



Growth pattern and otolith size of *Tor* spp. (Cyprinidae)

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ABSTRACT

The threat of decreasing populations of *Tor* species continues to increase due to intensive fishing, habitat destruction and infrequent cultivation efforts. Monitoring of this group of fish must be carried out routinely to reveal the population conditions of fish. This research aims to reveal the population conditions of fish through an analytical approach to the length-weight relationship and fish otolith size. All fish samples were then taken for otoliths to measure their size and analyzed further using a scanning electron microscope (SEM). The research was conducted in the Tangkahan River, North Sumatra, Indonesia from January-March, 2023. The results showed that 43 samples of *T. douronensis*, 34 samples of *T. tambra*, and 24 samples of *T. tambroides* had *b* values of 2.853, 2.757, and 2.353, respectively. The *b* value in this study indicated that the fish had a negative allometric growth pattern. The size of the otoliths of the three *Tor* species shows that *T. tambra* has the highest length (the distance measured from the anterior to the posterior of the of sagitta otolith) on average reaching 9.31 mm, while *T. tambroides* and *T. douronensis* only reach 1.53 mm and 1.83 mm. The results were confirmed by ANOVA showing significant differences ($P < 0.05$) in the mean value of otolith size based on *Tor* species, where the otolith size of *T. tambra* was significantly different compared to the other two species. The condition of *Tor* species in the Tangkahan River has experienced ecological pressure. This indication was concluded from the results of the analysis of the length-weight relationship of fish which showed *b* value < 3 (negative allometric). The results show that the characteristics and size of the otoliths can differentiate *Tor* species and facilitate identification efforts related to management and conservation.

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Introduction

The inland waters of North Sumatra contain high levels of ichthyofauna resources. This region has many large rivers, lakes and peat swamps (Hehanussa, 2000; Desrita *et al.*, 2018). Therefore, these inland waters provide habitat for various species of fish in North Sumatra. However, habitat degradation continually due to land conversion and deforestation (Van Beukering *et al.*, 2003). Due to these causes, several species of fish were threatened and difficult to adapt. This is indicated shown by the presence of fish that are increasingly difficult to find, such as the group of fish from the Genus *Tor*.

The Genus *Tor* consists of several fish species that has important economic value in North Sumatra. This fish is widely distributed in the rivers and lakes

of North Sumatra. Three species of *Tor* have been identified in North Sumatra, namely *Tor douronensis*, *T. tambra*, and *T. tambroides* (Desrita *et al.*, 2018; Barus *et al.*, 2023). However, due to habitat degradation and intensification of fishing, it has resulted in a significant decline in the *Tor* species population in recent decades (De Silva *et al.*, 2004).

River areas are vulnerable to ecological change and *Tor* species are highly impacted by changes in river habitat (Cooke *et al.*, 2012; Pinder *et al.*, 2019). Sand and rock mining that occurs upstream of rivers has changed the river's ecomorphology so that the function of stone as a water retainer is lost and causes the river to become shallow (Stucchi & Bocchiola, 2023). Apart from that, the rocks in the river are areas for spawning, sheltering and nurturing of fish (Rai,

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2008), which have a very significant impact on reducing the fish population if this area is damaged. River rocks that have been mined in rivers cause fish to lose their habitat and initiate fish to move to other places.

Research on *Tor* species that has been conducted in North Sumatra includes diversity and habitat conditions (Desrita *et al.*, 2018; Desrita *et al.*, 2019a; Desrita *et al.*, 2020; Paramitha and Larashati, 2020; Sinuraya *et al.*, 2022), morphology and genetics (Simanjuntak *et al.*, 2018; Larashati *et al.*, 2022; Rahayu *et al.*, 2022; Barus *et al.*, 2023), reproduction (Desrita *et al.*, 2019b), environmental bioindicators (Ezraneti *et al.*, 2021; Almunadiya, *et al.*, 2023), while studies regarding the condition and size of *Tor* otoliths have never been reported in North Sumatra.

Analysis of the length-weight relationship serves to evaluate the growth patterns, relative condition of population, food availability and body shape of fish (Heydarnejad, 2009; Roul *et al.*, 2020). Meanwhile, analysis of otolith size is an effort to determine fish species (Pavlov, 2016). This study aims to assess the condition and size of the otoliths of three *Tor* species, namely *Tor douronensis*, *T. tambra*, and *T. tambroides*, to provide baseline biological data for population monitoring, species differentiation, and sustainable fisheries management. This research provides fundamental biological information about three *Tor* species distributed in North Sumatra, Indonesia, and offers insights into their future fishery management. Understanding otolith characteristics can provide valuable insights into fish age, growth patterns, and habitat conditions, which are crucial for sustainable fisheries management and conservation efforts (Gebremedhin *et al.*, 2021). Despite extensive research on diversity, morphology, and reproduction of *Tor* species, no study has examined their otolith characteristics, which are essential for understanding species identification and population dynamics.

Materials and Methods

Time and site

This research was conducted in the Tangkahan River, Kab. Langkat, North Sumatra, Indonesia from January to March, 2023 (Figure 1). The samples that have been collected are then transported to the Biology Laboratory, Medan State University, Indonesia for the identification process.

Sampling procedure

Fish sampling locations were conducted purposively based on information from fishermen who usually catch *Tor* fish. Fishing is done using casting nets (0.5 inch mesh size) and fishing rods. Catching is carried out from 07:00 am to 18:00 pm along the river line. The fish that have been caught are then measured for total length (TL)

using a digital caliper (error 0.01 mm) and body weight with a analytical scales (error 0.01 g), then the fish are stored in a cool box so that the otolith tissue is not damaged and then transformed to the Biology Laboratory of Medan State University, Indonesia for further analysis.

Length-Weight Relationship (LWR)

The identified fish were then weighed using analytical scales (error 0.01 g) and total length measured using digital calipers (error 0.01 mm). LWR analysis was carried out using the Liner Allometric Model (LAM) guided by De-Robertis and William (2008): $W = e^{0.56(aL^b)}$, W is weight, L is total length of fish, a is constant and b is geometric for fish body proportion, e is variance of residuals of LAM, and 0.56 is correction factor.



Figure 1. Research location (red star) at Tangkahan River, Kab. Langkat, North Sumatra, Indonesia where samples were taken for *Tor* spp. (coordinate point: 3°45'50.46" N; 98°14'52.66" E).

Otolith samples were collected from each species (all sampel) of fish by dissecting the dorsal part of the fish's head starting from the tip of the snout towards the posterior of the fish's head using a scalpel (Iqbal *et al.*, 2013). The otolith is then separated from the fish head which has been split into two parts. Each fish has a pair of otoliths (left and right). Next, the otolith is rinsed with distilled water three times and the membrane covering the otolith is removed/cleaned. Then the otolith is cleaned again with a 10% potassium hydroxide solution to clean it of all unnecessary dirt. In the next stage, the otoliths were left in an alcohol solution with varying concentrations (30%, 50%, 70% and 90%) for 60 seconds. then observed with a Zeiss Stemi 2000 stereo microscope. Otolith characterization was carried out using a Scanning Electron Microscope (SEM) at the integrated laboratory at the University of North Sumatra, Indonesia.

Data analysis

Data of TL and fish weight were analyzed statistically based on sex and species using Analysis of Variance (ANOVA) at 95% level. Otolith size was

also analyzed statistically (ANOVA) based on species. Data on growth patterns (b) and coefficient of determination (r^2) were analyzed descriptively.

Results

The results of the analysis during the research collected 43 samples of *T. douronensis* (19 males and 24 females), 34 samples of *T. tambra* (18 males and 16 females) and 24 samples of *T. tambroides* (9 males and 15 females). The number of *T. tambroides* is the lowest among other species, this is probably because the population continues to decline due to exploitation and environmental damage. Based on the total length of the fish, *T. douronensis* has the smallest average size (males 153.14 mm and females 153.85 mm) compared to *T. tambra* (males 197.22 mm and females 209.68 mm) and *T. tambroides* (males 190.36 mm and females 260.91 mm) (Table 1). The results were confirmed by ANOVA showing significant differences ($P < 0.05$) in the mean values of TL and body weight based on sex and species of *Tor* fish (Figure 2, Figure 3).

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The average size of otoliths in *T. tambra* reached 9.31 mm, followed by *T. douronensis* 1.83 mm, and *T. tambroides* 1.53 mm, where the otolith size of *T. tambra* was significantly different ($P < 0.05$) compared to the other two species).

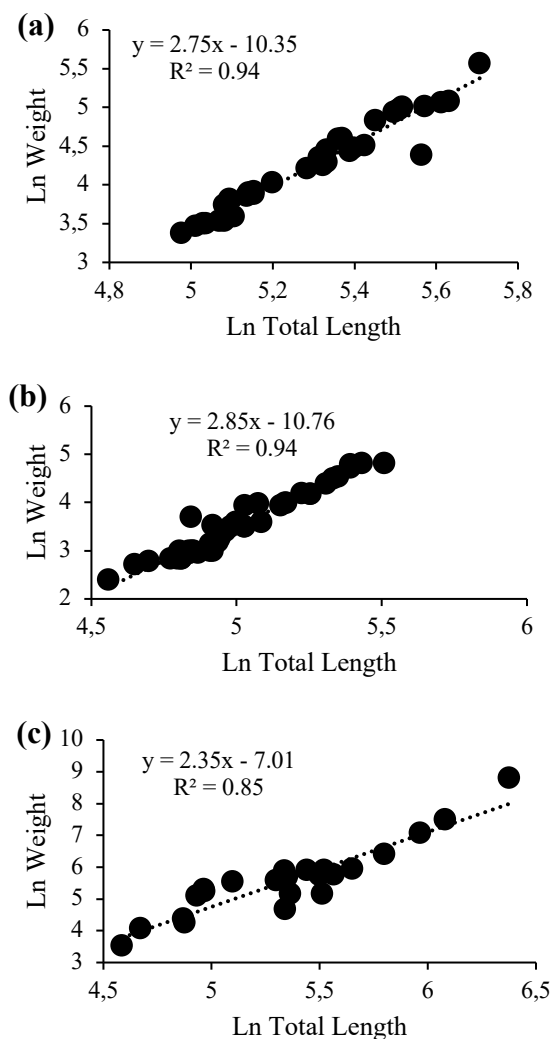


Figure 2. Length weight relationship of (a) *T. douronensis*, (b) *T. tambra*, and (c) *T. tambroides*.

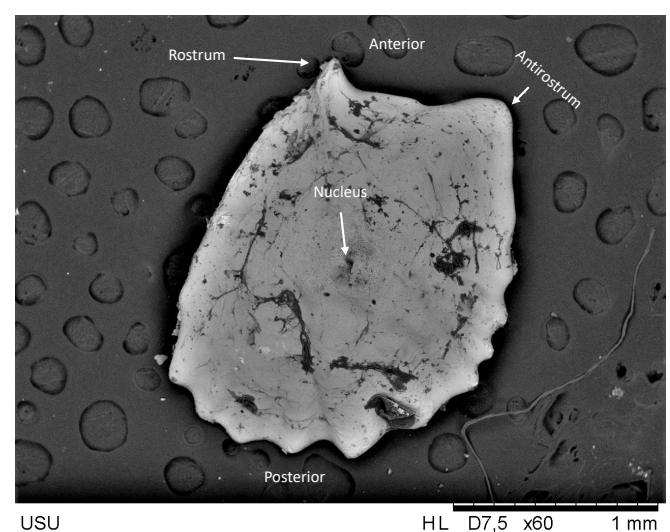


Figure 3. Sagitta otolith structure of *T. douronensis*.

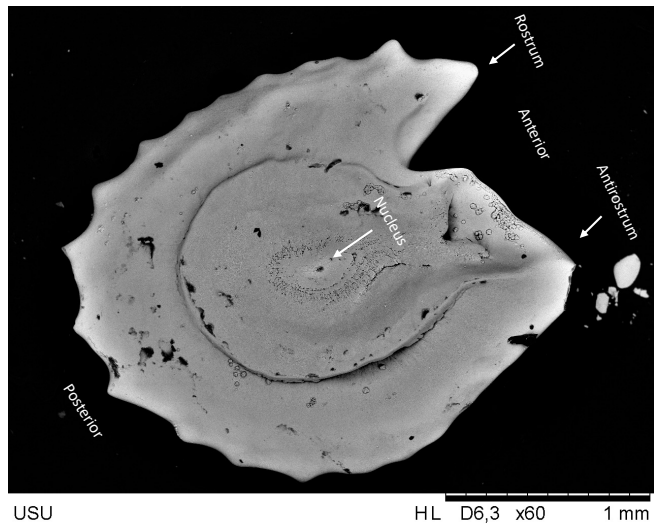


Figure 4. Sagitta otolith structure of *T. tambra*.

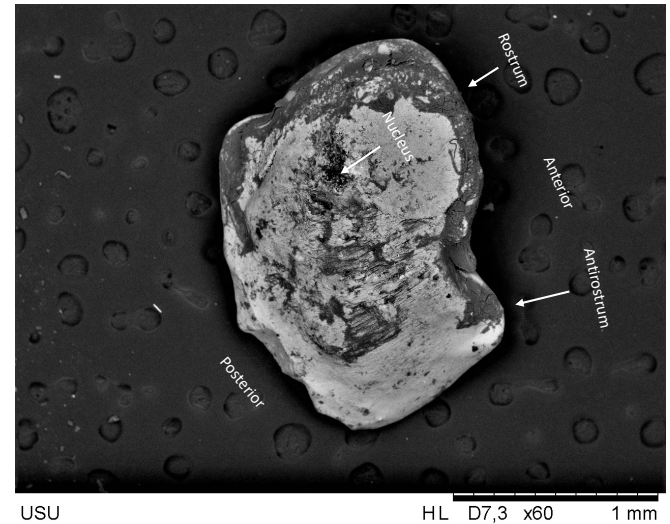


Figure 5. Sagitta otolith structure of *T. tambroides*.

Table 1. Analysis of variance (ANOVA) based on total length and body weight from three species of *Tor*. Different superscripts on the same row indicate significant differences ($P < 0.05$).

Parameters	<i>T. douronensis</i>	<i>T. tambra</i>	<i>T. tambroides</i>	<i>T. douronensis</i>	<i>T. tambra</i>	<i>T. tambroides</i>
	Male (fish)			Female (fish)		
	19	18	9	24	16	15
Total length (mm)	95.5-228.86 (153.14±40.23) ^a	145-301 (197.22±48.58) ^b	130.45-285.12 (190.36±60.56) ^b	109.74-247.1 (153.85±35.1) ^a	153-279 (209.68±36.32) ^b	130.8-588.05 (260.91±126.54) ^c
Weight (g)	11-122 (45.31±34.19) ^a	29-260 (77.75±61.2) ^a	185-374 (259.11±64.37) ^b	16-122 (41.21±31.18) ^a	33-160 (87.18±40.91) ^a	131-892 (318.33±210.82) ^b

Table 2. Data analysis of growth pattern (b) and coefficient of determination (r^2) from three species of *Tor* (M = male and F = female). Different superscripts on the same row indicate significant differences ($P < 0.05$).

Parameters	<i>T. douronensis</i>		<i>T. tambra</i>		<i>T. tambroides</i>	
	M	F	M	F	M	F
Individual	19	24	18	16	9	15
Otolith length (mm)	1-3 (1.83±0.58) ^a		7-12.6 (9.31±1.34) ^b		1.43-1.70 (1.53±0.06) ^a	
b	2.81	2.91	2.72	2.78	1.46	2.52
b M+F	2.85		2.75		2.35	
r^2	0.94	0.94	0.92	0.96	0.80	0.90
r^2 M+F	0.93		0.94		0.85	

Discussion

From the results, we found that the gender of females *Tor* species have a higher b value than males (Table 1 and Table 2). This indicates that female fish are generally plumper than males. Factors that can influence this include the gonad size of female fish which can reach 10-14% of body weight (Shahi et al., 2014; Zuraidah et al., 2018), while for males it is only around 7% (Hendri and Baihaqi, 2015). In addition, the weight of female fish may be greater because they prefer larger food sources, have a greater feeding ratio, and spend more time foraging (Fryxell et al.,

2015). The fecundity factor also causes female fish to be larger than males (Sabet et al., 2011; Jacquemin and Pyron, 2016).

However, based on the average b value for *T. tambra* which reached 2.75, it was lower compared to those caught in the Nagan River, Aceh (2.84). The b value for *T. tambroides* in this study was higher compared to *T. tambroides* collected from the Atu Suasah and Lawe Melang Rivers, Aceh with values of 1.1 and 1.12 (Haser et al., 2022). Furthermore, other *Tor* species that are harvested in several countries include *T. tor* which has b values reaching 2.17, 2.43,

3.03, and 3.63 which are harvested from the Balochistan River, Pakistan (Narejo et al., 2014), Ganga River, India (Kamboj et al., 2020), Himalayan Plateau, India (Lal et al., 2016), and Narmada River, India (Ujjania et al., 2013); *T. putitora* has *b* values reaching 2.98 and 3.14 which were harvested from the Poonch River, India (Awat et al., 2020) and the Himalayan Highlands, India (Lal et al., 2016); *T. khudree* has a *b* value of 3.31 which was harvested from the Godavari River, India (Lal et al., 2016).

The average size of otoliths in *T. tambra* reached 9.31 mm, followed by *T. douronensis* 1.83 mm, and *T. tambroides* 1.53 mm, where the otolith size of *T. tambra* was significantly different ($P < 0.05$) compared to the other two species). These results reveal that there are significant differences in otolith size between different species. Apart from that, differences were also found in the shape of the otolith surface, especially in the shape of the anterior and posterior parts of the otolith. Similar results were also revealed by Tuset et al. (2003) and He et al. (2018) regarding the comparison of the sagittal morphology of *Scomber* spp. and *Serranus* spp. otolith.

Conclusion

The results of the length-weight relationship analysis of three *Tor* species in the Tangkahan River showed a *b* value < 3 (negative allometric). This value shows that fish tend to be elongate shape. The average size of otoliths in *T. tambra* reached 9.31 mm, followed by *T. douronensis* 1.83 mm, and *T. tambroides* 1.53 mm, where the otolith size of *T. tambra* was significantly different ($P < 0.05$) compared to the other two species).

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