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Note

Relationship between fish and otolith dimensions of flathead sillago *Sillaginopsis panijus* (Hamilton, 1822) (Perciformes: Sillaginidae) in the north-western Bay of Bengal

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ABSTRACT

The present study established the fish body and otolith dimension relationships of flathead sillago *Sillaginopsis panijus* (Hamilton, 1822), to assist the interpretation of growth. A total of 413 specimens were collected fortnightly from September 2018 to August 2019 off north-western Bay of Bengal. The samples ranged between 142-394 mm in total length and 16-413.1 g in total weight. With fish growth, positive correlation was observed between the fish and otolith morphometric parameters. The highest coefficient of determination (R^2) was observed between total length and otolith weight (R^2=0.9198), followed by otolith weight and otolith width (R^2=0.896). These results provide baseline information on the dimensional relationship between fish length and otolith size of this species in Indian waters, which will be helpful in future studies on food and feeding habits, growth and stock structure.

Keywords: Coefficient of determination, Correlation, Growth rings, Life history, Morphometry, Sagitta

Otoliths play an important role as it records the information on life history of fishes and are useful for studying fish ecology, fish age, growth and ontogeny (Gerard and Malca, 2011). It is also used in palaeontology (for identification of fossil fishes), stratigraphy, archaeology, zoogeography (Tuset *et al*., 2008; Aguilera *et al*., 2013), stock identification (Begg and Brown, 2000) and for studying feeding habits (Tarkan *et al*., 2007). They are responsible for the balance, orientation and auditory reception in fishes (Campana, 2004; Bostanci *et al*., 2015). Fish otolith varies with the size and shape among the species and individuals and so is the most commonly used hard part for morphometric analysis (Eroglu and Sen, 2009). Due to large size and distinct growth rings, the left sagittal otolith is commonly used to determine the age and growth of fishes (Beamish and Chilton, 1982; Boehlert, 1985; Summerfelt and Hall, 1987). The shape and size of otoliths also vary between cold water and warm water species (Torres *et al*., 2000). As there is no information on the dimensional relationship of otolith and fish size of *Sillaginopsis panijus* (Hamilton, 1822), the present study was undertaken to establish the relationship between otolith and fish body morphometry.

The relationship between length of fish and otolith gives a significant estimation for fish size and biomass in their natural habitat (Echeverria, 1987; Gamboa, 1991; Martin-Smith, 1996; Garcia *et al*., 1998; Waessle *et al*., 2003). Relationship between the total length and otolith dimensions is very crucial for establishing prey-predator relationships (Zan *et al*., 2015), since the equational relationship of fish size from otolith size of more species from a particular area provides details on the trophic interaction among species (Aneesh Kumar *et al*., 2017a). Relationship between fish length and otolith size has been used successfully by several authors (Battaglia *et al*., 2010; Humston *et al*., 2015; Zan *et al*., 2015; Yilmaz *et al*., 2015) for species management studies. All these applications of otolith are very much pertinent in the area of pollution, overfishing, habitat degradation and climate change to conserve and manage a fish stock and its habitat.

The family Sillaginidae comprises 14 species along the Indian coast (Froese and Pauly, 2019) and 6 species along the north-western Bay of Bengal (Barman *et al*., 2007). Flathead sillago *Sillaginopsis panijus* (Hamilton, 1822), a monotypic species under family Sillaginidae is a demersal inshore marine and estuarine fish distributed in Pondicherry located northward along the Coromandel coast in India, Padma delta of Bangladesh, Myanmar, southward to Malaysia and rarely in the Indonesian

Archipelago (Krishnayya, 1963; McKay, 1992). It fetches high price ($2.8-4.9) due to its high demand, especially along north-western Bay of Bengal. The species forms an important fishery along the coast of India. It is mostly targeted by gillnets and shore seines in inshore and estuarine waters, whereas less catch is observed in trawls. The preferential food items are crustaceans, algae and fish (Mookerjee *et al*., 1946). Even though the species holds significance along the Indian coast, particularly the north-western Bay of Bengal, there is no information available on the biological parameters. Hence, the present study aimed to analyse the fish and otolith dimensions, which will serve as baseline information for further study on age, growth, stock structure and biomass for the management of the species.

Specimens of *S. panijus* were collected fortnightly from various locations *viz,* Kirtonia (21º34'20.0784''N; 87º22'32.4336"E), Bahabalpur (21º30'46.6812"N; 87º6'54. 2484"E), Balaramgadi landing centres (21º28'22.5048''N; 87º3′18.9792″E) and Dhamra (20º47'34.89''N; 86º54'01.38''E) and Paradeep fishing harbours (20º17'22.97''N; 86º42'25.51''E) in the north-western Bay of Bengal between September 2018 and August 2019 (Fig. 1). Specimens were collected using various gear types such as trawls (30-35 mm mesh size), gillnets (15-55 mm mesh size) and shore seines (7-15 mm bag mesh size). Fishes were transported to Puri Field Centre of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI), Odisha, for further study. A total of 413 specimens were collected during the observation period. The total length (TL) and total weight (TW) of the fish was measured to the nearest 1 mm and 0.01 g respectively.

The sagittal otoliths were removed from the fish head by "up through the gills method" (Secor *et al*., 1992). A total of 826 otoliths were removed from 413 individuals. The otoliths were cleaned with water, air-dried and stored in individual vials. The length (OL), width (OW) and weights (OWE) of the otoliths were recorded. OL was measured as the greatest distance between anterior and posterior otolith margin and OW as the greatest distance from dorsal to the ventral margin of otolith (Fig. 2). For measuring the otolith size, images were taken under a stereo microscope linked to a video camera at 1.25X resolution and otolith length and width were measured using imaging software (Digimizer) to the nearest 0.01 µm. The OWE were measured using electronic balance (Aczet CY 224) with an accuracy of 0.0001 g. The left and right otoliths were measured separately. Damaged and broken

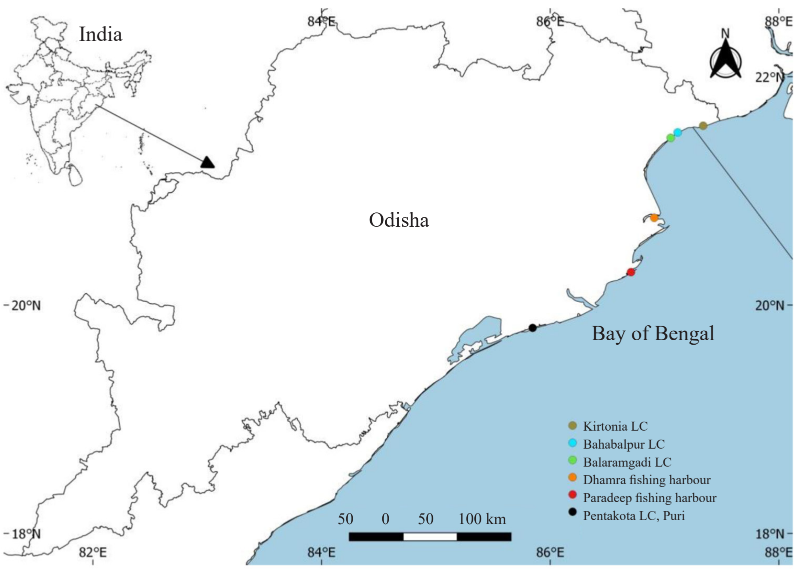
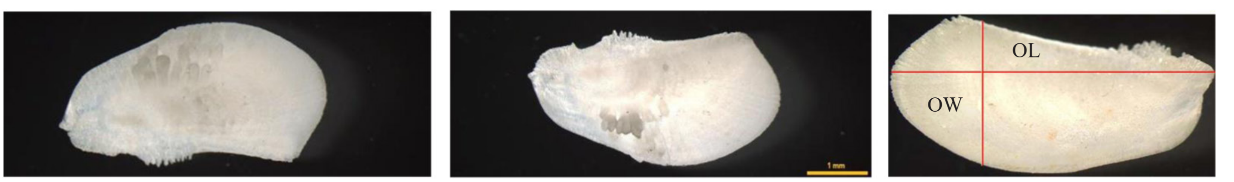


Fig. 1. Map showing sampling sites of *S. panijus*



(a) (b) (c)

Fig. 2. Otolith of *S. panijus.* (a) Left otolith, (b) Right otolith, (c) Otolith length (OL) and Otolith width (OW)

otoliths were not considered in the study. As paired t-test showed that the differences between right and left otoliths were not significant (p>0.05), only one otolith (left otolith of 413 numbers) was used and analysed for the relationship with fish length.

The relationship between the otolith size (OL, OW and OWE) and fish size (total length-TL and total weight-TW) was determined using both exponential and linear regression models (Zar, 1984). The linear regression equation and exponential equation used to understand the relationship between fish length and different otolith measurements was in the form $Y = a + b \times X$ (linear) and $Y = a \times X^b$ formats, respectively; where a is the intercept and b the coefficient value (slope). The coefficient of determination (R^2) was also estimated to understand the strength of the relationships. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS 22.0) and regression models were compiled under Excel software (Microsoft Excel, 2007) for determining the relationships between fish size and otolith size. The significance level of the dimensional relationship was p<0.05.

A total of 413 specimens of *S. panijus* were considered for the present study with the range of total length and total weight between 142-394 mm and 16-413.1 g respectively. The details of mean and range of fish body and otolith measurements is mentioned in Table 1. The homogeneity of variances was not significant (Levene's test, p>0.05) between the left and right otolith and therefore, either of the otoliths can be considered for age studies in *S. panijus*.

The regression analysis showed that a moderate to strong positive relationship between the total length-otolith length, total length-otolith width, total length-otolith weight, total weight-otolith length, total weight-otolith width, total weight-otolith weight, otolith length-otolith width, otolith length-otolith width and otolith weight-otolith width existed (Table 2, Fig. 4). The linear regression model showed that there was a medium to strong correlation existing between fish length-otolith length (R^2=0.84) and fish weight-otolith weight (R^2=0.87). However, the highest coefficient of determination (R^2) was observed between total length and otolith weight (R^2=0.92), followed by otolith weight and otolith width (R^2=0.9).

Table1. Fish body and otolith parameters (n = 413)

Parameters	Mean±SD	Range
Total length (mm)	259.13±52.15	142-394
Total weight (g)	119.27±81.64	16-413.1
Otolith length (mm)	3.844±0.41	2.64-4.95
Otolith width (mm)	2.143±0.28	1.41-2.9
Otolith weight (g)	0.039±0.01	0.01-0.07

All the morphometric relationships in this study showed a strong correlation with each other. The fish body measurements with the otolith measurements had a direct positive correlation indicating that the otolith grows substantially with fish growth. The otolith is helpful in the identification of the species and the linear relationship between the fish length and otolith length is useful in determining fish length from the otolith length (Souza *et al*., 2019). There are well-documented studies in Indian perspective from other species (Jawad *et al.,* 2011; Kumar *et al*., 2012; Aneesh Kumar *et al.,* 2017a, b), but till date no such study on *S. panijus* has been conducted around the globe. The present study forms the first report on this species regarding fish measurement-otolith measurement relations in this species. However, the growth rings of *Sillago sihama* (Forsskal, 1775), which belongs to the same family of *S. panijus*, have been observed and studied along the Indian coast (Radhakrishnan, 1954). The changes in the length, width and weight of the otolith are good fit to the fish total length, than the fish total weight. The alterations of fish size-otolith size relation is due to the large changes in the age, sex composition, changes in fishing regulation in terms of gear restriction and fishing strategies (more common in tropical species) and different methods used for analysis (Clark, 1992; Ma *et al*., 2010). For *S. panijus*, fishing continues year round despite the regulation of fishing ban during mid of April to mid of June, as this species is mostly available in the inshore and estuarine waters, where fishing is allowed even during the ban period. Morphology and morphometric studies are a promising approach for stock identification, but interpreting patterns of variance is difficult (Kumar *et al*., 2012). The otolith size also changes and differs in different size ranges of the fish (Fig. 3). These variations are due to the $CaCO_3$ deposition in the sagitta and the effect of biological factors during different developmental stages (Echeverria and Volpedo, 1999; Wei *et al*., 2010). In adults, the calcium deposition is more in the front part of the otolith which facilitates increase in the length of the otolith. Fish otolith microchemistry also plays a promising role in fish life history studies, but the limitations associated with the high cost and requirement of sophisticated instruments, makes this method complex. Hence, the relation between otolith length and weight measurements and the length-weight of fish is the simplest method for finding the information on a population or stock (Souza *et al*., 2019).

For further investigations on stock assessment and for studying the population dynamics of the species, monthly measurements of the otolith dimensions are to be considered. During the sampling period, care was taken to cover all the size ranges of the specimens and therefore, results of the present study provide baseline

Table 2. Regression equation and coefficient of determination (R^2) for linear and exponential relations between the body and otolith measurements and among the otolith measurements

Relationship	Regression equation		R^2	
	Linear	Exponential	LR	ER
TL *vs* OL	$y = 0.0072x + 1.9708$	$y = 2.3414e^{0.0019x}$	$R^2 = 0.84$	$R^2 = 0.83$
TL *vs* OW	$y = 0.0051x + 0.8183$	$y = 1.1449e^{0.0024x}$	$R^2 = 0.87$	$R^2 = 0.87$
TL *vs* OWE	$y = 0.0003x - 0.0293$	$y = 0.0063e^{0.0068x}$	$R^2 = 0.92$	$R^2 = 0.92$
TW *vs* OL	$y = 0.0043x + 3.3259$	$y = 3.3448e^{0.0011x}$	$R^2 = 0.77$	$R^2 = 0.71$
TW *vs* OW	$y = 0.0031x + 1.7731$	$y = 1.7934e^{0.0014x}$	$R^2 = 0.78$	$R^2 = 0.75$
TW *vs* OWE	$y = 0.0002x + 0.0196$	$y = 0.0227e^{0.004x}$	$R^2 = 0.87$	$R^2 = 0.79$
OL *vs* OW	$y = 0.6463x - 0.3416$	$y = 0.6619e^{0.3033x}$	$R^2 = 0.86$	$R^2 = 0.87$
OL *vs* OWE	$y = 0.0325x - 0.0856$	$y = 0.0014e^{0.8514x}$	$R^2 = 0.86$	$R^2 = 0.9$
OW *vs* OWE	$y = 0.0476x - 0.0629$	$y = 0.0026e^{1.2323x}$	$R^2 = 0.9$	$R^2 = 0.9$

(a) (b) (c)

Fig. 3. Variation of size and shape of otolith with increment in body size of *S. panijus.* (a) TL = 159 mm, TW = 20.5 g, OL = 2.92 mm, OWE = 0.0181 g; (b) TL = 263 mm, TW = 98.2 g, OL = 3.954 mm, OWE = 0.0444 g; (c) TL = 360 mm, TW = 363.1 g, OL = 4.826 mm, OWE = 0.076 g

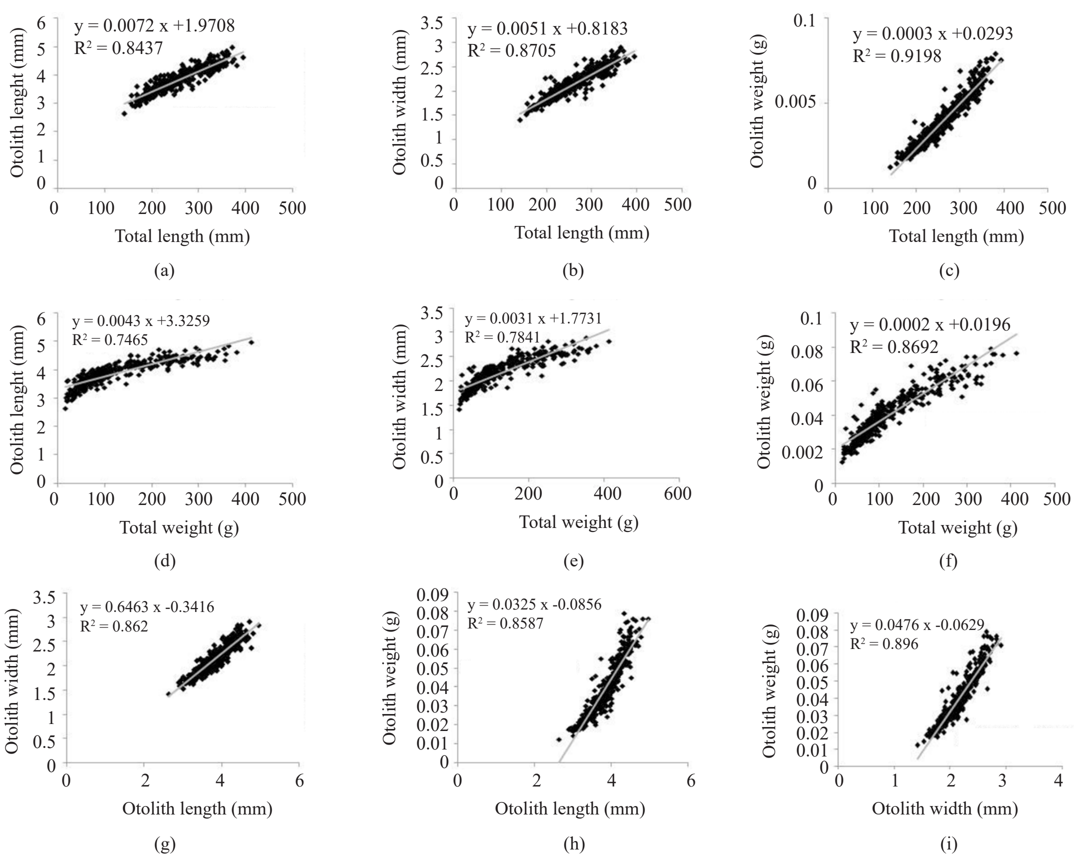


Fig. 4. Relationship between the fish size-otolith size and among the otolith measures of *S. panijus*

information on relationship between fish and otolith dimensions of the species in the north-western Bay of Bengal which will be helpful for formulating management and conservation measures in future.

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