MORPHOLOGICAL DESCRIPTIONS OF OTOLITHS FROM 22 SPECIES OF RAY-FINNED FISHES (CHORDATA: ACTINOPTERYGII) COLLECTED IN XUAN THUY NATIONAL PARK, NINH BINH PROVINCE

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ABSTRACT

Otoliths possess species-specific morphological traits, making them valuable tools for fish identification. However, knowledge of otolith morphology in ray-finned fishes remains limited, both globally and within Vietnam. This study examined 67 specimens representing 22 species of ray-finned fishes collected using trap nets in 2019 from Xuan Thuy National Park (in Ninh Binh province), aiming to describe their otolith morphology. Detailed descriptions are provided for the otoliths of 22 species in 15 families and 9 orders. Among these, otolith data for 12 species are newly reported at the global level, while 10 represent new records for Vietnam. For each species, the dataset includes otolith images, concise morphological descriptions, and comparisons with congeners or conspecifics from other regions. Within the same order, family, or genus, otolith morphology tends to be similar. However, detailed structures show clear differences between species, even within the same genus. These results confirm the species-specific characteristics of otoliths and provide a reliable data source for fish identification in the study area, thereby supporting precise taxonomic classification and forming a scientific basis for proposing appropriate conservation strategies, especially for rare, endemic, or threatened species.

MÔ TẢ HÌNH THÁI ĐÁ TAI CỦA 22 LOÀI CÁ VÂY TIA (CHORDATA: ACTINOPTERYGII) TẠI VƯỜN QUỐC GIA XUÂN THỦY, TỈNH NINH BÌNH

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TỪ KHÓA

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Đa dạng
Cá vây tia
Rừng ngập mặn
Miền Bắc Việt Nam

TÓM TẮT

Đá tai (otolith) có hình thái đặc trưng cho từng loài, do đó là đặc điểm lý tưởng được sử dụng để định loại cá. Tuy nhiên, hiểu biết về hình thái otolith của cá xương vẫn còn hạn chế trên thế giới cũng như tại Việt Nam. Nghiên cứu này phân tích 67 mẫu của 22 loài cá vây tia thu thập bằng lưới bát quái năm 2019 tại Vườn quốc gia Xuân Thủy (tỉnh Ninh Bình) nhằm mô tả đặc điểm hình thái đá tai. Kết quả nghiên cứu đã mô tả chi tiết đá tai của 22 loài thuộc 15 họ và 9 bộ, trong đó 12 loài là dẫn liệu mới cho thế giới và 10 loài mới được ghi nhận tại Việt Nam. Dữ liệu cho mỗi loài bao gồm hình ảnh đá tai, mô tả đặc điểm hình thái đặc trưng và so sánh với các loài cùng giống, họ hoặc cùng loài ở khu vực khác. Trong cùng một bộ, họ, giống, hình thái đá tai có xu hướng tương đồng, nhưng cấu tạo chi tiết có sự khác biệt rõ giữa các loài ngay cả trong cùng một giống. Những kết quả này khẳng định đặc điểm hình thái đặc trưng theo loài của xương tai và cung cấp nguồn dữ liệu tin cậy cho việc định danh cá tại khu vực nghiên cứu, từ đó hỗ trợ phân loại chính xác và làm cơ sở khoa học để đề xuất các chiến lược bảo tồn phù hợp, đặc biệt đối với các loài cá quý hiếm, đặc hữu hoặc đang bị đe dọa.

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1. Introduction

Otoliths are calcified structures located in the inner ear of bony fishes [1], functioning in both hearing and balance [2]. Their shape and morphometric features are species-specific, making them valuable tools for fish identification. As internal structures protected within the skull, otoliths are less influenced by environmental conditions compared to external features [3]. Therefore, using preserved internal structures such as otoliths can provide more reliable characteristics for accurate species identification.

Xuan Thuy National Park, located in Ninh Binh province, lies at the Ba Lat estuary - the largest estuary in northern Vietnam. It is considered an important inundation site for biodiversity conservation in the coastal region of the Red River Delta. This area is characterized by mangroves, boasting the highest biodiversity and providing daily food sources for local people [4]. Until now, a total of 122 fish species have been recorded in Xuan Thuy National Park [5] and 43 species of gobies are reported in the study of Pham et al. [6].

In Vietnam, there are a few works on otolith morphology, focusing only on early stages, e.g., sand whiting *Sillago sihama* [7] and *Nuchequula nuchalis* in the Tien Yen estuary [8], Tiger bass (*Terapon jabua*) in Kalong estuary [9]. For adult fish, Tran et al. [10] described the morphology of two gizzard shads, *Clupanodon thrissa* and *Nematalosa nasus*, and examined otolith microchemistry to elucidate their life history. In Ba Lat estuary, next to Xuan Thuy National Park, Vu et al. [11] examined morphological traits of nine species of gobies. They provided images of all nine species and morphological changes with growth of four species (i.e., *Butis koilomatodon, Tridentiger barbatus, Glossogobius olivaceus,* and *G. giuris*). Thus, the present study contributes important new data on the otolith morphology of 22 bony fish species, supporting future taxonomic research and other studies involving otolith analysis.

2. Methodology

2.1. Materials and methods

A total of 63 pairs of sagittal otoliths from 22 bony fish species in Xuan Thuy National Park were examined in this study (Table 1). Photographs of the fish were taken to aid in species identification. Specimens were fixed in 80% ethanol immediately after collection in the field and subsequently preserved in the same solution in the laboratory. In addition, formalin-preserved specimens of these species were used to confirm identification at the species level.

Fish species were identified based on morphological characteristics using the following references [12]-[16]. After extraction, sagittal otoliths were rinsed with water and observed under a magnifying glass. Otolith length and breadth were measured along their longest axis using a Nikon binocular magnifier (Figure 1). The examined otoliths were then fixed and preserved in 70% ethanol.

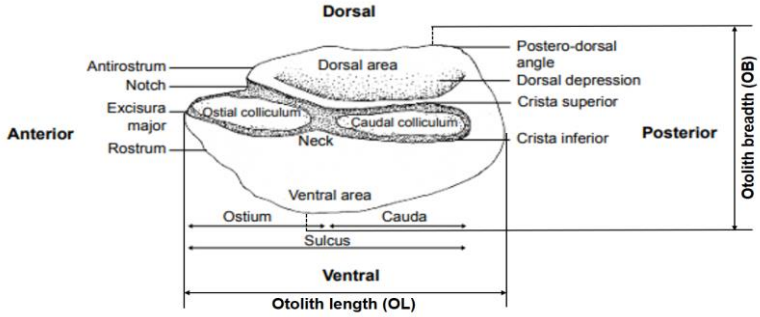


Figure 1. *Sagitta structure and measurements in bony fish* [18]

Otolith morphological descriptions followed Secor et al. [17] and Lin & Chang [18] (Figure 1). All photos of sagittae show the fish's total length (TL), length of left and right sagittae (LL, RL), breadth of left and right sagittae (LB, RB). Photos of otoliths of 22 species in the present study were taken using a Pentax camera on the magnifying glass, then edited by Photoshop CS6 software.

Table 1. *Data of ray-finned fish collected from Xuan Thuy National Park were used in the present study*

Order	Name	Standard length (SL)	No. of specimens	No. of otolith removed		No. of otolith described	
				Left	Right	Left	Right
I	**Characiformes**						
I.1	**Serrasalmidae**						
1	*Piaractus brachypomus* (Cuvier, 1818)	78.6	1	1	1	1	1
II	**Gobiiformes**						
II.1	**Odontobutidae**						
2	*Bostrychus sinensis* Lacepède, 1801	175.0	1	1	1	1	1
II.2	**Oxudercidae**						
3	*Apocryptodon punctatus* Tomiyama, 1934	41.7–48.5	2	2	2	1	1
4	*Boleophthalmus pectinirostris* (Linnaeus, 1758)	59.9–72.2	4	4	4	1	1
II.3	**Gobiidae**						
5	*Acanthogobius flavimanus* (Temminck & Schlegel, 1845)	152.0	1	1	1	1	1
6	*Acentrogobius moloanus* (Herre, 1927)	50.9–60.8	10	10	9	10	9
7	*Tridentiger bifasciatus* Steindachner, 1881	62.7–72.8	3	3	3	1	1
III	**Anabantiformes**						
III.1	**Osphronemidae**						
8	*Macropodus opercularis* (Linnaeus, 1758)	36.8–39.7	3	3	3	1	1
9	*Trichopsis vittata* (Cuvier, 1831)	31.8–40.6	4	3	4	1	1
IV	**Carangiformes**						
IV.1	**Cynoglossidae**						
10	*Cynoglossus bilineatus* (Lacepède, 1802)	71.9–97.3	3	2	2	1	1
V	**Mugiliformes**						
V.1	**Mugilidae**						
11	Mugilidae sp.	36.1–95.2	13	13	13	13	13
VI	**Blenniiformes**						
VI.1	**Blenniidae**						
12	*Omobranchus fasciolatoceps* (Richardson, 1846)	83.4	1	1	1	1	1
13	*Omobranchus punctatus* (Valenciennes, 1836)	79.4	1	1	0	1	0
VII	**Perciformes**						
VII.1	**Platycephalidae**						
14	*Platycephalus indicus* (Linnaeus, 1758)	66.1–15.3	9	8	9	8	9
VIII	**Centrarchiformes**						
VIII.1	**Terapontidae**						
15	*Terapon jarbua* (Forsskål, 1775)	47.0	1	1	1	1	1
IX	**Acanthuriformes**						
IX.1	**Gerreidae**						
16	*Gerres limbatus* Cuvier, 1830	74.0 –137.0	2	2	2	1	1
IX.2	**Sillaginidae**						
17	*Sillago sihama* (Forsskål, 1775)	122.4	1	1	1	1	1
IX.3	**Lutjanidae**						
18	*Lutjanus argentimaculatus* (Forsskål, 1775)	70.5	1	1	1	1	1
19	*Lutjanus russellii* (Bleeker, 1849)	91.1	1	1	1	1	1
IX.4	**Leiognathidae**						
20	*Nuchequula blochii* (Valenciennes, 1835)	33.3–38.0	3	3	3	1	1
IX.5	**Sparidae**						
21	*Acanthopagrus* sp. (Forsskål, 1775)	160.5	1	1	1	1	1
22	*Acanthopagrus latus* (Houttuyn, 1782)	70.6	1	1	1	1	1
	Total		**67**	**64**	**63**	**50**	**49**

3. Results and discussion

The present study provides the first brief descriptions of the otoliths of all 22 fish species examined from Xuan Thuy National Park, located in Ninh Binh province. Based on a review of existing literature on otolith morphology from both global and Vietnamese sources, the present study indicates that 12 of the 22 species represent new otolith records for the world, while 10 species provide new data for Vietnam. Below are the key features of the examined otoliths (Figure 2.1–2.22), along with comparisons to their congeners, when available.

3.1. New records for the world (12 species)

Bostrychus sinensis. The otoliths were hexagonal-shaped (Figure 2.2). The dorsal and ventral margins were strongly serrated, especially the ventral margin. The sulcus was shallow. The rostrum and antirostrum were hard to distinguish. The notch was deep.

Apocryptodon punctatus. The sagitta had an eliptic shape (Figure 2.3). The dorsal margin was smooth, while the ventral margin was slightly serrated. The rostrum protruded anteriorly and was easily distinguishable from the antirostrum.

Boleophthalmus pectinirostris. The otolith was pentagonal with nearly smooth dorsal and ventral margins, showing slight serrations (Figure 2.4). The sulcus was deep and distinct. The antirostrum extended inward and upward, while the notch was deep. The postrostrum was rounded and curved upward. Its sagitta closely resembled that of *B. dussumieri*, another species in this genus, as described by Ghanbarifardi et al. [3].

Acanthogobius flavimanus. The otolith was pentagonal (Figure 2.5). The dorsal margin was nearly smooth, while the ventral margin was irregularly dentate. The sulcus was small and difficult to detect. The rostrum was longer than the antirostrum, and the notch was very shallow.

Acentrogobius moloanus. The otolith was hexagonal in shape (Figure 2.6). Both the dorsal and ventral margins were lightly serrated. The sulcus was hard to detect, and the rostrum and antirostrum were difficult to differentiate. The cauda was crenated and elongated posteriorly. Compared to the otolith of *A. viridipunctatus* in Vu et al. [11], the otoliths of *A. moloanus* have an indistinct sulcus and make it difficult to distinguish the rostrum and antirostrum. However, they differ in shape, as *A. viridipunctatus* has a flat oval form.

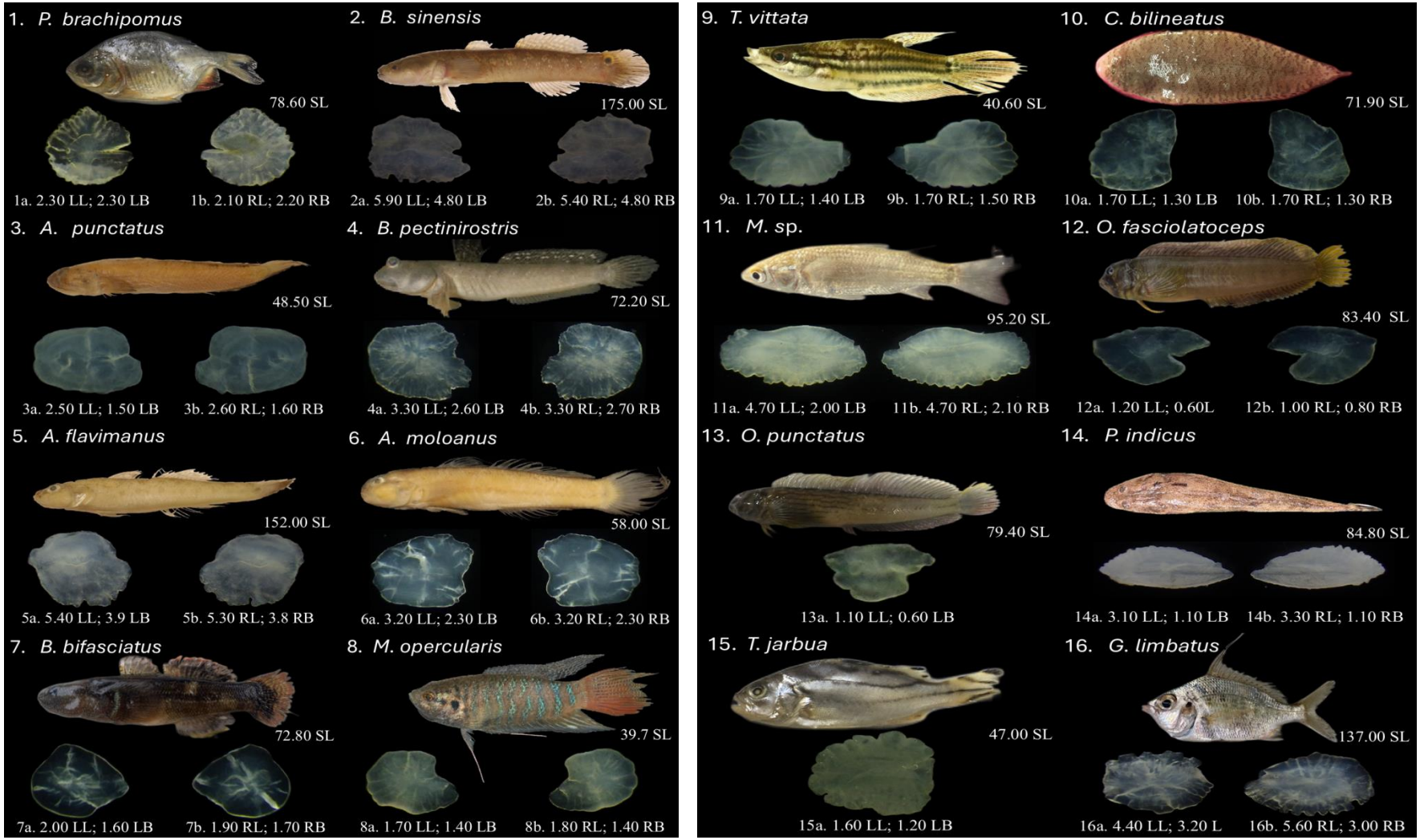
Tridentiger bifasciatus. The otolith was oval with smooth dorsal and ventral margins (Figure 2.7). The sulcus, rostrum, and antirostrum were indistinct. The otolith of another species in this genus, *T. barbatus*, described by Vu et al. [11], is similar to that of *T. bifasciatus* in having a deep sulcus and a convex rostrum but differs in shape.

Trichopsis vittata. The sagittal otoliths were discoid with a rough surface (Figure 2.9). The outer margin was serrated on both dorsal and ventral sides. The distance between the rostrum and antirostrum was short. The postrostrum bent downward.

Cynoglossus bilineatus. *C. bilineatus* had sagitta with triangular-shaped, approximately heart-shaped (Figure 2.10). The dorsal and ventral margins were nearly entire. The sulcus was dim. The rostrum and notch were absent. The cauda was gradually wider.

Omobranchus fasciolatoceps. The sagittal otoliths were ovate and nearly transparent (Figure 2.12). The dorsal margin was slightly serrated, and the ventral margin smooth. The sulcus was faint and hard to find. The antirostrum protruded anteriorly, and the postrostrum was triangular, curving upward.

Omobranchus punctatus. The sagittal otoliths were ovate, similar to *O. fasciolatoceps* (Figure 2.13). The dorsal and ventral margins were absent, and the sulcus was shallow. The antirostrum protruded anteriorly and was easy to distinguish from the rostrum. The notch was shallow, and the postrostrum elongated posteriorly.


1. P. brachipomus
78.60 SL
1a. 2.30 LL; 2.30 LB
1b. 2.10 RL; 2.20 RB
2. B. sinensis
175.00 SL
2a. 5.90 LL; 4.80 LB
2b. 5.40 RL; 4.80 RB
3. A. punctatus
48.50 SL
3a. 2.50 LL; 1.50 LB
3b. 2.60 RL; 1.60 RB
4. B. pectinirostris
72.20 SL
4a. 3.30 LL; 2.60 LB
4b. 3.30 RL; 2.70 RB
5. A. flavimanus
152.00 SL
5a. 5.40 LL; 3.9 LB
5b. 5.30 RL; 3.8 RB
6. A. moloanus
58.00 SL
6a. 3.20 LL; 2.30 LB
6b. 3.20 RL; 2.30 RB
7. B. bifasciatus
72.80 SL
7a. 2.00 LL; 1.60 LB
7b. 1.90 RL; 1.70 RB
8. M. opercularis
39.7 SL
8a. 1.70 LL; 1.40 LB
8b. 1.80 RL; 1.40 RB
9. T. vittata
40.60 SL
9a. 1.70 LL; 1.40 LB
9b. 1.70 RL; 1.50 RB
10. C. bilineatus
71.90 SL
10a. 1.70 LL; 1.30 LB
10b. 1.70 RL; 1.30 RB
11. M. sp.
95.20 SL
11a. 4.70 LL; 2.00 LB
11b. 4.70 RL; 2.10 RB
12. O. fasciolatoceps
83.40 SL
12a. 1.20 LL; 0.60L
12b. 1.00 RL; 0.80 RB
13. O. punctatus
79.40 SL
13a. 1.10 LL; 0.60 LB
14. P. indicus
84.80 SL
14a. 3.10 LL; 1.10 LB
14b. 3.30 RL; 1.10 RB
15. T. jarbua
47.00 SL
15a. 1.60 LL; 1.20 LB
16. G. limbatus
137.00 SL
16a. 4.40 LL; 3.20 L
16b. 5.60 RL; 3.00 RB

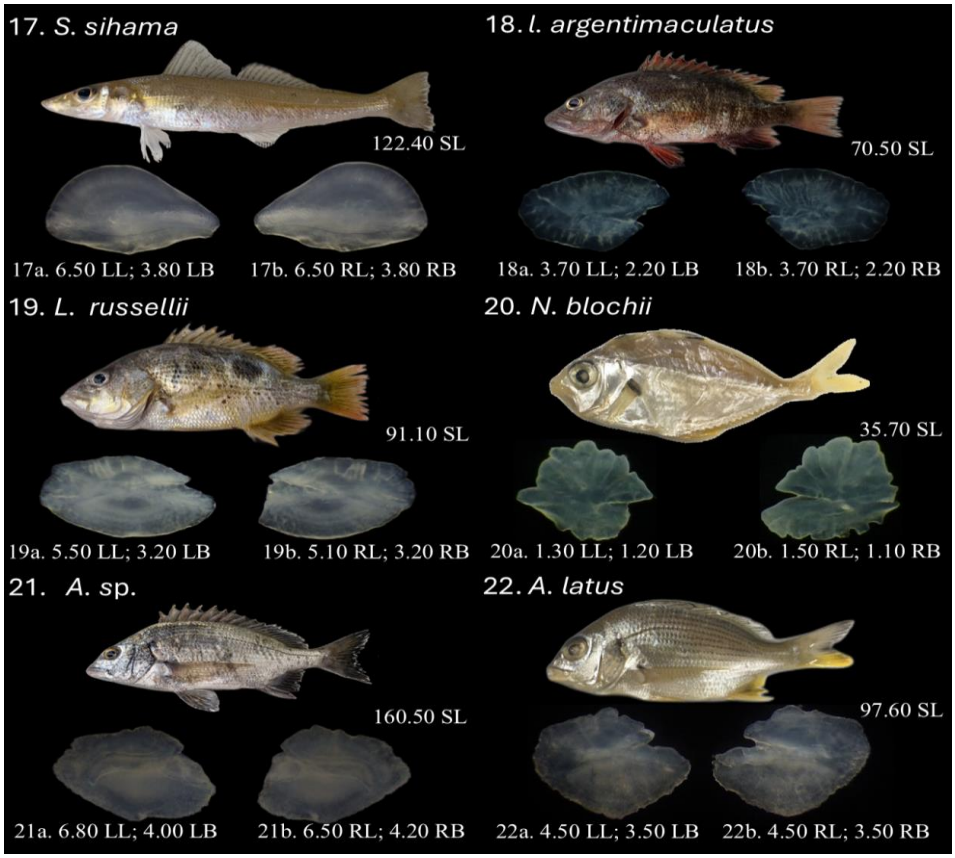


Figure 2. *Sagittae of studied bony fish species in Xuan Thuy National Park, Ninh Binh province SL: Standard length; LL: Length of left sagitta; LB: Breadth of left sagitta; RL: Length of right sagitta; RB: Breadth of right sagittal: The order of fish (1-22) follows Table 1.*

Gerres limbatus. The sagittal otoliths were pentagonal, with deep crenations on both the dorsal and ventral margins (Figure 2.16). The sulcus was deep and well-defined. The rostrum protruded anteriorly and was distinct from the antirostrum. The notch was slightly shallow. Compared to Lin and Chang [18], this description resembles *G. macracanthus* in having a deep sulcus and a well-defined rostrum but differs in otolith shape.

Nuchequula blochii. The sagittal otoliths are rhomboidal with pronounced crenations on both margins (Figure 2.20). The sulcus was ostial and deep, with a pronounced notch extending downward, clearly separating the rostrum and antirostrum. The postrostrum curved posteriorly. Compared to another species in this genus, *N. nuchalis* described by Tran et al. [7], this description matches at larval and juvenile stages in having a deep sulcus and a curved postrostrum but differs in otolith shape, as *N. nuchalis* exhibits shape variations with growth.

3.2. New data for Vietnam (10 species)

Piaractus brachypomus. The sagittal otoliths were discoid-shaped with serrated dorsal and ventral margins (Figure 2.1). The sulcus was difficult to observe. The rostrum and antirostrum were of equal length and separated by a short distance. The notch was slightly deep, while the postrostrum was rounded and curved. This description aligns with Ghazwan's [19] research, particularly in the crenation of the margins.

Macropodus opercularis. The sagittal otoliths were oval (Figure 2.8). The dorsal and ventral margins were slightly crenate. The sulcus was shallow and difficult to define. The rostrum protruded anteriorly, forming a triangular shape. The distance between the rostrum and antirostrum was distinct and easily identifiable. This description is similar to that in Lin and Chang [18].

Mugilidae sp. The sagitta was spindle-shaped (Figure 2.11). The dorsal margin was flat, the posterior margin was lobated, and the ventral margin was irregularly dentate. The sulcus was deep and easily observed. The rostrum and antirostrum were close to each other, with a shallow notch. The postrostrum was fan-shaped, serrated, and curved upward. Its morphology resembled *Chelon affinis* as described by Lin & Chang [18], but further studies are needed for accurate species identification.

Platycephalus indicus. The otolith was oblong with pointed anterior and posterior ends (Figure 2.14). The dorsal and ventral margins were slightly dentate. The sulcus was ostial, deep, and nearly straight. The rostrum was elongated and curved upward, featuring a deep notch and a constricted neck. The postrostrum was pointed. Its characteristics matched those described by Lin & Chang [18], though variations were observed due to differences in otolith size.

Terapon jarbua. The sagittae of *Terapon jarbua* are oval in shape, opaque white, with serrated margins, a deep sulcus, and a caudal that extends and curves ventrally (Figure 2.15). These features differ from those in its larval and juvenile stages, which exhibit a stable shape with a pointed rostrum, rounded antirostrum, distinct segmented grooves, and a filled notch [9]. This is a new record of otolith characteristics in adult individuals of this species, contributing to a more complete dataset for species identification across developmental stages.

Sillago sihama. The otolith was tear-drop shaped with a smooth surface (Figure 2.17). The sulcus was deep and distinct, with no rostrum, antirostrum, or notch. The ostium was oval, and the cauda was elongated and bent downward at the posterior. The present study confirms that the otolith is species-specific, in line with the findings of Mirhadi et al. [21], who described otoliths of this species collected in Persian Gulf. Compared with larval and juvenile stages [9], sagitta in the present study is different in shape as the rostrum becomes more pointed (Figure 2.17).

Lutjanus argentimaculatus. The sagittal otoliths were pentagonal (Figure 2.18). The ventral margin had faint serrations. The sulcus was deep and ostial. The rostrum protruded anteriorly and was clearly distinct from the antirostrum. The notch was slightly deep. Sadighzadeh et al. [20] also described the otolith of *L. argentimaculatus* as pentagonal with an ostial sulcus.

Lutjanus russellii. The sagittal otoliths were pentagonal and porcelain white (Figure 2.19). The dorsal and ventral margins were smooth. The sulcus was deep and well-defined. The rostrum extended anteriorly and was clearly distinct from the antirostrum. The notch was shallow. The ostium was oblong and bent downward, while the cauda was elongated and flexed ventrally. Compared to the description by Sadighzadeh et al. [20], the sagitta showed similarities in shape, a broad rostrum, and a small antirostrum. The otolith's shape is clearly similar between *L. russellii* and *L. argentimaculatus*.

Acanthopagrus sp. The otolith was elliptical in shape (Figure 2.21). The dorsal margin had more pronounced serrations than the ventral margin. The sulcus was deep and clear. The rostrum protruded anteriorly, distinguishing it from the antirostrum. The notch was deep, the postrostrum extended posteriorly, and the cauda was elongated, bending ventrally at the posterior. This description is similar to that of *Acanthopagrus berda* found in Taiwan [18].

Acanthopagrus latus. The sagittal otolith is elliptic with raised angles on both dorsal and ventral margins (Figure 2.22). Both margins are dentate and serrate. The sulcus is deep and ostial. The rostrum is large, protruding anteriorly, and distinct from the antirostrum. The notch is deep, and the cauda is elongated and flexed posteriorly. This otolith shows similar features to those described in Taiwan [18].

4. Conclusion

The present study provided the first detailed description of the otolith morphology of 22 ray-finned fish (Actinopterygii) species in Xuan Thuy National Park, including 12 species as new data in the world and 10 species as new records for Vietnam. Within the same order, family, or genus, otolith morphology tends to exhibit general similarities; however, detailed structural features often

reveal distinct differences between species, even among those within the same genus. Hence, the results obtained in the present study contribute to proving that otolith can be used for effective and accurate identifications. These findings have important practical implications, contributing to biodiversity conservation and management by enabling accurate species identification based on otolith morphology, particularly for rare, endemic, or threatened species. This provides a scientific basis for proposing effective and appropriate conservation measures. However, this study has some limitations, such as a limited sample size for certain species and the absence of otolith data across different developmental stages. Additionally, the influence of environmental factors on otolith morphology has not been analyzed and should be addressed in future research.

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