The use of otolith in growth estimation for *Glossogobius aureus* (Gobiiformes: Gobiidae)

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Abstract. Knowledge on morphology and size of otoliths and their correlation with fish sizes are essential in fish development determination. Yet, little is known about gobies in the Mekong Delta of Vietnam (VMD), including *Glossogobius aureus*, a commercial fish. This study was conducted from January 2020 to December 2020, in order to understand the morphology and size of otolith and their relationship with fish size, based on a cohort of 742 individuals. Fish was monthly caught by trawl nets in four sites, including Cai Rang - Can Tho (CRCT), Long Phu - Soc Trang (LPST), Hoa Binh - Bac Lieu (HBBL) and Dam Doi - Ca Mau (DDCM). The four sampling sites had apparent differences in environmental conditions, especially in salinity. Data analysis showed that otoliths' shapes were elliptic and the otolith surface on the side of the fish skull had is rough with deep depressions, whereas the reverse side had a smooth surface, without indentations. The top edge was irregular wavy lines, while the bottom edge was relatively flat. There was no difference in the size of the left and right otoliths, and the weight of otoliths varied with the season and site, but it does not change with the gender. The weight of the otolith was observed relationship with the total length (TL), weight (W), body height (BD) and head length (HL) at all study sites (r^2>0.61 for all cases). It indicated that the otolith weight could be considered as a criterion used to determine the size of fish.

Key Words: goby, morphology, Bac Lieu, Ca Mau, Soc Trang, Tra Vinh.

Introduction. Fish has a calcified structure located in the inner ear (Popper & Lu 2000; Campana 2004). This structure is known as otolith or hearing and balance organ (Popper et al 2005) and grows continuously during fish's life (Rodríguez Mendoza 2006; Nguyen & Dinh 2020; Dinh et al 2021b). The shape and morphometrics of otolith are used in fish ageing (Pino et al 2004; Metin et al 2011; Dinh et al 2015), and fish classification (Tuset et al 2006; Bani et al 2013). The otoliths are also used in fish size estimation via their relationship with fish morphometrics (Granadeiro & Silva 2000; Dehghani et al 2016; Nguyen & Dinh 2020; Dinh et al 2021b). Yet, knowledge of otolith morphology and mass is limited to gobies in the Vietnamese Mekong Delta (VMD) (Diep et al 2014; Tran et al 2020).

Glossogobius aureus is a species of the genus Glossogobius and is widely distributed in the Mekong Delta region (Dinh 2011; Tran et al 2013; Diep et al 2014; Le et al 2018; Tran et al 2020; Tran et al 2021), having a high economic value. Studies focus on its spawning traits (Nguyen et al 2014), food and feeding habit (Nguyen & Tran 2018), length-weight relations, growth pattern, condition factor and morphometric variations (Dinh 2014; Phan et al 2021). Studies on the otolith characteristics of *G. aureus* are still limited in VMD, where the species faces overexploitation (Dinh et al 2021c). Therefore, this study aimed to contribute to describing the otolith morphology and the relationship between the fish mass and size, as an indicator of the fish growth in VMD.

Material and Method

Fish collection and analysis. The study was conducted by collecting fish samples at four locations, including Cai Rang – Can Tho (CRCT), Long Phu – Soc Trang (LPST), Hoa Binh - Bac Lieu (HBBL) and Dam Doi - Ca Mau (DDCM) (Figure 1). The implementation period starts from January 2020 to December 2020. Fish samples were caught by local fishermen using trawl nets with a mesh of 1.5 cm in the cod-end. The four sampling sites had obvious differences in environmental conditions, especially in salinity. At CRCT, the freshwater environment persisted year-round, at LPST the freshwater was present in the wet season and the saltwater in the dry season. Meanwhile, in HBBL and DDCM, the environment had a high and stable salinity between the months of the year (Dinh et al 2021a). Fish, after being collected at the sampling sites, was fixed with 5% formol solution. After being transported to the laboratory, the fish was weighed (W) and the total length (TL), body height (BD) and head length (HL) were also measured. Then the sex of fish was determined based on the difference of the genital spines (oval shape in female fish and triangular shape in male fish). Finally, the fish was dissected to remove the otolith and determine the weight of the otolith using an analytical balance.

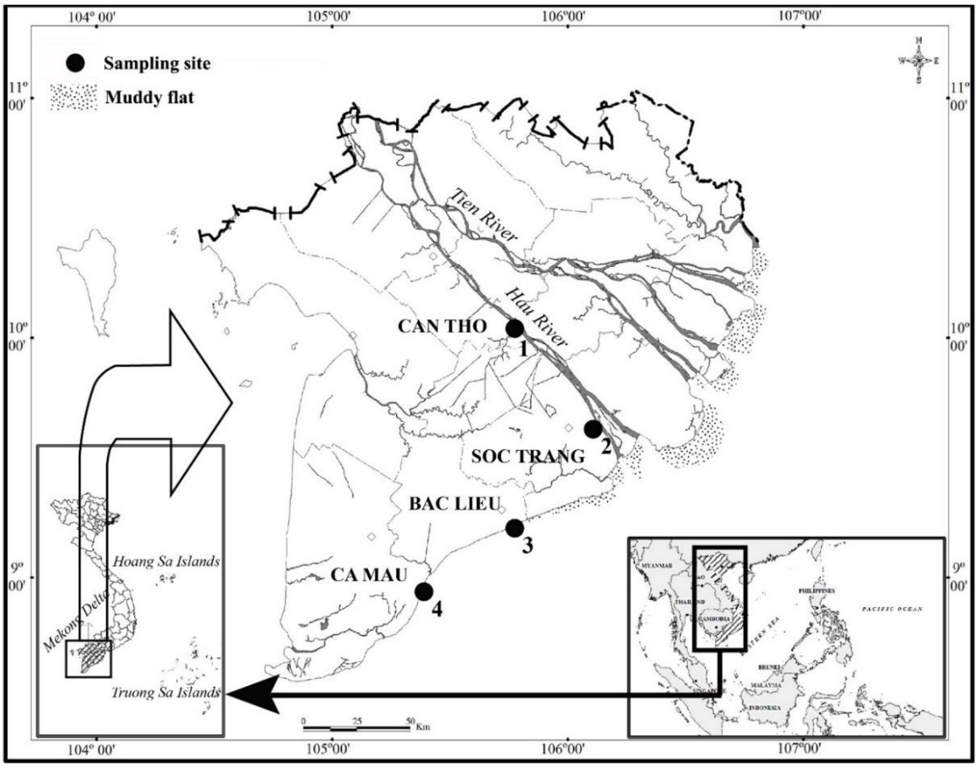

Figure 1. Sampling points in the Mekong Delta (•: sampling point; 1: Cai Rang – Can Tho; 2: Long Phu - Soc Trang; 3: Hoa Binh - Bac Lieu and 4: Dam Doi - Ca Mau) (modified from Dinh 2018).

Data analysis. The difference between the weight of left otoliths and right otolith was tested by a t-test (Matic-Skoko et al 2011). Two-way ANOVA determined the difference in otoliths weight between study sites. Besides, the relationship of the mass of otolith is proportional to the allometric traits.

Results

Otoliths. Data analysis results of 742 individuals of *G. aureus* showed that otoliths of all individuals had similar shapes (Figure 2). Although the left otolith and the right otolith had not exactly the same size and weight for each individual, they all had the same structure and resembled an ellipse. On each side of the otolith, there was a difference in the inner and outer faces. The inward side of the otolith had a rough surface with deep depressions. In contrast, the outward side of the otolith had a more smooth surface, without indentations, but with a prominence at the centre of the surface. Not only the difference in the two sides, but also the edges of the otolith had changed. The top edge was longer than the bottom edge. On the other hand, the top edge had undulating and irregular wavy lines, while the bottom edge was quite flat. The forward edge had the command vertex up, and the back edge had the vertex in the centre of the edge.

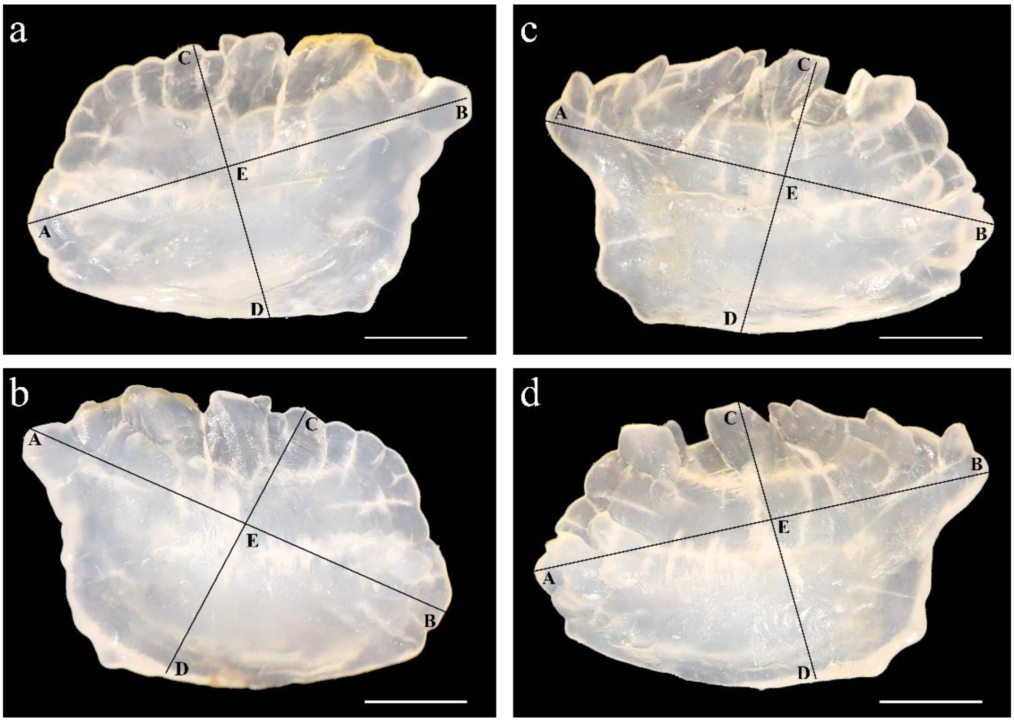

Figure 2. Goby otolith structure *Glossogobius aureus* (a: inner surface of left otolith; b: the outer surface of left otolith; c: inner right otolith; d: the outer surface of right otolith; AB: otolith length; CD: otolith width; E: centre point; scale: 1 mm).

The results of the analysis showed that there was no significant difference in the weight of left otolith (8.07±0.15 SE mg) and right otolith (7.98±0.15 SE mg) ($t=0.58$, $p>0.05$). So the left otolith was used to compare the weight of the otolith by season, gender and sites. The otolith weight (LOW) of *G. aureus* changed between the dry and wet seasons but did not change between male and female fish. In the wet season, the weight of the left otolith was 8.06±0.22 SE mg, and this value was smaller than in the dry season with the weight of 8.08±0.20 SE mg (t-test, $t=0.08$, $p<0.05$) (Table 1). It showed that the otoliths increased with the growth of fish through the stages. However, in *G. aureus*, the weight of otoliths in male fish (8.16±0.23 SE mg) was higher than that in female fish (7.98±0.20 SE mg). But this difference was not statistically significant ($t=0.56$, $p>0.05$) (Table 1). This result shows the uniform development of the body weight as well as the otolith weight in this species of fish.

Table 1

Variation in the otolith weight of *Glossogobius aureus* between sex and season

Comparison	*Groups*	*No. of fish*	*Mean (mg)*	*SE*	*p*
Left otolith weight	Female	360	8.16	0.23	0.09
	Male	382	7.98	0.20	
Left otolith weight	Dry season	336	8.08	0.20	0.01
	Wet season	406	8.06	0.22	

The weight of the otolith of *G. aureus* varied according to the study site (Figure 3). Specifically, according to the results processed by one-way ANOVA test, both left otoliths had the highest weight at CRCT (LOW=10.69±0.31 SE mg), the next in DDCM (LOW=8.41±0.28 SE mg) and the lowest one in LPST (LOW=6.89±0.34 SE mg) and HBBL (LOW=6.30±0.18) (F=47.96, p<0.05 for all cases).

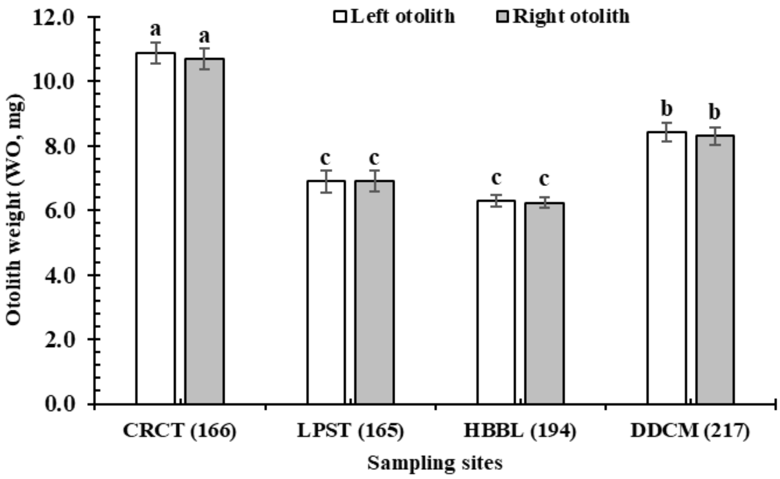

Figure 3. The change of otolith weight at the study sites (CRCT: Cai Rang, Can Tho; LPST: Long Phu, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DDCM: Dam Doi, Ca Mau; in number of fish individuals).

The relationship between otolith size and fish size. Because the weight of the left otolith and the right otolith of the *G. aureus* had the same value, so in this study, we used the left otolith weight to examine the relationship between the otolith weight and the morphological parameters of the fish. The results of this analysis show that the weight of the otolith (WO) of the *G. aureus* has a close relationship with the weight (W), total length (TL), body height (BD) and length of the body head (HL) of this fish.

At all four study sites, the r^2 indices for the relationship between otolith weight and fish weight was greater than 0.62 (Figure 4).

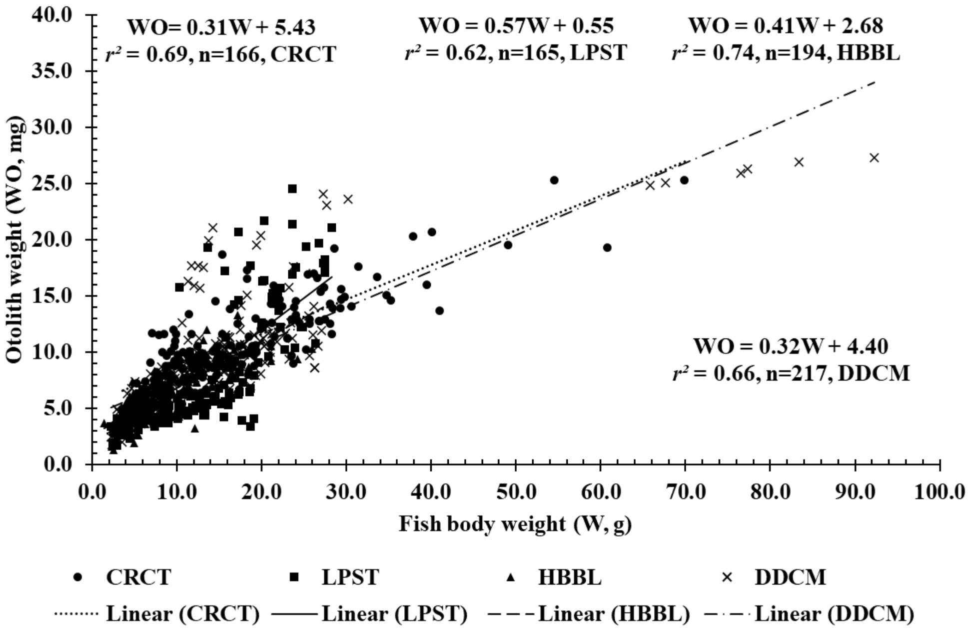

Figure 4. Relationship between otolith weight and body weight at the four sampling locations (CRCT: Cai Rang, Can Tho; LPST: Long Phu, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DDCM: Dam Doi, Ca Mau; n: number of fish).

HBBL was the point with the closest relationship because it had the highest coefficient of determination r^2 (0.74). Similarly to W, the relationship of otolith weight and fish body length was also quite close and positive $r^2>0.68$ and HBBL had the highest coefficient of determination $r^2=0.79$ (Figure 5). It was shown that in this fish, the development of otoliths had a strong relationship with the growth of fish. Besides TL and W, in this study, the relationship of WO with other morphological indicators of fish, such as body height (Figure 6) and head length (Figure 7), were also considered. Both these parameters have a close relationship with the otolith weight ($r^2>0.61$ for all cases). It was shown that the weight of *G. aureus* could be considered an indicator to determine the size of this fish.

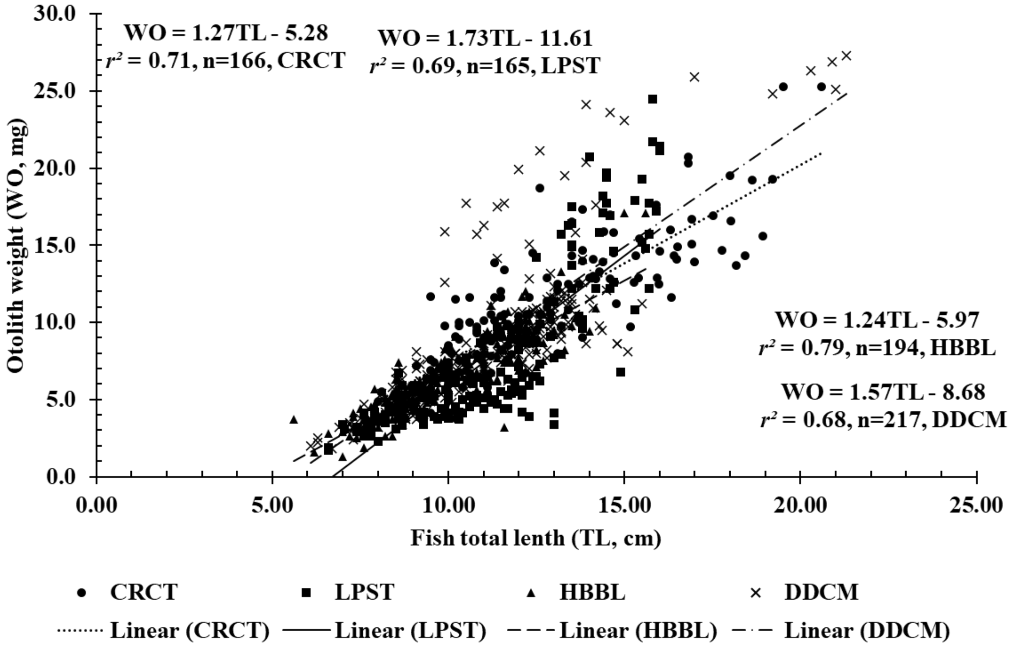

Figure 5. Relationship between otolith weight and total length at the four sampling locations (CRCT: Cai Rang, Can Tho; LPST: Long Phu, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DDCM: Dam Doi, Ca Mau; n: number of fish).

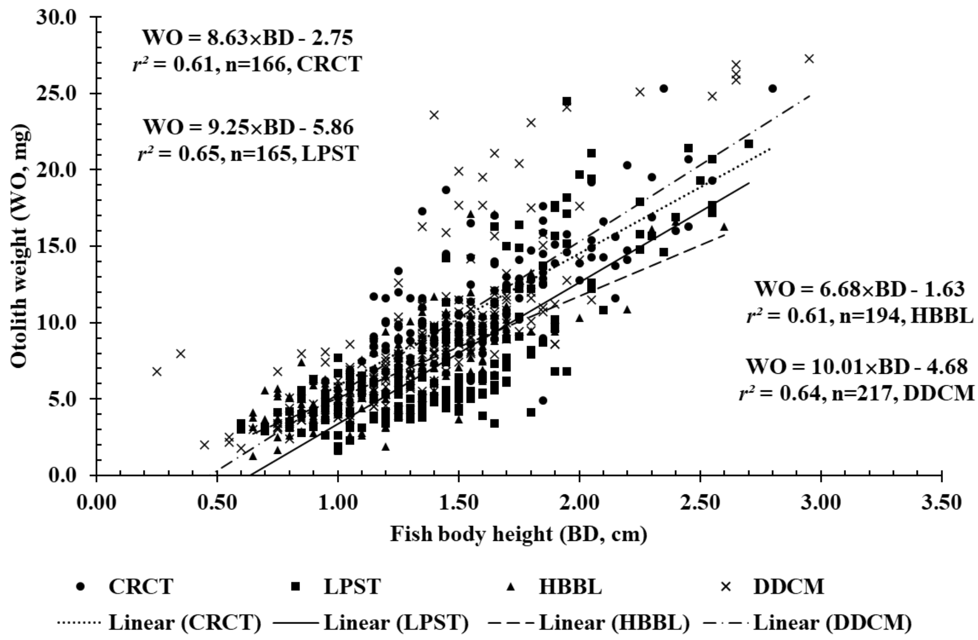

Figure 6. Relationship between otolith weight and body height at the four sampling locations (CRCT: Cai Rang, Can Tho; LPST: Long Phu, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DDCM: Dam Doi, Ca Mau; n: number of fish).

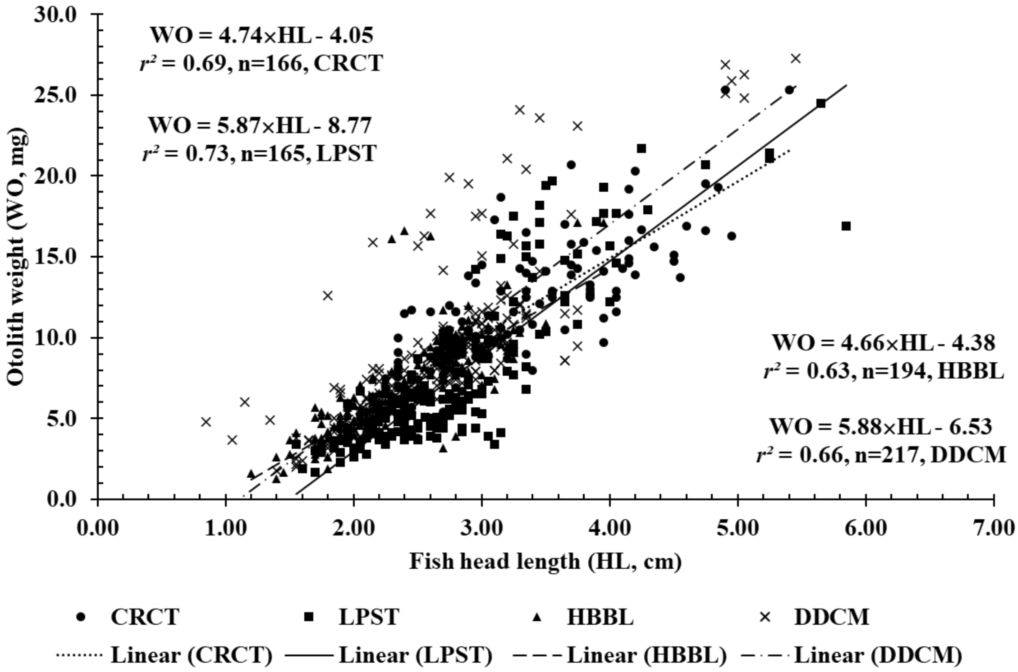

Figure 7. Relationship between otolith weight and head length at the four sampling locations (CRCT: Cai Rang, Can Tho; LPST: Long Phu, Soc Trang; HBBL: Hoa Binh, Bac Lieu; DDCM: Dam Doi, Ca Mau; n: number of fish).

Discussion. Similarities of left and right otolith of *G. aureus* were also seen in some other fish species living in VMD, such as *Glossogobius sparsipapillus* (Nguyen & Dinh 2020) and *Parapocryptes serperaster* (Dinh et al 2015). In the Mekong Delta, Vietnam and throughout the world, there were many fish species with similarities between the weight of left and right otolith. Some of these species include *Kurtus gulliveri* in Northern Australia (Berra & Aday 2004), *Thunnus thynnus* in the Mediterranean Sea (Megalofonou 2006), *Pagrus auratus* and *Platycephalus* in Southeast Australia (Hamer & Jenkins 2007), *Neogobius caspius*, *Ponticola bathybius* and *Ponticola gorlap* in Iran (Bani et al 2013) and *Trachinus draco* in Northern Tunisia (Fatnassi et al 2017).

The relationships of the weight of otoliths with the allometric traits in different areas showed that, at CRCT, it was suitable for predicting the fish growth, including the development of otoliths. The freshwater environment combined with the stability of environmental factors all year round might have created favorable conditions for fish development. Similarly to CRCT, the environment at DDCM also had a high stability in terms of environmental factors. However, this was an area of water with salinity greater than 30‰, so the development of otoliths was worse than at CRCT. In contrast, at LPST and HBBL, there were fluctuations in environmental factors, which led to the lowest value of the determination coefficient between the otolith weight and the size and weight of fish at these two locations. In *G. sparsipapillus*, the relationships of the otolith weight and the allometric traits at these four areas also had similar results compared to this study's results (Nguyen & Dinh 2020). Similar results were found in the species *Periophthalmodon septemradiatus* (Dinh et al 2021b).

In fish species in the Mekong Delta and around the world, there was also a close relationship between the weight of otoliths and their morphological indicators. Some species from other genera and families include *P. serperaster* (Dinh et al 2015), *N. caspius*, *Ponticola bathybius* and *Ponticola gorlap* in Iran (Bani et al 2013), *Engraulis japonicus* and *Sardinops melanostictus* distributed in the western North Pacific (Takasuka et al 2008), *Rastrelliger kanagurta* in Oman (Jawad et al 2011), *Trachurus declivis*, *Parequula melbournensis*, *Neosebastes scorpaenoides*, *Platycephalus aurimaculatus*, *Platycephalus bassensis*, *Platycephalus conatus*, *Lepidotrigla mulhalli* and *Lepidotrigla vanessa* from the northeast Tasmania waters, Australia (Park et al 2018). Especially, its congener, *G. sparsipapillus* living in VMD, had quite similar results (Nguyen & Dinh 2020), which were also found in *Butis koilomatodon* (Lam et al 2021) and *P. septemradiatus* (Dinh et al 2021b).

Conclusions. The results showed that otoliths had an elliptic shape and their size varied with the season and site but did not change with the gender. The observation of the otoliths weight's relationship with the total fish length, weight, body height and head length at all study sites, indicates that the otoliths weight could be considered as a growth indicator for this species.

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Conflict of interest. The authors declare no conflict of interest.

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