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Research article

Gastrointestinal morphology and feeding intensity of *Periophthalmus gracilis* caught from some coastal provinces in the Mekong Delta, Vietnam

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Abstract

This study provided data on gastrointestinal morphology and feeding intensity of slender mudskipper *Periophthalmus gracilis* distributed in some coastal provinces in the Mekong Delta, Vietnam (VMD). Fish specimens were sampled monthly by hand-catching, from 01/2022 to 12/2022, in four provinces in the VMD: Tra Vinh, Soc Trang, Bac Lieu, and Ca Mau. After sexing, the fish total length and weight, gut length, and gastrointestinal morphology were measured and described. The study showed that *Periophthalmus gracilis* had a protruding upper jaw with a longer upper jaw bone length. The teeth are large and sharp, with pointed molars and unevenly distributed in a row on the upper jaw. The tongue was short and had a round tip. The gastrointestinal had an elastic tube-shaped esophagus, a short sac-shaped stomach, and long, straight, curving tube intestines. The feeding intensity of the mudskipper varied by season and month, with differences between males and females. These findings provided new information on the mudskipper's gastrointestinal morphology and feeding habit.

Keywords: : Feeding intensity, Gastrointestinal morphology, Gastro-somatic index, *Periophthalmus gracilis*

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INTRODUCTION

The Mekong Delta is one of Vietnam's significant biogeographical and geographical regions, with various natural features. With flat topography and no prominent elevations, this region comprises 13 provinces and cities in the southern part of Vietnam, including Can Tho, An Giang, Kien Giang, Tien Giang, Hau Giang, Long An, Dong Thap, Ben Tre, Vinh Long, Tra Vinh, Soc Trang, Bac Lieu, and Ca Mau (Le et al., 2006). The climate is tropical monsoon, with two distinct wet and dry seasons, with average annual temperatures ranging from 25-27°C and average rainfall from 1,200 to 2,500 mm per year (General Statistics Office, 2021). The region boasts numerous significant rivers, such as the Tien, Hau, Mekong, and Bassac Rivers. So, the system of fish species in this forest is significantly developed with high diversity. According to Tran et al. (2013), this area has about 320 species of fish with nearly 80 families. Some fish families in this area have unique characteristics, especially Oxudercidae, with the ability to live in aquatic and terrestrial environments.

Periophthalmus gracilis belongs to the family Oxudercidae with 32 genera and 58 species (Nguyen, 2005), distributed in the Indo-Pacific and Western Pacific regions (Froese and Pauly, 2021). In Southeast Asia, this fish is found in the coastal mudflats of Singapore, Indonesia, Malaysia, Thailand, and Vietnam (Khaironizam and Norma-Rashid, 2002; Larson et al., 2008; Tran, 2013; Diep et al., 2014; Tran and Dinh, 2020; Tran and Dinh, 2021b). This fish is exploited for food and sold as ornamental fish in Taiwan and Japan (Ip et al., 1990). *Periophthalmus gracilis* lives in coastal estuarine mudflats, where brackish and saltwater habitats exist (Murdy, 1989; Kottelat et al., 1993; Jaafar et al., 2009). They have distinctive physiological and behavioral characteristics because of their ability to survive out of water for several hours (Murdy, 1989; Jaafar et al., 2009). According to Murdy and Zeehan (2017), mudskippers are unique fish; their gills have an evolved part that acts as "lungs", allowing them can live in the water and mudflats for a short time. Also, they are environmental indicators for mangrove ecosystems (Murdy and Zeehan, 2017). Dinh et al. (2022) studied factors influencing morphological traits of *Periophthalmus gracilis* Eggert, 1935 in several coastal provinces in the Mekong Delta. However, there is no data on its gastrointestinal tract morphology and gastro-somatic index (GI)− an indicator for feeding intensity. Therefore, the study was conducted to supply data on the gastrointestinal tract morphology and GI of this mudskipper and to analyze the interactions of sex, size, season, and sampling site on the GI variation of this fish. The findings of this study can provide valuable information for further artificial culture study on this species.

MATERIALS AND METHODS

Sample collection and sample analysis

Periophthalmus gracilis samples were collected periodically once a month and continuously for 12 months from January to December 2022 at four coastal locations in the VMD, including Duyen Hai (Tra Vinh province), Tran De (Soc Trang province), Dong Hai (Bac Lieu province), and Dam Doi (Ca Mau province) (Figure 1). Fish samples were collected by hand-catching in coastal mudflats, anesthetized with MS222, and stored in 10% formalin solution, and then these samples were then expressed to the laboratory for further studies. The fish weight (W, 0.01 g) and total length (TL, 0.1 cm) was determined before removing the gastrointestinal for further analysis. The use of fish was approved by The Council for Science and Education, School of Education, Can Tho University (Animal Welfare Assessment number: BQ2020-03/KSP).

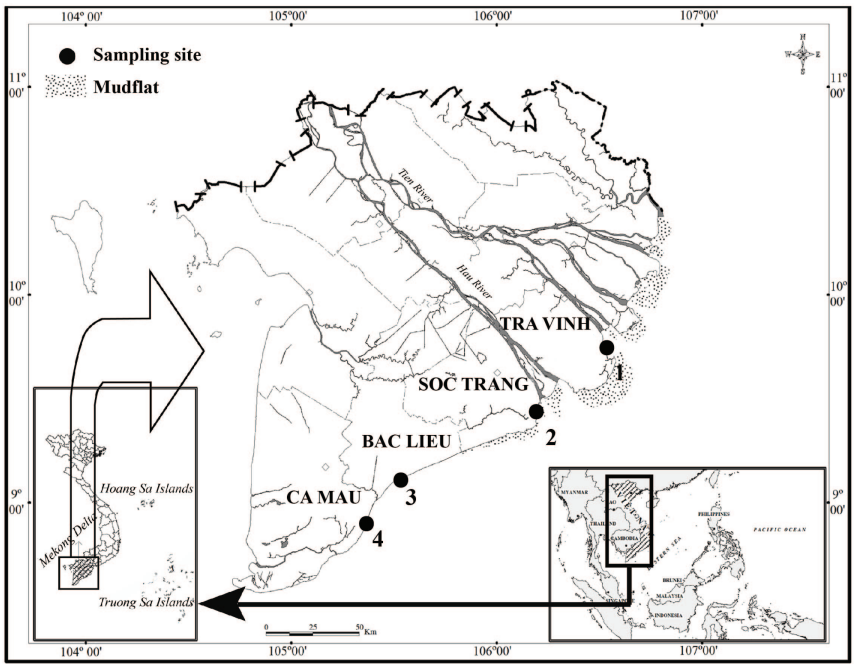


Figure 1 Sampling site in the Mekong Delta, Vietnam (1: Duyen Hai - Tra Vinh; 2: Tran De - Soc Trang; 3: Dong Hai - Bac Lieu; 4: Dam Doi - Ca Mau; modified from Dinh (2018)).

The gastrointestinal morphology of mudskipper was described based on the method of Nikolsky (1963). The feeding intensity of fish was determined based on the gastro-somatic index (*GI*=gut weight/fish weight) described by Desai (1970).

Data analysis

The PERMANOVA added in PRIMER v.6 software was used to verify the variation of *GI* concerning sex, size, season, month, site, sex × season, sex × site, size × season, size × site, and season × site. The test was conducted at the 5% significance level.

RESULTS

Gastrointestinal tract morphology

Analysis results of 1,288 (649 females and 639 males) showed that *Periophthalmus gracilis* had a protruding upper jaw and longer maxillary bone (Figure 2), indicating that they captured prey from the substrate rather than the bottom. *Periophthalmus gracilis,* like other mudskippers, had teeth that were large and unevenly distributed in one jaw, and the molars were sharp, pointed, and arranged in a row on the upper jaw. This dental morphology was necessary for their feeding behavior, which primarily involved capturing and crushing small invertebrates and fish on muddy or sandy substrates (Figure 3).



Figure 2 Fish head and mouth.

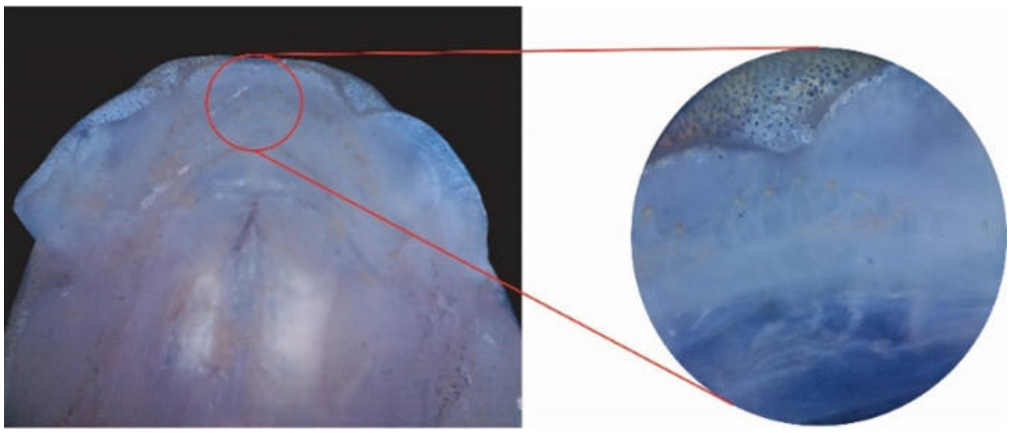


Figure 3 Teeth of fish.

The average body length of *Periophthalmus gracilis* was 4.41±0.02 SE cm, while the average gut length was 1.95±0.02 SE cm. The relative gut length value was 0.44±0.02 SE and less than one, indicating that this fish belonged to carnivores. The mudskipper's tongue was motionless and short, and its tip was round and connected to the gill arches of the fish. The gill rakers (Figure 4), finger-like projections on the gill arches, were large, coarse, arranged in a row, and directed towards the oropharynx. These gill rakers helped prevent unwanted particles from entering the fish's respiratory system while allowing water to pass over the gill filaments, where gas exchange occurs.

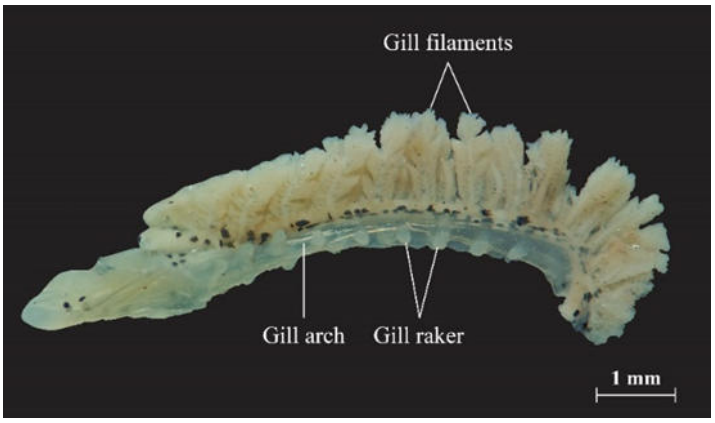


Figure 4 A gill arch of fish. .

Like other fish species, *Periophthalmus gracilis* had a large and elastic esophagus that helped transport food from the mouth to the stomach. However, the esophagus did not have many folds inside to support the passage of food; instead, it was relatively smooth and muscular. The mudskipper's stomach was located at the end of the esophagus and had a short and sac-shaped structure (Figure 5). The thick and muscular stomach walls allowed solid contractions to mix, mix, and break down food. The stomach also had many folds or rugae inside, which increased its surface area and allowed it to hold more significant amounts of food.

After the stomach, the intestine of *Periophthalmus gracilis* continued as a long, straight, and curving tube, which was adapted to maximize nutrient absorption. However, the intestine was not short; it could be pretty long, sometimes up to several times the length of the fish's body. The intestine walls were relatively thin and smooth, without many folds or rugae, allowing easy food passage and efficient nutrient absorption (Figure 5).

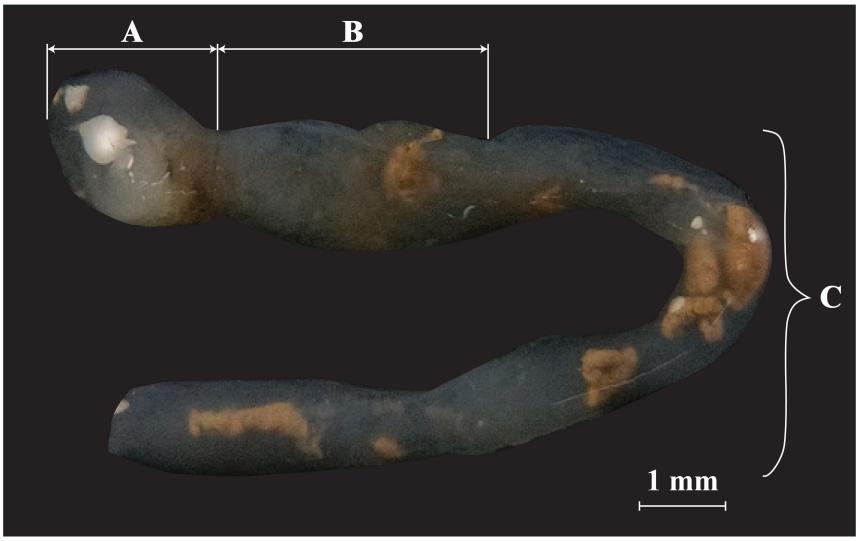


Figure 5 Gastrointestinal morphology of *Periophthalmus gracilis* (A: esophagus; B: stomach; C: intestines).

Feeding intensity

The GI of this species varied with sex (Pseudo-F=44.81, p=0.00), season (Pseudo-F=119.96, p=0.00), and size × season (Pseudo-F=4.24, p=0.05), but not other factors. Typically, Periophthalmus gracilis had an average GI of 4.13±0.10 SE, and its feeding intensity remained stable concerning fish size (Pseudo-F=0.32, p=0.81). Mature and immature fish did not show significant differences in GI values, with mature mudskippers having a GI value of 4.11±0.07 SE and immature mudskippers having a GI value of 4.16±0.13 SE.

In addition, the intensity of females (4.48±0.10 SE) was significantly higher ($p<0.05$) than in males (3.77±0.09 SE). This difference could result from the increased nutritional requirements of the female during development or spawning. Similarly, the feeding intensity of this fish was significantly different by season ($p<0.05$), with the GI value in the dry season considerably higher than that of the wet season. This value in the dry and wet seasons was 0.63±0.01 and 0.59±0.00 SE, respectively.

Similar to the season, the GI of this species also varied with the month ($p<0.05$, Figure 6). The highest GI value was observed in October (3.63±0.20 SE), while the lowest was recorded in January (1.77±0.06 SE), with GI values ranging from 1.90-2.96 for the remaining months.

The study found that the feeding intensity of *Periophthalmus gracilis* remained stable and consistent across all four sampling sites, with an average GI value ranging from 4.01-4.21. Interestingly, the highest GI value was observed in Bac Lieu (4.21±0.09 SE), while the lowest was recorded in Ca Mau (4.01±0.12 SE). In Tra Vinh and Soc Trang sites, the GI value was determined to be 4.11±0.08 SE and 4.19±0.06 SE, respectively. However, the feeding intensity of the fish varied depending on changes in their environment.

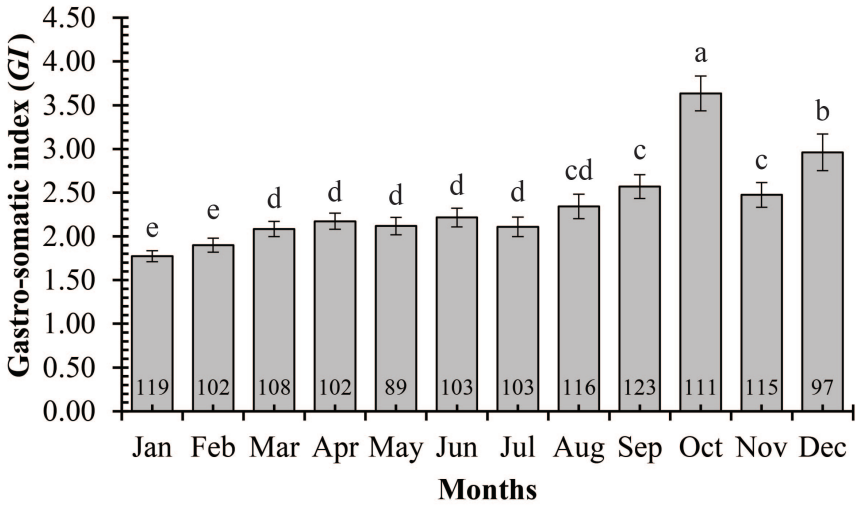


Figure 6 The variation in the gastro-somatic index of *Periophthalmus gracilis* concerning site (different letters (a, b, c, and d): significant differences).

The *Periophthalmus gracilis* gastro-somatic index analysis revealed that gender, size, season, and site did not significantly affect GI when examined in pairs ($p>0.05$). The interaction of sex and size (Pseudo-F=3.39, p=0.05), sex and season (Pseudo-F=1.05, p=0.28), sex and site (Pseudo-F=1.99, p=0.10), size and season (Pseudo-F=0.05, p=0.99), size and site (Pseudo-F=0.77, p=0.50), and season and site (Pseudo-F=2.36, p=0.07) were found to be non-significant. Additionally, the interaction of sex, size, season, and site (Pseudo-F=0.87, p=0.45) was also non-significant. This finding aligned with a previous study conducted by Dinh et al. (2018), which found that interactions between fish size and site, fish size and season, and site and season do not affect the feeding intensity changes in *Periophthalmodon septemradiatus*.

DISCUSSION

The structure of the digestive tract in this fish showed that this is a carnivorous fish with outstanding features such as sharp molars, short gill rakers, and short intestine. Similar results were found in some other mudskipper species of the Mekong Delta, such as *Periophthalmodon schlosseri* (Tran et al., 2019a), *Periophthalmus variabilisis* (Dinh et al., 2021; Tran and Dinh, 2021a). Besides, similar characteristics were also found in some of the fish species of the Gobiidae, including *Oxyeleotris urophthalmus* (Toan and Dinh, 2014), *Eleotris melanosoma* (Vo et al., 2014; Dinh et al., 2017a), *Periophthalmodon schlosseri* (Zulkifli et al., 2012; Tran et al., 2019a), and *Periophthalmodon septemradiatus* (Dinh et al., 2018).

The GI of this species varied significantly by sex and season, showing that this index was volatile in this fish. The females had a higher GI value than the males, indicating that the females needed to accumulate more energy for reproduction. The seasonal variation in GI showed that, during the dry season, it was easier for this fish to obtain food, which might lead to a higher

GI. These findings are consistent with previous studies on other fish species, e.g., *Parapocryptes serperaster* (Dinh et al., 2017b), *Eleotris melanosoma* (Vo et al., 2014), and *Stigmatogobius pleurostigma* (Dinh and Tran, 2018) in the Mekong Delta. However, GI of *Periophthalmus gracilis* was relatively low compared to other mudskipper species in the Mekong Delta, Vietnam, such as *Periophthalmodon schlosseri* (Tran et al., 2019b), *Periophthalmus variabilis* (Hua et al., 2023) or even some species of Gobiidae like *Periophthalmodon septemradiatus* (Dinh et al., 2018), *Parapocryptes serperaster* (Dinh et al., 2017b), *Eleotris melanosoma* (Dinh et al., 2017a). It was clear that rainfall and changes in the environments of the two different seasons strongly affect the feeding intensity of slender mudskippers. *Periophthalmus variabilis* also had significant changes in GI value in two seasons (Tran and Dinh, 2021a), as well as *Eleotris melanosoma* (Dinh et al., 2017a) and *Stigmatogobius pleurostigma* (Dinh and Tran, 2018).

CONCLUSIONS

Periophthalmus gracilis was a carnivorous fish with a unique mouth morphology that allowed it to catch prey at the bottom. Its teeth were large and unevenly distributed in one jaw, with sharp, pointed molars arranged in a row. The fish had a short, thick-walled stomach with many folds to hold large food and a long, elastic intestine with numerous folds for high elasticity. The study found that the gastro-somatic index of the fish is influenced by sex and season but not size and site. Female mudskippers had a different prey-catching intensity than males, but mature and immature fish groups displayed the same intensity. The results provided valuable data on the feeding habit of *Periophthalmus gracilis* in VMD, which could be used to inform future research on its aquaculture.

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AUTHOR CONTRIBUTIONS

U Van Hua; Investigation, methodology, formal analysis, manuscript preparation, editing, and finalization
Quang Minh Dinh; Conceptualization and design of the experiment, investigation, supervision, editing, and finalization
Ton Huu Duc Nguyen; Conceptualization and design of the experiment, investigation, editing, and finalization

CONFLICT OF INTEREST

We have no conflict of interest.

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