Biosystems Diversity

ISSN 2519-8513 (Print)
ISSN 2520-2529 (Online)
Biosyst. Divers.

Growth patterns, condition factors and morphological variations in *Barbonymus schwanefeldii* from Indonesia

Y. Akmal*, **, M. Yunus*, H. Plumeriastuti*, Y. Dhamayanti*, M. Radhi**, I. Irfannur**, M. Muliari***, I. Zulfahmi****, A. S. Batubara*****, F. M. Nur******

* *Universitas Airlangga, Surabaya, Indonesia*
** *Universitas Almuslim, Bireuen, Indonesia*
*** *Universitas Malikussaleh, Aceh Utara, Indonesia*
**** *Universitas Syiah Kuala, Banda Aceh, Indonesia*
***** *Universitas Negeri Medan, North Sumatra, Indonesia*
****** *National Research and Innovation Agency, Cibinong, Indonesia*

Article info
Received 08.01.2025
Received in revised form 10.02.2025
Accepted 11.02.2025

Universitas Airlangga, Surabaya, Indonesia. Tel.: +62-852-604-946-48. E-mail: yusrizalakmal@umuslim.ac.id

Universitas Almuslim, Bireuen, Indonesia. Tel.: +62-822-597-809-75. E-mail: irfannur@umuslim.ac.id

Universitas Airlangga, Surabaya. Indonesia. Tel.: +62-813-573-350-95. E-mail: muchammad-y@fkh.unair.ac.id

Universitas Airlangga, Surabaya. Indonesia. Tel.: +62-877-1146-2134. E-mail: hani-p@fkh.unair.ac.id

Universitas Airlangga, Indonesia. Tel.: +62-821-318-482-27. E-mail: yeni-d@fkh.unair.ac.id

Universitas Malikussaleh, Aceh Utara, Indonesia. Tel.: +62-852-601-401-15. E-mail: muliari@unimal.ac.id

Universitas Negeri Medan, Medan, 20221, Indonesia. Tel.: +62-852-606-147-36. E-mail: agungsbb@unimed.ac.id

National Research and Innovation Agency, Cibinong, 16911, Indonesia. Tel.: +62-852-479-555-28. E-mail: fir-manmn19@gmail.com

Akmal, Y., Yunus, M., Plumeriastuti, H., Dhamayanti, Y., Radhi, M., Irfannur, I., Muliari, M., Zulfahmi, I., Batubara, A. S., & Nur, F. M. (2025). Growth patterns, condition factors and morphological variations in Barbonymus schwanefeldii from Indonesia. Biosystems Diversity, 33(2), e2533. doi:10.15421/012533

Tinfoil barb (*Barbonymus schwanefeldii*) is one of Indonesia's native fish species which has economic value as a consumption and ornamental fish. This species is also found in the Leuser Ecosystem Area, specifically the Keureuto, Bunin, and Sikundur Rivers, Aceh Province, Indonesia. However, studies regarding the length-weight relationship, condition factors, meristics and morphometric variations of this species have not yet been undertaken, especially in the Leuser Ecosystem Area. So this research on these characteristics is important as a basis for managing these fish in the Leuser Ecosystem Area. Samples were collected in three locations (Bunin River, Keureuto River and Sikundur River) over a period of nine months using nets, gillnets and fishing rods. Fish length and weight were measured in situ using digital scales and calipers. Meristic and morphometric analyses were also performed in this study to reveal possible intraspecies differences. A total of 24 morphometric and 9 meristic characters were measured in this study. A total of 208 *B. schwanefeldii* samples were collected in this study with a total of 70 males and 138 females. The total number of *B. schwanefeldii* catches in the Keureuto, Bunin, and Sikundur River reached 57, 110, 41 samples, respectively. Based on the results of observations at the three research locations, it shows that female fish were more dominant, where the ratio between male:female for the three locations respectively was between 1:2.33 (Bunin River), 1:1.71 (Keureuto River), and 1:1.56 (Sikundur River). *B. schwanefeldii* collected from the Keureuto River and Sikundur River had a negative allometric growth pattern, while those from the Bunin River had a positive allometric growth pattern. Comparative meristic and morphometric analysis showed that *B. schwanefeldii* collected from the Keureuto River and Sikundur River had high similarities, while *B. schwanefeldii* from the Bunin River were relatively different. The results of this research succeeded in revealing morphological variations between *B. schwanefeldii* populations which are related to adaptation to different habitats.

Keywords: tinfoil barb; native fish; Leuser Ecosystem Area; meristic; morphometric.

Introduction

Tinfoil barb (*Barbonymus schwanefeldii*) is a native fish species found in the Leuser Ecosystem Area, specifically the Keureuto, Bunin, and Sikundur Rivers, Aceh Province, Indonesia. Tropical river systems such as this support some of the most productive inland fisheries (Poomchaivej et al., 2024). There is still little information regarding uncontrolled environmental factors influencing fish biology, especially *B. schwanefeldii* (Rahman & Fathi, 2022). *B. schwanefeldii* is a freshwater fish found in subtropical and tropical areas (Mansour et al., 2016).

The Keureuto, Bunin and Sikundur River ecosystems are important habitats for the diversity of flora and fauna in Aceh Province. This ecosystem provides shelter for various organisms, but its condition continues to decline due to forest destruction, conversion, invasion of non-native species, and pollution. Therefore, ecological assessment is very important with regard to conservation (Herlihy et al., 2020), especially for *B. schwanefeldii*. This ecological assessment can take the form of analyzing the length-weight relationship and condition factors (Tran et al., 2021). The length-weight relationship of fish involves recording the weight corresponding to a certain length (Mulfizar et al., 2012), while the condition factor involves assessing the body condition or health of fish populations (Oliveira et al., 2020). Condition factors are the main parameters of fish populations' stock (Deng et al., 2020; Hammock et al., 2022).

Ecological factors also play a role in variations of organism morphology (Kenthao & Jearranaiprepame, 2020; Mahyudi & Merdekawati, 2021), so the authors also analyzed the possibility of variations in *B. schwanefeldii* morphology between research locations. Morphological studies are important for establishing the relationship of species to their habitat conditions and establishing conservation programs (Gonzalez-Martinez et al., 2020). Morphological analysis can be carried out by morphometric measurements of fish including total length, head length, tail peduncle length, standard length, caudal fin length, caudal peduncle height, dorsal fin height, body width, eye and mouth width (Prafiadi & Maturahmah, 2020; Akmal et al., 2022; Suleman & Djonu, 2022; Zega et al., 2024).

So far, no information has been reported regarding *B. schwanefeldii* stock in the Keureuto, Bunin and Sikundur Rivers, Leuser Ecosystem Area. The research aims to determine the length-weight relationship, condition factors, and morphometrics of *B. schwanefeldii* in the Leuser Ecosystem Area as a basis for future conservation efforts.

Materials and methods

The sampling was conducted at 3 different locations, determining the sampling location using the purposive sampling method. The details of the sampling location are as follows; location 1 is located in Geureudong Pase, North Aceh Regency (4° 53' 53.0" N, 97° 04' 23.9" E), location 2 is located in Serbajadi, East Aceh Regency (4° 29' 19.3" N, 97° 36' 12.4" E), location 3 is located in Tenggulun, Aceh Tamiang Regency (3° 55' 45" N, 97° 56' 30" E) (Fig. 1).

Samples were collected for 9 months from October 2023 – June 2024. The sampling process was assisted by fishermen and the fish landed in fresh condition. The fishing was carried out using 3 types of fishing equipment such as nets (net size 2 cm), gillnets (net sizes 3, 4, and 5 cm), and fishing rods. 10 sets of gill nets (2 m high and 20 m long) were spread across the river with a distance of 50 m between nets. The gill nets were spread for 12 hours, namely in the evening at 18:00 pm and lifted at 06:00 am, then spread in the morning 06:30 am and lifted at 18:30 pm. The caught fish samples were then weighed and their morphometric characteristics were measured. The scales used were digital scales with an accuracy of 0.01 g, and morphometric measurements were carried out using calipers with an accuracy of 0.01 mm. The fish was dissected in the pelvic area to observe sex and growth stage.

Analysis of the length-weight relationship and condition factors. Analysis of the length-weight relationship uses the following formula by Froese (2006):

$$W = aL^b$$

where: W = body weight (g), a = intercept, L = total length (mm), and b = slope.

To test the value of b = 3 or b ≠ 3, a t-test (partial test) is carried out, with the hypothesis:

H0 : b = 3, the relationship between length and weight is isometric;

H1 : b ≠ 3, the relationship between length and weight is allometric.

Positive allometric, if b > 3 (weight increase is faster than length increase).

Negative allometric, if b < 3 (length increase is faster than weight increase).

The condition factor is calculated based on the length and weight of the fish using the following formula:

$$K = \frac{W}{aL^b}$$

where: K = condition factor, L = total length (mm), W = body weight (g), a and b = constant.

Morphometric analysis. The measured morphometric characters of *B. schwanefeldii* totaled 24 characters including the head with 8 characters, namely ED, IW, HW, HD, MXBL, SNBL, SNL and HL, the fins with 8 characters, namely DBL, DFH, LUCL, LMCL, LCLL, ABL, PVL and PCL, and body totaling 8 characters, namely PCL, BD, CPD, CPL, TL, SL, PAL, and PPL (Fig. 3). The morphometric measurement data obtained was then transformed using the formula referring to Batubara et al. (2018): Data Transformation = (Morphometric measurement data x 100%) / Total length.

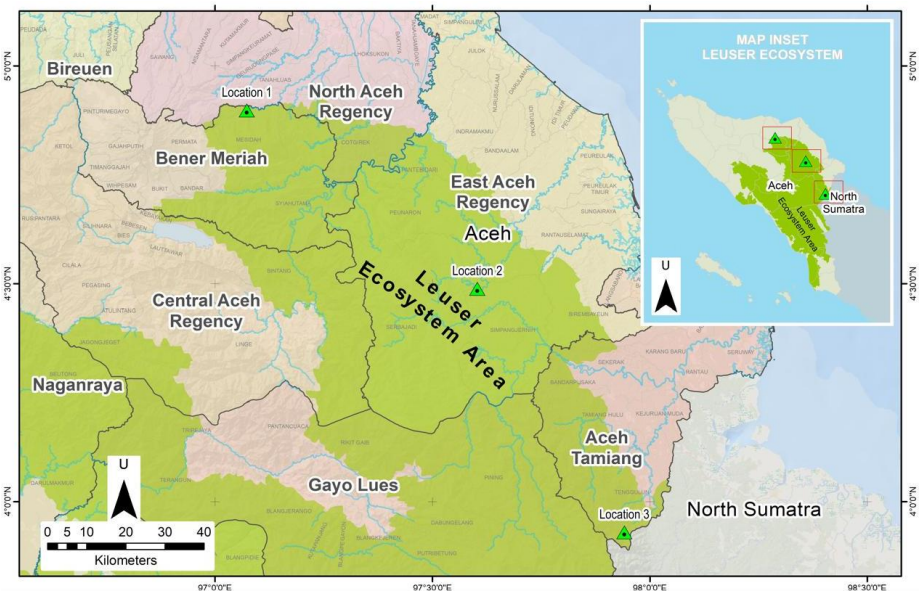

Fig. 1. *Barbonymus schwanefeldii* sampling locations marked with a green triangle: location 1 is the Keureuto River, Geureudong Pase, North Aceh Regency; location 2 is Bunin River, Serbajadi, East Aceh Regency; location 3 is the Sikundur River, Tenggulun, Aceh Tamiang Regency

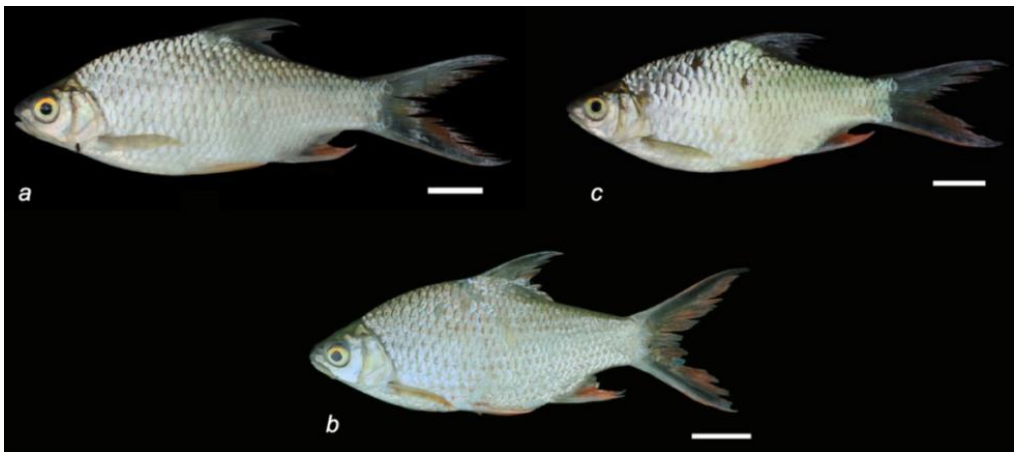

Fig. 2. Samples of *Barbonymus schwanefeldii* fish obtained from the Keureuto River (*a* with a scale bar of 2 cm), the Bunin River (*b* with a scale bar of 3 cm), the Sikundur River (*c*) with a scale bar of 2 cm

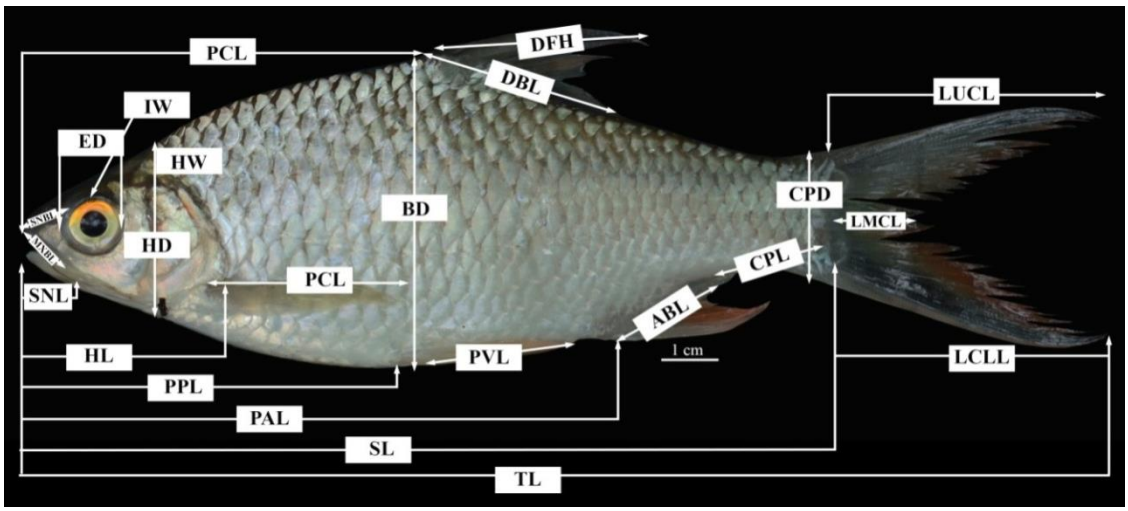

Fig. 3. Measurement of 24 morphometric characters of *Barbonymus schwanefeldii*: Keterangan: anal fin base length (ABL), body depth (BD), caudal peduncle depth (CPD), caudal peduncle length (CPL), dorsal fin base length (DBL), dorsal fin height (DFH), eye diameter (ED), head height (HD), head length (HL), head width (HW), interorbital width (IW), lower caudal lobe length (LCLL), middle caudal lobe length (LMCL), upper caudal lobe length (LUCL), maxillary barbel length (MXBL), preanal length (PAL), pectoral fin length (PCL), predorsal length (PDL), prepelvic length (PPL), pelvic fin length (PVL), standard length (SL), snout barbel length (SNBL), snout length (SNL), total length (TL)

Analysis of habitat conditions. Analysis of habitat conditions such as substrate, vegetation cover was carried out by direct spatial sensing at the sampling location, for other parameters such as current speed, temperature, pH, DO (Dissolved Oxygen), brightness and depth of waters, COD (Chemical Oxygen Demand), BOD (Biological Oxygen Demand) using a measuring device. Current velocity measurements were tested using a flow meter, temperature measurements were tested with a digital thermometer, pH measurements were tested with a digital pH meter, DO measurements were tested with a DO meter, and brightness and depth measurements were tested using Secchi disk tool. Specifically for COD and BOD analysis, samples were collected first in 600 mL sample bottles, then transported and analyzed at the Environmental Quality Testing Laboratory, Department of Chemical Engineering, Faculty of Engineering, Universitas Syiah Kuala, Indonesia.

Data analysis. Data on fish size composition, length-weight relationship, condition factors, and habitat parameters were analyzed descriptively and presented in tables and figures. Morphometric data were analyzed using ANOVA and Discriminant Analysis using SPSS software ver. 21.

Results

Composition and size distribution. The total number of *B. schwanefeldii* catches in the Keureuto River area was 57 samples which were divided into 3 categories, namely juveniles, subadults, and matures. The highest percentage of fish catches in the Keureuto River was dominated by juveniles, while the lowest percentage was mature, with a value of 47.4% and 24.6%, respectively (Table 1 and Fig 4). Based on the results, the high presence of juveniles in the Keureuto River is probably influenced by the condition of their habitat, where *B. schwanefeldii* during the juvenile period prefer shallow habitat conditions with low brightness and strong currents (Table 5).

The total catch of *B. schwanefeldii* in the Bunin River area was 110 samples, where the highest percentage of fish catches in the Bunin River was dominated by matures, while the lowest presentation was juveniles with a value of 60.0% and 10.9%, respectively (Table 1, Fig. 4). Based on the percentage results, it shows that the high presence of mature fish in the Bunin River is possibly related to their habitat conditions, which are characterized by warm temperatures, and are supported by higher brightness and depth conditions, with more closed vegetation cover (Table 5).

The total catch of *B. schwanefeldii* in the Sikundur River area was 41 samples, where the highest percentage was dominated by juveniles, while the lowest percentage was subadults with respective values of 48.8% and 17.1% (Table 1, Fig 4). Based on the results, the high presence of juveniles in the Sikundur River is likely influenced by the shallow habitat with low brightness, and supported by strong currents (Table 5).

Table 1
Composition and size distribution of *Barbonymus schwanefeldii* in the Leuser Ecosystem Area based on research location

Parameters	Keureuto River	Bunin River	Sikundur River
Number of samples, fish	57	110	41
Total sample weight, g	5596	21082	3268
Total length range, cm	12.4–28.9	18.6–32.4	13.4–28.9
Body weight range, g	23–193	64–393	25–135
Female	36	77	25
Male	21	33	16
Sex ratio (M:F)	1:1.71	1:2.33	1:1.56

Class of length and weight. There are seven length class intervals of *B. schwanefeldii* which were obtained from the Leuser Ecosystem Area, where the largest size fish was found in the Bunin River with a length ranging from 30.4–32.4 cm and the smallest size was found in Keureuto and Sikundur rivers ranging from 12.4–14.4 cm. Meanwhile, the longest size of *B. schwanefeldii* from the Keureuto and Sikundur rivers ranged from 27.4–29.4 cm (Fig. 5a).

There were nine weight class intervals of *B. schwanefeldii* in this study, where *B. schwanefeldii* from the Sikundur River were found in three class intervals, namely 24–64, 65–106, and 107–148 g. Fish samples from the Keureuto River were divided into 4 class intervals, namely 23–64, 65–106, 107–148, and 191–232 g. Meanwhile, fish samples from the Bunin River were distributed in all weight class intervals (Fig. 5b).

Analysis of the length-weight relationship and condition factors. Analysis of the length-weight relationship of *B. schwanefeldii* from three different rivers showed that fish from the Keureuto and Sikundur Rivers had a negative allometric growth pattern (2.4268 and 1.9229), while fish from the Bunin River had a positive allometric growth pattern (3.0684). The results of the coefficient of determination (R^2) from the Keureuto, Bunin and Sikundur Rivers were obtained of 0.937, 0.899, and 0.532, respectively (Fig. 6). The condition factor values from the three locations start from the highest value of 2.87 from the Bunin River, 1.29 from the Keureuto River, and 0.80 from the Sikundur River.

Meristic and morphometric analysis. The results of the analysis of the meristic characters of *B. schwanefeldii* show that fish collected from the Bunin River were relatively different from the other two rivers in almost all meristic characters, while fish from the Keureuto and Sikundur rivers had high similarities in meristic characters (Table 2).

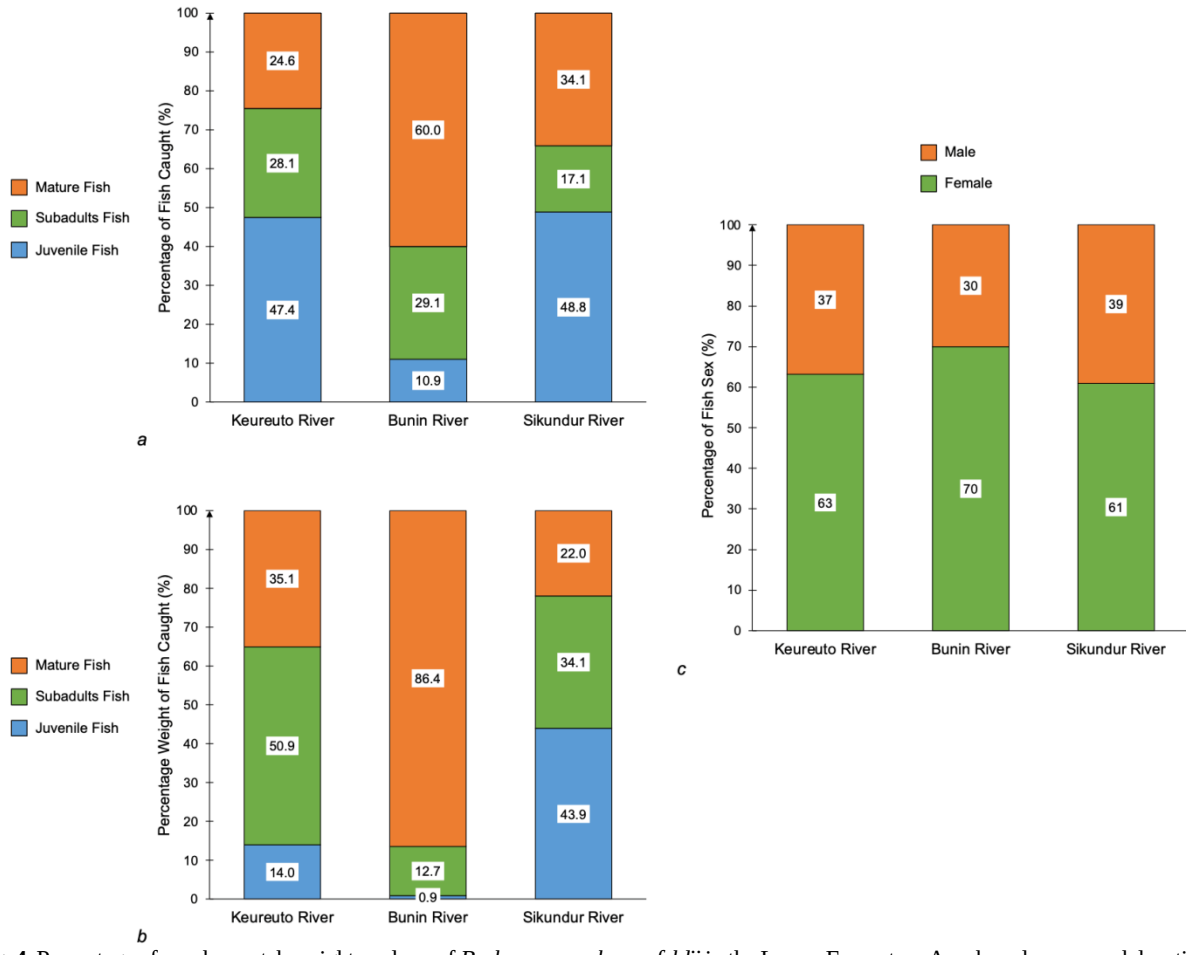

Fig. 4. Percentage of number, catch weight, and sex of *Barbonymus schwanefeldii* in the Leuser Ecosystem Area based on research location

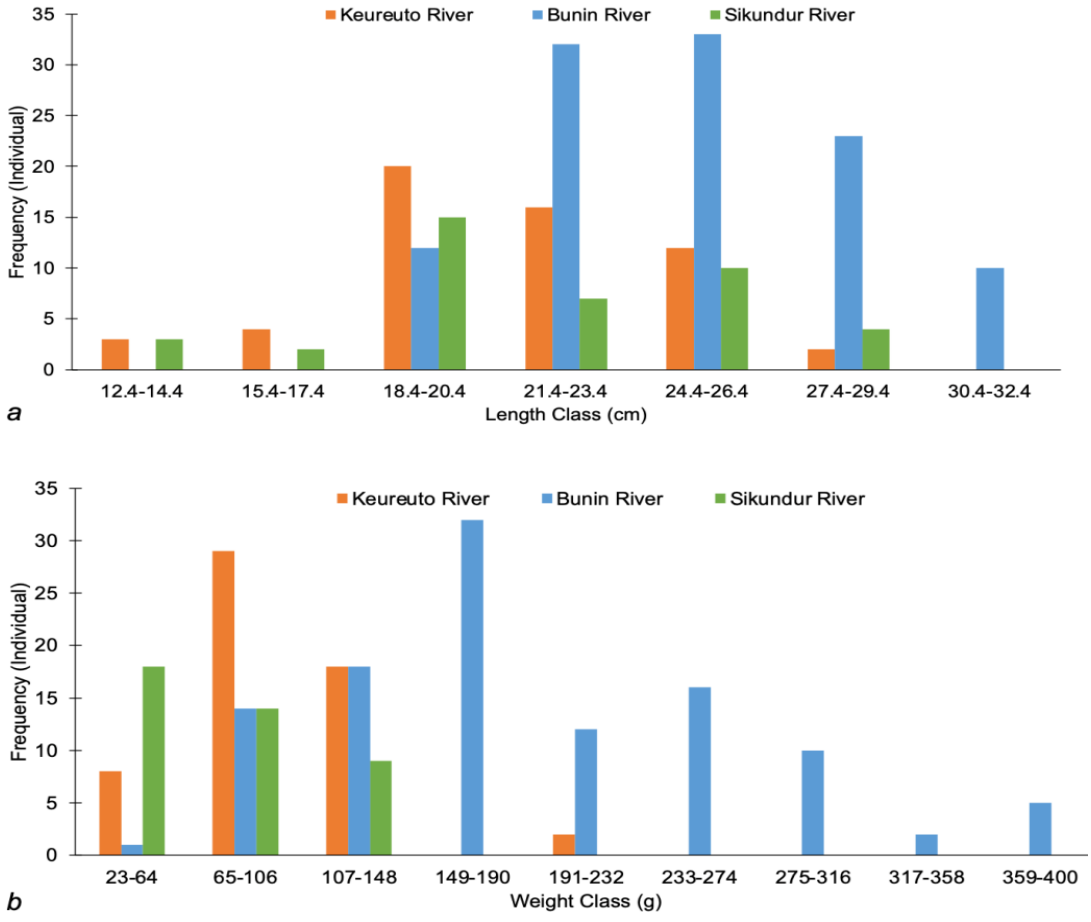

Fig. 5. Interval of length and weight classes of *Barbonymus schwanefeldii* in the Leuser Ecosystem Area

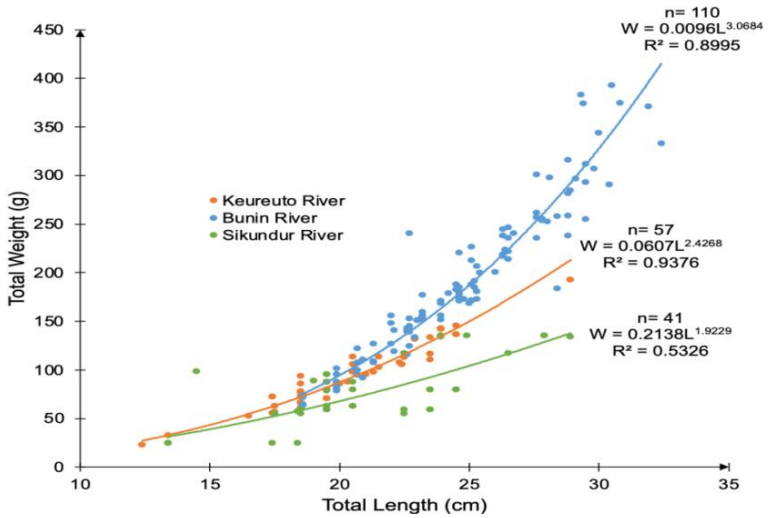

Fig. 6. Analysis of the length-weight relationship of *Barbonymus schwanefeldii* from the Leuser Ecosystem Area

Table 2
Meristic analysis of *Barbonymus schwanefeldii* in the Leuser Ecosystem Area

No.	Code	Keureuto River	Bunin River	Sikundur River
1	Dorsal fin (D)	I. 9–10	I. 9	I. 9–10
2	Pectoral fin (P)	I. 14–16	I. 15–16	I. 14–16
3	Pelvic fins (V)	I–III. 8–10	I. 9	I–III. 8–10
4	Anal fin (A)	I–II. 7	I. 7	I–II. 7
5	Number of lateral scales	32–34	34–35	32–34
6	Number of dorsal scales	12–15	11–15	12–15
7	Number of upper caudal peduncle scales	11–15	13–15	11–15
8	Number of circular scales on the caudal peduncle	15–19	15–17	15–19
9	Number of circular scales on the body	19–25	21–23	19–25

Morphometric analysis of *B. schwanefeldii* shows that the differentiating characters between samples from the Bunin River versus the Keureuto River and Sikundur River are the most numerous compared to the differentiating characters between samples from the Keureuto River and Sikundur River, where each has a value of 95.7% and 21.7% (Table 4). There are 22 characters distinguishing the Bunin River from the Keureuto River and the Sikundur River (ABL, BD, CPD, CPL, DBL, DFH, ED, HD, HL, HW, IW, LCLL, LMCL, LUCL, MXBL, PAL, PCL, PDL, PPL, PVL, SL, and SNBL), while the Keureuto River and Sikundur River have 5 differentiating characters (BD, DFH, HD, HW, and LCLL). If we observe the similarities and differences in the morphometric characters of the three fish populations, it shows that the morphometric characters of the samples from the Keureuto River and the Sikundur River are more similar, while the morphometric characters of the samples from the Bunin River are not similar to those of the Keureuto River and Sikundur River (Tables 3 and 4). The results of the discriminant function analysis also concluded the same thing, namely that the morphometrics of samples from the Keureuto River and Sikundur River had almost the same pattern (Fig. 7).

Physicochemical parameters of rivers. The results of water quality measurements from the three rivers show that the Sikundur River has the highest current speed (26.99 m/s), followed by the Bunin River (26.31 m/s) and the Keureuto River (11.46 m/s). The highest value of water temperatures was recorded in the Bunin River reaching 28.1 ℃, while the other two rivers were <26.0 ℃. The three rivers have a pH that tends to be alkaline (> 7) with dissolved oxygen ranging from 6.35 ppm in the Keureuto River, 7.92 ppm in the Bunin River, and 8.52 ppm in the Sikundur River. The Bunin River has the highest average depth value reaching 305.25 cm with a rocky substrate with vegetation cover of up to 80%, while the river with the shallowest depth is the Keureuto River (110.42) with a large rocky substrate with vegetation cover of 40% (Table 5).

Table 3
Transformation values of morphometric characters of *Barbonymus schwanefeldii* based on ANOVA analysis in the Keureuto River, Bunin River and Sikundur River (mean ± standard deviation (min–max)

No.	Code	Keureuto River	Bunin River	Sikundur River
1	ABL	15.06 ± 3.54^b (10.10–24.25)	12.44 ± 1.37^a (9.00–16.40)	16.21 ± 3.68^b (10.21–25.38)
2	BD	36.21 ± 7.18^b (25.20–51.66)	29.03 ± 2.38^a (23.30–32.90)	38.65 ± 7.09^c (28.33–53.64)
3	CPD	10.18 ± 0.85^a (8.65–11.89)	10.97 ± 0.76^b (8.88–12.80)	10.12 ± 0.97^a (8.65–14.28)
4	CPL	12.56 ± 3.74^b (5.95–20.00)	7.70 ± 1.37^a (5.04–11.10)	13.54 ± 3.54^b (7.47–20.00)
5	DBL	23.63 ± 7.80^b (12.10–40.23)	14.75 ± 2.11^a (10.50–20.00)	25.89 ± 7.90^b (11.47–43.48)
6	DFH	26.25 ± 7.62^b (14.10–43.45)	17.09 ± 1.74^a (12.30–20.90)	28.67 ± 7.58^c (18.53–46.52)
7	ED	9.15 ± 3.83^b (4.23–17.59)	4.83 ± 0.58^a (3.46–5.95)	10.26 ± 3.71^b (5.26–19.08)
8	HD	23.48 ± 8.03^b (13.00–40.06)	14.91 ± 1.38^a (11.60–17.90)	25.95 ± 7.68^c (15.84–43.32)
9	HL	24.93 ± 7.90^b (14.50–41.90)	17.42 ± 1.77^a (12.60–20.90)	27.17 ± 7.74^b (15.63–45.05)
10	HW	12.37 ± 3.46^b (7.00–19.40)	10.06 ± 1.52^a (5.10–13.30)	13.63 ± 3.28^c (9.16–20.65)
11	IW	3.00 ± 1.22^a (1.30–5.40)	5.08 ± 1.30^b (2.09–8.42)	3.03 ± 1.13^a (1.46–4.68)
12	LCLL	33.63 ± 7.12^b (23.60–49.08)	21.77 ± 2.03^a (17.00–26.70)	35.85 ± 6.87^c (26.78–51.85)
13	LMCL	10.90 ± 3.54^b (6.67–19.08)	6.41 ± 1.26^a (2.65–9.24)	11.96 ± 3.39^b (7.26–20.49)
14	LUCL	33.18 ± 7.22^b (23.70–48.33)	24.58 ± 2.54^a (19.60–31.50)	35.43 ± 7.12^b (25.58–51.14)
15	MXBL	10.33 ± 3.68^b (3.81–16.78)	5.55 ± 0.91^a (3.47–9.07)	11.09 ± 3.62^b (3.89–17.77)
16	PAL	70.45 ± 18.91^b (48.00–110.60)	48.96 ± 4.11^a (40.90–67.00)	76.04 ± 18.29^b (46.89–118.20)
17	PCL	19.54 ± 2.78^b (15.70–25.83)	16.29 ± 1.58^a (12.90–21.70)	20.39 ± 2.87^b (16.58–26.58)
18	PDL	42.93 ± 6.77^b (31.90–56.81)	36.52 ± 3.02^a (30.10–41.50)	44.93 ± 6.48^b (34.73–58.42)
19	PPL	40.57 ± 6.38^b (32.10–55.23)	33.40 ± 2.89^a (26.50–45.60)	42.45 ± 6.62^b (31.63–57.66)
20	PVL	16.82 ± 3.28^b (11.90–23.62)	12.89 ± 3.58^a (8.92–35.80)	18.06 ± 3.09^b (14.18–24.67)
21	SL	88.53 ± 17.38^b (64.30–123.20)	69.64 ± 5.27^a (57.50–79.10)	93.89 ± 16.61^b (72.09–130.10)
22	SNBL	3.89 ± 0.55^a (2.23–4.63)	4.75 ± 1.17^b (2.54–8.00)	3.91 ± 0.54^a (2.33–4.62)
23	SNL	4.15 ± 0.54^a (2.51–4.92)	3.96 ± 0.80^a (1.97–5.67)	4.12 ± 0.60^a (2.60–4.90)

Note: different superscripts on the same row indicate significant difference.

Table 4
Morphometric characters that contribute to differentiating the three *Barbonymus schwanefeldii* populations

Comparison	Differentiating character	Differences, %	Character morphometrics
Bunin River vs Keureuto River	22 from 23	95.65	ABL, BD, CPD, CPL, DBL, DFH, ED, HD, HL, HW, IW, LCLL, LMCL, LUCL, MXBL, PAL, PCL, PDL, PPL, PVL, SL, SNBL
Keureuto River vs Sikundur River	5 from 23	21.74	BD, DFH, HD, HW, LCLL
Bunin River vs Sikundur River	22 from 23	95.65	ABL, BD, CPD, CPL, DBL, DFH, ED, HD, HL, HW, IW, LCLL, LMCL, LUCL, MXBL, PAL, PCL, PDL, PPL, PVL, SL, SNBL

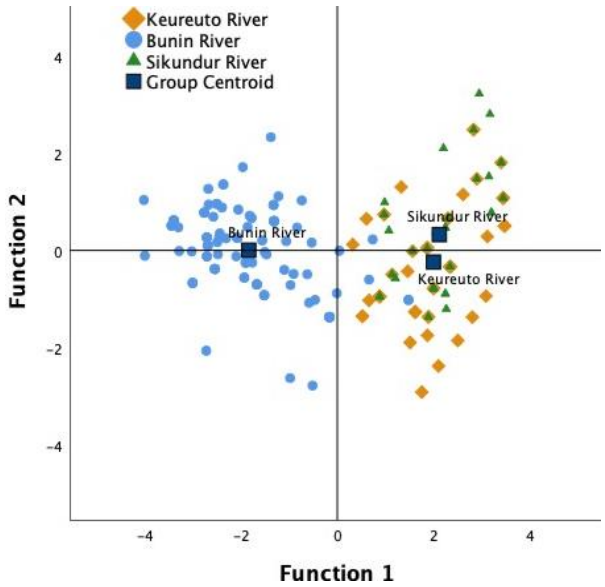

Fig. 7. Discriminant function analysis between *Barbonymus schwanefeldii* from the Bunin River, Keureuto River, and Sikundur River

Table 5
Physicochemical parameters in the Keureuto River, Bunin River and Sikundur River (mean ± standard deviation (min-max))

No.	Parameter	Keureuto River	Bunin River	Sikundur River
1	Current speed, m/s	11.46 ± 0.17 (5.81–23.91)	26.31± 0.31 (7.07–70.20)	26.99 ± 0.25 (5.38–45.79)
2	Temperature, ℃	25.56 ± 0.56 (24.90–26.40)	28.10 ± 0.29 (27.70–28.40)	25.82± 0.17 (25.00–26.80)
3	pH	8.28 ± 0.12 (7.96–8.62)	8.28 ± 0.23 (8.21–8.38)	7.83 ± 0.20 (7.39–8.20)
4	DO, ppm	6.35 ± 0.29 (5.30–7.40)	7.92 ± 0.06 (7.70–8.30)	8.52 ± 0.15 (8.20–9.10)
5	Brightness, cm	121.88 ± 9.26 (45.00–180.00)	285.96 ± 15.58 (22.50–745.00)	186.25 ± 6.72 (52.50–340.00)
6	Water depth, cm	110.42 ± 0.21 (30.00–200.00)	305.25 ± 0.12 (15.00–890.00)	134.17 ± 5.20 (35.00–260.00)
7	Substrate	large rocks	rocky	gravel
8	Vegetation cover, %	40	80	50

Discussion

Freshwater habitats are one of the aquatic ecosystems that are vulnerable to damage and pollution (Bortolini-Rosales & Reyes-Aldana, 2023). On the other hand, freshwater habitats are ecosystems for aquatic animals such as fish, where these biota are constituent components of freshwater ecosystems such as rivers, swamps and lakes (Wahab & Cahyati, 2021). In the waters of the Aceh Province, there are two species of *Barbonymus*, namely *B. schwanefeldii* and *B. gonionotus* (Batubara et al., 2018). *B. schwanefeldii* is found in the Leuser Ecosystem Area, where this fish is an important resource for local communities (Karim et al., 2021). In nature, the abundance and growth of these fish are also influenced by water quality (Desrita et al., 2021; Suhada et al., 2022). Based on the results of observations at three research locations, it shows that female fish are more dominant, where the ratio between male:female for the three locations respectively is between 1:2.33 (Bunin River), 1:1.71 (Keureuto River), and 1:1.56 (Sikundur River).

The results of the research show that the Bunin River has a depth of up to 305.25 cm with a large rocky substrate and many adult fish are found with sizes from 18.40 cm. This river has a temperature with average value of 28.10 °C, pH 8.28, dissolved oxygen 7.92 ppm, current speed that can reach 26.30 m/s and brightness 285.96 cm. So it is suspected that this area is a spawning and nurturing area for these fish. Nurdin et al. (2015) reported, shallow habitat with relatively fast currents and high brightness intensity is the habitat for this fish to reproduce. *Barbonymus* species are often found in waters with strong currents and are highly dependent on high oxygen levels for their survival, as shown by research showing that this species is more abundant in habitats with high DO values (Hertika et al., 2021; Soo et al., 2021). In addition, DO fluctuations in rivers can also be influenced by photosynthesis processes and surface aeration, which function as oxygen sources (Ferreira et al., 2022; Goncharov et al., 2022).

In the juvenile phase, this fish is able to maintain its growth by consuming additional food at high water temperatures (Nyanti et al. 2018). *Barbonymus* juvenile are highly dependent on natural food such as zooplankton, phytoplankton and insect larvae (Sobczak et al., 2002; Desrita et al., 2021). As they age, juvenile begin to switch to a more diverse diet, including insects, worms, and aquatic plants (Gante et al., 2008; Chang, 2023). Meanwhile, adult fish tend to be omnivores, which means they eat a variety of food, including plants, insects and small fish (Desrita et al., 2021; Chang, 2023). Hastuti et al. (2024) added that temperature affects growth. Furthermore, this is also supported by higher brightness and depth conditions, with vegetation cover reaching 80% which is rich in natural food sources for these fish. Optimal pH ranges between 6–7 (Oktavia et al. 2024). As one moves downstream of the river, the temperature and pH concentration increases (Yolanda et al. 2023). Temperature variations have a significant effect on the growth of *B. gonionotus*, with optimal temperatures between 27–30 °C, and higher temperatures can cause stress and increase the need for food to maintain energy (Tang et al., 2017; Hertika et al., 2021). The optimal temperature range for *Barbonymus* fish from Malaysia is 30–31 °C for adult habitat, while for spawning it is in the 25–27 °C temperature range (Musa et al., 2023; Khanam et al., 2024).

The frequency of the highest length class of *B. schwanefeldii* in the Keureuto River is 18.4–20.4 cm with a total weight of 65–106 g, followed by the Bunin River in the length class of 24.4–26.4 cm with a total weight of 149–190 g, and the Sikundur River in the length class of 18.4–20.4 cm with a total weight of 23–64 g. In this study, the longest *B. schwanefeldii* reached 32.4 cm, which is relatively smaller when compared with *B. schwanefeldii* from the Mahaweli River, Sri Lanka, which can reach a length of 35.0 cm (Wijesinghe et al., 2024), but larger than *B. schwanefeldii* from the Belumai River, Deli Serdang, North Sumatra which only reaches 19.4 cm (Aisyah et al., 2017).

Growth patterns and condition factors of fish provide basic data on biological aspects for resource management (Muslim et al., 2023). The length-weight relationship of *B. schwanefeldii* in 3 different river locations showed two category, in the Keureuto River and Sikundur River it showed a negative allometric growth pattern, while in the Bunin River it showed positive allometric results. Kusmini et al. (2018) reported that the growth pattern of *B. schwanefeldii* in the waters of Jambi and West Kalimantan was negative allometric. Differences in growth patterns in fish are related to food availability, gonad maturity, and body shape. The results of the coefficient of determination (R^2) obtained from each location were between 0.532–0.937, while the *B. schwanefeldii* in West Kalimantan had a determination value obtained of 0.81–0.89 (Kusmini et al., 2018).

Morphometric analysis of *B. schwanefeldii* shows that the distinguishing characters between *B. schwanefeldii* from the Bunin River versus the Keureuto River and the Sikundur River are visible in almost all characters (22 of 23 morphometric characters were significantly different), while *B. schwanefeldii* from the Keureuto River and the Sikundur River are relative similar (5 of 23 morphometric characters were significantly different). These findings indicate the existence of morphometric variations between fish populations in the area (Asmamaw & Tessema, 2021). Based on the results of meristic analysis on 9 characters, it shows that the meristics between the Keureuto River and the Sikundur River are identical, in contrast to the Bunin River population where almost all meristic characters are relatively different from the other two populations.

Conclusion

A total of 208 *B. schwanefeldii* samples were successfully collected in this study with a total of 70 males and 138 females (1:1.97). *B. schwanefeldii* collected from the Keureuto River and Sikundur River had a negative allometric growth pattern, while those from the Bunin River had a positive allometric growth pattern. Morphometric analysis showed that *B. schwanefeldii* from the Keureuto River and Sikundur River had high similarities, and were inversely proportional to *B. schwanefeldii* from the Bunin River. The results of this research reveal that there are morphological variations between *B. schwanefeldii* populations in the Leuser Ecosystem Area.

The author would like to thank the the Education Financing Service Center, Ministry of Education, Culture, Research, and Technology, through the Indonesian Scholarship Program (Number: 00573/J5.2.3./BPI.06/9/2022).

The authors declare that they have no competing interests in this paper.

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