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Length-weight relationships and condition factors of 30 species from the Upper Syr Darya drainage, Uzbekistan

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Abstract: Length-weight relationships (LWRs) were estimated for 30 fish species, i.e. *Abbottina rivularis*, *Alburnus chalcoides*, *A. oblongus*, *A. taeniatus*, *Carassius gibelio*, *Channa argus*, *Cottus spinulosus*, *Cyprinus carpio*, *Gambusia holbrooki*, *Glyptosternon oschanini*, *Gobio lepidolaemus*, *Hemiculter leucisculus*, *Hypophthalmichthys nobilis*, *Iskandaria kuschakewitschi*, *Luciobarbus conocephalus*, *Micropercops cinctus*, *Opsariichthys bidens*, *Pelecus cultratus*, *Petroleuciscus squaliusculus*, *Pseudorasbora parva*, *Rhinogobius* cf. *lindbergi*, *Rhodeus ocellatus*, *Sabanejewia aralensis*, *Salmo oxianus*, *Schizothorax eurystomus*, *Triplophysa daryoae*, *T. elegans*, *T. ferganaensis*, *T. labiata*, and *T. strauchii* from the Upper Syr Darya drainage, Uzbekistan. The LWR parameters were determined using a linear logarithmic regression model of the weight against the length, in which values for the slope of the regression, b, that were higher and lower than three indicated positive and negative allometric growth, respectively. The estimated values of parameter b ranged from 2.719 (*Cyprinus carpio*) to 3.442 (*Pelecus cultratus*). The correlation coefficient (r^2) values varied from 0.945 to 0.998, indicating a strong positive relationship between the length and weight. This study established new maximum TLs for three species (*Glyptosternon oschanini*, *Gobio lepidolaemus*, and *Petroleuciscus squaliusculus*) and presented LWRs for the first time for 17 fish species in the inland waters of Uzbekistan, including seven previously unreported in FishBase.

Key words: Freshwater fishes, morphology, length-weight relationship, condition factor

Assessing fish growth parameters is vital for ecological studies, as it helps in understanding population status and the impact of biological and environmental factors (Mouludi-Saleh et al., 2023). Furthermore, it aids in assessing fish stock structure and managing growth patterns (isometric or allometric) within the somatic compartment (Çiçek et al., 2022). A critical aspect of fish growth studies is the length-weight relationship (LWR), as this metric provides valuable insights for assessing fish stock structure and comparing growth patterns across different populations (Froese, 2006; Karimov et al., 2024). Additionally, the condition factor serves as an important indicator of a fish's general physiological health and well-being (Le Cren, 1951; Hossain et al., 2006).

The Syr Darya is the longest endorheic river in Central Asia and originates at the confluence of the Naryn and Kara Darya rivers in the Fergana Valley. The exact number of fish species inhabiting the river remains unclear, with estimates ranging from 39 to 54 (Berg, 1949; Turdakov, 1963; Kamilov, 1964; Vundtsettel, 1994). The pace of taxonomic research on the basin's ichthyofauna has noticeably accelerated in recent years (Thoni et al., 2017; Sheraliev and Peng, 2021; Sideleva, 2021; Sheraliev et al., 2022b, 2024). Due to the high number of endemic fish species in the river, which are irreplaceable components of the ecosystem, special conservation studies are crucial. The fish growth parameters provide valuable information for conservation biologists working to understand and manage endemic fish populations in this region.

Building on previous studies that documented LWR data for six fish species in the Syr Darya (Sheraliev et al., 2022a; Karimov et al., 2024), this work expands the analysis to encompass 30 species. In the current study, the LWRs were calculated for 17 endemic and indigenous species, as well as 13 introduced species, from the Upper Syr Darya drainage. Data collection spanned from 2016 onward, utilizing both fresh and formalin-fixed specimens.

During 2016–2024, a total 2064 fish species were collected using a small-mesh net (1 × 1 mm). After anesthesia, the fish specimens were dried using a paper tissue and their total length (TL) and total weight (TW) were measured using a digital caliper to the nearest 0.01

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mm and a digital scale to the nearest 0.01 g, respectively. The LWRs were calculated using the equation TW = a × TL^b, where TW is the total weight (g), TL is the total length (cm), a is the intercept, and b is the slope. Fulton's condition factor (K_F) was assessed using K_F = (TW/TL^3) × 100 according to Fulton (1904). Hence, the relative condition factor (K_R), which indicates changes in form or condition as the length increases, was calculated using the equation K_R = 100 × TW / (a × TL^b) (Froese, 2006). The 95% confidence limits (CLs) of a and b, and the coefficient of determination (r^2) were determined using the equations of Sparre and Venema (1998). All the statistical analyses were performed using Microsoft Excel 2019 software (Microsoft Corp., Redmond, WA, USA).

The present work investigated the LWRs and condition factors of 30 fish species from the Upper Syr Darya drainage. The species status, sample size, maximum and minimum of the total length and weight, sampling locations, and time are given in Table 1. The LWR parameters, regression parameters a and b, 95% CLs of a and b, type of growth, and the coefficient of determination (r^2), and condition factors are given in Table 2. For all the studied species, the r^2 between the length and weight ranged from 0.945 to 0.998, the a-value ranged from 0.0011 to 0.0380, and the b-values ranged from 2.719 in *Cyprinus carpio* to 3.442 in *Pelecus cultratus*. The mean value of the Fulton's condition factor of the studied species ranged from 0.469 in *Pelecus cultratus* to 1.782 in *Carassius gibelio*. On the other hand, the relative condition factor had a very narrow range of 100.07 (*Alburnus oblongus*) to 101.12 (*Iskandaria kuschakewitschi*), with a mean of 100.39 ± 0.228.

While the ideal b-value in the LWR equations is considered to be 3.0 (Le Cren, 1951), the expected range falls between 2.5 and 3.5 (Froese, 2006). The results of the current study were consistent with the expected range. Fish with a b-value >3 prioritize weight gain over length growth (Islam et al., 2017). Conversely, a b-value <3 suggests the fish allocate more energy toward axial elongation, potentially for improved foraging and predator evasion (Yang et al., 2021). The calculations performed in the present study showed that, in *Channa argus*, *Cyprinus carpio*, *Hypophthalmichthys nobilis*, *Rhinogobius* cf. *lindbergi*, and *Triplophysa labiata*, parameter *b* was significantly lower than 3.0 (Table 2). Research suggests that the b-value is a flexible metric, influenced by a multitude of factors. These factors encompass abiotic conditions (habitat type, seasonality, location), biological characteristics (sex, maturity, health, feeding status, competition, river/pond food availability), and human influence (fishing gear bias, sample size, specimen size range) (Hossain et al., 2006; De Giosa et al., 2014; Islam et al., 2017; Mouludi-Saleh et al., 2023; Karimov et al., 2024). The current study reports the first LWR data for 17 species, including *Abbottina rivularis*, *Alburnus chalcoides*, *A. oblongus*, *A. taeniatus*, *Channa argus*, *Gambusia holbrooki*, *Hemiculter leucisculus*, *Luciobarbus conocephalus*, *Micropercops cinctus*, *Pelecus cultratus*, *Petroleuciscus squaliusculus*, *Pseudorasbora parva*, *Rhinogobius* cf. *lindbergi*, *Rhodeus ocellatus*, *Salmo oxianus*, *Triplophysa elegans*, and *T. labiata* from the inland waters of Uzbekistan. The LWR data presented herein for fish species in the Upper Syr Darya drainage offers valuable insights into their growth patterns. This information can significantly contribute to improved fish management and conservation strategies for the region.

Table 1. Species status, descriptive statistics of the length and weight, sampling localities, and time for 30 fish species from the Upper Syr Darya drainage, Uzbekistan (n: number of individuals, I: introduced species, C: common species, E: endemic species, *: maximum length bigger than given in FishBase, **: new maximum TL not given in FishBase).

Species	Species status	n	TL (cm)		TW (g)		Drainage	Geographic coordinate	Year	Maximum length in FishBase
			Min	Max	Min	Max				
Abbottina rivularis	I	54	3.85	10.75	0.54	16.73	Kara Darya River	40.914524, 71.895101	2023	18.9
							Margilansay River	40.398408, 71.766314		
Alburnus chalcoides	C	10	9.64	13.25	6.83	17.91	Kara Darya River	40.914524, 71.895101	2023	40.0
Alburnus oblongus	C	8	6.65	10.52	2.76	12.22	Achangaran River	41.111041, 70.340867	2023	14.2
Alburnus taeniatus	C	310	2.61	7.07	0.14	3.56	Kara Darya River	40.914524, 71.895101	2023	9.0
Carassius gibelio	I	15	3.69	15.74	0.96	67.32	Kara Darya River	40.914524, 71.895101	2023	46.6
Channa argus	I	17	22.52	37.61	88.29	382.15	Syr Darya River	40.882262, 71.692570	2024	100.0

Table 1. (Continued.)

Cottus spinulosus	E	24	4.56	9.92	1.09	13.96	Sokh River	39.943814, 71.142293	2023	10.3
							Margilansay River	40.307407, 71.802089		
Cyprinus carpio	C	21	14.66	30.45	56.48	403.44	Syr Darya River	40.882262, 71.692570	2024	120.0
Gambusia holbrooki	I	336	1.48	5.03	0.04	1.68	Kara Darya River	40.878262, 72.323062	2023	8.0
							Margilansay River	40.307407, 71.802089		
*Glyptosternon oschanini***	C	48	6.88	21.00	2.90	103.50	Kara Darya River	40.917506, 71.903040	2023	-
							Naryn River	41.104675, 72.046324		
							Margilansay River	40.364795, 71.802953		
							Chodaksoy River	41.070715, 70.704651	2024	
*Gobio lepidolaemus***	C	131	3.03	12.69	0.40	26.52	Kara Darya River	40.878262, 72.323062	2023	-
							Margilansay River	40.398408, 71.766314		
Hemiculter leucisculus	I	12	8.63	16.61	4.71	43.27	Kara Darya River	40.914524, 71.895101	2023	29.0
Hypophthalmichthys nobilis	I	22	20.71	30.37	94.24	275.64	Syr Darya River	40.882262, 71.692570	2024	146.0
Iskandaria kuschakewitschi	E	94	2.92	10.10	0.10	5.93	Kara Darya River	40.914524, 71.895101	2023	14.6
							Chodaksoy River	41.070715, 70.704651		
							Oltiariqsoy River	40.275204, 71.531670	2024	
							Great Fergana Canal	40.487107, 70.924399	2023	
Luciobarbus conocephalus	C	42	5.89	33.60	1.83	377.25	Kara Darya River	40.914524, 71.895101	2023	-
							Syr Darya River	40.882779, 71.438565	2016	
Micropercops cinctus	I	20	2.93	6.38	0.23	3.47	Margilansay River	40.307407, 71.802089	2023	8.0
Opsariichthys bidens	I	45	3.22	14.96	0.29	29.50	Kara Darya River	40.878262, 72.323062	2023	26.1
Pelecus cultratus	C	11	21.50	30.70	45.60	149.68	Syr Darya River	40.882779, 71.438565	2016	60.0
*Petroleuciscus squaliusculus**	E	33	5.66	13.16	2.28	34.86	Oltiariqsoy River	40.290938, 71.520489	2023	13.0
Pseudorasbora parva	I	80	3.17	9.24	0.30	10.50	Kara Darya River	40.878262, 72.323062	2023	12.5
							Margilansay River	40.398408, 71.766314		
Rhinogobius cf. *lindbergi*	I	20	4.21	5.84	0.81	1.89	Oltiariqsoy River	40.339132, 71.497101	2023	-
							Margilansay River	40.380438, 71.797432		

Table 1. (Continued.)

Rhodeus ocellatus	I	77	2.44	7.36	0.14	6.60	Kara Darya River	40.878262, 72.323062	2023	9.2
							Margilansay River	40.380438, 71.797432		
Sabanejewia aralensis	C	25	3.96	8.48	0.30	3.90	Kara Darya River	40.878262, 72.323062	2023	-
Salmo oxianus	C	30	11.52	25.06	15.73	178.51	Naryn River	41.104675, 72.046324	2021	-
Schizothorax eurystomus	C	80	3.57	22.00	0.40	103.40	Kara Darya River	40.914524, 71.895101	2023	35.5
							Margilansay River	40.398408, 71.766314		
							Chodaksoy River	41.070715, 70.704651		
							Oltiariqsoy River	40.277586, 71.529869		
							Isfayramsay River	40.286413, 71.991829		
Triplophysa daryoae	E	40	4.32	10.47	0.59	10.00	Sokh River	39.943814, 71.142293	2024	-
Triplophysa elegans	E	80	3.97	11.36	0.50	10.73	Achangaran River	41.110963, 70.340678	2023	-
Triplophysa ferganaensis	E	70	3.54	12.48	0.35	16.97	Shohimardonsoy River	39.962767, 71.759742	2023	-
							Oltiariqsoy River	40.290938, 71.520489		
							Isfayramsay River	40.286413, 71.991829		
Triplophysa labiata	I	59	2.84	18.17	0.22	30.84	Kara Darya River	40.878262, 72.323062	2023	23.0
							Great Fergana Canal	40.487107, 70.924399	2020	
Triplophysa strauchii	I	250	4.36	15.92	0.75	35.80	Kara Darya River	40.878262, 72.323062	2023	25.0
							Margilansay River	40.398408, 71.766314		

The condition factor (K_F) and exponent (b) in LWRs are directly linked. When b = 3, the K_F remains constant at one. However, any deviation from b = 3, whether higher or lower, will cause the condition factor to change accordingly, either increasing or decreasing (Soni and Ujjania, 2017). This study found that the average value of Fulton's condition factor for most of the studied species fell within the expected range, although some species deviated from this norm (Table 2). Relative condition factor (K_R) values below 100 suggest that the fish are experiencing low food availability and high predator presence. On the contrary, higher K_R values indicate an abundance of prey and low predation pressure (Froese, 2006; Sabido-Itza et al., 2016). In the current study, the mean K_R value across all the studied species was 100.39 ± 0.228. In light of the K_R value of 100 in all the studied species, it can be concluded that these fish populations are likely experiencing relatively stable food resources and predator presence within their environment.

Table 2. Descriptive statistics and estimated parameters of LWRs and condition factors for 30 fish species from the Upper Syr Darya drainage, Uzbekistan (a: intercept, b: slope, r^2: coefficient of determination, CL: confidence limits, GT: growth type, I: isometric growth, A–: negative allometric growth, A+: positive allometric growth, SD: standard deviation, *: first listing species for the LWRs in the inland waters of Uzbekistan, bold font: no LWR references in FishBase).

Species	LWR parameters						Fulton's condition				Relative condition			
	a	b	CL of a	CL of b	GT	r^2	Min	Max	Mean	SD	Min	Max	Mean	SD
*Abbottina rivularis**	0.0075	3.204	0.0062–0.0091	3.108–3.299	A+	0.989	0.902	1.348	1.142	0.116	80.94	115.90	100.37	8.92
*Alburnus chalcoides**	0.0037	3.316	0.0015–0.0088	2.958–3.673	A+	0.979	0.713	0.873	0.793	0.049	92.88	107.76	100.12	5.19
*Alburnus oblongus**	0.0064	**3.206**	0.0042-0.0097	3.007-3.404	A+	0.995	0.924	1.050	0.983	0.053	93.30	107.13	100.07	3.99
*Alburnus taeniatus**	0.0111	**2.949**	0.0101–0.0122	2.888–3.009	I	0.967	0.787	1.292	1.034	0.098	74.76	124.73	100.45	9.46
Carassius gibelio	0.0187	2.975	0.0139–0.0252	2.836–3.114	I	0.993	1.380	2.029	1.782	0.169	77.70	113.91	100.45	9.45
*Channa argus**	0.0144	2.797	0.0087–0.0239	2.647–2.946	A–	0.990	0.645	0.822	0.723	0.043	91.97	109.16	100.11	4.81
Cottus spinulosus	0.0093	3.225	0.0063–0.0138	3.012–3.438	A+	0.977	1.150	1.689	1.421	0.152	84.21	117.39	100.47	9.95
Cyprinus carpio	0.0380	2.719	0.0255–0.0565	2.594–2.844	A–	0.990	1.364	1.818	1.560	0.134	88.83	116.67	100.16	5.90
*Gambusia holbrooki**	0.0077	3.422	0.0071–0.0084	3.350–3.495	A+	0.962	0.863	1.736	1.262	0.158	73.10	137.55	100.58	10.90
Glyptosternon oschanini	0.0098	3.038	0.0074–0.0130	2.926–3.151	I	0.984	0.787	1.381	1.086	0.121	74.01	127.97	100.62	11.21
Gobio lepidolaemus	0.0099	3.139	0.0087–0.0112	3.075–3.203	A+	0.986	0.962	1.597	1.298	0.130	77.99	125.74	100.45	9.54
*Hemiculter leucisculus**	0.0046	3.238	0.0026–0.0081	3.012–3.464	A+	0.989	0.734	0.945	0.836	0.073	90.18	115.03	100.24	7.29
Hypophthalmichthys nobilis	0.0145	2.896	0.0068–0.0308	2.657–3.135	A–	0.968	0.984	1.119	1.048	0.044	93.27	106.43	100.08	4.09
Iskandaria kuschakewitschi	0.0070	2.915	0.0056–0.0088	2.795–3.035	I	0.961	0.401	0.857	0.602	0.095	62.81	144.18	101.12	15.65
*Luciobarbus conocephalus**	0.0110	2.934	0.0097–0.0125	2.890–2.979	I	0.998	0.789	1.042	0.919	0.072	88.22	113.52	100.25	7.10
*Micropercops cinctus**	0.0067	3.378	0.0044–0.0101	3.102–3.655	A+	0.972	0.759	1.349	1.176	0.151	74.10	119.78	100.65	11.54
Opsariichthys bidens	0.0082	3.077	0.0072–0.0093	3.014–3.139	I	0.996	0.765	1.256	0.963	0.092	85.28	127.24	100.38	8.87
*Pelecus cultratus**	0.0011	**3.442**	0.0003–0.0040	3.050–3.834	A+	0.974	0.400	0.517	0.469	0.038	90.28	112.64	100.19	6.51
*Petroleuciscus squaliusculus**	0.0074	**3.285**	0.0051–0.0107	3.112–3.458	A+	0.979	1.115	1.703	1.367	0.151	84.72	123.74	100.43	9.57
*Pseudorasbora parva**	0.0073	3.262	0.0063–0.0085	3.179–3.346	A+	0.987	0.919	1.522	1.181	0.141	84.30	126.59	100.47	9.84
Rhinogobius cf. *lindbergi**	0.0128	**2.808**	0.0076–0.0216	2.482–3.135	A–	0.945	0.857	1.136	0.948	0.068	90.54	116.51	100.22	6.84
*Rhodeus ocellatus**	0.0081	3.339	0.0069–0.0094	3.245–3.433	A+	0.985	0.909	1.758	1.394	0.152	82.90	124.53	100.37	8.67
Sabanejewia aralensis	0.0055	3.078	0.0037–0.0080	2.867–3.290	I	0.974	0.458	0.790	0.634	0.066	75.06	123.86	100.55	10.50
*Salmo oxianus**	0.0065	**3.178**	0.0049–0.0086	3.075–3.281	A+	0.993	0.925	1.300	1.064	0.090	87.57	116.42	100.24	7.08
Schizothorax eurystomus	0.0105	2.994	0.0094–0.0117	2.946–3.042	I	0.995	0.844	1.237	1.037	0.097	81.80	119.88	100.44	9.37
Triplophysa daryoae	0.0049	3.236	0.0040–0.0061	3.139–3.334	A+	0.992	0.679	0.949	0.814	0.073	88.84	114.25	100.24	7.03
*Triplophysa elegans**	0.0074	**3.012**	0.0067–0.0082	2.960–3.065	I	0.994	0.638	0.871	0.759	0.050	84.43	114.97	100.22	6.64
Triplophysa ferganaensis	0.0083	2.985	0.0066–0.0105	2.884–3.086	I	0.981	0.607	0.995	0.809	0.090	75.43	123.90	100.58	11.16
*Triplophysa labiata**	0.0109	2.723	0.0096–0.0125	2.654–2.794	A–	0.991	0.493	0.960	0.653	0.109	83.90	140.23	100.62	11.54
Triplophysa strauchii	0.0099	2.923	0.0088–0.0112	2.867–2.979	I	0.977	0.538	1.169	0.847	0.098	65.07	140.96	100.68	11.58

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