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Sagittal otolith morphology and biometric relationships of three snakehead species from the upper Brahmaputra Basin, India

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ABSTRACT

Morphometrics of sagittal otolith of three snakeheads species; *Channa punctata* (Bloch, 1793), *Channa gachua* (Hamilton, 1822) and *Channa striata* (Bloch, 1793) from the upper Brahmaputra Basin, India were investigated. The study revealed variations in otolith sizes and shapes among the three species. Largest sagittal otolith was observed in *C. striata* followed by *C. punctata* and *C. gachua*. Evaluation of relationships of total length and fish weight with sagittal length, width and mass indicated that all the three species are inclined towards a particular otolith morphometric character. The findings of the present study provides novel morphological as well as biometric data for predicting the length and weight of the fishes which may serve as important identification tool for the fishes along with the associated morphometric characters.

INTRODUCTION

North-east India is blessed with diverse aquatic habitats which harbours a rich repository of ichthyofaunal resource including Channid species **(Vishwanath and Geetakumari, 2009)**. The channids, also known as snakeheads are native to Asian and African continents inhabiting in swampy areas and small water bodies **(Ruber *et al.*, 2020)**. The group comprises of three distinct genera; *Parachanna*, *Channa* and *Aenigmachanna* **(Britz *et al.*, 2019; Praveenraj *et al.*, 2019)** and the genus *Channa* shows the highest species diversity with 48 valid species. According to **Praveenraj *et al.* (2020)**, 19 species of *Channa* are reported from Eastern Himalayan region, out of which 11 species are endemic. Three species of *Channa* viz. *Channa punctata*, *Channa gachua* and *Channa striata* are ubiquitous in the upper Brahmaputra basin of Assam, India. Significant work related to their biology (**Dasgupta, 2000; Ali *et al.*, 2013**), ecology **(Goswami *et al.*, 2006)** and taxonomy **(Lakra *et al.*, 2010; Choudhury and Dutta, 2013; Dey *et al.*, 2014)** have been successfully carried out. However, detailed study regarding their otolith morphology and relationships studies are still unavailable. Otoliths or earstones are crystalline structures composing mainly of calcium carbonate and 0.2 to 10% organic matter **(Campana, 1999)**. In most teleost fishes, they are found at the back of cranium and serves as an organ of balancing and hearing in fishes **(Platt and Popper, 1981; Gauldie, 1988)**. Majority of bony fishes consist of three pair of otoliths: lapillus, asteriscus and sagittae, of which the sagittae are the largest in size **(Harvey *et al*., 2000; Zorica *et al*., 2010)**. They shows the highest morphological variability in different groups of fishes **(Kumar *et al*., 2012)** leading to their applications in different otolith related studies. Given their multipurpose utilities, they have been successfully used to study different aspects of fish biology. Morphological characteristics of otoliths have been extensively studied to understand ontogeny of the fish **(Volpedo and Echeverria, 1999; Tombari *et al*., 2005; Gonzalez Naya *et al*., 2012)**, biology and environment **(Gauldie, 1988; Torres *et al*., 2000; Volpedo and Echeverria, 2003)** and paleontological studies **(Carpenter *et al*., 2003; Jawad *et al*., 2011)**. Otoliths are also widely studied for fish phylogeny **(Gaemers, 1984; Nolf, 1985)**, stock identification and relationships **(Smith *et al*., 2002; De Vries *et al*., 2002; Tuset *et al*., 2003; Poulet *et al*., 2004)**, gut content analysis for prey identification **(Reid, 1995; Bowen, 2000)**, ecomorphology **(Torres *et al*., 2000; Volpedo and Echeverria, 2003)** and systematics **(Lombarte *et al*., 1991; Smale *et al*., 1995; Volpedo and Echeverria, 2000)**. Keeping these in view, a detailed study was conducted to understand the otolith morphology of three snakehead species found in upper Brahmaputra basin of India. The present investigation focuses on establishing data about their general otolith morphology as well as their biometric relationship between different otolithmorphometrics such as otolith length, width and mass with that of total length and fish weight of studied species.

MATERIALS AND METHODS

Samples of *C. punctata*, *C. gachua* and *C. striata* were collected from two important fish landing centres of Dibrugarh district in upper Assam, India, from August 2017 to February 2018. Sampling stations included Lezai (27̊ 18' 41.56'' N 94̊ 49' 17.23'' E) and Bogibeel (27̊ 23' 05.47''N 94̊ 47'19.52''E) fish landing centres of Dibrugarh district **(Fig. 1)**. The sampling stations were selected due to high species diversity in those area. Fishes were identified based on the morphological diagnostic characters given by **Vishwanath and Geetakumari (2009)**. Total length (TL) of the sample specimens were measured using a digital verniercalliper to the nearest millimetre (mm). The fishes were weighed to the nearest 0.001g using standard analytical balance (Shimadzu, Japan). The sagittae were extracted out from otic capsules of the specimens and washed in 70% alcohol. The sagittae were allowed to dry and stored in glass vials for further studies. Both left and right sagittae were kept separately. Using digital callipers, otolith length (OL) and otolith width (OW) were measured precisely. The otolith mass (OM) was also measured to the nearest 0.001g. The morphological descriptions of the sagittae were studied following **Tuset *et al*. (2008)**. Log converted simple linear regression model LogY=bLogX+Loga was used to establish the morphometric relationships of OL, OW and OM with TL and FW of the studied species.And paired t-test was performed to detect the difference between right and left sagittae. In case of absence of any significant differences, either one of left or right otolith was selected randomly to establish relationships between different parameters.

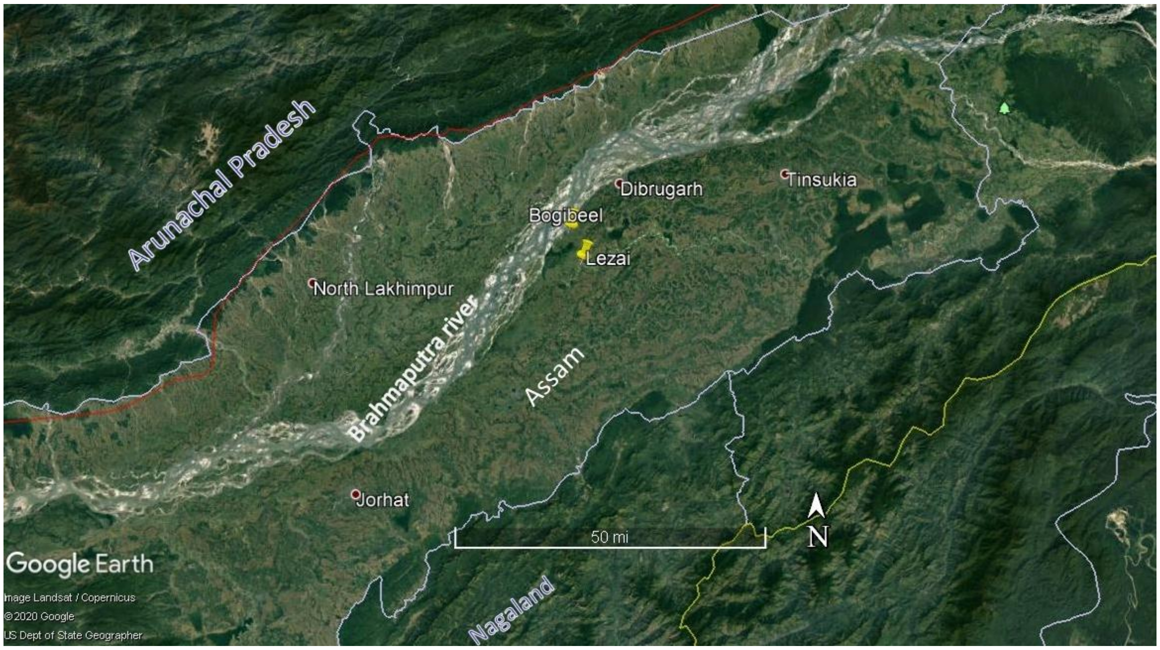

Fig. 1: Geographical location of different sampling sites in Dibrugarh district of upper Assam, India.

RESULTS

1. **Morphological description of sagittal otolith of three different snakeheads**

1.1.*Channa punctata* **(Figs. 2A & 3A)**:
Shape: Pentagonal with entire margin. *Sulcus acusticus*: ostial. *Ostium*: discoidal shaped. *Cauda*: tubular and curved. *Anterior edge*: double peaked. *Posterior edge*: rounded, short and broad rostrum; antirostrum very short and pointed.

1.2. *Channa gachua* **(Figs. 2B & 3B):**
Shape: elliptical with entire margins. *Sulcus acusticus*: ostial. *Ostium*: funnel-like. *Cauda*: tubular and curled away from the posterior margin. *Anterior region*: double peaked; rostrum is short and round; antirostrum very short and double peaked. *Posterior region*: double peaked with very short postrostrum and postantirostrum.

1.3. *Channa striata* (**Figs. 2C & 3C**):
Shape: oval shaped crenate dorsal and ventral edges. *Sulcus acusticus*: ostial type. *Ostium*: funnel-like and shorter than cauda. *Cauda*: tubular, markedly curved and far away from posterior margin. *Anterior edge*: round. *Posterior edge*: round.

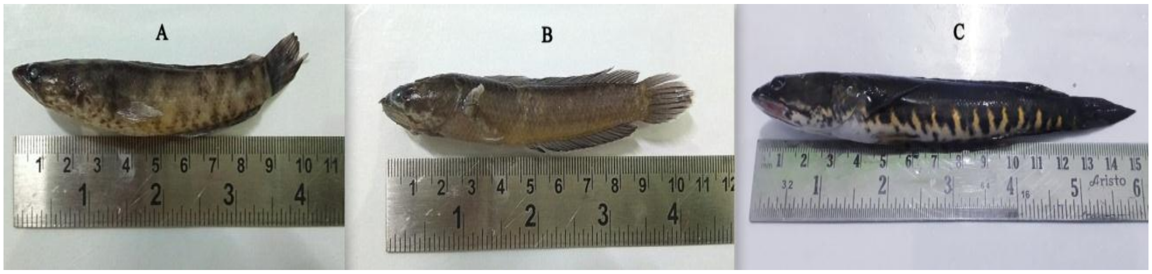

Fig. 2:Three studied species of *Channa*. A. *Channapunctata*B. *Channagachua* C. *Channastriata*

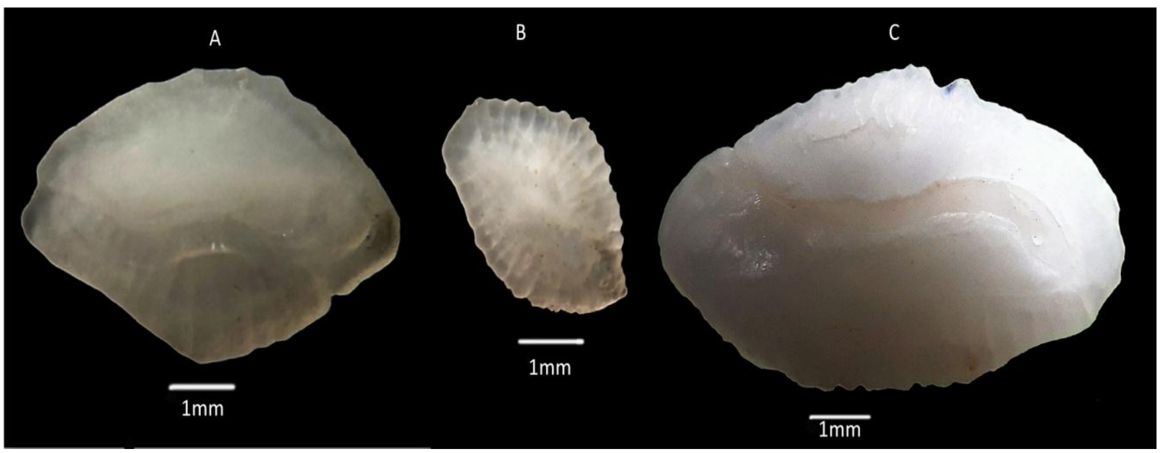

Fig.3:Sagittal otolith of three studied species of *Channa*: A. *Channa punctata* B. *Channa gachua* C. *Channa striata*

2. **Morphometric analysis**

Total 269 (N) specimens of three species of *Channa* (*C.punctata, C. gachua* and *C. striata*) were taken into consideration in the current investigation **(Fig.2)**. The study revealed variation in structure and size of sagittae of the three studied species. Of the three species, largest sagittae was observed in *C. striata* whereas *C. gachua* recorded the smallest otolith **(Table 1)**.

It was observed that all relationships between total length and otolith length, width and mass showed negative allometry (*b*<3) in the three studied species **(Table 2)**. However, relationships between fish weight and otolith length, width showed positive allometry (*b*>3) in *C. punctata* and *C. gachua* **(Table 3)**. In *C. striata*, the same relationship showed negative allometry (*b*<3). In all species, relationship between OM and fish weight showed negative allometry (*b*<3).

Coefficient of determination (r^2) value was determined during relationship studies. r^2 with respect to total length **(Table 2)** was found highest in OL-TL relationship in *C. punctata* (0.80) and lowest in OW-TL relationship in *C. striata* (0.33). Similarly, with respect to fish weight **(Table 3)**, r^2 value was highest in (OL-FW) in *C. punctata* (0.86) and lowest in OM-FW in *C. gachua* (0.43). In all three investigated species, OL gave better estimations for total length and fish weight (r^2 ranged from 0.57 to 0.86) except for *C.striata* where OM provided better result with fish body weight (r^2= 0.76). And it was observed that, in case of *C. gachua*, r^2 values for OL-TL and OW-TL as well as OL-FW and OW-FW were found similar (0.73 and 0.79 respectively).

Table 1: Size ranges of three snakehead fishes from upper Brahmaputra basin, India.

Species	N	TL (cm)	BW (g)	OL(cm)	OW(cm)	OM(g)
Channa punctata (Bloch, 1793)	101	7-14.78	6.5-60.37	0.438-0.759	0.278-0.504	0.012-0.045
Channa gachua (Hamilton, 1822)	94	5.14-14.2	3.17-36.21	0.266-0.464	0.19-0.442	0.001-0.018
Channa striata (Bloch, 1793)	74	15.5-30.1	59.77-269	0.519-1.065	0.336-0.773	0.046-0.139

*N: number of individuals, TL: total length, BW: body weight, OL: otolith length, OW: otolith width, OM: otolith mass.

Table 2: Relationships between total length (TL) and different otolith morphometric characters of three studied species of *Channa*.

Species	Relationships	Length-weight Regression		Parameters of relationships			95% CL	
		a	b	SE (a)	SE (b)	r^2	a	b
C.punctata	OL -TL	1.2815	1.1834	0.0147	0.0591	0.80	1.2523-1.3107	1.0660-1.3007
C. gachua		1.4921	1.2838	0.0353	0.0798	0.73	1.4219-1.5623	1.1252-1.4425
C.striata		1.4095	0.7959	0.0078	0.0759	0.60	1.3938-1.4252	0.6446-0.9473
C.punctata	OW-TL	1.4764	1.1383	0.0262	0.0617	0.77	1.4242-1.5286	1.0157-1.2608
C. gachua		1.5681	1.1016	0.0400	0.0698	0.73	1.4868-1.6495	0.9629-1.2403
C.striata		1.5491	0.7113	0.0319	0.1168	0.33	1.4854-1.6129	0.4784-0.9442
C.punctata	OM-TL	1.7439	0.4584	0.0461	0.0279	0.73	1.6578-1.8408	0.4029-.5239
C. gachua		1.6527	0.3373	0.804	0.0375	0.46	1.4929-1.8124	0.2626-0.4120
C.striata		1.8900	0.5044	0.0520	0.0485	0.59	1.7862-1.9937	0.4076-0.6011

*OL: otolith length, OW: otolith width, OM: otolith mass, TL: total length, a: intercept, b: slope, SE: standard error, r^2: coefficient of determination, CL: confidence limit.

Table 3: Relationships between fish weight and different otolith morphometric characters of three studied species of *Channa*.

Species	Relationships	Length-weight Regression		Parameters of relationships			95% CL	
		a	b	SE (a)	SE (b)	r^2	a	b
C.punctata	OL -FW	2.1450	3.6534	0.0357	0.1439	0.86	2.0741-2.2159	3.3678-3.9389
C. gachua		2.6757	3.8922	0.0914	0.2077	0.79	2.4940-2.8574	3.4795-4.3049
C.striata		2.2720	1.5882	0.0164	0.161	0.57	2.2392-2.3046	1.2654-1.9111
C.punctata	OW-FW	2.7098	3.4333	0.0624	0.1461	0.84	2.5860-2.8337	3.1432-3.7233
C. gachua		3.0079	3.4663	0.1081	0.1851	0.79	2.7932-3.2227	3.1186-3.8541
C.striata		2.6344	1.7450	0.0592	0.2624	0.47	2.5163-2.7526	1.3129-2.1771
C.punctata	OM- FW	3.6179	1.4451	0.1102	0.0670	0.82	3.3992-3.8367	1.3120-1.5781
C. gachua		3.0213	0.9565	0.2421	0.1133	0.43	2.5404-3.5023	0.7316-1.1820
C.striata		3.4923	1.2567	0.0875	0.0817	0.76	3.3178-3.6668	1.0936-1.4197

*OL: otolith length, OW: otolith width, OM: otolith mass, FW: fish weight (g),
a: intercept, b: slope, SE: standard error, r^2: coefficient of determination, CL: confidence limit.

DISCUSSION

Morphometrics of saccular otoliths have been widely used to understand the biology of fishes. They have unique form, weight, growth, consistency and chemical composition **(Zorica *et al*., 2010)** and are easy to access **(Nolf, 1985)**. Morphometric relationships of sagittae of Indian freshwater fishes are very scanty. Our current study on morphometrics of sagittal otolith of three species of *Channa* is the first detailed study on this genus. The results of the current study revealed variation in sagittal shape and size in the three snakehead species. Differences were observed overall sagittal shape, cauda, anterior and posterior edges. Similarity was observed only in sulcus acusticus. These morphological characters are considered to be relevant in fish identification as they show variations among them **(Tuset *et al*., 2008)**. In this regard, **Sonowal *et al*. (2020)** had established taxonomic keys based on sagittal characters of seven species of *Channa* from the upper Assam region of India. Biometric relationship of total length (TL) and fish weight (FW) of three *Channa* species with different otolith variables showed that each species has their own specificity and leans towards a particular otolith morphometric character. Similar result were also observed on studies of morphology as well as morphometrics of sagittal characters such as otolith length, width and mass in Cichilids, Gobids and halfbeaks was found to be species specific **(Gaemers, 1984; Bani *et al*., 2013; Jaramillo *et al*., 2014; Sonowal *et al*., 2020)**. In the present study, otolith length of *C. punctata* and *C. gachua* showed highest linearity towards both total length and fish weight whereas in *C. striata*, it was otolith mass whose highest linearity towards fish weight. The observed linear relationships between otolith measurements and body size is influenced by growth rate and different developmental stages of the species **(Mugaya and Tanaka, 1992; Campana, 2004)**. Linear relationships of otolith mass towards fish weight in *C. striata* may be due to larger sagitta size as compared to the other studied species.Studies also revealed thatotolith mass is highly sensitive to variations in growth rate as well as change in fish metabolism **(Reznik *et al*.,1989; Secor and Dean, 1989; Pawson, 1990).** Furthermore, otolith mass shows an increasing trend over time with greater proportion than otolith length and otolith width **(Munk and Smikrud, 2002)**. Earlier investigations also observed that otolith length is appropriate for predicting length of small sized fishes while otolith mass for larger sized one due to the precision in measuring otolith mass **(Hunt, 1992)**.

In some earlier reports, it was observed that prediction of size of a fish by considering a single morphometric character alone is not encouragable **(Park *et al*., 2018)**. Hence, it is essential to use all the three morphometric characters of otolith to assess and analyze biometric data of fishes. In otolith study, there are possibilities of getting mechanical damage during its extraction process. The variations observed in otolith characters in fishes may be due to combination of certain factors. Many researchers have put possible reasons for such variations. **Volpedo and Echeverria (1999)** observed that variations in $CaCO_3$ deposition during sagittae development contributes major factor in variations of otolith characters. Similar result was also observed in sciaenids found in Northwest Coast of India **(Kumar *et al*., 2012)**. **Bani *et al*. (2013)** also suggested that morphological, anatomical as well as cytological characteristics of the skull might play crucial role in variation in morphometrics of sagittal otolith. And environmental factors such as water temperature, depth, mineral and food availability **(Lombarte and Fortuno, 1992; Lombarte and Lleonart, 1993; Arellano *et al*., 1995; Aguirre and Lombarte, 1999)** also play an important role in interspecific variation of otolith characters. Similarly, fish growth **(Campana, 2004)**, structure and location of biological factors such as bovine carbonic anhydrase, bovine serum albumin, carboxymethyl chitosan and glutamic acid **(Li *et al*., 2010)** also contribute the same variation in otolith. Therefore, it is necessary that both biometric data as well as otolith morphology are taken into consideration in estimating fish size as well as their taxonomy among the three studied snakehead species.

CONCLUSION

Analysis of morphometric relationships of sagittae of three species of *Channa* with total length and body weight indicated that otolith length, width and otolith mass could be good indicators for predicting the length and weight of the studied fishes. However, all otolith variables are needed to be taken under consideration for estimation of fish sizes. For precise estimations, the employed regression equations in the current study may be used for similar size group of the fishes. Data generated from the present study might be useful in better understanding of the ontogeny, taxonomy,fish phylogeny, biology and ecology of the studied species in near future.

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