Morphological and Morphometric Characteristics of Otolith Tinfoil Barb (*Barbonymus Schwanefeldii* Bleeker, 1854) in The Kamijoro Dam, Kulon Progo Regency

Navida Vinca Hanif*[1], Astuti[1], Ainun Rodhiyah Nurhayati[1], Maryam Tirta Nuur[1], Nurul Azizah Puteri Rahma Dewi[1], Tony Budi Satriyo[1], Eko Hardianto[1]

[1]Department of Fisheries, Faculty of Agriculture, Universitas Gadjah Mada, Jl. Flora, Bulaksumur, Yogyakarta 555281, Indonesia
*Author: navidavincahanif@mail.ugm.ac.id

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Abstract

The Tinfoil barb (*Barbonymus schwanefeldii*) is a freshwater fish in the family Cyprinidae, commonly found in Southeast Asia, including the waters of the Kamijoro Dam in Yogyakarta. This study aims to analyse the morphological and morphometric characteristics of the otoliths of Tinfoil barb across fish size classes. The study was conducted from October to December 2025. A total of 267 Tinfoil barb samples were collected and grouped into three size classes: small (8.5 – 14.9 cm), medium (15.0 – 18.9 cm), and large (19.0 – 29.0 cm). The otoliths used were of the sagitta type, and the following parameters were measured: length, width, area, perimeter, weight, and six otolith shape indices. The result showed that Tinfoil barb otoliths are asymmetrically elliptical in shape with a heterosulcoid sulcus type. All analyzed otolith morphometric parameters showed a significant increase as fish body size increased ($p < 0.001$). The small-sized group showed mean values for the OL, OW, OA, OP, and OWt parameters of 0.282 ± 0.044 cm; 0.219 ± 0.030 cm; 0.042 ± 0.012 cm²; 0.933 ± 0.149 cm; and 0.002 ± 0.001 g. The medium-sized class had mean values for OL, OW, OA, OP, and OWt parameters of 0.352 ± 0.037 cm; 0.261 ± 0.021 cm; 0.060 ± 0.010 cm²; 1.176 ± 0.125 cm; and 0.004 ± 0.001 g. The large size class showed average values for OL, OW, OA, OP, and OWt of 1.518 ± 6.000 cm; 1.383 ± 6.023 cm; 1.152 ± 6.063 cm²; 2.719 ± 5.813 cm; and 1.036 ± 6.084 g. The relationship between fish length and otolith parameters was positive, with a coefficient of determination value ranging from indices that reflect ontogenetic changes, namely a decrease in roundness, form factor, and rectangularity, as well as an increase in circularity, aspect ratio, and ellipticity, indicating a change in shape from a transparent, round form to a more elongated, compact, and complex one.

Keywords: population, tengadak, shape index, and waters

Introduction

The Kamijoro Dam is a water resources infrastructure facility located on the border between Bantul and Kulon Progo Regencies in the Special Region of Yogyakarta. It dams the Progo River and provides irrigation water for the Pijenan District, covering an area of 2,370 hectares. According to Kementerian PUPR (2015), the dam's primary functions are to provide irrigation water, raw water, and flood control during the rainy season. Beyond its hydrological functions, the dam area has become a tourist attraction and a public space for local community fishing. These activities indicate that the waters of the Kamijoro Dam possess significant biological resource potential, particularly in terms of the diversity of freshwater fish inhabiting the Progo River.

One of the fish species frequently caught in the Kamijoro Dam area is the Tinfoil barb (*Barbonymus schwanefeldii*). This fish belongs to the family Cyprinidae, is benthopelagic, and is widely distributed in Southeast

Asian waters, including Java and Kalimantan (Dahruddin *et al*., 2021; Froese & Pauly, 2025; van der Laan & Fricke, 2023). The Tinfoil barb holds significant economic value as both a food and an ornamental fish (Apriani *et al*., 2025). Optimal management of fishery resources requires adequate biological information, including studies on otolith structure. In addition, research by Akmal *et al* (2025) succeeded in revealing morphological variations between *B. schwanefeldii* populations related to adaptation to different habitats. Another study showed that *B. schwanenfeldii* and *Barbonymus* sp. have overlapping morphological characteristics, while *B. gonionotus* is clearly different. Therefore, it is assumed that *B. schwanenfeldii* and *Barbonymus* sp. are the same species of *B. schwanenfeldii* (Batubara *et al*., 2018; Efizon *et al.*, 2021). Although geographical environmental conditions can be the main factor in the occurrence of different external morphological and otolith adaptations; however, with the analysis of morphological and otolith descriptions, it turns out that they can be used as indicators of genus apomorphy (Samuel *et al.,* 2025). Although there are many floating net cages in general waters, the results of research by Sari *et al.* (2022) show that there are no significant morphological and meristic differences between fish living in areas with cages or in areas without floating net cages.

Otoliths (fish ear stones) are hard structures composed of calcium carbonate and organic proteins found in the inner ear of teleost fish (Popper & Fay, 2011). In addition to serving as organs of balance and hearing, otoliths exhibit specific morphological and morphometric characteristics that vary by species, making them useful for species identification, stock assessment, and aquatic ecological studies (Campana, 2004). Morphometric parameters of otoliths, such as length, width, area, perimeter, and weight, as well as shape indices (roundness, form factor, aspect ratio, circularity, rectangularity, and ellipticity), can reflect differences in habitat, life history, and environmental factors that influence fish growth (Tuset *et al*., 2008; Kontas & Bostanci, 2015). Furthermore, the research results of Bostancı and Yedier (2018) stated that otolith morphometry can provide an easy and reliable discrimination tool for invasive fish populations. According to Chalupnicki and Dittman (2016) using a new laboratory method to enter the brain cavity from the ventral side of the fish to expose the otoliths more easily than other otolith extraction methods found in the literature. Also according to D'Iglio *et al.* (2024) comprehensive research on otoliths shows variability in geographically related otolith features and size, which may be related to genetics, environmental conditions, and variations in living habits. Research into otoliths (fish ear stones) provides vital demographic data—such as age, growth rates, stock structure, and migration patterns—needed to understand fishing impacts, define harvest strategies, and support sustainable management in tropical fisheries (Green *et al.*, 2009).

Fish body size indicates an individual's growth stage. Small fish are generally referred to as juveniles, while large fish represent the adult stage. The relationship between water quality and the psychological response of juvenile tinfoil barb fish, recorded an optimal pH of around 6-7 (Oktavia *et al.*, 2024) As body size increases, the otolith also undergoes structural development, as evidenced by changes in its morphology and morphometry. In small fish, otoliths tend to be transparent with an immature morphological structure; conversely, in adult fish, the morphology of the otolith becomes denser, opaque, and more complex (Campana & Thorrold, 2001). Therefore, analysis of variations in fish size is a key factor in understanding the ontogenetic growth patterns of otoliths, which can be used to estimate fish age and life history. According to Breton *et al*. (2013), using the Huggins mark–recapture model were simple method for correcting length-frequency estimates for imperfect detection could be widely applied when mark–recapture data are available. According to Erzini (1990) the use of the modified Bhattacharya method, shows that life history characteristics must be taken into account when designing sampling strategies for length frequency-based analysis. In addition, several researchers concluded that otolith shape analysis can help fish identification activities (Rai & Rani, 2022).

Although the Tinfoil barb has ecological and economic value, research on its otolith characteristics remains very limited, particularly in Indonesian waters. This study aims to: (1) analyze the morphological characteristics of Tinfoil barb (*Barbonymus schwanefeldii*) otoliths found in the Kamijoro Dam area; (2) analyze the relationship between otolith morphometric parameters and Tinfoil barb body size; and (3) describe variations in the shape and size of Tinfoil barb otoliths based on fish size classes. The results of this study are expected to provide scientific data on the otolith characteristics of the Tinfoil barb as a basic reference for fish biology studies in tropical waters and to support strategies for the sustainable management and conservation of fish resources. If public waters are managed properly, according to Kartamihardja *et al*. (2009), it will have an impact on increasing production by at least 20% and ecological function, so that inland public water fisheries can be used as a mainstay for the economic development of the community, especially fishermen.

Materials and Methods

Study Site

The study was conducted at the Kamijoro Dam, located on the border of Bantul and Kulon Progo Regencies in the Special Region of Yogyakarta, specifically along the Progo River. Fish and otolith samples were collected from October to December 2025. Sample analysis was performed at the performed at

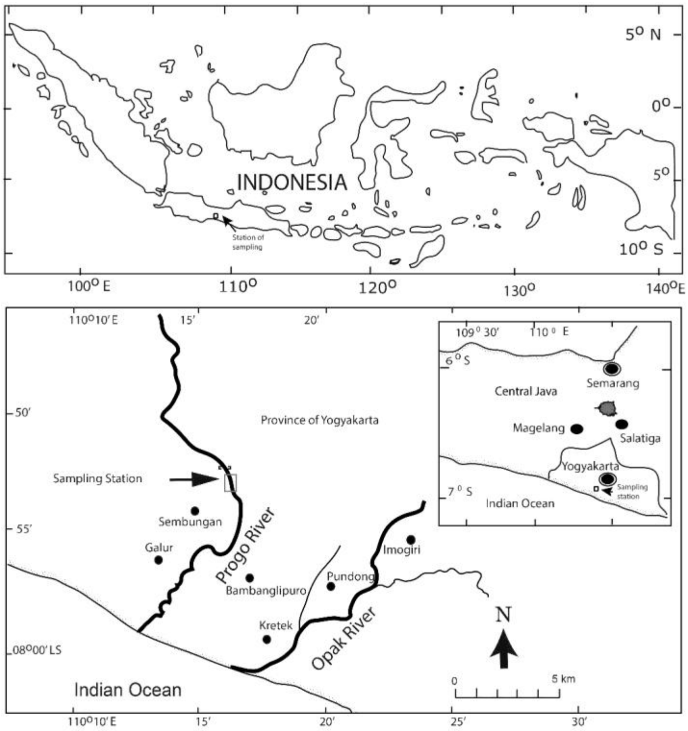

Figure 1. Map of the Kamijoro dam located downstream of the Progo River as a sampling for fish sampling

the Fisheries Resource Management Laboratory and the Aquatic Ecology Laboratory, Department of Fisheries, Gadjah Mada University (Fig. 1).

Sample Collection and Handling

Samples of Tinfoil barb (*Barbonymus schwanefeldii*) were collected from catches made using Wadhong gandul fishing gear in the waters around the Kamijoro Dam. The collected fish were stored in a cool box filled with ice to maintain their quality during transport to the laboratory. Next, the fish were measured for total length (TL) to 0.1 cm precision with a ruler and weighed on a digital scale. The fish were then dissected to determine sex based on gonad observation. The otolith samples from the right and left sides were morphometrically similar.

The asteriscus otoliths are oval, elongated, and have a regular surface (Kantun *et al*., 2024).

Fish Size Class Grouping

Size class grouping based on total fish length used the Sturges (1926) formula to determine the optimal number of classes, calculated as:

$$K = 1 + 3.3 \log n$$
n = Total number of samples

Based on the calculation results, the class interval obtained was 6.83 cm (rounded to 7 cm). The fish were grouped into three size classes: small (8.5 – 14.9 cm; juvenile phase), medium (15.0 – 18.9 cm; subadult phase), and large (19.0 – 29.0 cm; adult phase). The classification of size classes into three categories is based on a general approach in otolith morphometric research that accounts

Table 1. Morphometric indices of otolith shape

Shape Index	Formula	Description
Roundness (R_O)	$4O_A/\pi O_L^2$	Compares the otolith shape with a perfect circle. $R_O = 1$ indicates a perfect circular shape.
Form Factor (F_F)	$4\pi O_A/O_P^2$	Indicates the level of surface regularity of the otolith. $F_F = 1$ indicates a regular surface $F_F < 1$ indicates an irregular surface
Rectangularity (R_t)	$O_A/(O_L.O_W)$	Indicates the variation in otolith length and width relative to the area. $R_t = 1$ indicates a perfectly rectangular otolith.
Circularity (C)	O_P^2/O_A	Compares the otolith shape with a perfect circle. $C = 0$ indicates a perfect circular shape.
Aspect ratio (A_R)	O_L/O_W	Determines the otolith shape. $A_R > 1$ indicates an elongated otolith shape.
Ellipticity (E)	$\frac{OL - OW}{(OL + OW)}$	Indicates the occurrence of proportional changes in axes. $E < 1$ indicates an oval-shaped otolith.

for variations in fish body size across growth phases, such as juvenile, subadult, and adult. Based on the calculation results, the class interval obtained was 6.83 cm (rounded to 7 cm). The fish were grouped into three size classes: small (8.5 – 14.9 cm; juvenile phase), medium (15.0 – 18.9 cm; subadult phase), and large (19.0 – 29.0 cm; adult phase). The classification of size classes into three categories is based on a general approach in otolith morphometric research that accounts for variations in fish body size across growth phases, such as juvenile, subadult, and adult. This statement is supported by otolith studies showing that otolith structure and morphology change as individuals grow from juveniles to adults (Tonheim *et al*., 2020).

Otolith Extraction

Extraction of sagitta-type otoliths was performed using the ventral method through the gill cavity (up-through-the-gills method), as described by Secor *et al*. (1992). The fish were placed with their ventral side facing upward, and the gill arches were placed with their ventral side facing upward, and the gill arches were incised to expose the opercular cavity. The shiny white sagitta otolith was removed from the otic capsule behind the eye socket using fine-tipped forceps. The otolith was then cleaned of attached tissues with bleach (Bayclin), dried at room temperature, and stored in a labeled, sealed plastic cup.

Otolith Imaging and Morphometric Measurements

Otolith images were captured using a cell phone camera and a mini photobox with a black paper background to optimize contrast. The otoliths were placed on graph paper as a calibration scale, with the sulcus acustucis oriented upward. Otolith morphometric parameters were measured using ImageJ software, including: otolith length (OL; cm), otolith width (Ow; cm), otolith area (OA; cm^2) and otolith perimeter (OP; cm). Otolith weight (OWt; g) was measured using an analytical balance with a precision of 0.0001 g.

Figure 2. Morphology of Tinfoil barb (*Barbonymus schwanefeldii*)
(source: FishBase, 2025)

Otolith Shape Indices

Six otolith shape indices were calculated from the morphometric parameters using formula from Tuset *et al*. (2003) and Kontas & Bostanci (2015) (Table 1).

Data Analysis

The data were statistically analyzed using OriginPro 2026 software. Descriptive statis-tics (minimum, maximum, mean, and standard deviation) were presented for all otolith morphometric parameters based on variations in body size, sex, and otolith location (left and right). The Shapiro-Wilk test was used to assess the normality of the data. Since the data were not normally distributed ($p < 0.05$), comparisons were made using nonparametric approaches: the Kruskal-Wallis test to compare morpho-metric differences among fish size groups, and the Wilcoxon Signed-Rank test to compare left and right otoliths and to assess differences between sexes. Effect size (r) was calculated to assess the practical significance of the fdings. According to Mesa *et al*. (2020), the otolith morphology analysis model is highly dependent on the species. From the existing models, the K-nearest neighbor model can be considered the best.

Analysis of the relationship between fish body length and otolith morphometric parameters was performed using simple linear regression with the equation y = a + bx, where y is the otolith morphometric para-meter, a is the intercept, b is the slope, and x is the fish body length. The coefficient of determination (R^2) was used to assess the proportion of variation in otolith size explained by fish body length (Cohen, 2016).

Result

A total of 300 Tinfoil barb (*Barbonymus schwanefeldii*) (Figure 2) were successfully caught, consisting of 161 males and 139 females. A total of 267 pairs of otoliths were collected, comprising 143 pairs from males and 124 pairs from females. Data grouping revealed 132 small, 99 medium, and 36 large individuals. The data indicate that the Tinfoil barb population in the Kamijoro Dam during the study period was dominated by small to medium-sized individuals.

Morphological Characteristics of Tinfoil Barb Otolith

The otoliths used are of the sagitta type, the largest otoliths in fish and most commonly used in studies of morphology, age, and identification. Observations of Tinfoil barb otoliths reveal anterior, dorsal, ventral, and posterior regions. The anterior region has two projections: the elongated, pointed rostrum and the shorter antirostrum. Between these two sections lies a gap known as the excisura. The notch is a shallow identation along the dorsal margin, while the posterior margin features an irregular, serrated edge. The core marks the starting point of otolith formation, and the primordium is an irregular ring surrounding the core. There is also the sulcus acusticus, which consists of two parts: the ostium at the anterior end and the cauda at the posterior end. Upon observation, the otolith of the Tinfoil barb is asymmetrical and relatively irregular, with a heterosulcoid sulcus acusticus (Figure 3.).

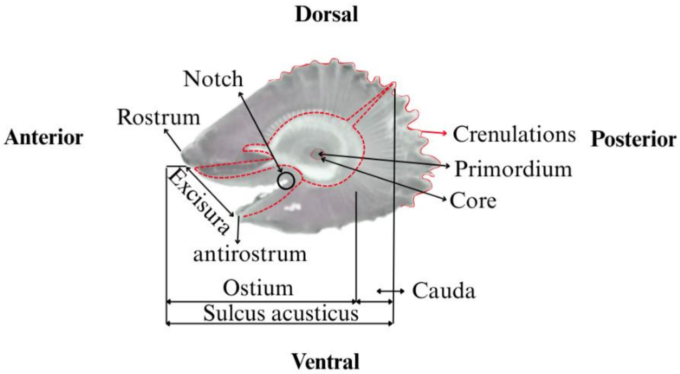

Figure 3. Morphology of the otoliths of the Tinfoil barb

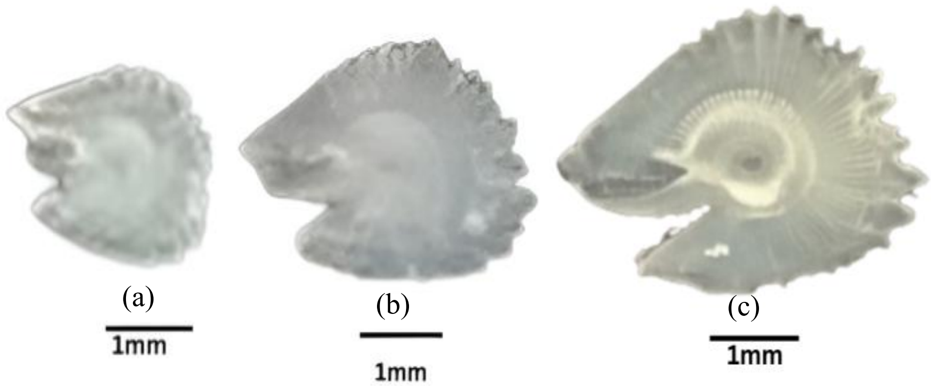

Figure 4. Variations in the otoliths of Tinfoil barb
(a) small-sized otolith (8.5 – 14.9 cm TL), (b) Medium-sized otolith (15.0 – 18.9 cm TL),
(c) Large-sized otoliths (19.0 – 29.0 cm TL)

Table 2. Morphometric averages of Tinfoil barb otolith

Parameters	Measurement results		
	Min	Maks	Mean±SD
Otolith length (OL/cm)	0.188	0.802	0.337±0.097
Otolith width (OW/cm)	0.169	0.567	0.254±0.065
Otolith area (OA/cm^2)	0.022	0.271	0.060±0.040
Otolith perimeter (OP/cm)	0.611	2.764	1.128±0.354
Otolith weight (OWt/g)	0.0009	0.016	0.004±0.002

Table 3. Morphometric averages of Tinfoil barb otoliths based on size variation

Para-meters	Measurement results								
	Small size			Medium size			Large size		
	Min	Maks	Mean±SD	Min	Maks	Mean±SD	Min	Maks	Mean±SD
OL/cm	0.188	0.388	0.282±0.044	0.242	0.443	0.352±0.037	0.339	0.802	0.504±0.152
OW/cm	0.169	0.308	0.219±0.030	0.204	0.310	0.261±0.021	0.239	0.567	0.365±0.107
OA/cm²	0.022	0.078	0.042±0.012	0.035	0.083	0.060±0.010	0.051	0.271	0.127±0.076
OP/cm	0.611	1.322	0.933±0.149	0.856	1.459	1.176±0.125	1.115	2.764	1.741±0.574
OWt/g	0.0009	0.0038	0.002±0.001	0.0027	0.0065	0.004±0.001	0.0032	0.016	0.007±0.003

Variations in fish body size provide the basis for examining the otolith morphology of the Tinfoil barb. Otoliths from small fish show an early stage of development, with the rostrum and antirostrum not yet having undergone significant elongation, crenulation on the posterior and ventral surface still not very distinct, and the sulcus acusticus not very clear. Medium-sized otoliths show quite noticeable differences: the rostrum and antirostrum begin to elongate, the crenulation becomes more distinct, and the excisura begins to deepen. Large fish otoliths exhibit a more complex shape, with a clearly visible and elongated rostrum and antirostrum, a deeper excisura, more pronounced crenulation, a thicker, denser, and more opaque otolith, and an acoustic sulcus that is recognizable with clear boundaries (Figure 4).

Morphometric Characteristics of Tinfoil Barb Otoliths

Morphometric analysis of otoliths in Tinfoil barb was conducted to assess variation in body size, sex, and otolith location. The overall results of the otolith morphometric measurements showed an average otolith length (OL) of 0.337 ± 0.097 cm, otolith width (OW) of 0.254 ± 0.065 cm, otolith area (OA) of 0.006 ± 0.040 cm², otolith perimeter (OP) of 1.128 ± 0.354 cm, and otolith weight (OWt) of 0.004 ± 0.002 g (Table 2).

Morphometric measurements of otoliths based on variations in fish body size increased. The small classes showed an average OL of 0.282 ± 0.044 cm. OW 0.219 ± 0.030 cm. OA 0.042 ± 0.012 cm². OP 0.933 ± 0.149 cm and OWt 0.002 ± 0.001 g.. The medium-sized class had an average OL of 0.352 ± 0.037 cm. OW 0.261 ± 0.021 cm. OA 0.060 ± 0.010 cm². OP 1.176 ± 0.125 cm; OWt 0.004 ± 0.001 g. The large size class showed an average OL of 0.504 ± 0.152 cm. OW 0.365 ± 0.107 cm. OA 0.127 ± 0.076 cm². OP 1.741 ± 0.574 cm; OWt 0.007 ± 0.003 g (Table 3).

Based on sex, the morphometric values of male fish otoliths were slightly larger than those of female fish otoliths for some para -

Table 4. Morphometric analysis of Tinfoil barb otoliths by sex.

Parameters	Male (n = 143)			Famale (n = 124)		
	Min	Maks	Mean±SD	Min	Maks	Mean±SD
OL/cm	0.188	0.802	0.346±0.118	0.221	0.717	0.327±0.065
OW/cm	0.169	0.567	0.260±0.079	0.170	0.493	0.247±0.042
OA/cm²	0.023	0.271	0.064±0.049	0.022	0.231	0.055±0.023
OP/cm	0.611	2.764	1.161±0.242	0.693	2.635	1.091±0.246
OWt/g	0.0009	0.0153	0.004±0.002	0.0012	0.0166	0.004±0.002

Table 5. Otolith morphometrics based on location

Parameter	Left (n=267)			Right (n=267)		
	Min	Maks	Mean±SD	Min	Maks	Mean±SD
OL/cm	0.185	0.801	0.336±0.098	0.191	0.810	0.338±0.097
OW/cm	0.160	0.571	0.253±0.065	0.167	0.563	0.255±0.065
OA/cm²	0.020	0.271	0.059±0.039	0.022	0.271	0.060±0.040
OP/cm	0.601	2.690	1.116±0.355	0.601	2.839	1.140±0.358
OWt/g	0.0008	0.0167	0.004±0.002	0.0008	0.0165	0.004±0.002

meters; however. The average otolith weight was the same for both sexes (Table 4). Morphometric measurements based on otolith location revealed very small differences and showed that the left and right otoliths were relatively similar (Table 5).

The results show that the morphometric characteristics of the left and right otoliths differ only slightly and are generally similar. To support this finding, statistical tests were conducted using OriginPro 2026 software. Therefore, a normality test was performed first as a prerequisite for the statistical tests.

Normality Test

A normality test is conducted to determine whether the data are normally distributed. The results of this normality test will be used to determine which statistical test to use in the subsequent analysis: a parametric test if the data are normally distributed, or a non-parametric test if they are not. The normality of the data representing differences in morphometric values between the left and right otoliths was assessed using the Shapiro-Wilk test.

The result of the normality test using the Shapiro-Wilk test showed that, of the five parameters, only one parameter was normally distributed, while the rest were not normally distributed because they had p-values less than 0.05 ($p < 0.05$). A p-value smaller than the significance level of 0.05 indicates that the data do not meet the requirements for a normal distribution, so parametric statistical analysis cannot be used. Therefore, the analysis of differences between the left and right otoliths was performed using the nonparametric Wilcoxon signed-rank test. This is a statistical method for comparing two paired samples when the data are normally distributed.

Wilcoxon Signed-Rank Test

The test results showed significant differences in all otolith morphometric parameters, except for otolith weight, which did not differ significantly. Based on the effect size (r), the parameters of length, width, and circumference fall into the small effect category, otolith area into the moderate effect category, while weight shows no effect. Although statistically significant, the diffe-rences are biologically classified as small to moderate. In line with the study's focus on fish size variation, further analysis used only the left otolith as a representative sample to ensure consistency (Table 6).

Table 6. Wilcoxon signed-rank

Parameters	W	Z	*p-value*	Effect Size (r)	Category
OL/cm	13776.5	-2.62686	0.00862	0.1607	Small*
OW/cm	12603	3.26214	0.00111	0.1996	Small*
OA/cm²	6329	-6.04088	<0.0001	0.3696	Moderate**
OP/cm	12210	-4.1689	<0.0001	0.25513	Small*
OWt/g	0	0	1	0	No effect***

*small: $0.10 \leq r < 0.30$
**moderate: $0.30 \leq r < 0.50$
***no effect: $r = 0$

Table 7. Otolith shape index results based on size variation

Shape index	Small size	Medium size	Large size	Description
Roundness (R_o)	0.666±0.04	0.652±0.029	0.642±0.027	The less rounded
Form factor (F_F)	0.617±0.114	0.558±0.089	0.516±0.066	The edges are more complex
Rectangularity (R_t)	0.663±0.07	0.62±0.062	0.596±0.047	They deviate from a rectangle
Circularity (C)	21.242±5.045	23.098±3.745	24.76±3.137	Less and less round
Aspect ratio (A_R)	1.289±0.096	1.347±0.098	1.376±0.088	More and more elongated
Ellipticity (E)	0.125±0.036	0.146±0.035	0.157±0.031	More and more elliptical

Morphometric Differences in Otoliths Among Fish Size Groups

The results of the Kruskal-Wallis test showed that all otolith parameters differed sig-nificantly among fish size groups (*p*-value < 0.0001). The median values of all parameters increased consistently with increasing fish size classes. The median otolith length increased from 0.280 cm in the small size group to 0.424 cm in the large size group. Increases were also observed in otolith width (0.216 cm to 0.302 cm), otolith area (0.040 cm² to 0.081 cm²), otolith circumference (0.909 cm to 1.365 cm), and otolith weight (0.0022 g to 0.0065 g).

Otolith Shape Index

Analysis of the otolith shape index revealed variation in values across fish size classes. The descriptors roundness (R_o), Form factor (F_F), and Rectangularity (R_t) showed a decrease in values as fish size incre-ased: R_o from 0.666 ± 0.04 to 0.642 ± 0.027; F_F from 0.617 ± 0.114 to 0.516 ± 0.066; and R_t from 0.663 ± 0.07 to 0.596 ± 0.047. Conversely, the values of the circularity (C), aspect ratio (A_R), and Ellipticity (E) increased: C from 21.242 ± 5.045 to 24.76 ± 3.137; A_R from 1.289 ± 0.096 to 1.376 ± 0.088; and E from 0.125 ± 0.036 to 0.157 ± 0.031 (Table 7).

The Relationship Between the Length of Tinfoil Barb and Otolith Morphometry

The results of the linear regression analysis showed a positive relationship between the body length of Tinfoil barb and all otolith morphometric parameters, such that each increase in body length, width, area, perimeter, and weight of the otolith was associated with an increase in body length. The coefficient of determination (R^2) values for these five parameters ranged from to 0.50707 to 0.081368, indicating that most of the variation in otolith size can be explained by variations in fish body length. Quan-titatively, every 1 cm increase in otolith length with $R^2 = 0.64369$ (63.37%), while the

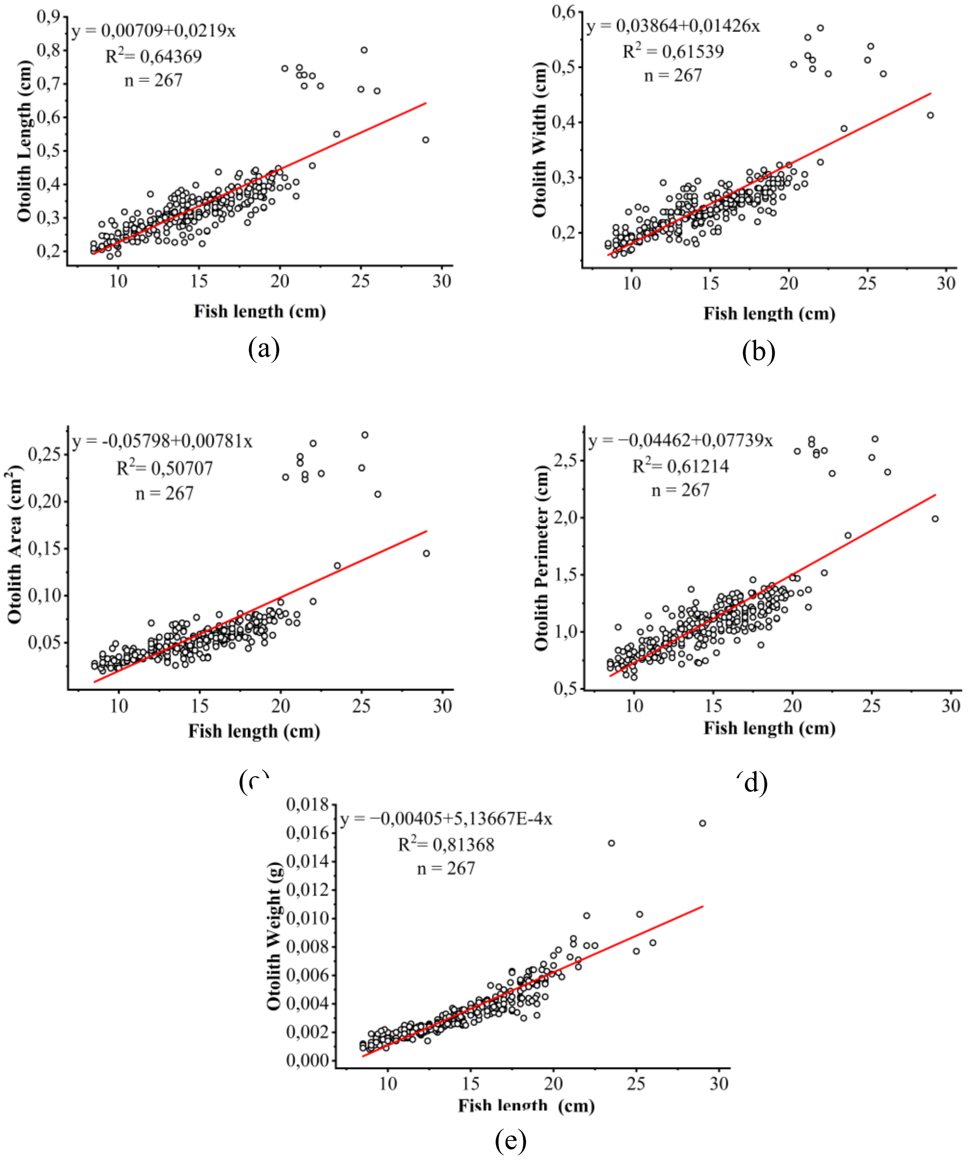

Figure 5. Relationship between the length of Tinfoil barb and otolith morphometric parameters: (a) otolith length, (b) otolith width, (c) otolith area, (d) otolith perimeter, and (e) otolith weight.

R^2 values for otolith width, area, perimeter, and weight are, respectively, 0.61539 (61.54%), 0.50707 (50.71%), 0.61214 (61.21%), and 0.81368 (81.37%). Thus, these values con-firm that otolith morphometric growth occurs in tandem with the growth of the fish's body length.

Discussion

The sagitta otolith of the Tinfoil barb exhibits an asymmetrical elliptical shape with a heterosulcoid acoustic sulcus, which is cha-racteristic of the Cyprinidae family (Lombarte & Cruz, 2007). The presence of an elongated rostrum, antirostrum, excisura, notch, and crenulation on the posterior mar-gin indicates an uneven pattern of calcium carbonate deposition throughout growth (Campana, 2004). Morphological development from small to large sizes reflects a complex biomineralization process that occurs throughout the fish's life. At small size, the otolith remains transparent and has a simple structure because daily deposition of aragonite crystals is still in its early stages (Mille *et al*., 2016). This lack of otoliths biomineralization process of fish knowledge, it can lead to misinterpretation of the different types of signals (e.g., optical or chemical) that provide basic data for research in fish ecology, fisheries management, and species conservation (Pontual *et al*, 2024). As the fish grows, the otolith becomes denser, more opaque, and more complex, with distinct annular lines that record daily or annual growth (Kang *et al*., 2025). These changes are consistent with the findings of Tuset *et al.* (2008) that otolith morphology evolves with age and body size. Meanwhile, according to Hasugian *et al*. (2021), Tinfoil Barb is classified as an omnivore based on analysis of food types and the ratio of intestinal length to total length.

All otolith morphometric parameters (length, width, area, perimeter, weight) increased significantly with fish body size ($p < 0.001$). This indicates positive allometric growth between the otolith and the body, a finding supported by studies on other Cyprinidae fish (Nimesh *et al*., 2021; Kontas & Bostanci, 2015). The increase in median values from small to large sizes indicates continuous calcium carbonate deposition along the otolith margins throughout the fish's lifespan (Campana, 2004). The results study by Fatiqin *et al*., 2022 showed that the morphometric measurements of *Barbodes schwanenfeldii* obtained in the Rupit River waters were smaller than those of Barbodes schwanenfeldii fish found in other river waters because these waters had experienced heavy metal pollution.

Sex differences were relatively small, suggesting that otolith size is more influenced by somatic growth than by reproductive factors. These results are consistent with the findings of Musaa *et al*. (2023) on *Barbonymus schwanefeldii* in Lake Kenyir, Malaysia. Similarly, the differences between the left and right otoliths were statistically significant but had a small to moderate effect size, making them biologically insignificant. Lychakov (2013) added that low bilateral asymmetry supports optimal hearing and balance function. For sexual maturity conditions, the results of research by Kusmini *et al*. (2023) showed that male tinfoil barb fish reached sexual maturity at a standard length of 16.01±1.18 cm, while females at 15.79±1.23 cm.

Changes in the otolith shape indices from small to large sizes show a clear ontogenetic pattern. Decreases in roundness, form factor, and rectangularity, and increases in circularity, aspect ratio, and ellipticity, indicate that the otoliths change from a round shape to a more elongated, elliptical, and complex shape as the fish grow. This is cause by uneven calcium carbonate deposition along different axes, resulting in the edges of the otolith developing more prominently in the longitudinal direction (Tuset *et al*., 2003). These changes are also related to the development of sensory function; larger, more elongated otoliths can alter the mechanical response to sound vibrations and linear acceleration (Popper & Lu, 2000). These findings are consistent with studies on *Barbus tauricus* (Kontas & Bostanci, 2015) and *Rhodeus amarus* (Saygin *et al*., 2020), which show that the otolith shape index is sensitive to ontogenetic growth and environmental conditions.

Linear regression analysis revealed a strong positive relationship between total fish length and all otolith morphometric parameters, with R^2 values ranging from 0.507 to 0.814. The highest R^2 value for otolith weight (0.814) indicates that biomineral accumulation during growth is closely linked to increases in body size. Otolith weight is the most appropriate parameter for estimating fish size, as has also been reported in other species (Bhakta *et al*., 2020; Ankita & Khan, 2022). This relationship reinforces the notion that otoliths are structures that grow throughout an individual's lifetime and reflect its growth history (Campana, 2004; Andrialovanirina *et al*., 2026). Overall, the study's results confirm that Tinfoil barb otoliths exhibit specific morphological and morphometric characteristics, vary ontogenetically, and can serve as indicators of growth and population identification. This study provides a scientific basis for the management of Tinfoil barb resources at the Kamijoro Dam.

Conclussion

The sagittal otoliths of the Tinfoil barb (Barbonymus schwanefeldii) at the Kamijoro Dam are asymmetrical, elliptical, and exhibit a heterosulcoid sulcus pattern, a characteristic feature of the Cyprinidae family, and their structural complexity increases with body size. Morphometrically, all parameters (length, width, area, perimeter, and otolith weight) showed a highly significant positive correlation with total fish length, with otolith weight being the most reliable parameter for estimating somatic growth. Shape index analysis revealed distinct ontogenetic changes, characterized by decreases in roundness, form factor, and rectangularity, and increases in circularity, aspect ratio, and roundness, form factor, and rectangularity, and increases in circularity, aspect ratio, and ellipticity, reflecting a transformation in shape from round in small fish to elongated and complex in large fish. These results confirm that Tinfoil barb otoliths serve as an effective biological archive for estimating body size and for studying population dynamics, thereby contributing to sustainable fisheries management in tropical reservoir ecosystems.

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