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2 # Length and Weight Relationship, Condition Factor, and Morphometric Characteristics of Eleven Freshwater Fish Species in Koto Panjang Reservoir, Indonesia

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38 A B S T R A C T

This study analyzes the species composition, length-weight relationship (LWR), condition factor, and
2 morphometric and meristic characteristics of eleven freshwater fish species in Kota Panjang Reservoir, Indonesia. Fresh specimens were collected from September 2023 to February 2024. Results show that among the sampled species, two belong to Order Anabantiformes, three to Order Siluriformes, and six to Order Cypriniformes. The Order Siluriformes has the lowest species composition, with Hemibagrus wyckii at 3.09%, while the Order Cypriniformes has the highest, with Barbonymus schwanefeldii at 15.25%. The LWR coefficient b ranges from 1.693 to 3.151. Of the species studied, only Hemisilurus heterorhynchus (b = 2.174), Clarias teijsmanni (b = 2.046), Anabas testudineus (b = 2.375), Labiobarbus festivus (b = 2.305), and Rasbora argyrotaenia (b = 1.693) fall
1 outside the expected range of 2.5 < b less than < 3.5. One species exhibits positive allometric growth (+), seven show negative allometric growth (-), and three display isometric growth (I). Fulton's condition factor (Kc) averages between 0.73 ± 0.15 and 4.96 ± 0.63, indicating morphological variation. The allometric condition factor (Ka) ranges from 0.87 ± 0.18 to 26.25 ± 4.05, reflecting differences in resource availability and competition. Relative condition factor (Kn) values range from 1.00 ± 0.09 to 2.51 ± 0.55, indicating good growth. Morphometric analysis shows Rasbora argyrotaenia has the smallest average total length, head length, and body depth, while *Hemibagrus*
2 *wyckii* has the largest. The results provide new data on the length-weight relationship, condition factor, and morphometric characteristics of eleven selected freshwater fish species in Kota Panjang Reservoir, Indonesia, and offer up-to-date information on the remaining species in the study area. These findings could have a significant impact on species stock assessments and help identify priority species for domestication.

2 Keywords: Length-weight relationship; growth pattern; Fulton's condition index; morphometric and meristic; Koto Panjang Reservoir

1. Introduction

8 Kampar Kanan is one of the largest rivers in Riau Province with a length of approximately 213.5 km and a width ranging from 125 to 143 meters in some parts. Geographically, this part of the river is located after the Koto Panjang Reservoir. This river originates from the upper reaches of the Bukit Barisan mountains in Lima Puluh Kota and Pasaman Regency, West Sumatra Province, Indonesia, flowing into the Siak River in the Bengkalis region, Riau Province, and finally into the Strait of Malacca [1].

4 Since 1996, the upper reaches of the Kampar Kanan River at a geographical position of 0°17'23.76"N and 100°52'53.39"E have been dammed into a reservoir called the Koto Panjang Reservoir. The height of the dam-reservoir is 96 meters, and it is situated at an elevation of 85 meters above sea level. The estimated inundated area covers around 12,400 hectares, with water depths ranging from 9.8 to 28.6 meters [2]. Before the construction of the Koto Panjang Reservoir, the river played an essential role as a source of clean water for the community, supporting agriculture and fisheries as primary livelihoods. In addition, this area provides raw materials such as sand and stone for the construction industry. Furthermore, the region offers interesting tourism opportunities, especially along the riverbanks, with its stunning natural beauty.

This reservoir has multiple functions, including being a hydroelectric power plant with a capacity of 114 MW, as well as irrigation, tourism, and fisheries. Due to the construction of the reservoir, the characteristics of the aquatic ecosystem in terms of abiotic and biotic are affected [3]. Similar to other rivers, dam construction can cause mortality and failure of fish migration [4, 5]. Changes in stream hydrological regimes from lotic to lentic can also affect water retention in reservoirs, leading to a decrease in native and an increase in exotic species [6, 7].

More than 44 species of fish live in the Koto Panjang Reservoir, including *Hemibagrus wyckii*, *Barbonymus schwanefeldii*, *Puntioplites bulu*, *Diplocheilichthys pleurotaenia*, *Ompok hypophthalmus*, *Wallago leerii*, *Channa lucius*, *Anabas testudineus*, and *Thyninichthy polylepis* [8]. To support local food security, exotic fish species such as tilapia (*Oreochromis niloticus)*, and carp (*Cyprnus carpio)*, can also be found through floating net cage farming [9].

The fish are caught by small-scale fishermen using non-selective fishing gear such as trap, cast, gill, and drag nets, then sold in traditional markets in the area [10]. However, the use of harmful fishing gear, habitat degradation, and the impact of invasive species can threaten the survival of native fish species in the Koto Panjang Reservoir [3, 11]. This underscores the need to manage fisheries resources that have substantial economic value in a sustainable and environmentally friendly manner.

Length-weight relationship (LWR) analysis plays an important role in fisheries development and conservation evaluation of endangered species. Using available data, the LWR approach effectively considers fish biomass [12]. It also estimates fish length based on weight in a given environment, which ultimately results in estimates of biomass and population growth [13]. Furthermore, species composition, relative abundance, and frequency of occurrence have long been considered as key indicators in assessing biological communities. According to Thomson [14], fish abundance is a key parameter in monitoring fish populations. Various methods are available to estimate fish abundance and species composition, with traditional approaches usually involving the selection of sites or sampling units in a water body, followed by counting the number of fish caught at those sites. Species composition and abundance are influenced by a variety of factors, including overfishing, dam construction, habitat destruction, and biological pollution [15,16]. Occurrence frequency is used to measure various parameters that provide an overview of fish populations and their ecosystem dynamics, such as length-weight distribution and fishing frequency [17].

In addition to length-weight data, species composition, and relative abundance, condition factor (K) data for each fish species are also needed. This parameter indicates welfare based on the hypothesis that fish that weigh more at a certain length indicate better physiological conditions [18]. Additionally, the expected value of b ranges between 2.5 < less < 3.5 [13]. On the other hand, morphological characteristics of fish play an important role in identifying the taxonomic classification of a genus or species and distinguishing differences between geographically diverse populations. This information serves as an initial step to study ontogeny and evolution and can be used to manage genetic stocks sustainably and prevent possible declines in genetic diversity during the domestication process [19]. This study aims to estimate the species composition, relative abundance, occurrence percentage, LWR, condition factor, and morphometric and meristic characteristics of eleven economically important fish species caught in the Koto Panjang Reservoir, Riau Province, Indonesia. The results of this study are expected to improve understanding of the growth process and contribute to future fisheries conservation and management efforts.

Apart from length-weight data, condition factor (K) data for each type of fish is also needed. This parameter indicates welfare based on the hypothesis that fish that weigh more at a certain length show better physiological conditions [18] On the other hand, the morphological characteristics of fish play a crucial role in identifying the taxonomic classification of a genus or species and discerning differences between geographically variant populations. This information serves as an initial step for studying ontogeny and evolution and could be used to manage genetic stocks sustainably and prevent the decline in genetic diversity that may occur during the domestication process. [19].

This study aimed to estimate the species composition, relative abundance, percentage occurrence, LWR, condition factors, and morphometric and meristic characteristics of eleven economically important fish species caught in the Koto Panjang Reservoir, Riau Province, Indonesia. The results are expected to enhance understanding of the growth process and contribute to future conservation efforts and fisheries management.

2. Materials and methods

2.1. Study area and fishing gear used.

This study was conducted in Koto Panjang Reservoir, located in the upstream area of the Kampar Kanan River, Kampar Regency, Riau Province, Indonesia. The reservoir is situated at the geographical coordinates of 0°20'12.30" N and 100°44'27.26" E on the island of Sumatra. Water released from the Koto Panjang Reservoir flows downstream into the Kampar Kanan River, merges with the Siak River, and eventually empties into the Strait of Malacca (Figure 1).

Fishing is done using traps and gill net fishing gear. Traps is made of woven bamboo rattan; the front part is cylindrical with a diameter of 80 cm, while the back part is cone-shaped with a length of 2 meters. The gill net is rectangular with a monofilament thread length of 60 meters and a depth of 10 meters, with a mesh size of 1.25 and 2.5 inches. The traps fishing gear is used at the bottom of the reservoir at a depth of 2 to 4 meters and is operated between 18.00 and 06.00 to catch demersal fish including Bagridae, Siluridae, Claridae, Channidae, and Anabantidae using chicken intestine bait. The gill net fishing gear is operated passively on the water surface. Five types of fish caught, namely *H. wyckii*, *C. lucius*, *A. testudineus*, *H. heterorhynchus*, and *C. teijsmanni* were caught in September to December 2023 which is the transition season from the dry season to the rainy season. This can affect the condition of the reservoir and fish behavior. Furthermore, in January to February 2024 is the peak of the rainy season. This can affect the condition of the reservoir such as increasing water turbidity and increasing reservoir water level elevation, there are six types of fish caught, namely *B. schwanefeldii*, *P. bulu*, *D. pleurotaenia*, *L. festivus*, R. *argyrotaenia*, and *T. polylepis*. Furthermore, eleven fish species were sampled because during the fishing period, only eleven species were predominantly caught using fishing gear in the form of traps and gill nets. The IUCN Red List Categories and Status for eleven fish species per year 2019 and 2020 are presented in Table 1.

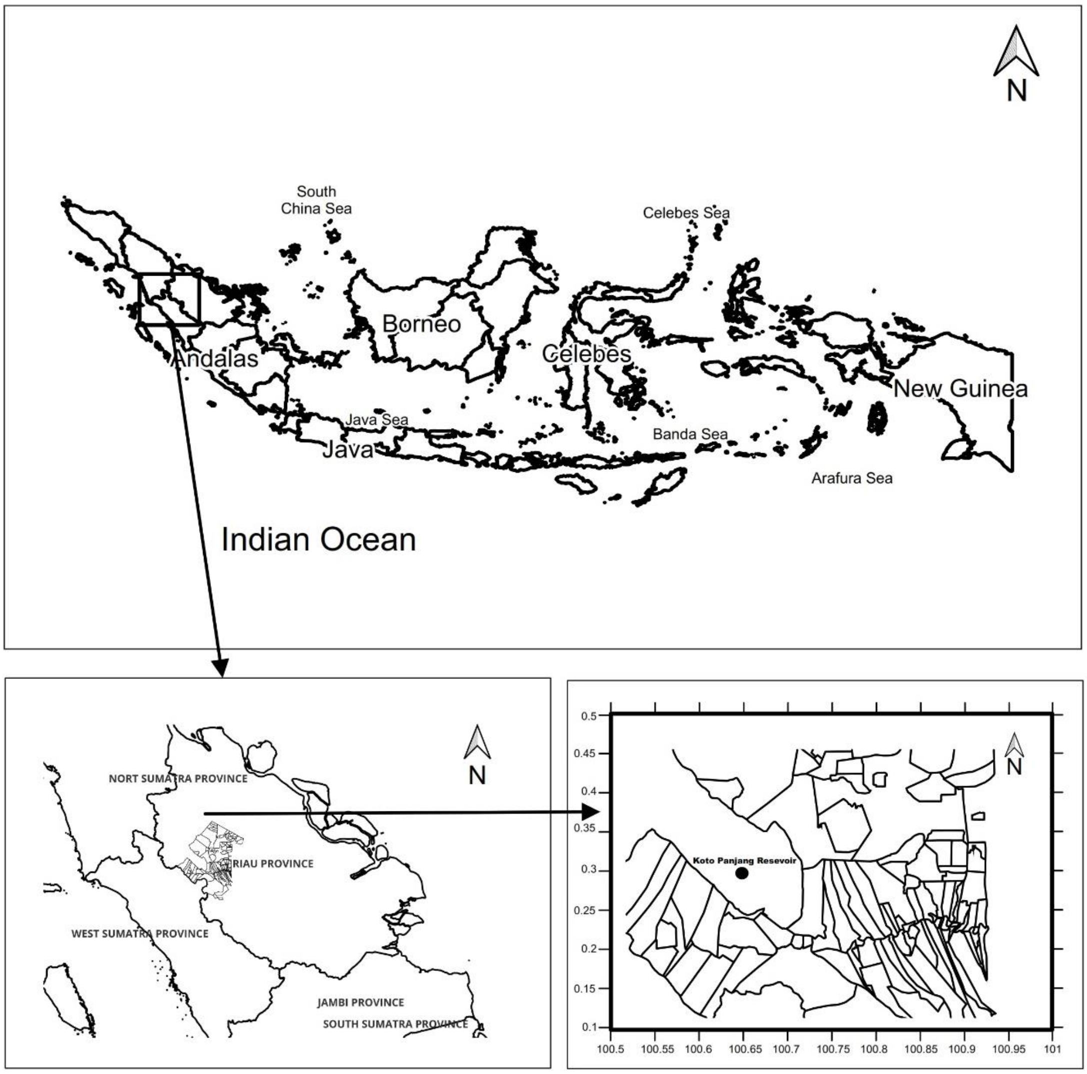

FIGURE 1: Study site map in Koto Panjang Reservoir Kampar Kanan River, Kampar Regency, Riau Province

2.2. Laboratory procedure

12 After harvest, the fish specimens were transported in a cold box with a temperature of about 10 °C
8 to the Fish Biology Laboratory, Department of Aquaculture, Faculty of Fisheries and Marine
Universitas Bung Hatta, Padang, Indonesia, to measure the length, weight, and morphometric
characteristics. Classification and taxonomic identification of sample specimens were carried out
4 using the standard keys [20,21] Subsequently, the weight precision of each specimen was measured
using a balance scale (OHAUS model CT 6000 USA) with an accuracy of 0.1 g, and the lengths were
1 assessed through a meter ruler with 0.1 mm accuracy. The sex (male or female) of each fish collected
was recorded.

The morphometric characteristics of eleven fish species caught were measured using a 0.01 mm precision digital caliper (Made in China), focusing on parameters including total, standard, fork, and head length, body depth, body girth, peduncle depth, caudal peduncle length, pre-dorsal length, pre-pelvic length, and eye diameter. Meanwhile, meristic characteristics namely the number of hard and soft rays on the dorsal, caudal, anal, pectoral, and ventral fin were counted directly using a binocular magnifier equipped with two adjustable lenses, enabling three-dimensional imaging and detailed magnification for accurate calculation of fish fin radii. Morphometric characteristics were measured from ten randomly selected fish, while meristic traits were calculated from five fish also selected randomly.

2.3. Data analysis

Data analysis was performed using SPSS software version 16 after previously removing outlier data. Furthermore, the regression equation $W = a L^b$ was used to determine the LWR, where parameters ´a´ and 'b' were obtained by transforming the log-log equation, namely $\text{Log } W = \log (a) + b \log (L)$. In this equation, ´W' represents the weight of fish in grams (g), ´L' denotes the total length (TL) of fish in centimeters (cm), 'a´ is a constant (intercept), and ´b´ is the slope (change in weight in weight per unit change in length) of the regression by Froese [13]. The 95% confidence interval (CI) of the total length and weight was also analyzed, while the accuracy of the samples was assessed with the coefficient of determination (r^2).

The Fulton condition factor (K*c*) was estimated using the Fulton formula [22], formulated as $kc = 100{*}W/L^3$, where W is the total weight of the fish sample, and L is the standard length of the fish sample. The allometric condition factor (K*a*) was estimated using the formula from Bagenal and Tesch [18], namely $ka = 100{*}W/L^b$, where W is the total weight of the fish sample (g), L is the standard length of the fish sample (cm), and b is a constant in the length-weight. Meanwhile, the relative weight condition factor (K*n*) was determined using the Le Cren formula [23], $Kn = W/We$, where W is the weight of the fish sample (g), and We is the theoretical weight calculated as $L^{b,}$ and a is a constant in the length-weight.

3. Results

3.1.Categories and IUCN red list status, and species composition

Eleven types of fish from the families Bagridae, Siluridae, Claridae, Channidae, Anabantidae, and Cyprinidae were collected from the Koto Panjang Reservoir in Indonesia. Information regarding the IUCN Red List categories and status in 2019 and 2020 is presented in Table 1.

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TABLE 1: Categories and IUCN Red List Status for Eleven Species in 2019 and 2020 in Koto Panjang Reservoir

	Ordo	Family	Species	IUCN Categories for Species Conservation Status, 2019	The IUCN Red List Status	Occurrence
32	Siluriformes	Bagridae	*Hemibagrus wyckii* (Bleeker, 1858)	Least Concern (LC)	The IUCN Red List of Threatened Species in 2019	Indigenous species
		Siluridae	*Hemisilurus heterorhynchus* (Bleeker, 1854)	Least Concern (LC)	The IUCN Red List of Threatened Species in 2019	Indigenous species
		Clariidae	*Clarias teijsmanni* (Bleeker, 1857)	Not evaluated	No report from IUCN	Indigenous species
31	Anabantiformes	Channidae	*Channa lucius* (Cuvier, 1831)	Least Concern (LC).	The IUCN Red List of Threatened Species in 2019	Indigenous species
17		Anabantidae	*Anabas testudineus* (Bloch, 1792)	Least Concern (LC)	The IUCN Red List of Threatened Species in 2019	Indigenous species
	Cypriniformes	Cyprinidae	*Barbonymus schwanefeldii* (Bleeker, 1854)	Least Concern (LC)	The IUCN Red List of Threatened Species in 2019	Indigenous species
3			*Puntioplites bulu* (Bleeker, 1851)	Least Concern (LC)	The IUCN Red List of Threatened Species in 2019	Indigenous species
			Diplocheilichthys pleurotaenia (Bleeker, 1855)	Data Deficient (DD)	The IUCN Red List of Threatened Species in 2020	Indigenous species
			Labiobarbus festivus (Heckel, 1843)	Data Deficient (DD)	The IUCN Red List of Threatened Species in 2019	Indigenous species
			Rasbora argyrotaenia (Bleeker, 1849)	Least Concern (LC)	The IUCN Red List of Threatened Species in 2020	Indigenous species
			Thynnichthys polylepis (Bleeker, 1860)	Least Concern (LC)	The IUCN Red List of Threatened Species in 2020	Indigenous species

3.2. Species composition

The total samples collected were 485 specimens, with the percentage of each species being as follows: *H. wyckii* (3.09%), *H. heterorhynchus* (6.19%), *C. teijsmanni* (6.19%), *C. lucius* (12, 58%), *A. testudineus* (11.75%), *B. schwanefeldii* (15.26%), *P. feather* (8.25%), *D. pleurotaenia* (7.84%), *L. fetivus* (8.25%), *R. argyrotaenia* (10.31%), and *T. polylepis* (10.31%). Further information about fish species and the sex is presented in Table 2.

1

TABLE 2: Species Composition, Relative Abundance, and Percentage Occurrence of Eleven Fish Species in Koto Panjang Reservoir

Family	Species	N	% by no	Sex (%) F	M
Bagridae	*Hemibagrus wyckii*	15	3.09	33.33	66.66
Siluridae	*Hemisilurus heterorhynchus*	30	6.19	33.33	66.66
Clariidae	*Clarias teijsmanni*	30	6.19	66.66	33.33
Channidae	*Channa lucius*	61	12.58	65.67	34.43
Anabantidae	*Anabas testudineus*	57	11.75	29.82	70.17
Cyprinidae	*Barbonymus schwanefeldii*	74	15.25	41.89	58.10
Cyprinidae	*Puntioplites bulu*	40	8.25	62.5	37.5
Cyprinidae	*Diplocheilichthys pleurotaenia*	38	7.84	36.84	63.16
Cyprinidae	*Labiobarbus festivus*	40	8.25	50.0	50.0
Cyprinidae	*Rasbora argyrotaenia*	50	10.31	24.0	76.0
Cyprinidae	*Thynnichthys polylepis*	50	10.31	52.0	48.0
Total		485	100		

N: sample size; % = percentage; F: female; M: male; no = number

3.3. Length-weight relationship

Table 3 presents descriptive statistics for eleven fish species, including length and weight, used as parameters 'a' and 'b' in each LWR equation and the coefficient of determination (r^2). The range of 'a' values for each species was 0.010 to 0.259, while 'b' values ranged from 1.693 to 3.151. The range of r^2 values obtained was between 0.61 and 0.95, confirming the validity and reliability of the LWR measurement. Furthermore, the LWR relationship in each species consistently showed a significant correlation ($p < 0.001$).

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This study identified variations in the growth types of eleven fish species, with one species, namely *H. wyckii*, showing a positive allometric growth type, while the other three, including *C. lucius*, *B. schwanefeldii*, and *P. bulu*, demonstrated isometric growth. Seven other species, including *C. teijsmanni*, *A. testudineus*, *D. pleurotaenia*, *L. fetivus*, *R. argyrotaenia*, and *T. polylepis*, showed a negative allometric growth type (Table 3).

Based on the research results, the average smallest standard length and smallest weight were 7.74 ± 1.12 cm and 8.29 ± 4.27 g in *R. argyrotaenia*, with a moderate degree of correlation ($r = 0.77$), while the average largest standard length and total weight were 39.79 ± 4.82 cm and 2,112.67 ± 889.88 g in *H. wyckii* with a high degree of correlation ($r = 0.90$). In addition, species that had smaller standard lengths (95% confidence interval) compared to the data recorded in FishBase were *H. wyckii* (41.82 cm vs. 71 cm), *H. heterorhynchus* (17.10 cm vs. 80 cm), *C. lucius* (30.68 cm vs. 53 cm), *A. testudineus* (9.02 cm vs. 25 cm), *B. schwanefeldii* (23.88 cm vs. 35 cm), *P. bulu* (23.39 cm vs. 44.33 cm), *L. festivus* (23.06 cm vs. 33.7 cm), *R. argyrotaenia* (8.06 cm vs. 14 cm) and *T. polylepis* (15.54 cm vs. 18 cm). Meanwhile, *D. pleurotaenia* (23.30 cm vs. 22.5 cm), and *C. teijsmanni* (23.77 cm vs. 22 cm) had higher values than those recorded in FishBase.

3.4. Condition factor

27 Table 4 shows the values of Fulton's (K*c*), allometric (K*a*), and relative weight condition factor (K*n*) of eleven fish species caught in the Koto Panjang reservoir. The mean value of K*c* for different species varied between 0.73 ± 0.15 and 4.96 ± 0.63 as summarized in Figure 2. *H. heterorhynchus*, *D. pleurotaenia*, *L. festivus* and *T. polylepis* had values < 1.0, while K*c* for *H. wyckii*, *C. teijsmanni*, *C. lucius*, *A. testudineus*, *B. schwanefeldii* and *P. bulu* was > 1.0. Furthermore, in Figuru 3, the mean value of Ka exceeds or equals 3 for six species namely *H. heterorhynchus* (14.70 ± 4.65), *C. teijsmanni* (26.25 ± 4.05), *A. testudineus* (15.07 ± 1.36), *D. pleurotaenia* (3.60 ± 0.34), *L. festivus* (8.32 ± 0.36), and *R. argyrotaenia* (17.31 ± 0.38). While the mean value of K*n* for eleven species ranged from 1.00 ± 0.08 and 2.51 ± 0.55. *R. argyrotaenia* had the lowest value of 1.00 ± 0.08, while *C. lucius* recorded the highest value of 2.51 ± 0.55 (Figure 4).

2

TABLE 3: Descriptive Statistics and Parameters for LWR and Growth of Eleven Fish Species in Koto Panjang Reservoir.

Species	N	LWRs parameters								t-test	P value	Growth type
		Mean SL (cm)	CI 95% of SL (cm)	Mean Wt (g)	CI 95% of TW (g)	a	b	r	r^2			
Hemibagrus wyckii	15	39.79 ± 4.82	37.12 - 41.82	2,112.67 ± 889.88	1,527.67 - 2697.66	0.010	3.151	0.90	0.82	7.79	0.001	(+)
Hemisilurus heterorhynchus	30	16.39 ± 2.00	15.67 - 17.10	22.92 ± 10.76	22.90 - 26.76	0.076	2.174	0.77	0.61	6.48	0.001	(-)
Clarias teijsmanni	30	23.77 ± 2.00	23.06 - 24.48	133.74 ± 41.37	118.97 - 148.51	0.259	2.046	0.87	0.77	9.60	0.001	(-)
Channa lucius	61	28.44 ± 2.24	26.20 - 30.68	252.72 ± 63.03	189.69 - 315.75	0.012	2.956	0.91	0.83	17.10	0.001	(I)
Anabas testudineus	57	7.87 ± 1.15	6.72 - 9.02	24.91 ± 10.12	14.79 - 35.03	0.178	2.375	0.93	0.89	29.46	0.001	(-)
Barbonymus schwanefeldii	74	23.27 ± 2.60	22.67 - 23.88	149.49 ± 4.10	137.19 - 161.78	0.012	2.978	0.92	0.86	21.14	0.001	(I)
Puntioplites bulu	40	21.63 ± 2.46	20.36 - 23.39	243.69 ± 82.84	218.03 - 269.34	0.029	2.927	0.91	0.84	14.39	0.001	(I)
Diplocheilichthys pleurotaenia	38	22.40 ± 2.84	21.49 - 23.30	106.85 ± 30.37	97.20 - 116.49	0.037	2.555	0.97	0.94	23.87	0.001	(-)
Labiobarbus festivus	40	22.25 ± 2.61	21.43 - 23.06	108.18 ± 28.37	99.38 - 116.97	0.083	2.305	0.93	0.88	16.36	0.001	(-)
Rasbora argyrotaenia	50	7.74 ± 1.12	7.43 - 8.06	8.29 ± 4.27	7.10 - 9.40	0.172	1.693	0.97	0.95	31.13	0.001	(-)
Thynnichthys polylepis	50	14.72 ± 2.96	13.90 - 15.54	25.70 ± 13.31	22.01 - 29.39	0.008	2.932	0.95	0.91	22.20	0.001	(-)

30

N: sample size; SL: standard length; TW: total weight; Min; minimum; Max: maximum; SD: standard deviation; CI: confidence interval, (+) = positive allometric; (-) = negative allometric; (I) = isometric

TABLE 4: Condition Factors (K*c*, K*a*, K*n*) for Eleven Fish Species in Koto Panjang Reservoir.

Species	N	Fulton's condition factor (K*c* values)				The allometric condition factor (K*a* values)				Relative weight condition factor (K*n* values)			
		Mean ± SD	SE	Range (K*c* values)		Mean ± SD	SE	Range (K*a*-values)		Mean ± SD	SE	Range (K*n*-values)	
				Min.	Max			Min.	Max.			Min.	Max.
Hemibagrus wyckii	15	3.24 ± 0.60	0.16	2.45	4.06	1.86 ± 0.06	0.09	1.39	2.67	1.03 ± 0.20	0.05	0.77	1.48
Hemisilurus heterorhynchus	30	0.89 ± 0.40	0.08	0.55	2.10	14.70 ± 4.65	0.21	9.47	25.30	1.01 ± 0.32	0.03	0.65	1.75
Clarias teijsmanni	30	1.57 ± 0.34	0.06	1.02	2.70	26.25 ± 4.05	0.74	17.31	37.12	1.01 ± 0.16	0.02	0.67	1.43
Channa lucius	61	1.08 ± 0.12	0.01	0.86	1.45	1.25 ± 0.13	0.02	0.79	1.51	2.51 ± 0.55	0.08	1.23	3.49
Anabas testudineus	57	4.96 ± 0.63	0.08	3.90	7.79	15.07 ± 1.36	0.11	12.06	19.7	1.00 ± 0.09	0.01	0.80	1.28
Barbonymus schwanefeldii	74	1.15 ± 0.20	0.02	0.80	1.53	2.91 ± 0.42	0.02	2.10	3.74	1.01 ± 0.14	0.02	0.71	1.35
Puntioplites bulu	40	2.33 ± 0.34	0.05	1.68	3.05	2.24 ± 0.33	0.05	1.62	2.94	1.02 ± 0.15	0.02	0.72	1.29
Diplocheilichthys pleurotaenia	38	0.93 ± 0.15	0.02	0.78	1.21	3.60 ± 0.34	0.05	3.11	4.46	1.00 ± 0.09	0.02	0.87	1.24
Labiobarbus festivus	40	0.96 ± 0.16	0.02	0.80	1.63	8.32 ± 0.36	0.15	6.75	10.48	1.01 ± 0.12	0.02	0.82	1.28
Rasbora argyrotaenia	50	1.02 ± 0.31	0.04	0.60	1.76	17.31 ± 0.38	0.19	16.39	18.29	1.00 ± 0.08	0.01	0.95	1.06
Thynnichthys polylepis	50	0.73 ± 0.15	0.12	0.44	1.25	0.87 ± 0.18	0.03	0.52	1.47	1.02 ± 0.21	0.08	0.61	1.71

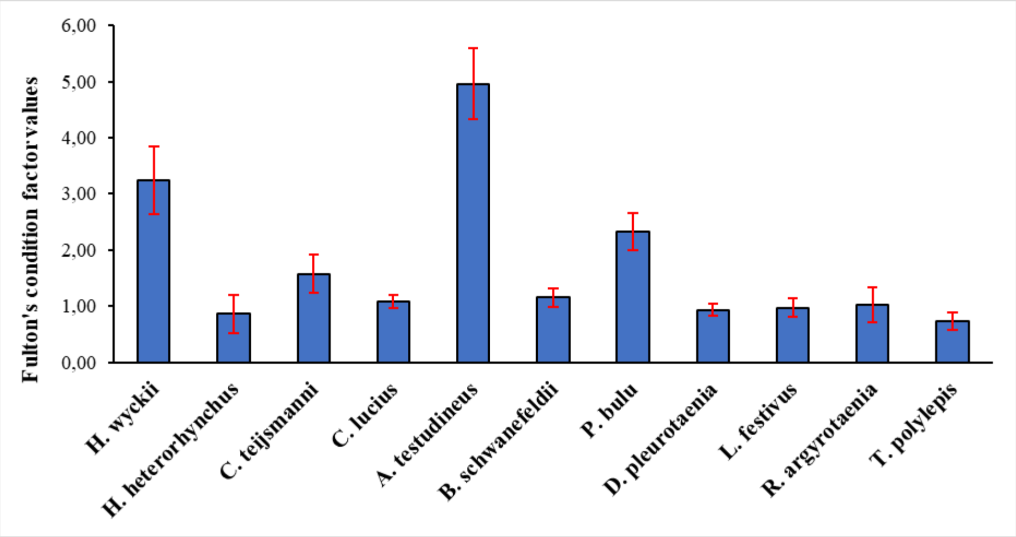

FIGURE 2: Fulton's condition factor (K*c*) for eleven fish species in Koto Panjang Reservoir.

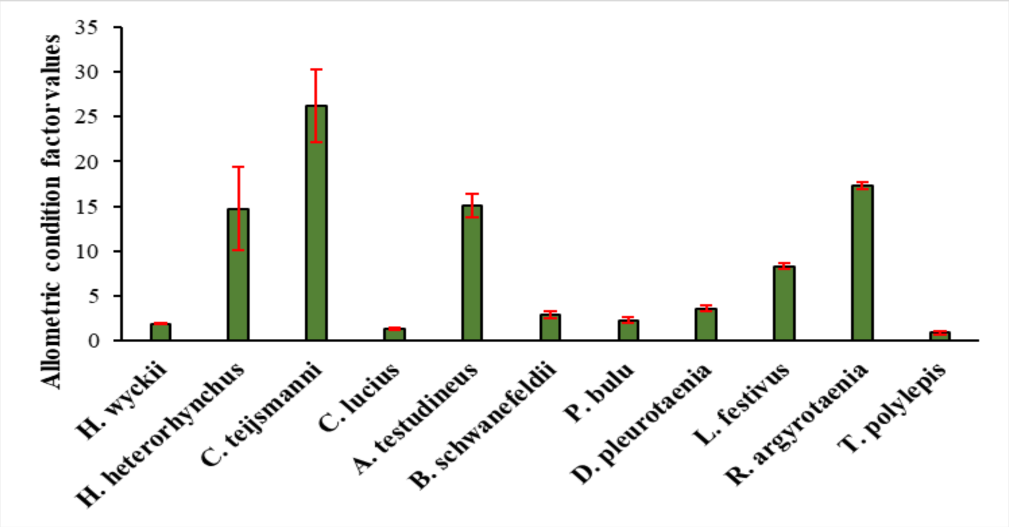

FIGURE 3: Allometric condition factor (K*a*) for eleven fish species in Koto Panjang Reservoir

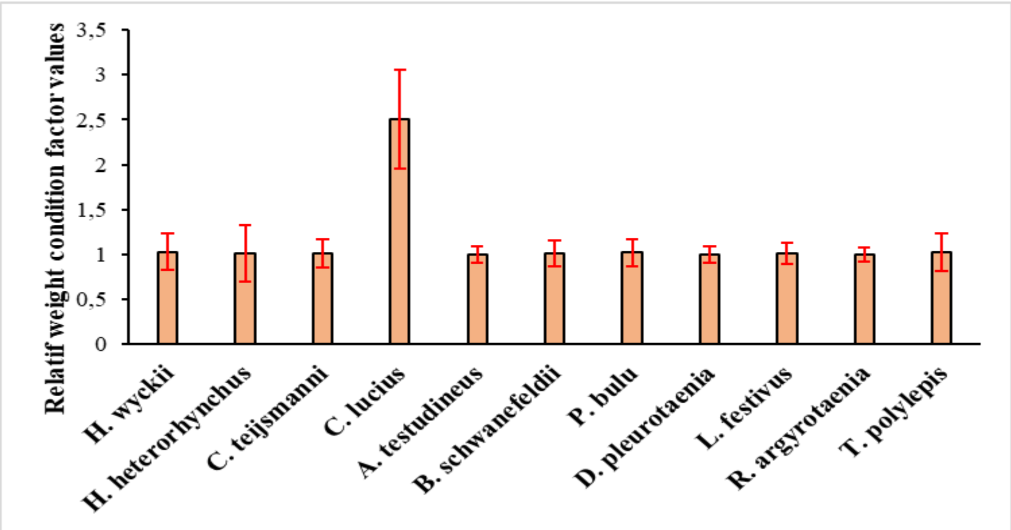

FIGURE 4: Relative condition factor (K*n*) for eleven fish species in Koto Panjang Reservoir

3.5. Morphometric and meristic characteristics

Table 5 summarizes the mean, minimum, and maximum range values of the morphometric characteristics of eleven fish species in Koto Panjang Reservoir. *H. wyckii* (Bleeker, 1858) showed the highest mean standard length (SL) value of 39.79 ± 4.82 cm and body weight (WT) value of 2,112.67 ± 889.88 g. Conversely, *R. Argyrotaenia* (Bleeker, 1849) had the lowest mean standard length and weight values of 7.74 ± 1.12 cm and 8.29 ± 4.27 g. The smallest mean body depth value was found in *R. argyrotaenia* at 1.66 ± 0.36 cm, accompanied by a mean body girth value of 3.33 ± 0.72 cm. The highest mean body depth (BD) was recorded in *P. bulu* (8.34 ± 0.82 cm), equivalent to 15.72% of SL, which also had the highest mean body girth (BG) of 16.69 ± 1.63 cm.

Meristic character data from various types of fish are presented in Table 6. In this study, several data from dorsal fins, caudal fins, anal fins, ventral fins, and pelvic fins were found, showing differences and similarities in number when compared with previous research reports, which are represented by numbers in parentheses.

TABLE 5: Mean, Minimum, and Maximum Range Values of the Morphometric Characteristics of Eleven Fish Species in Koto Panjang Reservoir

Species	No of fishes	TL (range, cm)	SL (range, cm)	HL (range, cm)	BD (range, cm)	BG (range, cm)	FL (range, cm)	PD (range, cm)	CPL (range, cm)	PDL (range, cm)	PPL (range, cm)	EY (range, cm)	Wt (range, g)
Hemibagrus wyckii	10	48.49 ± 6.48 (37.39 - 55.96)	39.79 ± 4.82 (30.4 – 45.0)	11.73 ± 1.50 (9.12 -13.05)	7.43 ± 0.95 (5.78 - 8.05)	16.08 ± 2.18 (13.28 - 19.88)	44.61 ± 5.96 (34.4 - 1.48)	3.13 ± 0.40 (2.43 - 3.64)	6.65 ± 0.85 (5.17 - 7.74)	16.42 ± 2.10 (12.77 - 19.1)	21.11 ± 2.70 (16.42 - 24.57)	1.17 ± 0.15 (0.91 - 1.37)	1,979.70 ± 716.05 (832 - 2,835)
Hemisilurus heterorhynchus	10	16.39 ± 2.00 (13.2 - 20.9)	14.16 ± 1.89 (10.08 - 18.2)	2.49 ± 0.26 (2.32 - 3.06)	2.98 ± 0.53 (3.05 - 4.22)	5.95 ± 1.07 (4.78 - 8.44)	14.87 ± 2.18 (11.4 - 20)	0.53 ± 0.17 (0.62 - 0.77)	0.38 ± 0.12 (0.36 - 0.6)	4.13 ± 0.53 (3.06 - 5.37)	4.30 ± 0.90 (3.50 - 6.50)	0.31 ± 0.07 (0.21 - 0.46)	22.92 ± 10.76 (14.33 - 51.10)
Clarias teijsmanni	10	23.77 ± 2.00 (21.5 - 26.8)	20.82 ± 1.83 (18.2 - 23.80)	5.16 ± 0.53 (4.30 - 5.92)	3.47 ± 0.40 (3.10 - 4.18)	6.94 ± 0.79 (6.20 - 8.36)	21.21 ± 2.09 (16.68 - 24.0)	1.24 ± 0.16 (0.94 - 1.48)	0.76 ± 0.37 (0.40 - 1.50)	5.99 ± 0.63 (5.01 - 6.95)	8.80 ± 1.22 (7.20 - 10.24)	0.27 ± 0.09 (0.20 - 0.38)	133.74 ± 41.37 (74.69 - 198.02)
Channa lucius	10	30.68 ± 4.81 (29.36 - 38)	25.05 ± 5.20 (17.1 - 32)	8.01 ± 1.44 (6.06 - 10.10)	5.09 ± 0.91 (3.72 - 6.21	8.07 ± 1.98 (3.55 - 10.22)	28.60 ± 4.92 (21.21 - 35.34)	2.54 ± 0.43 (1.89 - 3.15)	1.74 ± 0.36 (1.34 - 2.33)	11.65 ± 3.46 (9.70 - 16.17)	12.73 ± 2.45 (9.72 - 16.19)	1.02 ± 0.32 (0.67 - 1.02)	328.43 ± 134.65 (128.5 - 473.2)
Anabas testudineus	10	13.82 ± 1.53 (11.5 - 17.0)	11.11 ± 1.15 (9.0 - 13.5)	3.30 ± 0.48 (2.24 - 4.14)	3.72 ± 0.45 (3.10 - 4.74)	7.80 ± 0.95 (6.51 - 9.95)	12.72 ± 1.45 (10.37 - 16.0)	1.60 ± 0.22 (1.31 - 2.10)	0.70 ± 0.14 (0.51 - 0.82)	3.46 ± 0.41 (2.74 - 4.20)	4.01 ± 0.48 (3.09 - 4.50)	0.58 ± 0.11 (0.50 - 0.77)	48.82 ± 20.04 (36.20 - 103.35)
Barbonymus schwanefeldii	10	18.63 ± 2.45 (15.10 - 23.0)	14.05 ± 1.75 (11.5 - 17.22)	3.21 ± 0.29 3.06 - 3.79)	6.14 ± 0.76 (5.60 - 7.40)	12.90 ± 1.59 (10.14 - 15.54)	15.32 ± 1.65 (14.0 - 18.5)	2.10 ± 0.24 (1.96 - 2.51)	4.47 ± 2.98 (2.38 - 8.87)	6.91 ± 0.79 (6.84 - 8.35)	6.60 ± 0.85 (5.88 - 8.22)	1.21 ± 0.21 (1.05 - 1.59)	85.96 ± 21.18 (63.4 - 110.0)
Puntioplites bulu	10	24.40 ± 2.27 (20.5 - 27.4)	18.85 ± 1.69 (16.0 - 21.0)	5.05 ± 0.58 (4.30 - 6.01)	8.34 ± 0.82 (6.77 - 9.50)	16.69 ± 1.63 (13.54 - 19.0)	21.21 ± 2.06 (17.40 - 24.21)	2.58 ± 0.27 (2.22 - 3.19)	3.44 ± 0.24 (3.07 - 3.75)	9.62 ± 0.99 (8.00 - 11.35)	8.84 ± 0.98 (7.46 - 10.37)	1.51 ± 0.20 (1.18 - 1.79)	209.49 ± 43.04 (126.84 - 290.90)
Diplocheilichthys pleurotaenia	10	18.13 ± 1.96 (14.5 - 20.3)	14.25 ± 1.45 (11.5 - 16.0)	2.86 ± 0.31 (2.25- 3.30)	5.13 ± 0.52 (4.10 - 5.71)	10.27 ± 1.04 (8.21 - 11.42)	16.00 ± 1.62 (12.82 - 17.84)	1.87 ± 0.20 (1.51 - 2.10)	1.64 ± 0.26 (1.25 - 2.21)	5.45 ± 0.60 (4.35 - 6.20)	6.49 ± 0.69 (5.13 - 7.20)	0.79 ± 0.07 (0.57 - 0.89)	65.30 ± 20.85 (29.8 - 100.56)
Labiobarbus festivus	10	23.03 ± 3.64 (17.55 - 30.25)	19.03 ± 3.01 (14.5 - 25.0)	3.79 ± 0.64 (2.74 - 4.20)	5.87 ± 3.13 (4.26 - 7.15)	15.12 ± 3.88 (9.36 - 15.73)	22.21 ± 2.65 (17.71 - 26.52)	2.06 ± 0.88 (1.45 - 4.48)	3.16 ± 1.51 (2.09 - 7.33)	7.915 ± 0.93 (6.32 - 9.39)	12.26 ± 5.58 (8.48 - 27.49)	1.37 ± 0.63 (0.94 - 3.09)	71.24 ±2 6.57 (40.6 - 132.3)
Rasbora argyrotaenia	10	9.77 ± 1.34 (8.0 - 12.0)	7.74 ± 1.12 (6.40 - 9.50)	1.52 ± 0.22 (1.14 - 1.90)	1.66 ± 0.36 (1.25-2.30)	3.33 ± 0.72 (2.50 - 4.60)	8.50 ± 1.34 (6.80 - 10.80)	0.68 ± 0.14 (0.49 - 0.86)	1.04 ± 0.25 (0.62 - 1.33)	3.88 ± 0.64 (2.96 - 5.07)	3.57 ± 0.57 (2.80 - 4.27)	0.42 ± 0.16 (0.28 - 0.86)	8.29 ± 4.27 (3.62 - 15.41)
Thynnichthys polylepis	10	19.92 ± 1.55 (18.35 - 22.30	14.73 ± 3.74 (14.00 -18.6)	3.1 ± 0.25 (2.80 - 3.56)	4.85 ± 0.62 (4.0 - 5.92)	10.67 ± 1.36 (8.80 - 13.02)	18.29 ± 2.50 (15.2 - 22.72)	1.47 ± 0.23 (1.16 - 1.86)	2.22 ± 0.25 (1.9 - 2.68)	6.52 ± 0.90 (5.4 - 8.11)	8.68 ± 1.24 (7.2 - 10.88)	0.96 ± 0.13 (0.8 - 1.2)	56.102 ± 25.89 (26.9 - 95.46)

TL = Total length; SL = Standard length; HL = Head length; BD = Body depth; BG = Body girth; FL = Fork length; PD = Peduncle depth; CPL = Caudal peduncle length
PDL = Pre-dorsal length; PPL = Pre-pelvic length; EY = Eye diameter; WT = Weight; No = number; cm = centimeter

25
15

TABLE 6: Meristic Characteristics of Eleven Species Collected from the Koto Panjang Reservoir

Species	No. of fishes	Dorsal fin	Caudal fin	Anal fin	Pectoral fin	Ventral fin
Hemibagrus wyckii	5	i, 7 (7)	ii, 8 (1), ii, 8, i (1), iii, 8, i (1), iv, 9 (3)	i, 8 (8)	i, 9, 1 (1)	i, 5 (5)
Hemisilurus heterorhynchus	5	iii, 9 (9)	-	iii, 6 (6)	i, 13-14 (12-13)	i. 8 (8)
Clarias teijsmanni	5	i.71 (70)	Ii, 8 (7)	ii, 57 (60)	i, 8 (8)	i, 5 (60)
Channa lucius	5	i, 39 (38)	12-14 (13)	i, 28-29 (28-30)	32 (32)	10 (9)
Anabas testudineus	5	xvii,7-9 (9)	16-20 (19)	xi, 9-10 (8-10)	13-15 (13-14)	vi. 5 (6)
Barbonymus schwanefeldii	5	i,9 (8)	15-17 (17)	i, 6-8 (6-8)	i, 11-13 (12)	i. 8 (7)
Puntioplites bulu	5	iv, 8 (8)	22 (22)	iii, 5	i, 17-18 (17)	i, 9 (8)
Diplocheilichthys pleurotaenia	5	i,11-13 (12)	17 (16)	i,5 (5)	i, 12-15 (12-14)	i. 8 (8)
Labiobarbus festivus	5	i,23-26 (24-25)	20-22 (22)	i,7 (7)	i, 11-14 (12-14)	vi. 9 (9)
Rasbora argyrotaenia	5	ii,7 (7)	16 (15)	i, 3-5 (3-5)	i, 12-13 (13)	2.7 (7)
Thynnichthys polylepis	5	iii, 8 (9)	10.2.9 (10.2.9)	i,7-8 (7-8)	ii, 17 (18)	2.8 (8)

Note: the numbers in parentheses represent the number of fin rays calculated; black numbers make no difference; red numbers show differences

4. Discussion

Coefficient of determination ($r^2 > 0.77$) in linear regression for ten fish species in the context of LWR indicated a high degree of correlation between increasing length and body weight. However, an exception occurred in *H. heterorhynchus*, where the correlation coefficient was only 0.61. This finding is consistent with prior research on fish from diverse aquatic environments [24,25], with values "a" and "b" in the range that is in accordance with the findings in previous research reports [13]. Earlier studies also found variations in the 'b' value for LWR in different species [26-28]. This variation could be attributed to various factors, including the number of species analyzed, fishing season, sampling location, size and developmental stage of the specimen, feeding categories, environmental factors, as well as type of fishing gear used [18, 29]. The growth patterns of eleven fish species varied, comprising one species exhibiting positive allometry (9.09%), seven species displaying negative allometry (63.63%), and three species showing isometry (27.27%). The length and weight relationship of fish alongside the growth pattern depends on various factors, including stock and population size, body shape, feeding, swimming behavior, trophic level, sexual characteristics, gonad maturity level, as well as environmental conditions, namely low oxygen levels and temperature in highland waters [30-33]. Therefore, estimation of length-weight relationship (LWR) and condition factor (K) is essential in fisheries management as it provides valuable insights into the health and growth patterns of species. These parameters help in assessing the overall condition of fish populations, informing sustainable fishing practices, and monitoring ecosystem health, especially when long-term data or comparisons between sites are not available. Future research should seek to incorporate comparative analyses across multiple years or sites to deepen understanding of these dynamics.

In this study, the results of the analysis of the confidence interval (CI 95%) of the standard length (cm). Nine fish species sampled were smaller than the maximum total length of fish species recorded in FishBase, while two other species had a total length higher than that recorded in FishBase [34]. Nevertheless, it can be ensured that there are fish with lengths smaller than the fish samples in this study [34]. The impact of the hydrological regime shift from lotic (flowing water) to lentic (standing water) systems on the length-weight relationship and growth patterns of fish has not been fully understood. This transition can influence various environmental factors, such as food availability, water quality, and habitat, all of which play crucial roles in determining fish growth and condition. In lotic systems, the continuous flow of water can provide different oxygen levels and food sources compared to lentic systems, which typically have calmer waters and more stable environmental conditions but may experience greater fluctuations in temperature and water quality. Therefore, in-depth studies are needed to understand how this change from lotic to lentic systems affects the growth dynamics and health of fish populations. One of the main threats to freshwater biodiversity is the loss of connectivity within river systems due to anthropogenic barriers such as dams, land use change, hydrological disturbance, and over-exploitation [35,36]. Artificial barriers, including dams, dikes, or fishing nets, can potentially affect critical environmental variables, namely water flow, temperature, and substrate composition. These variables potentially change ecological design and structure, while also decreasing species richness, freshwater community growth types, and fish body size [37,38,39].

The K*c* values of the eleven fish species analyzed were not significantly different from research findings in other water areas [40,41], including for *C. punctata* which is the object of cultivation [42] [37]. The use of allometric condition factor (K*a*) is rare in cases where species exhibit allometric growth patterns or when the value of b is calculated with sufficient data to minimize errors [18]. Its application extends to assessing the feeding habits of different fish species [33, 43,44] and serving in different feeding regimes in laboratory experiments [42]. When a species exhibits an allometric growth pattern or when "b" equals #3.00, the allometric condition factor (K*a*) is considered more appropriate. In such cases, variations in the condition factor are directly related to differences in body weight and food intake. In this study, the average Ka values exceeded or were equal to 3 for six species, ranged from 1.86 to 2.91 for three species, and were less than 1 for one species. Several studies have used the relative condition factor (K*n*) to evaluate the condition of fish species. K*n* values below 1.0 indicate limited prey availability or elevated predator density, while values above 1.00 suggest an abundance of prey or reduced predator density [28]. In this study, *C. lucius* showed the highest performance with a Kn value of 2.51 ± 0.55. This condition is related to a carnivorous diet, while other species had a Kn value ranging from 1.0 to 1.03. Although carnivorous fish species, including *C. lucius*, *C. striata*, *H. wyckii*, *H. nemurus*, *P. pangasius*, and *W. leerii* inhabit the Koto Panjang reservoir [10], the presence does not seem to diminish the food availability for herbivorous fish, as evidenced by relative condition factor values equal to or greater than 1.0.

The morphological characteristics of fish play a crucial role in identifying the taxonomic classification of a genus or species and discerning differences between geographically variant populations. The analysis of morphological characteristics remains one of the oldest and most widely used methods for systematically studying fish [45]. The mean, minimum, and maximum ranges of morphometric characteristics, such as height and body girth, vary among the eleven species in Koto Panjang Reservoir. Morphometric characteristics of each fish species within an aquatic habitat depend on the order and family, type of fishing gear used, fishing area, food availability, sampling season, geographic influences [46], environmental conditions, and physiological state [13].

Based on the results, fish actively foraging during the day had larger eye diameters, ranging from 27.62 to 37.69% of the head length. This pattern was mainly observed in fish species from the families Cyprinidae, including *B. schwanefeldii*, *P. bulu*, *D. pleurotaenia*, *L. festivus*, R. *argyrotaenia*, and *T.*

polylepis, as well as Channidae namely *C. lucius*. On the other hand, fish that rely on the sense of smell to find food, such as the Bagridae, Siluridae, Clariidae, and Anabantidae, tend to have smaller eye diameters, ranging from 3.37 to 17.58% of the head length. Vision dominates as the main modality in diurnal fish living in shallow water habitats, but eye diameter depends on feeding habits [47,48]. Similar to other nocturnal fish, *A. annularis* [49] is a small planktivorous reef fish 7–10 cm in length, characterized by relatively large eyes up to 5 mm diameter, covering 47% of the head length and a relatively large mouth (8 mm). This fish shows strong selectivity towards larger prey [50,51], including *C. lucius*.

5. Conclusion

In conclusion, the analysis of fish species composition, length-weight relationships, condition factors, and morphometric and meristic data in Koto Panjang Reservoir provides significant contributions to the understanding of fish growth, accurate species identification, biodiversity, and reservoir ecosystem health. Among the eleven fish species analyzed, *B. schwanefeldii* had the highest percentage composition, while the lowest percentage was found in *H. wyckii*. The eleven fish species caught from these waters had consistent length-weight relationships for each species, indicating a significant correlation between the two morphological parameters with various growth patterns, including positive allometry, negative allometry, and isometry. Fulton's condition factor (K*c*), allometric (K*a*), and relative weight (K*n*) also varied between species, with some showing Kc values <1 and >1, and the Ka value showed variations in fish body shape and size. In addition, the Kc values of all fish species exceeded 1, indicating sufficient prey availability and low predators, as well as various good environmental conditions. This information provides a scientific basis for further research in analyzing aspects of biological reproduction by considering physicochemical parameters and food habits. The results of this study are also useful for policy makers in designing effective regulations for the conservation and management of fishery resources in the reservoir.

Data Availability

The data that support the findings of this study are openly available in Figshare at https://figshare.com/articles/dataset/_b_Length_and_b_b_Weight_Relationship_Condition_Factor_b_b_and_b_b_Morphometric_Characteristics_b_b_of_b_b_Eleven_Freshwater_Fish_Species_b_b_b_b_i_b_b_n_Koto_Panjang_Reservoir_Indonesia_b_/25801219, reference number 10.6084/m9.figshare.25801219.

Ethical Approval

The Animal Ethics Committee of the Institute for Research and Community Service at Bung Hatta University in Indonesia approved this study. Ethical permission was obtained to gather fish specimens from the Koto Panjang Reservoir and conduct measurements of length and weight at the Fish Biology Laboratory, located within the Department of Aquaculture at the Faculty of Fisheries and Marine.

6 **Conflicts of Interest**

The authors declare that there are no competing interests.

Authors' Contributions

Azrita Azrita, as Associate Professor, is responsible for data collection, analysis and preparation of the manuscript. Professor Hafrijal Syandri took part in designing the study as well as reviewing and editing the manuscript. Professor Netti Aryani took care of the research design, as well as reviewing and editing the manuscript thoroughly.

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