

ORIGINAL ARTICLE

Preliminary study of size distribution, length–weight relationship, and condition factor of penja fish (*Sicyopterus* spp.) from Mamuju waters, West Sulawesi, Indonesia

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Abstract

This study investigated the biological characteristics of *Sicyopterus* spp. (penja fish) in three estuarine–coastal systems: the Mamuju, Karema, and Simboro Rivers in Mamuju Regency, West Sulawesi, Indonesia. Sampling was conducted over a 12-month period, from March 2024 to March 2025, yielding 1,080 specimens (360 per river), comprising 505 females and 575 males. Total length (TL) ranged from 14.8 to 21.4 cm, total body weight 20.0 to 58.0 g. The Mamuju River recorded the highest mean TL (18.35 ± 0.09 cm), followed by the Karema (18.20 ± 0.10 cm) and Simboro Rivers (17.70 ± 0.09 cm). Mean body weight (BW) followed a similar pattern, with values of 39.60 ± 0.56 g, 38.50 ± 0.56 g, and 36.15 ± 0.49 g, respectively. Females generally exhibited slightly larger mean body sizes than males across the study sites. Length–weight analysis yielded regression coefficients (b) ranging from 2.723 to 2.804, indicating negative allometric growth ($b < 3$), whereby body weight increased at a proportionally lower rate than total length. The condition factor (K) also varied by sampling location, with values of 2.802 in the Mamuju River, 2.577 in the Karema River, and 2.393 in the Simboro River. Water quality assessments indicated generally suitable environmental conditions for *S. pugnans*, although spatial differences in water transparency and total suspended solids (TSS) were observed. These findings provide baseline information on the size structure, growth patterns, body condition, and environmental characteristics of *S. pugnans* across the three river systems, supporting future population monitoring and management in West Sulawesi.

Keywords: Penja fish, Condition factor, Fish morphometrics, Length–weight relationship, Mamuju

INTRODUCTION

Amphidromous gobies depend on connectivity among marine, estuarine, and freshwater habitats throughout their life cycle. Variation in hydrology, substrate, temperature, and habitat structure can influence their distribution and population characteristics, while connectivity between rivers and the sea facilitates dispersal and colonization of freshwater systems (Lisi et al. 2022; Wantania et al. 2025). This ecological dependence is particularly relevant in Sulawesi, where stream fish communities are strongly associated with habitat diversity and aquatic connectivity (Wantania et al. 2025). In West Sulawesi, amphidromous gobies are locally known as penja and are harvested around river and estuarine environments. However, penja does not necessarily represent a single species. Molecular identification of penja postlarvae from the Mandar River identified *Sicyopterus longifilis* de Beaufort, 1912 and *Stiphodon semoni* (Steindachner,

1900), indicating that the local penja fishery may comprise multiple amphidromous goby species (Nurjirana et al. 2021). Temporal variation in penja migration has also been reported, suggesting that the composition and abundance of migrating fish may change among periods (Nurjirana et al. 2022).

Biological studies in West Sulawesi have documented spatial variation in penja growth and body condition. In the Karama River, Mamuju, *S. longifilis* and *S. pugnans* showed differences in growth patterns among locations (Muthiadin et al. 2020). Similarly, *S. longifilis* from the Ummiding and Matama Rivers exhibited differences in length–weight relationships and condition factors between locations and sexes (Tikawati et al. 2024). These findings indicate that penja biological characteristics may vary among habitats, but size structure, length–weight relationships, and condition factor have not yet been jointly characterized across multiple coastal locations

in Mamuju.

Size distribution, length–weight relationship, and condition factor provide complementary information for describing fish populations. Size distribution describes the composition of individuals across length classes, the length–weight relationship indicates relative growth, and condition factor provides an index of relative body condition (Froese 2006). Together, they provide a more integrated characterization of population attributes than any single parameter. The length–weight relationship (LWR) is a fundamental tool in fish biology and fisheries science, providing valuable insights into biomass estimation, fish stock assessment, growth patterns, and the evaluation of fish condition (Jafari-Patcan et al. 2018; Abbasi et al. 2019; Eagderi et al. 2020; Mouludi-Saleh et al. 2021, 2023).

This study was conducted from March 2024 to March 2025 in the coastal waters of Karema, Simboro, and Mamuju, Mamuju District, West Sulawesi, Indonesia. Temperature, salinity, water pH, and substrate pH were measured in estuarine, mangrove, seagrass, and coral reef zones as supporting environmental information. The study aimed to characterize the size distribution, length–weight relationship, and condition factor of penja fish (amphidromous gobies) across the three locations and to provide baseline information on their biological characteristics in the Mamuju coastal region.

MATERIALS AND METHODS

Study area: The study was conducted in the coastal waters of Mamuju Regency, West Sulawesi, from March 2024 to March 2025. Sampling was carried out at three stations: Mamuju River (A), Karema River (B), and Simboro River (C). These locations were selected using purposive sampling, based on the presence of river estuaries that serve as habitats for penja fish. The spatial distribution of the sampling sites is presented in Figure 1.

Sampling procedure: Penja fish were sampled over a one-year period, with monthly collections at three sampling stations, using local fish collectors at each station. Samples were selected using a systematic random sampling method (Saputra et al. 2013), with inclusion criteria requiring specimens to be fresh, intact, and free from physical damage.

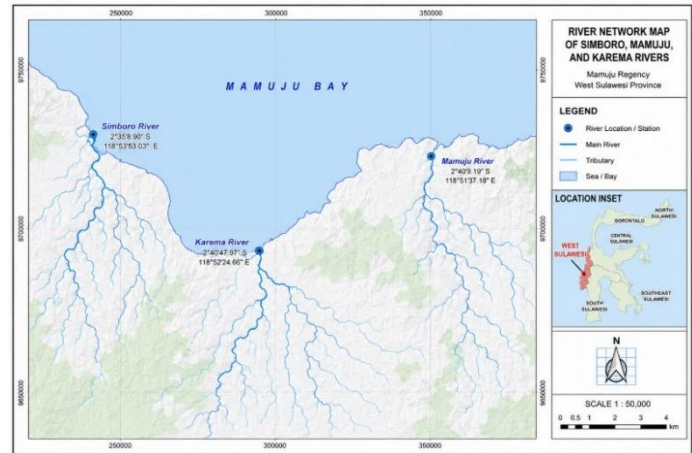


Fig.1. Locations of the three sampling stations: Karema waters (Station A; 2°40'47.97" S, 118°52'24.66" E), Simboro waters (Station B; 2°40'9.19" S, 118°51'37.18" E), and Mamuju waters (Station C; 2°39'58.90" S, 118°53'53.03" E), along with other detected locations.

The number of samples collected was adjusted according to the total catch landed at each station: 2–5% for catches of 60–100kg, 6% for 50 kg, 7.5–80% for 4–40kg, and 100% for catches of 1–3kg. Collected specimens were placed in a cool box and transported to the laboratory for further measurement and analysis. Total length was measured from the anterior tip of the head to the posterior end of the caudal fin using a digital caliper with a precision of 0.01mm. Body weight was determined using a digital balance with a precision of 0.01g. Sex was determined based on gonadal morphology by dissecting the abdominal cavity.

Data analysis

Morphological identification: Penja fish species identification was based on external morphological characteristics, including body shape, pigmentation patterns, head characteristics, mouth position, fin configuration, and other diagnostic features. Species determination was performed by comparing the morphological characteristics of the specimens with taxonomic descriptions and relevant identification literature. These identifications provided a taxonomic basis for the specimens before analyses of size structure, length–weight relationships, and condition factor. The identification of *Sicyopterus* species known locally as penja fish was conducted using a morphological identification key based on external characteristics. The traits examined included body shape, dorsal and lateral pigmentation patterns, head shape, mouth position and structure, upper-lip shape,

premaxillary tooth type, dorsal-fin configuration, and fin color patterns. Specimens with an upper lip lacking a median notch but possessing lateral notches on both sides, tricuspid premaxillary teeth, and an elongated first dorsal fin spine were identified as *S. longifilis* (Maeda & Saeki 2018; Froese & Pauly 2025). Specimens with bicuspid premaxillary teeth were identified as *S. pugnans*, while those exhibiting approximately eight saddle-like markings on the dorsal side with males displaying a metallic blue body coloration were identified as *S. lagocephalus* (Keith et al. 2015; Froese & Pauly 2025). Specimens that did not exhibit a complete set of diagnostic characteristics were recorded as *Sicyopterus* spp., and their identity should be confirmed through analysis of meristic characters or DNA barcoding (Nurjirana et al. 2019; Astuti et al. 2022).

Size structure: The size structure reflects the size composition of penja and is presented as a histogram. Descriptive statistical analyses were also performed to determine the minimum and maximum sizes and the modal size class of the fish (Saputra et al. 2021).

Length-weight relationship: The length-weight relationship of fish is conducted to determine the growth pattern of fish (Gani et al. 2020; Ningsih et al. 2023). The relationship is analyzed and determined using the following formula (Omar et al. 2020; Ningsih et al. 2023): $W = aL^b$, where W is the body weight (g), L is the total length (mm), a is the intercept, and b is the slope (regression coefficient). This equation is transformed into logarithmic form to obtain a linear equation: $\log W = \log a + b \log L$. The values a (intercept), b (regression coefficient), and r (correlation coefficient) are obtained through the least squares method (Omar et al. 2020). Growth patterns in fish consist of two types, namely isometric ($b=3$) and allometric ($b \neq 3$) growth when the increase in length and weight is balanced and unbalanced, respectively (Ningsih et al. 2023). The fish growth is positively allometric or hyperallometric when $b > 3$; hence, the increase in weight is greater than the increase in length. In contrast, when $b < 3$, fish growth is negatively allometric or hypoallometric; thus, the increase in length is more dominant than the increase in weight (Omar et al. 2020). Therefore, to determine the isometric or allometric nature of the length-weight relationship pattern, the test is conducted on the value

of b using the following formula (Omar et al. 2020):

$$t \text{ value} = \left| \frac{3-b}{S_b} \right|$$

Where: S_b is the standard error of ' b ' and the $t \text{ value} > t \text{ table}$ when b is different from 3. Conversely, when $t \text{ value} < t \text{ table}$, b equals 3. A test is conducted according to Ningsih et al. (2023) to compare the coefficient b between male and female fish with the following formula:

$$t \text{ value} = \frac{(b_1 - b_2)}{SE_{(b_1 - b_2)}} \quad SE_{(b_1 - b_2)} = \sqrt{(S_{b1})^2 + (S_{b2})^2}$$

Where: b_1 and b_2 : Female and male fish regression coefficients; SE_{b1} and SE_{b2} : Standard errors for female and male fish. The length-weight relationship of female and male fish is not significantly different when the $t \text{ value} < t \text{ table}$. Therefore, the data were combined to determine the length-weight relationship of combined male and female fish, compare the length-weight relationship by sampling location, and examine differences by dark and light moon phases at the two locations. The conclusion is that the length-weight relationship significantly differs when the $t \text{ value} > t \text{ table}$. Regression analysis (r) and determinant coefficient (R^2) were used to determine the relationship between fish length and weight. The total length and body weight data were analyzed using Microsoft Excel version 2022.

Condition factor: The condition factor can be determined by measuring the length and weighing the fish (Lanzoni et al. 2018; Amin & Sabrah 2019). If the fish growth is isometric, then the formula used to calculate the condition factor (Omar et al. 2020): If the value of $b=3$, the condition factor is calculated using the formula:

$$K = \frac{10^3 \times W}{L^3}$$

But if $b \neq 3$, the condition factor is calculated using the formula:

$$K = \frac{W}{a L^b}$$

Where K = condition factor; W = weight (grams); L = length (mm); a and b = constants derived from the regression of the length-weight relationship.

The condition factor is a numerical indicator of fish plumpness (Lagler 1961, as cited in Saputra et al. 2021). According to Effendie et al. (1987), as cited in



Fig.2. External morphology of *Sicyopterus pugnans* collected from the Mamuju River, West Sulawesi, Indonesia: (A) lateral view and (B) ventral view, showing the body shape, head, eyes, mouth, scales, dorsal, pectoral, pelvic, and anal fins, and caudal fin, including the pelvic suction disc.



Fig.3. External morphology of *Sicyopterus pugnans* collected from the Karema River, West Sulawesi, Indonesia: (A) lateral view and (B) ventral view, showing the body shape, head, eyes, mouth, scales, dorsal, pectoral, pelvic, and anal fins, and caudal fin, including the pelvic suction disc.

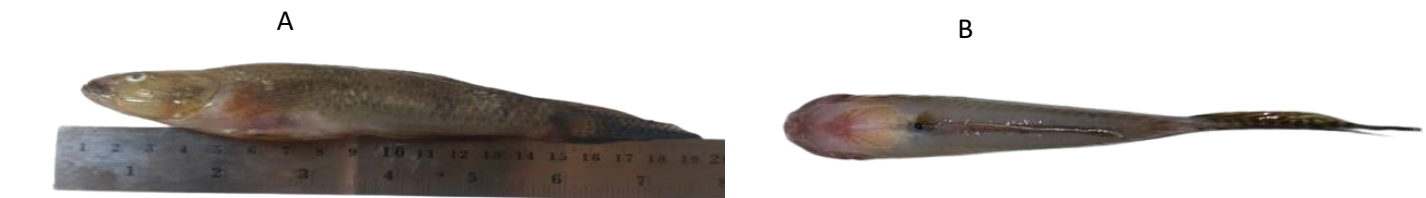


Fig.4. External morphology of *Sicyopterus pugnans* collected from the Simboro River, West Sulawesi, Indonesia: (A) lateral view and (B) ventral view, showing the body shape, head, eyes, mouth, scales, dorsal, pectoral, pelvic, and anal fins, and caudal fin, including the pelvic suction disc.

Saputra et al. (2021), CF values of 2–4 indicate a relatively compressed (flattened) body shape, whereas values of 1–3 indicate a less compressed body shape. Furthermore, t-tests were conducted to determine differences in condition factors between male and female fish and between dark and full-moon lunar phases in the Ummiding and Matama Rivers using Microsoft Excel version 2022.

Water quality: Water quality data were analyzed descriptively and presented in tabular form. The measured parameters were evaluated based on the applicable water quality standards stipulated in Government Regulation of the Republic of Indonesia No. 22 of 2021.

RESULTS

Penja fish specimens were identified as *S. pugnans* based on external morphological characteristics (Figs. 2–4). Accurate species identification provides a taxonomic basis for analyzing size structure, length–weight relationships, and condition factor. Penja fish

collected from the Mamuju, Karema, and Simboro Rivers shared several external morphological characteristics, including an elongated, slender body; brown to grayish-brown coloration; and transverse bands and dark spots on the body and fins. All specimens had two dorsal fins, although head shape, pigmentation, and fin characteristics varied among sampling sites. In specimens from the Simboro River, the pelvic fins appeared to form a sucker-like disc, a structure associated with attachment to substrates and movement in flowing-water habitats.

The penja fish discovered during research in the waters of Mamuju, specifically at the Mamuju River, Karema River, and Simboro River stations, have been morphologically identified as belonging to the genus *Sicyopterus* spp. These fish possess an elongated, somewhat cylindrical body, a relatively rounded head, a terminal mouth, and pelvic fins that are fused to form a suctorial disc sucker. This structure enables the fish to adhere to rocks or other substrates while inhabiting river environments with strong currents.

Table 1. Size Structure parameters of penja fish by sex and sampling station in Mamuju waters, West Sulawesi, Indonesia.

Station	S	n	Total Length (cm)		Body Weight (g)	
		Individuals	Range	Mean $\pm$ SE	Range	Mean $\pm$ SE
Mamuju River	F	190	15.3–20.9	18.10 $\pm$ 0.12	22.1–57.7	39.90 $\pm$ 0.75
	M	170	15.3–21.4	18.35 $\pm$ 0.14	21.2–58.0	39.60 $\pm$ 0.81
	C	360	15.3–21.4	18.35 $\pm$ 0.09	21.2–58.0	39.60 $\pm$ 0.56
Karema River	F	165	15.0–21.4	18.20 $\pm$ 0.14	20.0–57.0	38.50 $\pm$ 0.83
	M	195	15.2–21.0	18.10 $\pm$ 0.12	20.6–55.9	38.25 $\pm$ 0.73
	C	360	15.0–21.4	18.20 $\pm$ 0.10	20.0–57.0	38.50 $\pm$ 0.56
Simboro River	F	150	14.9–20.6	17.75 $\pm$ 0.13	20.0–51.8	35.90 $\pm$ 0.75
	M	210	14.8–20.6	17.70 $\pm$ 0.12	20.0–52.3	36.15 $\pm$ 0.64
	C	360	14.8–20.6	17.70 $\pm$ 0.09	20.0–52.3	36.15 $\pm$ 0.49

Note: S= sex; F= female; M= male; C= combined sexes; n= number of individuals; SE= standard error

Their coloration typically ranges from grayish to brownish, with patterns or spots that mimic the substrate and provide camouflage. Penja fish occur in sections of rivers with flowing water, rocky or gravelly substrates, and relatively clear water. The suckorial disc on the ventral side of the body is an adaptation to environments with strong currents. These fish generally live near the riverbed, using rock surfaces for both attachment and foraging. Observations indicate that penja fish from all three stations share similar morphological characteristics, although size, body coloration, and spotting patterns may vary based on habitat conditions at each site.

Size structure: A total of 1,080 penja fish were analyzed from three sampling stations, with 360 individuals collected at each station. The samples consisted of 505 females and 575 males, distributed as 190 females and 170 males in the Mamuju River, 165 females and 195 males in the Karema River, and 150 females and 210 males in the Simboro River (Table 1). The size structure of penja fish reveals variations in total length and body weight across the observation stations. Fish from the Mamuju River exhibit, on average, greater total length and body weight, whereas those from the Simboro River show the smallest average dimensions. The total length of all sampled fish ranges from 14.8 to 21.4cm, while body weight ranges from 20.0 to 58.0g. These size differences between stations are linked to environmental conditions, food availability, fish age, and the specific habitat characteristics of each river (Table 1).

Length-weight relationship: The length–weight relationship was analyzed separately for females, males, and combined sexes in the Mamuju, Karema,

and Simboro rivers (Table 2).

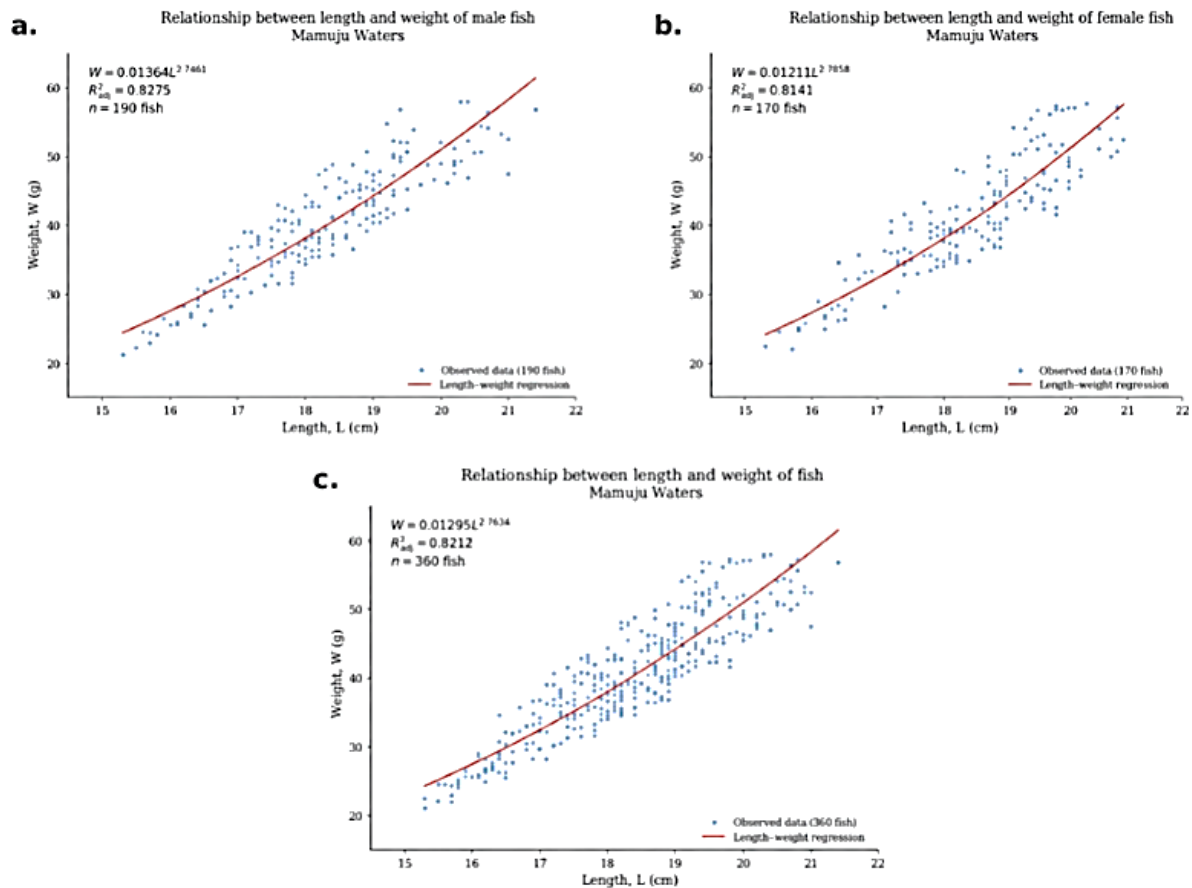
The analysis of the length–weight relationship indicates that all fish groups in the Mamuju, Karema, and Simboro rivers exhibit a negative allometric growth pattern, with regression coefficient b values ranging from 2.723 to 2.804. These values are lower than the isometric value of 3, indicating that the fish increase in length faster than they increase in weight. The coefficient of determination (R^2 values) range from 0.799 to 0.859, demonstrating a strong relationship between fish length and weight. These results suggest that body length significantly explains variation in fish weight across all study sites. The length-weight relationships of penja fish by sex across the Mamuju, Karema, and Simboro rivers are illustrated in Figures 5-7. The figures show the relationships between total length and body weight for females, males, and combined sexes at each sampling station.

Condition factor: Condition factor values varied across sampling stations and between sexes (Table 3). In the Mamuju River, mean condition factor values were 2.802 ± 0.040 for females ($n = 170$) and 2.787 ± 0.036 for males ($n = 190$), with ranges of 1.583–3.837 and 1.548–3.889, respectively. For both sexes combined ($n = 360$), values ranged from 1.5402 to 3.8743, with a mean of 2.795 ± 0.027 . In the Karema River, females ($n = 195$) had values ranging from 1.3710 to 1.5287, with a mean of 1.4502 ± 0.024 . In contrast, males ($n = 165$) ranged from 1.467 to 3.716, with a mean of 2.565 ± 0.036 , while the combined sexes ($n = 360$) ranged from 1.4389 to 3.740, with a mean of 2.569 ± 0.026 . In the Simboro River, the mean condition factor values were 2.411 ± 0.037 for females

Table 2. Length–weight relationship parameters of penja fish by sex and sampling station in Mamuju waters, West Sulawesi, Indonesia.

Station	S	<i>N</i>	Length–Weight Regression Parameters			Growth type
		Individuals	<i>a</i>	<i>b</i>	<i>R</i> ²	
Mamuju River	F	170	6.239	2.786	0.814	<i>negative allometric</i>
	M	190	6.018	2.746	0.827	<i>negative allometric</i>
	C	360	6.119	2.763	0.821	<i>negative allometric</i>
Karema River	F	195	5.979	2.804	0.859	<i>negative allometric</i>
	M	165	6.282	2.723	0.799	<i>negative allometric</i>
	C	360	6.098	2.771	0.834	<i>negative allometric</i>
Simboro River	F	150	6.209	2.759	0.824	<i>negative allometric</i>
	M	210	6.134	2.764	0.834	<i>negative allometric</i>
	C	360	6.161	2.762	0.831	<i>negative allometric</i>

Note: *n* = number of individuals; *a* = intercept; *b* = regression coefficient; *R*² = coefficient of determination; Growth patterns were classified as negative allometric when *b*<3, isometric when *b* = 3, and positive allometric when *b*>3.

**Fig.5.** Length–weight relationship of penja fish in the Mamuju River: (A) males, (B) females, and (C) combined sexes.

(*n* = 150) and 2.368 ± 0.031 for males (*n* = 210), with ranges of 1.414–3.393 and 1.440–3.468, respectively. For the combined sexes (*n* = 360), values ranged from 1.4184 to 3.4644, with a mean of 2.386 ± 0.023 .

Water quality: Water quality parameters measured in the Mamuju, Karema, and Simboro Rivers varied across sampling stations (Table 4). Water temperature was uniform at 30.5°C at all stations, whereas

transparency ranged from 2.11 to 4.20m. pH values ranged from 7.01 to 7.53, while lead (Pb) concentrations ranged from below the detection limit (BDL) to 0.007mg/L. Total suspended solids (TSS) ranged from 80 to 117mg/L, with the highest concentration in the Mamuju River and the lowest in the Simboro River.

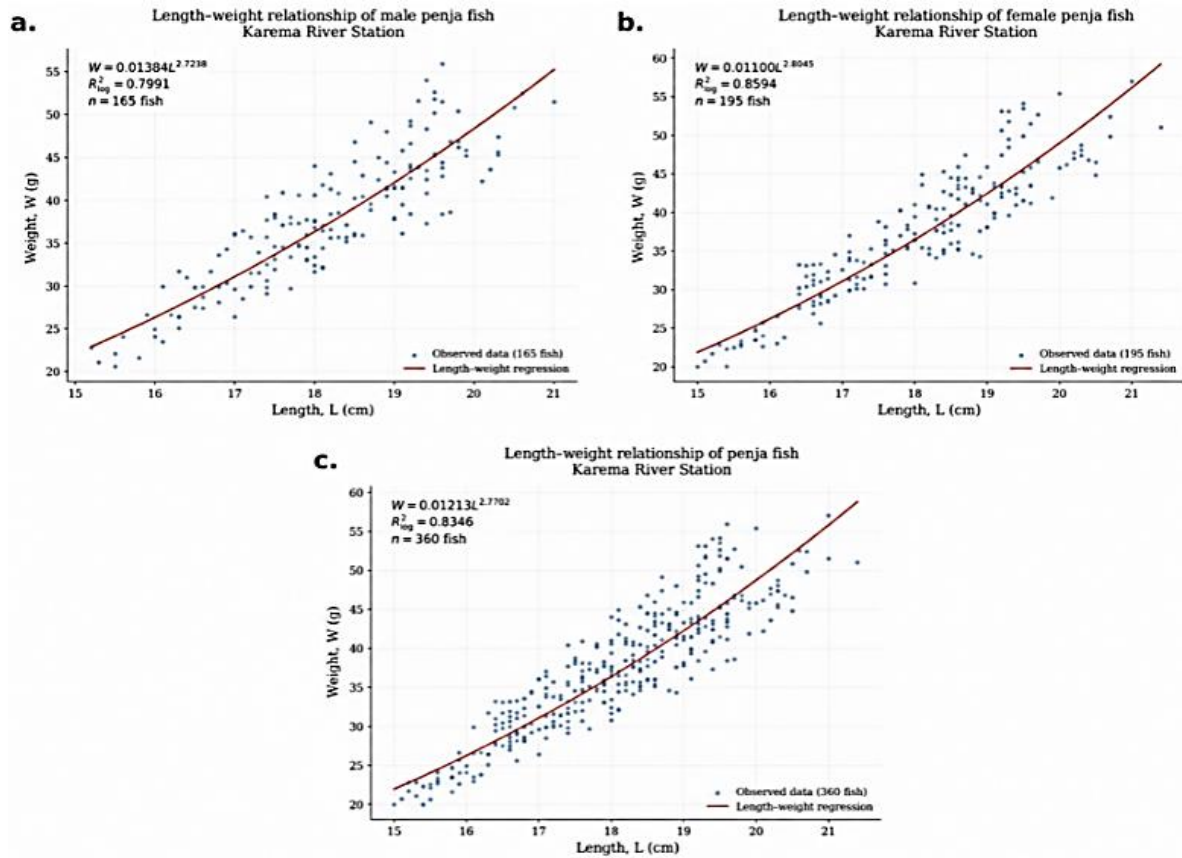


Fig.6. Length–weight relationship of penja fish in the Karema River: (A) males, (B) females, and (C) combined sexes.

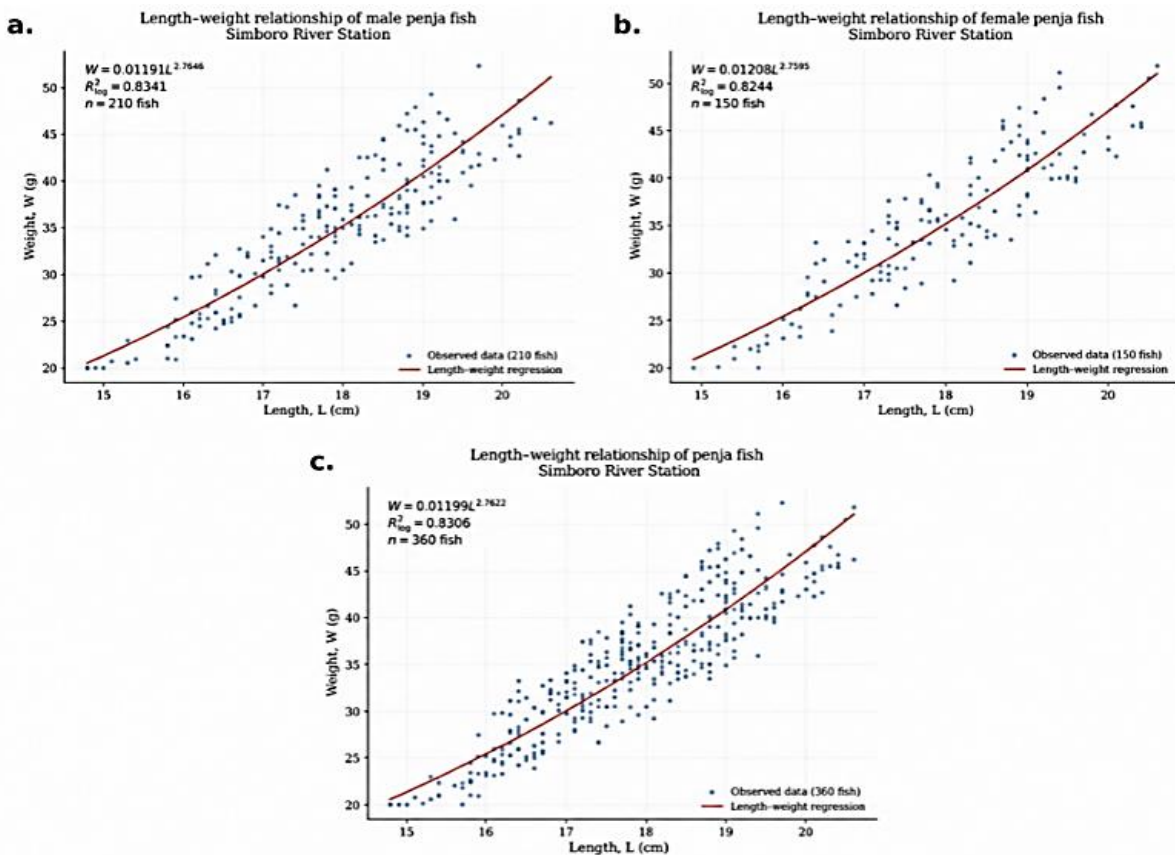


Fig.7. Length–weight relationship of penja fish in the Simboro River: (A) males, (B) females, and (C) Combined sexes.

Table 3. Condition factor parameters of penja fish by sex and sampling station in Mamuju waters, West Sulawesi, Indonesia.

Stations	S	N (Individual)	Condition Factor Values (K)	Average $\pm$ SE
Rivers Mamuju	F	170	2.810	2.803 $\pm$ 0.0043
	M	190	2.795	2.803 $\pm$ 0.0043
	C	360	2.802	2.803 $\pm$ 0.0043
Rivers Karema	F	195	2.579	2.576 $\pm$ 0.0020
	M	165	2.572	2.576 $\pm$ 0.0020
	C	360	2.577	2.576 $\pm$ 0.0020
Rivers Simboro	F	150	2.418	2.395 $\pm$ 0.0124
	M	210	2.375	2.395 $\pm$ 0.0124
	C	360	2.393	2.395 $\pm$ 0.0124

Note: S= sex; F= female; M= male; C= combined sexes; n= number of individuals; SE= standard error; K= Condition Factor

Salinity remained constant at 35ppt across all sampling stations. Dissolved oxygen (DO) ranged from 7.99 to 8.13mg/L, while biochemical oxygen demand (BOD) and chemical oxygen demand (COD) ranged from 0.92 to 1.20mg/L and 10.23 to 14.25mg/L, respectively. Comparison with the water quality criteria presented in Table 4 indicated that temperature, pH, Pb, salinity, DO, BOD, and COD met the specified standards at all sampling stations. However, transparency in the Mamuju River was below the reference criterion of >3m, while TSS concentrations in the Mamuju and Karema Rivers exceeded the specified limit of 80mg/L. In contrast, TSS concentration in the Simboro River met the prescribed limit.

DISCUSSION

The morphological features of the collected penja fish are consistent with characteristics reported for members of the genus *Sicyopterus*. Muthiadin et al. (2020) documented *S. pugnans* and *S. longifilis* in the Karama River, West Sulawesi. Astuti et al. (2022) also identified penja fish from the Budong-Budong River as *S. pugnans* using morphological characteristics supported by mitochondrial cytochrome c oxidase subunit I (COI) analysis. Nevertheless, interpret species-level identification in this study cautiously unless supported by diagnostic morphological or molecular evidence.

Penja fish biological characteristics varied among the three sampling sites and between sexes, particularly in body size, length-weight relationships, and condition factor. A total of 1,080 individuals were collected, with 360 specimens from each river. The sample comprised 505 females and 575 males.

Females outnumbered males in the Mamuju River, whereas males outnumbered females in the Karema and Simboro Rivers.

Based on the size structure, the penja fish observed across the three research stations had a total length ranging from 14.8-21.4cm and a body weight between 20.0-58.0g. This range indicates that the penja fish samples vary considerably in size. This size variation may reflect differences in age, growth, nutritional status, and the fish's ability to use the habitat in each river. Pasingi et al. (2024) reported that females of *S. longifilis* in the Bone River, Gorontalo, tended to attain larger body sizes than males. Differences between sexes may reflect sexual dimorphism and variation in energy allocation; however, these explanations require direct evidence and should be treated as potential interpretations rather than demonstrated mechanisms.

Penja fish from the Mamuju River exhibit the largest average size. Their mean total length ranges from 18.10-18.35cm, while their mean body weight ranges from 39.60-39.90g. Females have a slightly higher average body weight than males. This may be due to differences in growth rates between the sexes or to gonad development in females. However, as the size ranges for males and females overlap, these differences do not yet indicate a clear-cut distinction in size. In the Karema River, the average length of the fish ranges from 18.10-18.20cm, with an average body weight of 38.25-38.50g. Fish size at this station is similar to that in the Mamuju River, although body weight is slightly lower. The similar length range indicates that *penja* fish at both locations share a comparable size structure. Differences in body weight may be influenced by factors such as body condition,

Table 4. Water quality parameters in the Mamuju Rivers, Karema Rivers, and Simboro Rivers and their comparison with environmental quality standards based on Government Regulation No. 22 of 2021.

No.	Parameter	Mamuju River	Karema River	Simboro River	Quality Standards (Government Regulation No. 22 of 2021)	Remarks
1	Temperature (°C)	30.5	30.5	30.5	Natural conditions (maximum deviation $\pm 2^{\circ}\text{C}$)	Within acceptable range
2	Transparency (m)	2.11	3.2	4.2	> 3m	Mamuju: below standard; others meet standard
3	pH	7.01	7.42	7.53	6.5-8.5	Meets standard
4	Lead (Pb) (mg/L)	BDL-0.0078	BDL-0.0078	BDL-0.0068	0.05mg/L	Meets standard
5	Total Suspended Solids (mg/L)	117	90	80	80mg/L	Mamuju & Karema: exceed standard; Simboro: meets standard
6	Salinity (ppt)	35	35	35	Natural conditions	Within natural range
7	Dissolved oxygen (DO) (mg/L)	8.09	7.99	8.13	$\leq 4\text{mg/L}$	All stations meet the standard
8	Biochemical oxygen demand (BOD) (mg/L)	1.1	1.2	0.92	$\leq 3\text{ mg/L}$	All stations meet the standard
9	Chemical oxygen demand (COD) (mg/L)	14.25	10.23	12.31	$\leq 25\text{ mg/L}$	All stations meet the standard

Note: BDL= below detection limit; DO= dissolved oxygen; BOD= biochemical oxygen demand; COD= chemical oxygen demand; TSS= total suspended solids; TDS= total dissolved solids; Pb= lead. Water quality standards refer to the Government Regulation of the Republic of Indonesia No. 22 of 2021 concerning the Implementation of Environmental Protection and Management.

food availability, population density, or environmental conditions. Nur et al. (2018) reported temporal changes in the size structure of penja fish in the Karema River, while Muthiadin et al. (2020) documented differences in the growth patterns of *S. longifilis* among locations in the Karema River. Several interacting factors may influence body size, including age, food availability, current velocity, substrate characteristics, and habitat conditions.

Because the present study did not directly test these factors, their role in explaining the observed spatial patterns remains hypothetical.

Penja fish from the Simboro River have the smallest average size. Their mean total length ranges from 17.70-17.75cm, while their mean body weight ranges from 35.90-36.15g. These lower length and weight values, compared with those at the other two stations, suggest that the penja population in the

Simboro River may be dominated by younger individuals or experiencing slower growth. Environmental factors such as habitat quality, food availability, water currents, and water physicochemical conditions may contribute to these differences. Overall, the size structure of penja fish indicates that the Mamuju River has the largest average size, the Karema River falls in the middle, and the Simboro River has the smallest average size. This variation is significant for fisheries management, as size structure can be used to assess population status, growth patterns, and the age groups of the fish being caught. If the catch consists predominantly of small fish, it is necessary to review factors such as mesh size and the timing of fishing activities to ensure fish have the opportunity to grow and reproduce before being harvested.

Taxonomic identity is also relevant to the interpretation of penja size structure. The local name “penja” may refer to more than one species. DNA-based research on penja fish from the Mandar River, West Sulawesi, identified *S. longifilis* and *S. semoni* among the specimens examined (Nurjirana et al. 2021). Therefore, if identification in the present study relied mainly on external morphology or local terminology, differences in size structure could potentially reflect variation in species composition as well as biological or environmental differences. This limitation should be considered when comparing the present results with studies involving taxonomically confirmed species.

Previous studies have reported different length–weight patterns for *S. longifilis* in West Sulawesi. Tikawati et al. (2024) reported b -values of 3.025 for males and 2.842 for females in the Ummiding River, and 3.119 for males and 3.222 for females in the Matama River. Muthiadin et al. (2020) reported values of 3.003 in Kalumpang, 2.610 in Bonehau, 2.888 in Arassi, and 2.468 in Kalonding. Such variation suggests that growth patterns can differ among populations and locations, although direct comparisons should account for differences in species identification, sampling design, fish-size range, and analytical methods.

Potential factors associated with variation in length–weight relationships include size and age composition, sex, reproductive condition, and energy

allocation to somatic growth. Environmental characteristics, including food availability, water conditions, substrate type, and habitat alteration, may also be relevant (Froese 2006; Muthiadin et al. 2020). These relationships may be particularly complex in amphidromous fishes because they use different habitats during their life cycle. Other gobiid fishes also show variation in length–weight coefficients: Tran et al. (2021) reported values from 2.909 to 3.621 for 11 gobiid species in the Red River estuary, Vietnam, while Suwarni et al. (2022) reported values of 2.466 for males and 2.377 for females of *Glossogobius giuris*. Interpret differences among studies in the context of the populations, habitats, and methods examined, rather than by comparing them to the theoretical value of $b = 3$ alone.

Based on length–weight relationship analysis, 360 individual fish were analyzed at each location. In the Mamuju River, the sample consisted of 170 females and 190 males. In the Karema River, the sample included 195 females and 165 males, while in the Simboro River, it included 150 females and 210 males. Combined, males and females at each location totaled 360 individuals. The regression coefficient b values for all fish groups ranged from 2.723 to 2.804. Since these values are less than 3, the growth pattern of the fish at all locations is classified as negatively allometric. This pattern indicates that body length increases more rapidly than body weight. Consequently, the fish tend to grow in length first, resulting in a relatively slimmer body shape as they increase in size. In the Mamuju River, the b value for females was 2.786, while for males, it was 2.746. The slightly higher b value for females suggests that, for any given increase in length, females gain relatively more weight than males. Nevertheless, both groups exhibit a negatively allometric growth pattern. The combined b value of 2.763 indicates that the population as a whole also shows negative allometric growth.

In the Karema River, the b value is 2.804 for females, 2.723 for males, and 2.771 for the combined group. The highest b value in the entire table is 2.804 for females from the Karema River. This indicates that this group exhibits the greatest tendency toward weight gain compared to the other groups, although it has not yet reached an isometric growth pattern.

Conversely, the lowest b value is found in males from the Karema River (2.723), indicating a stronger tendency toward length increase relative to weight gain. In the Simboro River, the b values are 2.759 for females, 2.764 for males, and 2.762 for the combined group. These values are relatively close, suggesting that the difference in growth patterns between females and males at this location is not significant. This indicates that both males and females in the Simboro River share a relatively similar growth tendency: negative allometric growth.

The R^2 values range from 0.799 to 0.859, indicating a strong relationship between fish length and weight. The highest R^2 value is observed in females from the Karema River (0.859), meaning that approximately 85.9% of the variation in fish weight can be explained by variation in body length. The lowest R^2 value is found in males from the Karema River (0.799), implying that about 79.9% of the variation in fish weight is influenced by body length. The remaining variation is attributed to other factors, such as age, sex, gonad maturity stage, food availability, environmental conditions, season, and fish health status. The proportion of variation in weight explained by length may be affected by the size range, individual variability, and characteristics of the sampled population (Froese 2006; Tikawati et al. 2024).

The condition factor indicates relative body condition based on the relationship between fish length and weight. Variation in this factor among sites and sexes indicates that the condition of the sampled penja fish was not uniform across the study area. Possible influences include food availability, body size, sex, reproductive condition, and habitat characteristics (Froese 2006). In females, changes in body weight associated with gonadal development may affect condition factor during reproductive periods (Suwarni et al. 2022). Tikawati et al. (2024) likewise reported variation in the condition factor of *S. longifilis* from the Ummiding and Matama Rivers according to sex, sampling location, and lunar phase. Muthiadin et al. (2020) reported condition factor values of approximately 1.997-2.282 for *S. longifilis* at several locations in the Karema River. Differences among studies may reflect variation in fish size, habitat, population composition, sampling period, and calculation methods.

Water-quality measurements varied among the three sampling sites. The parameters assessed were temperature, pH, salinity, transparency, total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and lead (Pb). The results were compared with the reference criteria used in the study, including those in Government Regulation of the Republic of Indonesia No. 22 of 2021. The suitability of each parameter should be assessed against the specific water-use category and the relevant regulatory threshold.

Based on the penja fish condition results, the Mamuju River has the highest average condition factor (2.803 ± 0.004). This value shows that penja fish in the Mamuju River have relatively better or more contentious body condition than penja fish from other stations. The condition factor in the Karema River is 2.576 ± 0.002 , while the lowest value is in the Simboro River (2.395 ± 0.012). These differences show variation in fish condition between locations. This variation may be influenced by food availability, water quality, habitat, fish density, river currents, and environmental conditions at each station. The Mamuju River has higher condition factor values than the Karema River and the Simboro River. This suggests that the Mamuju River environment better supports penja growth and nutritional needs. In contrast, the low condition factor values in the Simboro River may indicate more limited food availability, greater environmental pressure, or less supportive habitat conditions.

The sex-based condition factor values in the Mamuju River were relatively close: female fish at 2.8104, male fish at 2.795, and combined at 2.803. The same condition was also seen in the Karema River, with a female value of 2.579 and a male value of 2.572. This shows that the difference in body condition between female and male fish is relatively small at the two stations. In the Simboro River, the condition factor for female fish is 2.418, while that for male fish is 2.375. Female fish have a slightly higher value than male fish. This difference may relate to physiological differences, gonad maturity levels, growth patterns, and energy requirements between female and male fish. The small SE values in the Mamuju River and Karema River show that the

average condition factor values are relatively consistent. Meanwhile, the SE value in the Simboro River is larger (0.012), indicating greater variation in condition factors between groups than at the other two stations.

Food availability can contribute to differences in condition factors, as adequate resources can support energy reserves and somatic growth. Habitat characteristics can also affect food availability and foraging opportunities. Habitat connectivity and environmental heterogeneity have been linked to the structure of fish communities, including amphidromus, in Sulawesi (Wantania et al. 2025). Thus, penja fish in the Mamuju River have the best body condition, while penja fish in the Simboro River have the lowest. A higher condition factor value indicates better physical condition and more efficient use of the environment and available food sources.

Water temperature was 30.5°C at all three sites, indicating similar thermal conditions during measurement. Temperature influences metabolic activity, energy expenditure, growth, and other physiological processes in fish. Because no spatial difference was recorded, temperature alone is unlikely to explain the observed differences in biological characteristics among the sites.

The pH values were 7.01 in the Mamuju River, 7.42 in the Karema River, and 7.53 in the Simboro River. All values fell within the reference range of 6.5–8.5 used in the study. These near-neutral to slightly alkaline values indicate broadly similar pH conditions across the sites. Maintaining suitable pH is important because substantial fluctuations can affect fish physiology and the chemical availability of substances in aquatic environments.

Salinity was 35 ppt at all three sampling sites, indicating strong marine influence at the sampled locations. This parameter is relevant to amphidromous fishes, whose life cycles involve movement among marine, estuarine, and freshwater habitats. Environmental changes along this continuum may influence habitat use and distribution. Ching et al. (2023) highlighted the importance of habitat connectivity in the life cycle of amphidromous gobiid fishes. Because the reported salinity is marine-level, confirm the precise sampling position and salinity measurements to ensure the site descriptions as

riverine or estuarine align with field conditions.

Water transparency was 2.11m in the Mamuju River, 3.20m in the Karema River, and 4.20m in the Simboro River. Based on the study's criterion, transparency greater than 3m met the reference value; therefore, Karema and Simboro met this criterion, whereas Mamuju did not. TSS concentrations were 117mg/L in Mamuju, 90mg/L in Karema, and 80mg/L in Simboro. The Mamuju River thus had both the lowest transparency and the highest TSS concentration. Higher TSS can increase turbidity and reduce light penetration, potentially affecting physical habitat conditions. Environmental and physicochemical characteristics have also been associated with the distribution of gobiid fishes in estuarine environments (Zhang et al. 2022). Nevertheless, this pattern reflects an association and does not, by itself, establish a causal relationship.

Dissolved oxygen concentrations were 8.09mg/L in the Mamuju River, 7.99mg/L in the Karema River, and 8.13mg/L in the Simboro River. These measurements indicate oxygenated conditions at the time of sampling. BOD values were 1.10, 1.20, and 0.92mg/L, respectively, while COD values were 14.25, 10.23, and 12.31mg/L for Mamuju, Karema, and Simboro. The BOD values were relatively low, indicating a comparatively low measured oxygen demand associated with biodegradable organic matter. The differences in COD suggest variation in the amount of chemically oxidizable substances among sites. Lead concentrations ranged from below the detection limit (BDL) to 0.007mg/L in the Mamuju and Karema Rivers and from BDL to 0.006mg/L in the Simboro River. These concentrations were below the study's 0.05 mg/L reference value. Interpretation should retain the detection-limit notation because BDL does not mean that lead was entirely absent.

Overall, the water-quality results indicate spatial differences among the sampled locations, particularly in transparency and TSS. Mamuju had lower transparency and higher TSS than Karema and Simboro. These differences may reflect habitat conditions and could be associated with variation in the biological characteristics of the sampled fish. However, because the study was observational and did not directly test causal mechanisms, these findings should be described as spatial associations rather than

evidence that water quality caused differences in fish size, growth, or condition.

The combined assessment of size structure, length–weight relationships, condition factor, and water quality provides complementary information on penja and their habitats. Size structure describes the distribution of captured individuals, length–weight relationships characterize the relationship between body length and weight, condition factor provides an index of relative body condition, and water-quality measurements describe selected environmental characteristics of each sampling site. Together, these indicators provide a broader description of the sampled populations than relying on a single biological measure (Froese 2006).

The spatial variation observed across the three sites suggests that penja fish were sampled under differing habitat conditions. This is relevant for amphidromous fishes because their life cycles depend on connectivity among marine, estuarine, and freshwater environments. Changes in connectivity, environmental quality, food availability, and fishing pressure may influence population structure and resource sustainability (Wantania et al. 2025). These findings can therefore serve as a baseline for future monitoring of penja fish in the Mamuju coastal region. Further research incorporating molecular species identification, gonadal maturity, food availability, habitat characteristics, and fishing pressure would help clarify the factors associated with observed differences among sites.

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مقاله کامل

مطالعه مقدماتی توزیع اندازه، رابطه طول-وزن و ضریب وضعیت ماهی پنیا (*Sicyopterus* spp.) در آب‌های ماموجو، سولاوسی غربی، اندونزی

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چکیده: این مطالعه با هدف بررسی ویژگی‌های زیستی ماهی‌های گونه *Sicyopterus* spp. (ماهی پنجا) در سه ناحیه مصبی-ساحلی شامل رودخانه‌های ماموجو، کارما و سیمبورو در ماموجو، استان سولاوسی غربی، اندونزی، انجام شد. نمونه‌برداری طی یک دوره ۱۲ ماهه، از مارس ۲۰۲۴ تا مارس ۲۰۲۵، صورت گرفت و در مجموع ۱۰۸۰ نمونه (۳۶۰ نمونه از هر رودخانه) جمع‌آوری شد که شامل ۵۰۵ قطعه ماهی ماده و ۵۷۵ قطعه ماهی نر بودند. طول کل (TL) نمونه‌ها در دامنه ۱۴/۸ تا ۲۱/۴ سانتی‌متر و وزن کل بدن در محدوده ۲۰/۰ تا ۵۸/۰ گرم قرار داشت. رودخانه ماموجو بیشترین میانگین طول کل بدن را نشان داد ($18/35 \pm 0/09$ سانتی‌متر) و پس از آن رودخانه‌های کارما ($18/20 \pm 0/1$ سانتی‌متر) و سیمبورو ($17/70 \pm 0/09$ سانتی‌متر) قرار گرفتند. میانگین وزن بدن (BW) نیز الگوی مشابهی دنبال کرد و به ترتیب برابر با $39/60 \pm 0/56$ ، $38/50 \pm 0/49$ و $36/15 \pm 0/49$ گرم بود. در مجموع، میانگین اندازه بدن ماهیان ماده در مقایسه با ماهیان نر، در ایستگاه‌های مورد مطالعه اندکی بیشتر بود. بررسی رابطه طول-وزن، ضرایب رگرسیونی (b) را در محدوده ۲/۷۲۳ تا ۲/۸۰۴ شان داد که بیانگر رشد آلومتریک منفی ($b < 3$) است؛ به این معنی که افزایش وزن بدن با نرخی متناسب کمتر از افزایش طول کل رخ می‌دهد. همچنین، شاخص وضعیت (K) برحسب محل نمونه‌برداری متفاوت بود و مقادیر آن در رودخانه‌های ماموجو، کارما و سیمبورو به ترتیب $2/577$ ، $2/393$ و $2/393$ به دست آمد. ارزیابی کیفیت آب نشان داد که شرایط محیطی در هر سه اکوسیستم، به‌طور کلی، برای گونه *S. pugnans* مناسب است؛ هرچند تفاوت‌های مکانی در شفافیت آب و میزان کل مواد جامد معلق (TSS) مشاهده شد. یافته‌های این پژوهش، اطلاعات پایه‌ای درباره ساختار اندازه، الگوهای رشد، وضعیت بدنی و ویژگی‌های محیطی *S. pugnans* در سه اکوسیستم رودخانه‌ای مذکور فراهم می‌کند و می‌تواند مبنایی برای پایش آتی جمعیت و تدوین راهبردهای مدیریتی و حفاظتی این گونه در سولاوسی غربی باشد.

کلمات کلیدی: ماهی پنجا، شاخص وضعیت، ریخت‌سنجی ماهیان، رابطه طول-وزن، ماموجو