL) and body-mass (W) ranges among sites (Table 2). These differences describe the size composition of the sampled commercial catches and should not be interpreted as direct estimates of population age structure, recruitment, abundance, or fishing pressure. The largest sampled individuals were from Tudakul, where TL reached 70.0 cm, and W reached 5485 g. Eastern Arnasay also showed a broad sample size range (TL 16.0 – 55.0 cm; W 50 – 2700 g). The Charvak sample contained the smallest individuals and covered TL 3.3 – 24.3 cm and W 0.9 – 263 g. Tuzkon (TL 5.7 – 33.0 cm; W 3.7 – 270 g) and Karakir (TL 9.3 – 32.5 cm; W 17 – 530 g) contained predominantly small to medium-sized fish relative to the other samples.

Zamonbobo had the narrowest and most right-shifted sampled interval (TL 33.0 – 46.5 cm; W 485 – 1280 g). Because LWR estimates depend on the size range represented, especially when that range is narrow, the unequal TL distributions among water bodies are an important limitation for direct comparison of regression parameters. No statistical correction for unequal size ranges was applied; all LWRs are therefore interpreted only within the observed ranges.

TABLE 2 Descriptive statistics and parameters of the length–weight relationship for six populations of *Cyprinus carpio* in Uzbekistan. n – number of individuals; TL – total length; W – total weight; Min – minimum; Max – maximum; a – intercept; b – slope; r^2 – coefficient of determination; CI – confidence interval; GT – growth type; I – not statistically distinguishable from isometry; –A – negative allometric growth. The 95% CI of b , growth type, and p values for $H_0: b = 3$ are based on HC3 heteroscedasticity-consistent standard errors.

Population	n	TL (cm)	W (g)	Length-weight relation parameters					GT	p (HC3), b vs 3
		Min–Max	Min–Max	a	b	r^2	95% CI of a	95% CI of b (HC3)		
Zamonbobo	39	33–46.5	485–1280	0.030	2.781	0.911	0.0105–0.0857	2.5032–3.0585	I	0.1182
Karakir	39	9.3–32.5	17–530	0.024	2.856	0.993	0.0189–0.0302	2.7731–2.9393	–A	0.0012
Tudakul	39	14–70	50–5485	0.014	3.046	0.993	0.0103–0.0190	2.9517–3.1404	I	0.3296
Charvak	39	3.3–24.3	0.9–263	0.015	3.032	0.989	0.0113–0.0199	2.7923–3.2714	I	0.7891
Eastern Arnasay	39	16–55	50–2700	0.012	3.086	0.990	0.0083–0.0170	2.9558–3.2156	I	0.1895
Tuzkon	39	5.7–33	3.7–270	0.036	2.667	0.960	0.0216–0.0591	2.4287–2.9059	–A	0.0076

3.2 Length-weight relationships

Population-specific LWRs differed among the six water bodies (Table 2; Figure 2). Within the observed size rang-

es, the power model $W = a \times TL^b$ showed high statistical fit, with r^2 values from 0.911 to 0.993. These high r^2 values indicate that length explained a large proportion of

variation in weight within the sampled data, but they do not by themselves demonstrate that the catches were biologically representative of the full populations.

The exponent b ranged from 2.667 to 3.086. Based on HC3 robust inference, Zamonbobo ($b = 2.781$, $p = 0.118$), Tudakul ($b = 3.046$, $p = 0.330$), Charvak ($b = 3.032$,

$p = 0.789$), and Eastern Arnasay ($b = 3.086$, $p = 0.189$) did not differ significantly from 3, and their HC3 95% confidence intervals included the isometric benchmark. These samples were therefore classified as not statistically distinguishable from isometric growth within their observed size ranges.

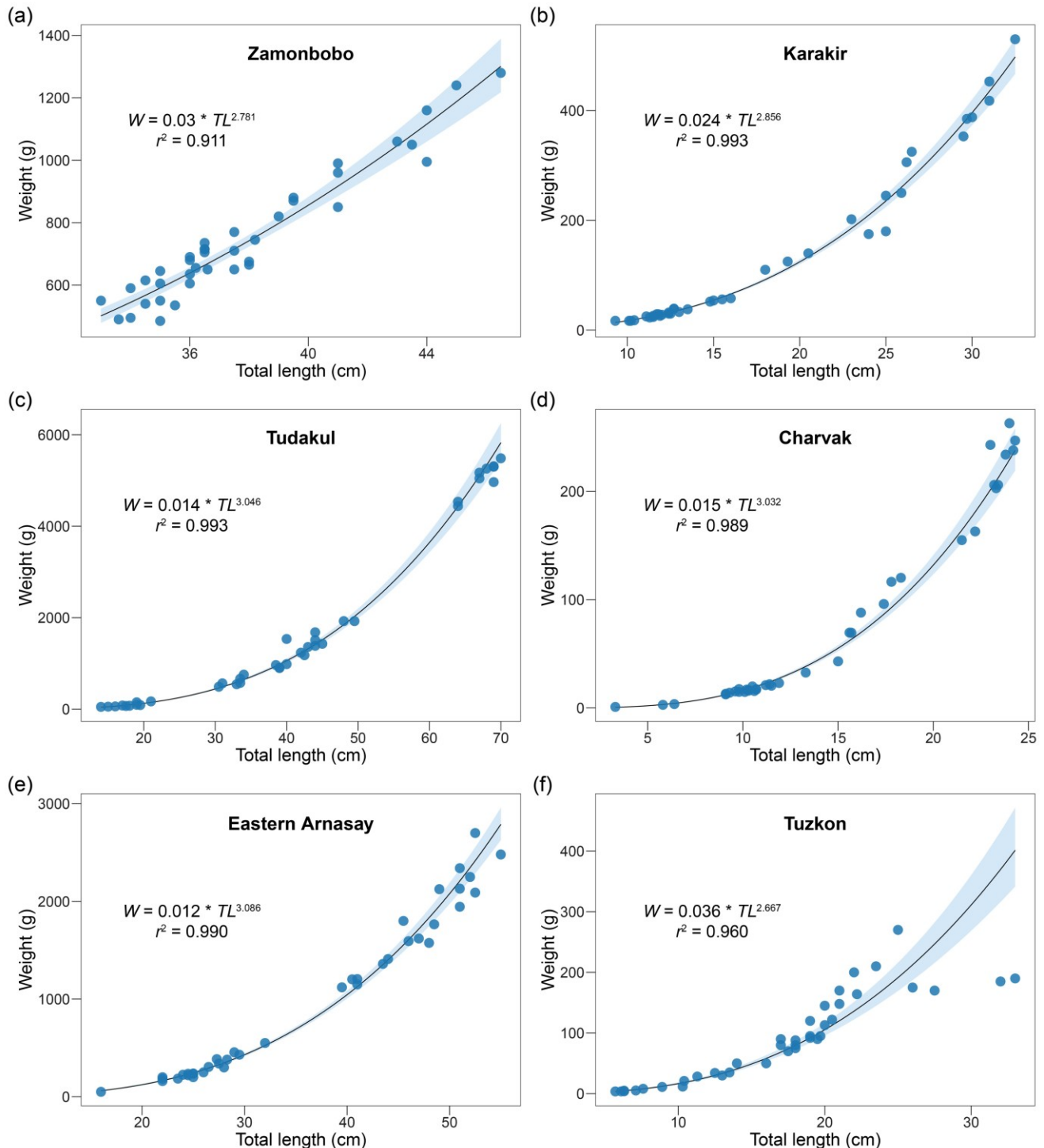


FIGURE 2 Length–weight relationships (LWRs) for six populations of *Cyprinus carpio*. Panels (a–f) show population-specific LWRs. Each plot shows observed data (blue points), fitted regression curves (black lines), and 95% confidence intervals (light-blue ribbons). The estimated LWR equations and coefficients of determination (r^2) are presented within each plot.

Karakir ($b = 2.856$, HC3 $p = 0.0012$) and Tuzkon ($b = 2.667$, HC3 $p = 0.0076$) showed significant negative allometry, with HC3 95% confidence intervals entirely below 3 (Karakir: 2.773–2.939; Tuzkon: 2.429–2.906). The magnitude of departure from the isometric benchmark was modest in Karakir ($\Delta b = -0.144$) and larger in Tuzkon ($\Delta b = -0.333$), indicating that statistical significance and biological magnitude were not identical across the two populations. Their r^2 values (0.993 and 0.960, respectively) describe model fit within the sampled size ranges and should not be interpreted as evidence of population representativeness.

The intercept a ranged from 0.012 in Eastern Arnasay to 0.036 in Tuzkon. Because a and b are mathematically coupled and both estimates are influenced by the sampled length range, a was not interpreted independently as a direct measure of body shape or habitat quality.

Residual diagnostics showed that the assumption of normality was not met for Zamonbobo (Shapiro–Wilk $p =$

0.015) or Tuzkon ($p = 0.014$), while heteroscedasticity was detected in Tudakul (Breusch–Pagan $p = 0.033$), Charvak ($p = 0.004$), and Tuzkon ($p = 0.006$). Karakir and Eastern Arnasay showed no significant departures in either diagnostic test ($p > 0.05$). Importantly, HC3 robust inference yielded the same growth-type classifications as the conventional tests: Karakir and Tuzkon were negatively allometric, whereas the remaining four populations were not statistically distinguishable from isometry (Table S1).

3.3 Condition factors

Relative condition factor (K_r) and Fulton's condition factor (K) were used to assess body condition across populations (Table 3; Figure 3). For all six populations, mean K_r values were close to the theoretical reference value of 1.0, ranging from 1.003 (Zamonbobo) to 1.030 (Tuzkon). Minimum and maximum K_r values indicated moderate individual-level variability, with the narrowest range observed in Zamonbobo (0.821 – 1.108) and the widest range in Tuzkon (0.473 – 1.470).

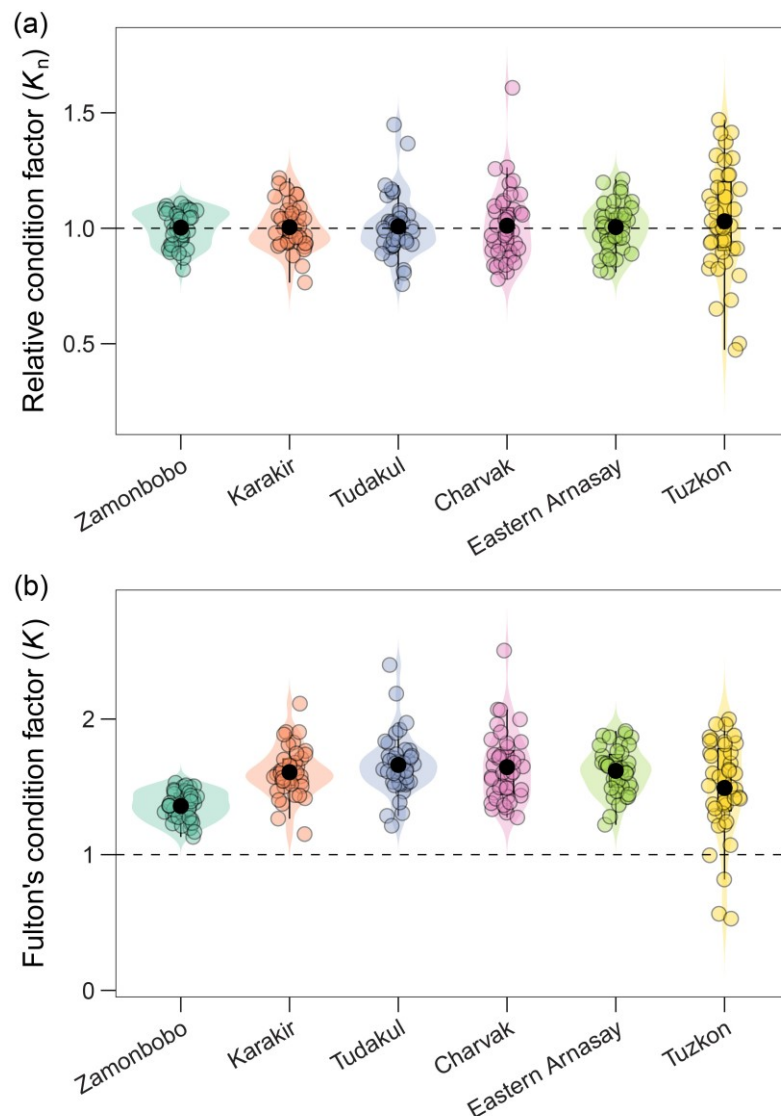


FIGURE 3 Condition factors for six populations of *Cyprinus carpio*: (a) relative condition factor (K_r); (b) Fulton's condition factor (K). The dashed horizontal line at 1.0 is the direct reference value for K_r ; for K it is shown only as a visual benchmark because Fulton's K has no universal expected value across samples. Welch's one-way ANOVA detected no significant differences among populations for K_r ($p = 0.991$), whereas K differed significantly ($p < 0.001$). Violin plots show the full distribution, boxplots indicate interquartile ranges, and bold points represent mean values.

TABLE 3 Summary statistics for relative condition factor (K_n) and Fulton's condition factor (K) across six populations of *Cyprinus carpio*.

Population	Min		Max		Mean		SD	
	K_n	K	K_n	K	K_n	K	K_n	K
Zamonbobo	0.821	1.131	1.108	1.530	1.003	1.359	0.075	0.106
Karakir	0.765	1.152	1.217	2.113	1.005	1.608	0.099	0.183
Tudakul	0.758	1.214	1.449	2.398	1.008	1.662	0.136	0.222
Charvak	0.780	1.274	1.608	2.504	1.011	1.645	0.160	0.256
Eastern Arnasay	0.809	1.221	1.212	1.911	1.005	1.618	0.103	0.171
Tuzkon	0.473	0.529	1.470	1.998	1.030	1.492	0.238	0.358

Diagnostic tests indicated departures from the assumptions of conventional one-way ANOVA. For K_n , the Shapiro–Wilk test of model residuals was significant ($W = 0.957$, $p < 0.001$), and median-centered Levene's test indicated heterogeneous variances ($F = 8.683$, $p < 0.001$). Accordingly, Welch's one-way ANOVA was used for primary inference and detected no significant population effect for K_n ($F_{(5, 104.65)} = 0.103$, $p = 0.991$; Table 4). Because K_n is calculated relative to each population's own fitted LWR, values close to 1 and limited among-population separation are partly expected from the standardization procedure and should not be interpreted as proof of identical ecological condition.

For Fulton's K , residual normality was also rejected (Shapiro–Wilk $W = 0.963$, $p < 0.001$), and variances were heterogeneous (Levene's $F = 7.576$, $p < 0.001$). Welch's ANOVA showed a significant population effect ($F_{(5, 103.65)} = 26.227$, $p < 0.001$; Table 4). This demonstrates heterogeneity in the observed weight-to-cubic-length ratio among

the sampled catches. However, because K is sensitive to fish size when b differs from 3, the result cannot be attributed directly to habitat quality or trophic conditions without accounting for contrasting size distributions and unmeasured environmental covariates.

Games–Howell post hoc comparisons detected no significant pairwise differences in K_n among populations (all adjusted $p \geq 0.983$; Table S2). For Fulton's K , Zamonbobo had significantly lower values than Karakir, Tudakul, Charvak, and Eastern Arnasay (all adjusted $p < 0.001$). Zamonbobo did not differ significantly from Tuzkon (adjusted $p = 0.249$), and no other pairwise comparison was significant (all adjusted $p \geq 0.136$; Table S2).

Taken together, K_n showed little separation after population-specific LWR standardization, whereas Fulton's K differed among sampled catches. The two indices therefore should be interpreted as complementary descriptive measures, with particular caution for K where b differs from 3 or sampled length ranges differ strongly.

TABLE 4 Diagnostic tests and Welch's one-way ANOVA for relative condition factor (K_n) and Fulton's condition factor (K) among six populations. Shapiro–Wilk tests assess residual normality and median-centered Levene's tests assess homogeneity of variances.

Condition	Shapiro W (p)	Levene F (p)	Welch F	df1	df2	p
K_n	0.957 (<0.001)	8.683 (<0.001)	0.103	5	104.65	0.991
K	0.963 (<0.001)	7.576 (<0.001)	26.227	5	103.65	<0.001

4 | DISCUSSION

The study detected clear spatial differences in LWR parameters and Fulton's condition factor among common carp samples from six water bodies of Uzbekistan. The fitted LWRs had high r^2 values within the observed size ranges (0.911 – 0.993), and b ranged from 2.667 to 3.086. These results establish differences among the sampled catches, but the present design did not measure hydrology, temperature, salinity, food availability, population density, or other candidate drivers. Accordingly, such variables can be discussed only as plausible hypotheses from the literature, not as empirically tested causes of the observed patterns (Mutethya and Yongo 2021; Sheraliev *et al.* 2022; Karimov *et al.* 2024; Namozov *et al.* 2025).

The strongest statistical departures from isometry occurred in Karakir and Tuzkon, where b was significantly below 3, whereas Zamonbobo, Tudakul, Charvak, and Eastern Arnasay were not statistically distinguishable from $b = 3$. Importantly, Zamonbobo had a relatively low point estimate ($b = 2.781$) but a confidence interval that included 3, illustrating how a restricted length range can reduce precision of slope estimation. The contrast between the modest departure in Karakir ($\Delta b = -0.144$) and the larger departure in Tuzkon ($\Delta b = -0.333$) also shows why p -values should be considered together with effect magnitude and confidence intervals rather than used alone to characterize biological differences (Froese *et al.* 2014; Dash *et al.* 2023; Rodríguez-García *et al.* 2023).

The condition-factor results require similar caution. K_n remained close to 1 in all populations and did not differ significantly under Welch's ANOVA. This is consistent with close agreement between observed weight and the weight predicted by each population-specific LWR, but it is also partly expected because K_n is calculated from those same fitted relationships. Thus, the insignificant K_n result should not be interpreted as evidence that ecological condition was identical among water bodies. Fulton's K differed significantly among populations under Welch's ANOVA, with Games–Howell comparisons localizing the significant differences to Zamonbobo versus Karakir, Tudakul, Charvak, and Eastern Arnasay. Nevertheless, K assumes cubic scaling and can vary with length when $b \neq 3$ (Froese 2006). The combination of different b values and markedly different sampled TL ranges therefore limits direct ecological interpretation of K differences.

Several methodological limitations affect the strength of inference. First, fish originated from commercial set-gillnet catches with mesh sizes of 16 – 50 mm, so gear selectivity could alter the size distribution represented at each site (Prchalová *et al.* 2009; Šmejkal *et al.* 2015; Jayasinghe *et al.* 2017). The quantitative effect of gear selectivity was not estimated, and no correction for unequal size ranges was applied. Second, only one overnight sampling event was conducted per water body, so within-site temporal and sampling-effort variability could not be quantified. Sampling occurred within a relatively narrow summer window (28 July–22 August 2025), which reduces broad seasonal mismatch among sites but does not capture within-year variation in growth or condition. Third, TL and W were recorded from fresh fish before formalin fixation; therefore, subsequent preservation in formalin and ethanol did not influence the measurements used for LWR or condition-factor analyses. Finally, a high r^2 describes statistical fit within a sample and should not be treated as evidence that the sample represents the entire population.

The present data are best viewed as a regional biometric baseline rather than a complete stock assessment. LWR parameters and condition indices alone do not provide estimates of fishing mortality, exploitation rate, spawning-stock biomass, recruitment, or sustainable harvest. Therefore, the results do not support prescriptions about allowable fishing pressure, stocking, or gear regulation for individual water bodies. Future assessments should combine standardized and replicated sampling with catch-per-unit-effort, age and maturity structure, sex, repeated seasonal sampling, and concurrent measurements of relevant environmental variables before management actions are inferred (Graham *et al.* 2007; Humphries *et al.* 2019; Griffiths *et al.* 2023).

Overall, the study demonstrates heterogeneity in biometric relationships among commercial catches of common carp across Uzbekistan while also showing the

importance of sampling structure and statistical assumptions for interpretation. Reporting b with robust inference, confidence intervals, and the magnitude of departure from 3, considering K together with K_n and sampled length ranges, and explicitly recognizing gear selectivity and limited sampling replication provides a more cautious framework for future population comparisons. Direct tests of ecological drivers will require additional environmental and stock-assessment data.

5 | CONCLUSIONS

The present study identified spatial variability in LWR parameters and condition indices among common carp (*Cyprinus carpio*) sampled from six water bodies of Uzbekistan. Population-specific LWRs showed high fit within the observed size ranges ($r^2 > 0.91$), and b ranged from 2.667 to 3.086. Karakir and Tuzkon showed significant negative allometry, whereas the other four populations were not statistically distinguishable from $b = 3$.

Fulton's K differed significantly among sampled populations, whereas K_n remained close to 1 and showed no significant among-population difference. Because K_n is standardized using each population-specific LWR, values close to unity are partly expected; conversely, K can be confounded by size structure when b differs from 3. The two indices should therefore be interpreted jointly and within the observed length ranges.

These results provide a useful regional biometric baseline, but they should not be interpreted as a direct assessment of habitat quality, fishing pressure, or sustainable harvest. Commercial gear selectivity, unequal sampled size ranges, single-event sampling at each water body, and the absence of concurrent environmental and stock-assessment data limit causal and management inference. Standardized replicated sampling across seasons, together with age structure, fishing-effort metrics, and environmental measurements, will be needed to test the mechanisms underlying the observed spatial differences and to support management decisions.

ACKNOWLEDGEMENTS

This work was carried out within the framework of the research program of the Institute of Zoology, Academy of Sciences of the Republic of Uzbekistan for 2025–2029, “1.2. Development of a digital information system of the fauna of the Bukhara and Navoi regions,” funded by the state budget, as well as within the framework of the fundamental project F-FA-2021-459 “Study of population phenotypic diversity and adaptive potential of hydrobiota for the theoretical substantiation of the development of fisheries in Uzbekistan.”

CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHORS' CONTRIBUTION

Conceptualization Jobir Sobirov; methodology, Jobir Sobirov and Sirojiddin Namozov; validation, Sirojiddin Namozov and Bakhtiyor Kamilov; formal analysis, Sirojiddin Namozov, Jobir Sobirov, Mukhayyo Atamuratova, Zuri Mustafayeva, Bobir Sobirov; investigation Sirojiddin Namozov, Jobir Sobirov, Mukhayyo Atamuratova, Zuri Mustafayeva, Bobir Sobirov, Bakhtiyor Kamilov, Dilorakhon Dekhkonova, Dilnoza Muratova and Nigora Sagindikova; resources, Sirojiddin Namozov, Jobir Sobirov, and Bakhtiyor Kamilov; data curation, Sirojiddin Namozov, Jobir Sobirov; writing – original draft preparation, Sirojiddin Namozov, Jobir Sobirov and Mukhayyo Atamuratova; writing – review and editing, Sirojiddin Namozov, Jobir Sobirov, Mukhayyo Atamuratova and Zuri Mustafayeva; supervision, Jobir Sobirov; project administration, Jobir Sobirov and Sirojiddin Namozov; funding acquisition, Jobir Sobirov, Sirojiddin Namozov and Bakhtiyor Kamilov.

AI-USE STATEMENT

ChatGPT was used to refine the English grammar and improve the manuscript's clarity.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on a reasonable request from the corresponding author.

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