Indian J. Fish., 67(4): 138-142, 2020
DOI: 10.21077/ijf.2020.67.4.97732-16

Note

Otolith measurements to estimate standard length of gobiid fish (Teleostei: Gobiiformes) from the Persian Gulf and Oman Sea

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ABSTRACT

The relationship between morphometric characters (length, weight and height) of otolith and fish standard length was determined for six intertidal gobiid species from the northern Persian Gulf and Oman Sea. A total of 144 sagittal otoliths were extracted and anlysed from *Periophthalmus waltoni, Boleophthalmus dussumieri*, *Scartelaos tenuis*, *Istigobius ornatus*, *Bathygobius meggitti* and *Trypauchen vagina*. Regression equations were derived and found that there is no significant difference in regression coefficients between left and right otoliths of the species studied. Results of the study showed that otolith length (OL) and height (OH) could estimate standard length in all the species studied except in *T. vagina*, where the otolith weight gave the best estimate of standard length. Results clearly indicated that otolith dimensions of the gobiid fishes studied could provide information about the species and size.

Keywords: Body size, Gobiiformes, Otolith dimensions, Regression

Gobiid fishes belonging to the order Gobiiformes are the most diverse group of teleostean fishes that live in salt, brackish and freshwater environments of tropical to sub-tropical waters (Nelson *et al*., 2016). They inhabit mangrove swamps, coral reefs, mudflats and rocky ecosystems and are important prey for some top predators such as birds and some fishes (Polgar and Lim, 2011). Identification and determining the size of fish species are an important part of trophic studies of top predators that usually require the analysis and identification of hard remains found in food samples in the digestive system (Ayllon *et al*., 2006). Examining the digested food remains such as scales and bones from stomach of predators is a way to identify the prey (Venu and Kurup, 2002; Akhilesh *et al*., 2013) and in some cases, these structures gives unrealistic information about prey and their size (Longenecker, 2008).

Fish ear stones (otoliths) are reliable hard structures that can simplify identification of prey and provide useful information about fish biomass by specific regression analysis of otolith dimension and weight (Waessle *et al*., 2003; Aneesh Kumar *et al*., 2017). Otolith is not digested in stomach of predators, so this structure is used to determine type and size of fish species. Otolith is calcareous structure located in the inner ear of teleostean fish (Popper *et al*., 2005). Among three types of otoliths, sagittae have diverse morphology in most groups of fish and employed in taxonomy (Lombarte *et al*., 2018), paleontology (Reichenbacher *et al*., 2018) and fisheries management (Carlson *et al*., 2017).

Reconstruction of size and mass of fish species from the sagitta found in stomach contents or faeces of predators may provide significant contributions to the understanding about food chain of predators. Several studies have documented relationship between sagittal morphometry and fish body sizes (Longenecker, 2008; Jawad and Al-Mamry, 2012; Aneesh Kumar *et al*., 2017). However, studies on relationships between otolith morphometry and weight with fish body measurements are unavailable for intertidal gobiid fishes from the Persian Gulf and Oman Sea. So, this study was undertaken to provide information about otolith morphology and the relationship between otolith measurements and fish body size of six gobiid species from the coastal waters of the northern Persian Gulf and Oman Sea. The data may be useful for researchers who would study food webs of predators to identify and determine the size of prey from recovered otolith.

Sampling was done during 2016-2017 from five sites of Iranian coastal waters of the Persian Gulf and Oman Sea (Table 1). Collected specimens were immediately euthanised using clove oil, fixed in 10% formalin and preserved in 70% ethanol. In the laboratory, the fishes were identified upto species level following Murdy (1989) and Carpenter and Niem (2001) and six species *viz*., *Periophthalmus waltoni* Koumans, 1941; *Boleophthalmus dussumieri* Valenciennes, 1837; *Scartelaos tenuis* (Day, 1876); *Istigobius ornatus* (Ruppell, 1830); *Bathygobius meggitti* (Hora and Mukerji, 1936) and

Table 1. Details of thespecies studied for otolith dimensions from five collection sites of the Iranian coastal waters of the Persian Gulf and Oman Sea

Family	Species	Sampling sites		N	Otolith height (OH) (Range)	Otolith length (OL) (Range)	Otolith weight (OW) (Range)	Standard length (SL) (Range)
		Location	Geographic Coordinates					
Gobiidae	*B. meggitti*	Oman Sea-Chabahar	N 25°20' E 60°36'	15	0.98-1.88	0.95-2.43	0.7-3.1	24.74-55.13
	T. vagina	Persian Gulf-Bandar Abbas	N 27°05' E 56°50'	18	3.5-4.6	2.73-3.42	11.6-23.2	123.92-142
	I. ornatus	Oman Sea-Chabahar	N 25°20' E 60°36'	35	1.31-2.57	1.28-2.7	0.3-4.1	21.33-78.77
Oxudercinae	*P. waltoni*	Persian Gulf-Minab	N 27°05' E 56°50'	39	2.36-4.13	2.54-4.21	2.3-20.8	49.63-101.78
	S. tenuis	Persian Gulf-Qeshm Island	N 26°59' E 56°12'	22	1.8-2.93	2.29-3.38	2.1-7.8	57.15-106.73
	B. dussumieri	Persian Gulf-Mahshahr	N 29°57' E 48°36'	15	1.76-5.15	1.92-4.76	1.5-21.4	37.59-123

N: Number of each specimens; Weight in mg; Otolith dimensions and standard length in mm

Trypauchen vagina (Bloch and Schneider, 1801) were recorded. In the next step, standard lengths (SL) of each specimens were measured using 0.01 mm digital vernier calipers (Hangzhou Maxwell Tools Co. Ltd, Zhejiang, China).

Sagitta was extracted from each side of the cranium, cleaned with 1% KOH followed by distilled water, dried and stored in labelled tubes. A total of 144 sagittal otoliths from six species belonging to two family *viz.,* Gobiidae and Oxudercidae were studied. Sagittae were photographed with Dino-lite camera mounted on a stereomicroscope (Olympus SZ-ST, Japan). Maximum otolith length (OL= Distance between the most anterior portion and the most posterior portion of otolith) and maximum otolith height (OH = Distance between the most dorsal portion and the most ventral portion of otolith) were measured to the nearest 0.01 mm by Dino capture software 2.1 (Fig. 1). The otolith weight (OW) was recorded to the nearest 0.01 mg using a digital scale.

In this study, we used power regressions ($y = ax^b$) to determine the relationship between otolith measurements (otolith length, height and weight) and standard length of gobiid fishes as in earlier studies (Tuset *et al*., 2010; Valinassab *et al*., 2012; Gimenez *et al*., 2016). The parameters of the power regressions *a* (intercept) and *b* (slope) were expressed by linear regression of the log transformed data (Koutrakis and Tsikliras, 2003). The calculated parameters of left and right otoliths were compared using *t*-test to investigate for any differences between these**.**

General morphology of sagitta in the species studied are shown in Fig. 1. Otoliths in all gobiid species were characterised by median and mesial sulcus and absence of rostrum, antirostrum, pseudorostrum and pseudoantirostrum. The sagitta of *I. ornatus* (Fig. 1d) and *S. tenuis* (Fig. 1c) are slightly similar to each other, in both species the sagittal otolith is square to rectangular in shape and dorsal rime anteriority elevated. In *I. ornatus,* dorsal and ventral margins are slightly crenate but in *S. tenuis* dorsal and ventral margins are smooth. *B. meggitti* otolith (Fig. 1e) has rectangular shape and the whole margin is smooth. Otolith of *T. vagina* is C shape (Fig. 1f), moderately elongate and moderately thick with *sulcus acusticus* median and small. The otoliths of *B. dussumieri* (Fig. 1b) and *P. waltoni* (Fig. 1a) are almost similar, the main difference is that whole rime of otolith of *B. dussumieri* has an irregular ruble.

Overall information on the six gobiid species studied for otolith dimensions is provided in Table 1. Among the species studied, otolith of *T. vagina* was the largest (OH = 3.88±0.28 mm; OL = 3.01±0.18 mm; OW = 18±3.95 mg; SL = 135.81±10.36 mm) and otolith of *B. meggitti* was observed to be smallest (OH = 1.48 ±0.26 mm; OL = 1.66±0.37 mm; OW = 1.32±0.61 mg; SL = 37.97±5.24 mm).

There was no statistically significant difference in regression coefficients between right and left otoliths. The relationship between otolith dimensions and weight with standard length of the species studied are shown in Table 2. A high value of the coefficient of correlation (R^2=0.95) and the lowest R^2 (0.54) were reported for otolith weight and otolith height of *T. vagina* respectively. Among the otolith parameters studied, otolith length calculated the best estimations of standard length of *P. waltoni* (R^2 = 0.88) and *B. dussumieri* (R^2 = 0.86). Otolith height of *S. tenuis*, *I. ornatus* and *B. meggitti* could determine more than 85% of fish standard length. Otolith weight was found to have high value of coefficient of correlation (R^2>0.80) in *B. dussumieri*, *T. vagina* and *S. tenuis* (Table 2). Among the otolith measurements, otolith length and height could predict more than 80% of the standard length of five species (Table 2).

Ear stone (otolith) is species-specific calcareous structure in the inner ear of the teleostean fish that has been used in ichthyology research (Schulz-Mirbach *et al*., 2019). Otolith morphology and morphometry are useful tools to identify fish species, paleontology research and to determine length-weight relationship of fishes (Sadighzadeh *et al.,* 2012; Park *et al.,* 2018; Reichenbacher *et al*., 2018). Although some studies have

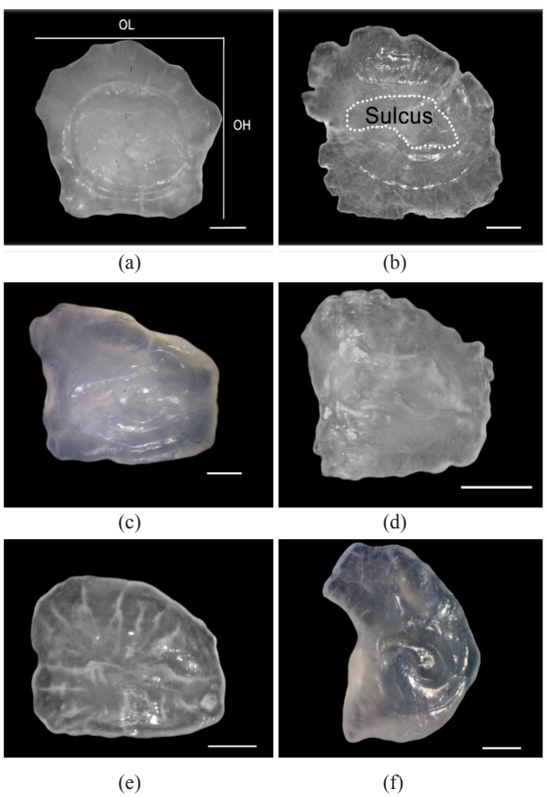

Fig. 1. Light microscope image of otolith from various species studied. (a) OL= Maximum otolith length; OH = Maximum otolith height. Family Oxudercinae: a - *P. waltoni*, b - *B. dussumieri*, c - *S. tenuis.* Family Gobiidae: d - *I. ornatus*, e - *B. meggitti*, f - *T. vagina*. Scale bar = 1 mm

been done to determine the relationship between otolith measurements and body size of fishes from the Persian Gulf and Oman Sea (Jawad *et al*., 2012; Dehghani *et al*., 2016), information on otolith of gobiid fish from this region was unavailable so far.

Results of this study showed otolith length and height could estimate more than 80% of the standard length of the species studied, except in *T. vagina*, where the otolith weight gave the best estimate of standard length (95%). The strong correlation between otolith dimensions and body size of fish suggests that somatic growth has a significant effect on otolith growth (Munk, 2012).

Factors such as distribution area, sex, ontogeny and chemical parameters of water would affect the shape and dimension of otolith (Karakulak *et al.*, 2006; Reichenbacher *et al.*, 2009; Bignami *et al.*, 2013). However, otolith is an accurate structure to identify and back calculate the prey biomass while examining stomach contents of predators (Battaglia *et al.*, 2015; Lombarte *et al.*, 2018).

In conclusion, our results showed that the shape and dimensions of the otolith (length, height and weight) of the gobiid fishes studied may be able to provide us with information about the species and size. Derivation of specific equations to determine standard length from otolith measurements for each species can provide basic information for feeding studies of the top predators in the Persian Gulf and Oman Sea.

Table 2. Regression parameters of relationship between otolith measurements and standard length of six species of gobiid fishes from the north Persian Gulf and Oman Sea

Species	Regression parameters							
	Relationship	a	SE (a)	95% CL	b	SE (b)	95% CL	R^2
B. meggitti	OL vs. SL	25.05	1.052	22.44-27.95	0.812	0.094	0.60-1.01	0.85
	OH vs. SL	25.09	1.047	22.68-27.75	1.034	0.87	0.79-1.27	0.87
	OW vs. SL	34.06	1.042	31.13-37.27	0.432	0.09	0.22-0.64	0.60
T. vagina	OL vs. SL	72.76	1.08	60.93-86-8	0.538	0.075	0.37-0.69	0.75
	OH vs. SL	71.45	1.14	53.23-75.31	0.45	0.1	0.23-0.67	0.54
	OW vs. SL	79.31	1.029	74.620-84.3	0.18	0.01	0.15-0.21	0.95
I. ornatus	OL vs. SL	16.50	1.09	14.04-20.53	1.60	0.12	1.31-1.82	0.83
	OH vs. SL	16.44	1.09	13.74-19.67	1.76	0.12	1.49-2.02	0.85
	OW vs. SL	39.82	1.04	36.14-42.98	0.44	0.05	0.35-0.55	0.72
P. waltoni	OL vs. SL	19.42	1.078	16.65-22.64	1.10	0.064	0.97-1.23	0.88
	OH vs. SL	21.51	1.08	18.33-25.24	1.09	0.071	0.94-1.23	0.86
	OW vs. SL	39.81	1.065	34.98-45.31	0.28	0.03	0.21-0.34	0.69
S. tenuis	OL vs. SL	21.71	1.17	13.06-25.32	1.23	0.14	1.10-1.72	0.81
	OH vs. SL	22.05	1.11	17.47-27.83	1.49	0.12	1.22-1.75	0.87
	OW vs. SL	41.47	1.07	35.40-48.77	0.41	0.04	0.32-0.52	0.80
B. dussumieri	OL vs. SL	19.11	1.18	13.84-28.39	1.14	0.123	0.86-1.40	0.86
	OH vs. SL	23.35	1.16	17.04-33.38	1.13	0.12	0.83-1.39	0.85
	OW vs. SL	36.20	1.10	29.6-46.12	0.39	0.04	0.28-0.47	0.86

OL: Otolith length, OH: Otolith height, OW: Otolith weight, SL: Standard length. R^2: Coefficient of determination, SE: Standard error, a: Intercept, b: Slope

Acknowledgements

The authors thank M. Rajaei and N. Sabbah for their kind help during fish sampling.

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Date of Receipt : 04.02.2020
Date of Acceptance : 24.09.2020