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ORIGINAL ARTICLE

Relationships between sagittal otolith and fish dimensions in Silver sillago, *Sillago sihama* (Fabricius 1775) in the Persian Gulf

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Abstract
The relationships between sagittal otolith dimensions and fish sizes are estimated for Silver Sillago (*Sillago sihama*) from the Persian Gulf. Three dimensions of the otolith (length, width and weight) were shown to be suitable factors for prediction of the length and weight of fish in this species based on calculated coefficients of determination values in linear and exponential regression relationships (r^2>0.76). There were no significant variations observed between the sizes of the left and right otoliths. The provided data will be useful for estimating fish size based on remnant otoliths in related studies in the Persian Gulf.

Keywords: Sillaginidae, Fish Ecology, Sagitta, Sillver sillago.

INTRODUCTION

The otoliths (inner ear) of teleost fish are three pairs of calcareous structures, including sagitta, asteriscus, and lapillus (Carlström 1963; Smale et al. 1995). There is a significant difference in the size of these structures. However, sagittal otoliths are commonly bigger and used more frequently for taxonomic and biological research (Morat et al. 2002; Bani et al. 2013). Otoliths morphology is one of the most valuable anatomical characters for taxonomic studies (Campana 2004). The fish size could be estimated by analyzing the relationship between the otolith and fish dimensions. The estimated relationships are useful in determining prey size from stomach and digestive tract contents (Gales 1988; Tuset et al. 2008; Bilge 2013) and also identifying fish populations or stocks, feeding ecology of fish predators, as well as aspects of paleontology, stratigraphy, archaeology, and zoogeography (Nolf 1995; Girone et al. 2006; Jawad et al. 2011; Young-Boyle 2015; Zan et al. 2015; Khanali et al. 2021).

Sillaginids are commercial fish species of small to moderate size (McKay 1992). *Sillago sihama* (Fabricius 1775) is one of the most economically important species among sillaginids and particularly inhabits shallow coastal waters with depths of 20-60 meters (Kaga 2013). In the northern Persian Gulf, they are often caught with fishing hooks and incidentally found in shrimp trawls. Previous studies on *S. sihama* stock in the region have mainly focused on their biology, contamination, and taxonomy (Alavi-Yeganeh et al. 2016; Khandan Barani et al. 2023). There are no previous reports on the relationships between otolith and fish dimensions for *S. sihama* from the Persian Gulf.

MATERIAL AND METHODS

A total of 49 adult specimens of *S. sihama* were collected during the period of August-September 2016 with a cast net (10mm mesh size) and a beach seine (15mm mesh size) in the coastal waters of Bandar-abbas, the Persian Gulf (27°10′ N, 56°20′ E) (Fig. 1).

The taxonomic identification was carried out based on McKay (1992) and Kaga (2013). Total length (TL) and standard length (SL) measurements were taken with a digital caliper (0.01mm accuracy), and body weight (BW) measurements were taken with a digital scale (0.1g accuracy). Sagittal otolith was extracted from the back of the cranium and then cleaned and stored in glass vials. Undamaged Sagittal otoliths were photographed using a stereomicroscope equipped with a camera. Digimizer Ver. 5.7.2 software was used to estimate the dimensions of otoliths (Khanali et al. 2021). Otolith length was measured from the horizontal distance between the anterior and the posterior tips of the otolith (Harvey et

Fig.1. Sampling site of *Sillago sihama* specimens from coastal water of Bandar-Abbas, Persian Gulf.

al. 2000) (Fig. 2). Otolith weight was measured using a digital balance to the nearest 0.0001g. The left and right otolith dimensions were compared for significant difference (paired student's t-test), and the result indicated a non-significant difference between the left and right otoliths (P>0.05). The relationships between fish standard length vs. otolith lengths, fish standard length vs. otolith width and fish weight vs. otolith weight were evaluated using a linear regression model (L), where Y= a + b X, where Y= Fish standard length (SL, mm) or Fish total Weight (FWE, g) and X= Otolith Length (OL, mm), Otolith Width (OW, mm) and Otolith Weight (OWE, g). 'a' and 'b' were the intercept and slope of estimated relationships (Gamboa 1991; Harvey et al. 2000; Morat et al. 2008; Battaglia et al. 2010; Zan et al. 2015; Khanali et al. 2021). The relationships between otolith length and width vs. fish weight were determined using an exponential regression model (E), Y= aXb where Y= Fish weight (FW, g) and X= Otolith Length (OL, mm) (Waessle et al. 2003). The regression analysis was done using Excel software (version 2010).

RESULTS

The average total length of collected specimens was 152.41mm (107.25-290.64mm), and the average weight appeared to be 26.63 g (7-77.6g). The otoliths

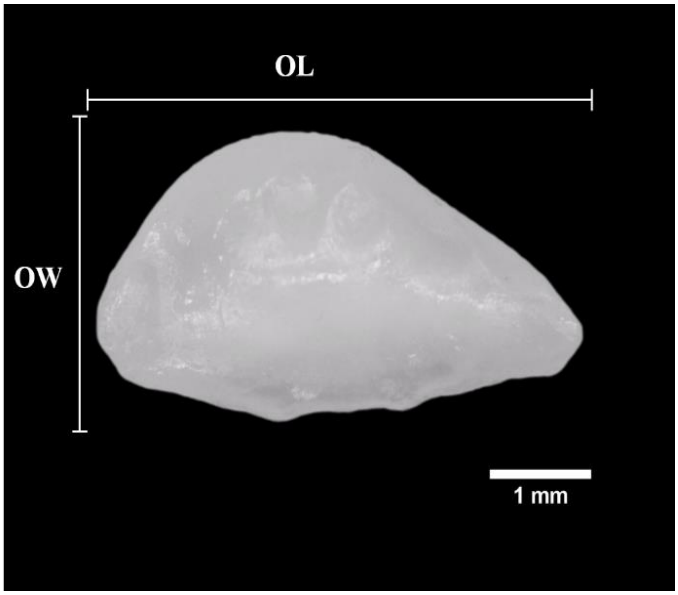

Fig.2. Sagittal otoliths of *Sillago sihama* (Right otolith, convex outer side) showing measurements analyzed in this study. OL: otolith length, OW: otolith width.

dimensions were 6.46mm (4.8–9.9mm) for otolith length, 3.52mm (2.7-5.02mm) for otolith width, and 0.042g (0.012-0.130g) for otolith weight (Table 1). No significant differences were observed between the measured dimensions of the left and right otoliths (t-test, P>0.05). The right otolith was used for the estimation of relationship equations. The regression models for the estimated relationships among otolith and fish parameters are presented in Table 2, along with their equations and correlation coefficients. The

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Table 1. Biometric data of the 49 silver sillago specimens and their otoliths collected from the Persian Gulf.

Variables	Fish			Otolith					
				Left			Right		
	TL (mm)	SL (mm)	Weight (g)	Length (mm)	Width (mm)	Weight (g)	Length (mm)	Width (mm)	Weight (g)
Mean ± SE	152.41±34.17	134.56±31.54	26.63±16.77	6.44±1.17	3.51±0.53	0.044±0.03	6.48±1.16	3.53±0.52	0.04±0.03
Range	107.25-290.64	93.3-268.28	7-77.6	4.8-9.69	2.82-5.02	0.01-0.13	4.87-9.95	2.7-4.92	0.01-0.13

Table 2. Parameters for the relationships Equation among fish and otolith dimensions in *Sillago sihama*. *a*: intercept *b*: regression slope, and r^2: coefficients of determination for linear and exponential relationships. FSL: Fish standard length (mm), FWE: Fish weight (g), OWE: Otolith weight (g).

Equation	a	b	r^2	Significance
FSL= a+b OL	23.81	18.94	0.88	$P<0.05$
FSL= a+b OW	48.25	34.95	0.81	$P<0.05$
FWE= a+b OWE	569.38	1.39	0.91	$P<0.05$
FWE= aOL^b	0.06	3.18	0.91	$P<0.05$

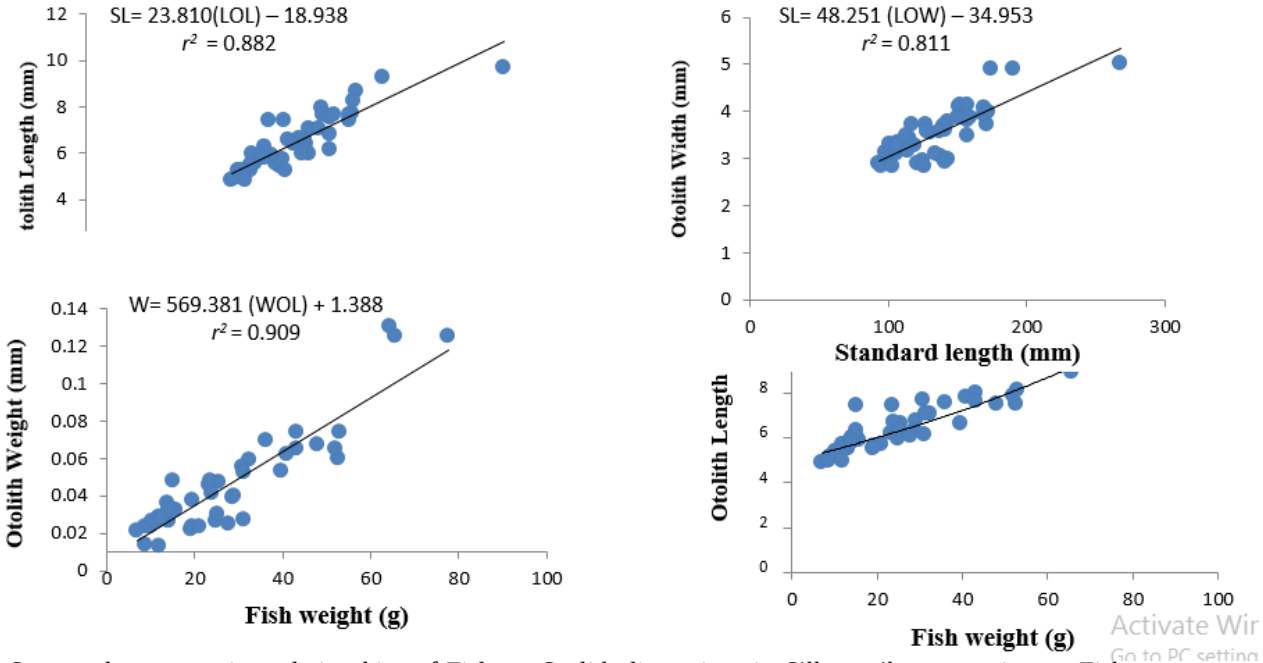

Fig.3. Scatter plots presenting relationships of Fish vs. Otolith dimensions in *Sillago sihama* specimens. Fish Standard Length *vs.* Otolith Length, Fish Standard length *vs.* Otolith Width**,** Fish weight *vs.* Otolith weight and Fish weight vs. Otolith Length.

OL-FSL, OW-FSL, OWE-FEW and FEW-OL relationships are also presented on the plate in Figure 3. The highest correlation coefficients were recorded as r^2= 0.91 for Fish weight (FWE) vs. Otolith weight (OW) and Fish Weight vs Otolith Length (OL) relationships.

DISUSSION

Otolith dimensions have been used to determine the fish sizes in various studies (Letourneur 2008; Bilge & Gulsahin 2014; Zan et al. 2015; Aneesh Kumar et al. 2017; Khanali et al. 2021; Quigley et al. 2023). Otolith dimensions and their relationship with other morphological parameters can be used as important parameters in aquatic ecological studies (Bachok et al.

2004; Byrd et al., 2020). There were no significant differences between the right and left otolith dimensions (P>0.05), indicating that the left and right otoliths could be used for back calculations with the same equation. According to the results, all three dimensions of the otolith (length, width, and weight) were significantly applicable for back-calculations. The observed stronger correlation coefficient for linear regression between Fish weight vs. otolith weight (r^2= 0.91) in comparison with other linear models may indicate more stability of weight parameters in back calculations. Accordingly, we propose otolith weight vs. fish weight regression as a proper relationship indicator for studying back-calculation in Silver Sillago. Similar results were reported regarding variability in the ventral and dorsal margins of otoliths within individuals (Khanali et al. 2021). *Sillago sihama* is a widely speared species and has an important role in the food web of the area as a prey fish; therefore, estimated relationships could be useful in further related studies. The present study revealed that the prey fish weight in piscivorous fishes can be estimated using fish weight vs. otolith weight, fish weight-otolith length, fish length vs. otolith length, and fish length vs. otolith length, respectively.

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مقاله کامل

رابطه بین ابعاد اتولیت ساجیتا و ماهی در شورت ماهی نقره‌ای *Sillago sihama* (Fabricius 1775) در خلیج فارس

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چکیده: در این مطالعه رابطه بین ابعاد اتولیت ساجیتا و ماهی در گونه شورت ماهی نقره‌ای *Sillago sihama* در خلیج فارس تخمین زده شده است. براساس روابط رگرسیونی خطی و نمایی و ضریب تبیین محاسبه شده (r^2>۰/۷۶) محاسبه شده، سه پارامتر از اتولیت (شامل طول، عرض و وزن اتولیت) از کارایی مناسبی برای تخمین طول و وزن ماهی برخوردارند. اختلاف معنی‌داری در مقایسه اتولیت‌های سمت چپ و راست مشاهده نشد. داده‌های حاصل از این تحقیق می‌تواند در محاسبه ابعاد ماهی بر مبنای استخوان اتولیت باقیمانده از آن مفید باشد.

کلمات‌کلیدی: شورت ماهیان، بوم‌شناسی ماهی، اتولیت ساجیتا، شورت ماهی نقره‌ای