Burrow Configuration and Utilization of the Blue-Spotted Mudskipper, *Boleophthalmus boddarti* Caught in Soc Trang, Vietnam

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ABSTRACT

The blue-spotted mudskipper, *Boleophthalmus boddarti*, is an important commercial fish species found in coastlines and estuaries in the Mekong Delta. This amphibious, mudflat inhabitant fish can directly respire air at mud surface. Despite its high economic value, information on biology and ecology, especially burrow structure is scarce. This study was carried out in order to understand burrow morphology and utilization purpose. The study was conducted for six months, from February to July 2013 in the Mekong Delta at Cu Lao Dung, Soc Trang province, Vietnam. The structure of the blue-spotted mudskipper burrow was studied by using resin castings on burrows *in situ* technique. Burrow structure of this species comprised one to two openings with "footmarks" made by its pectoral fins with one to two bulbous chambers. In general, burrow shapes were "I" and "U" types with one to two slightly slanting tunnels attaching the chambers together with some short cul-de-sac side branches. Moreover, the burrow had no mound at the opening. Results revealed that burrow structures have a strong relationship with fish size. The blue-spotted mudskipper uses a burrow as a place for foraging prey, living, refuge from predators, and spawning.

INTRODUCTION

Many species of fish from various habitats ranging from fresh to salt water have the ability to construct burrows for dwelling (Atkinson and Taylor, 1991; Clayton, 1993). Fish utilize their burrows as feeding grounds, for spawning and egg incubation, and protection from predator (Atkinson and Taylor 1991). The burrow structures of gobies and mudskippers are of various shapes such as U-shape, J-shape and Y-shape (Atkinson and Taylor, 1991; Ishimatsu *et al*., 1998), while burrows of goby, *Odontamblyopus lacepedii*, are irregular in shape (Gonzales *et al*., 2008). The blue-spotted mudskipper, *Boleophthalmus boddarti* (Fig. 1), a common amphibious fish dwelling in mudflats along the coastlines and estuaries in the Mekong Delta, is an important commercial species in this area (Dinh *et al*., 2013). This burrow builder mudskipper can directly breathe air from the surface in muddy areas. However, there is a lack of information on this species'

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morphology and distribution (Froese and Pauly, 2013), and feeding habits (Ravi, 2013). Information on its burrow configuration and utilization, especially in the Mekong Delta of Vietnam, is also inadequate. Therefore, understanding burrow configuration and its utilization would provide more detailed information on fish adaptation to muddy habitats, and fortunately, might lead to better management and conservation plans for this species.

Figure 1. Blue-spotted mudskipper, *Boleophthalmus boddarti*

MATERIALS AND METHODS

The study on burrow morphology and utilization of *B. boddarti* was carried out in inter-tidal mudflats during the dry season (February to April 2013), and wet season (from May to July 2013), in Cu Lao Dung, Soc Trang, Mekong Delta, Vietnam (9°26'3"N, 106°13'28"E, Fig. 2). Burrow casts were made monthly using polyester resin (En Chuan Chemical Industries Co., Ltd, Taiwan) mixed with a hardener (2% in volume) in a 500 ml bottle to inject *in situ* into burrow openings of *B. boddarti*. Before resin injection, mud was piled up around the burrow entrance to prevent spilling over of resin. After 24 hours, the hardened casts were carefully removed from the sediment by hands. Details for studying methodology were described by Atkinson and Chapman (1984). In the laboratory, the dimensions of the burrow casts were measured (unit: cm), such as burrow depth, maximum burrow width, maximum burrow length and burrow total length. Burrow openings and bulbous chambers were also counted and measured in cm (diameter).

Field observations were carried out monthly by monitoring fish activities in the study area. Activities were classified into feeding, protective, and reproductive behaviors. Fish were observed for 3 hours per day for 2 days during low tide, following

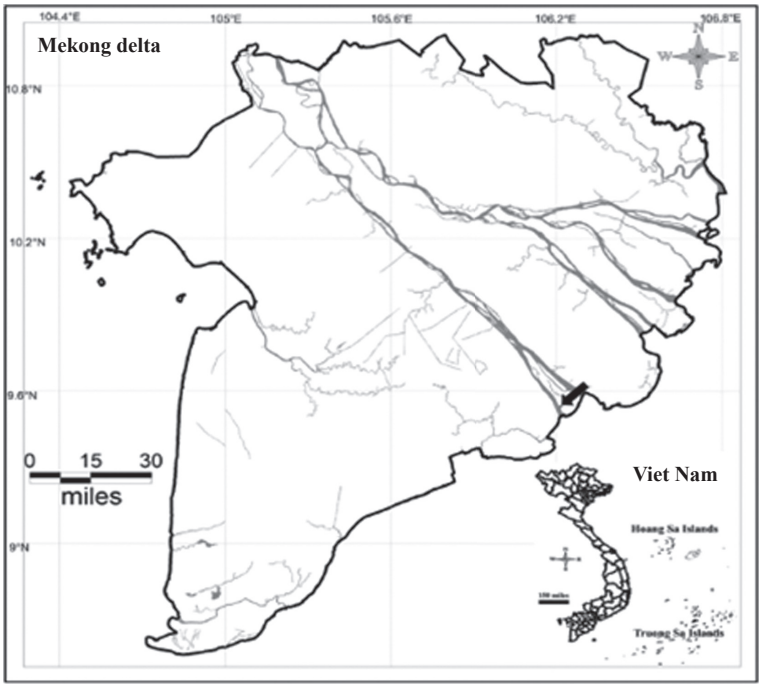

Figure 2. The study site located in Soc Trang, Mekong Delta, Vietnam (arrow shows sampling site; Mekong Delta)

the method of Bhatt et al. (2009). Inside the burrow, fish were observed through an endoscope camera (Video Borescope Inspection Camera, code: 177845, EXTECH Company). One hour daily observations were also conducted to check fish occupancy, movement activities, as well as presence of eggs or embryos, following the method of Ishimatsu *et al*. (2007). Entering direction onto the burrow would indicate purpose of burrow entrance, i.e. a fish entering a burrow head first indicated that the fish used the burrow for predator avoidance, but not for foraging prey, and, if the fish entered tail first, it showed that the burrow is used for feeding and protecting from predator (Able *et al*., 1982).

The Minitab package software v16.0 was used for regression analysis at 95% confidence level. In the regression analysis, fish total length was the independent variable, whereas dependent variables were the burrow measurements such as the number of openings, opening diameter, bulbous chambers, bulbous diameter, tunnel diameter, burrow depth, width and length, and total burrow length.

RESULTS

Burrow morphology and its relationship with fish size

A total of 10 burrow imitations were studied (Fig. 3). In general, the burrow structure of blue-spotted mudskipper contained one to two openings with non-

pattern "footmarks" made by its pectoral fins (Fig. 4C) with one to two bulbous chambers. There were two I-shaped (Fig. 4A) and eight U-shaped (Fig. 4B) burrows created. The burrow contained one to two slightly inclined tunnels connecting to bulbous chambers, some short cul-de-sac side branches, and all 10 burrows had no mound on the burrow opening (Fig. 4C). Entrance shape and its inner surface of tunnels were slightly round and smooth.

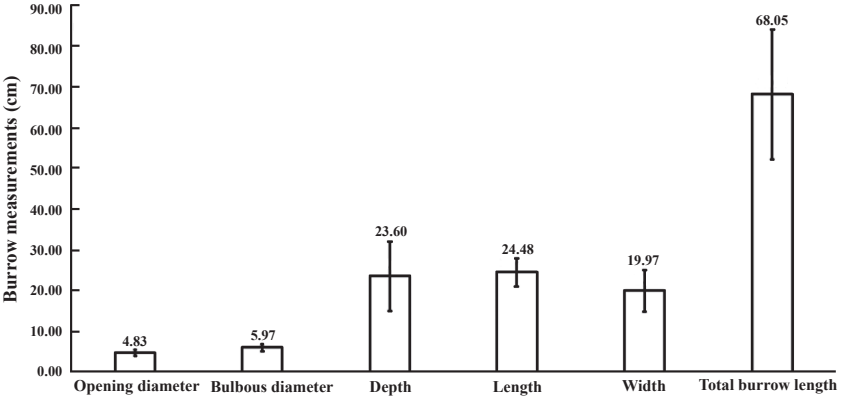

Figure 3. Burrow measurement dimensions of *Boleophthalmus boddarti*

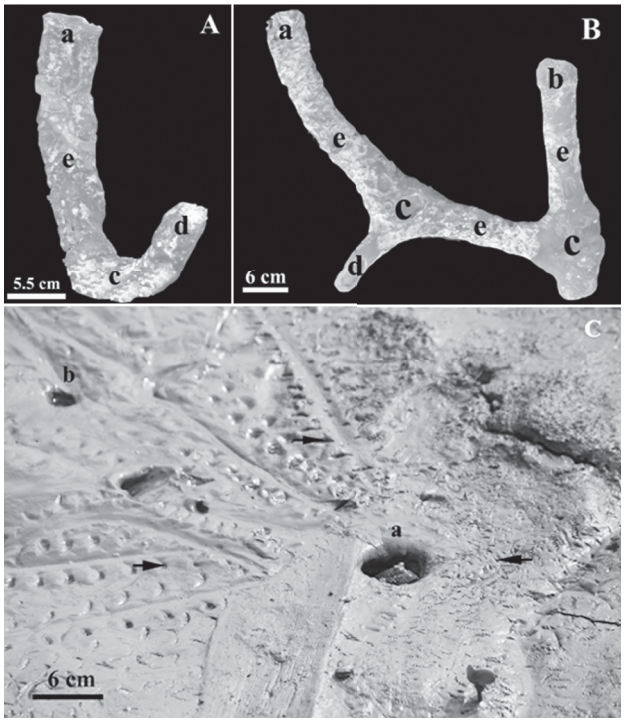

Figure 4. I-shaped burrow (A), U-shaped burrow (B) and burrow openings (C) (a: main opening, b: sub-opening, and c: bulbous chamber, d: cul-de-sac branch, e: tunnel, and arrow: "foot print")

The size of fish found inside the burrows ranged between 12.4 and 16.5 cm (TL). Furthermore, it was found that the size of fish (TL) was strongly related with burrow depth (P = 0.001), burrow width (P = 0.001), burrow length (P = 0.004) and total burrow length (P = 0.001). This was indicated by the high coefficients of determination (R^2, Fig. 5A, B, C, D), which were 0.977, 0.788, 0.666 and 0.977, respectively. Results showed that the burrow size would increase along with fish size.

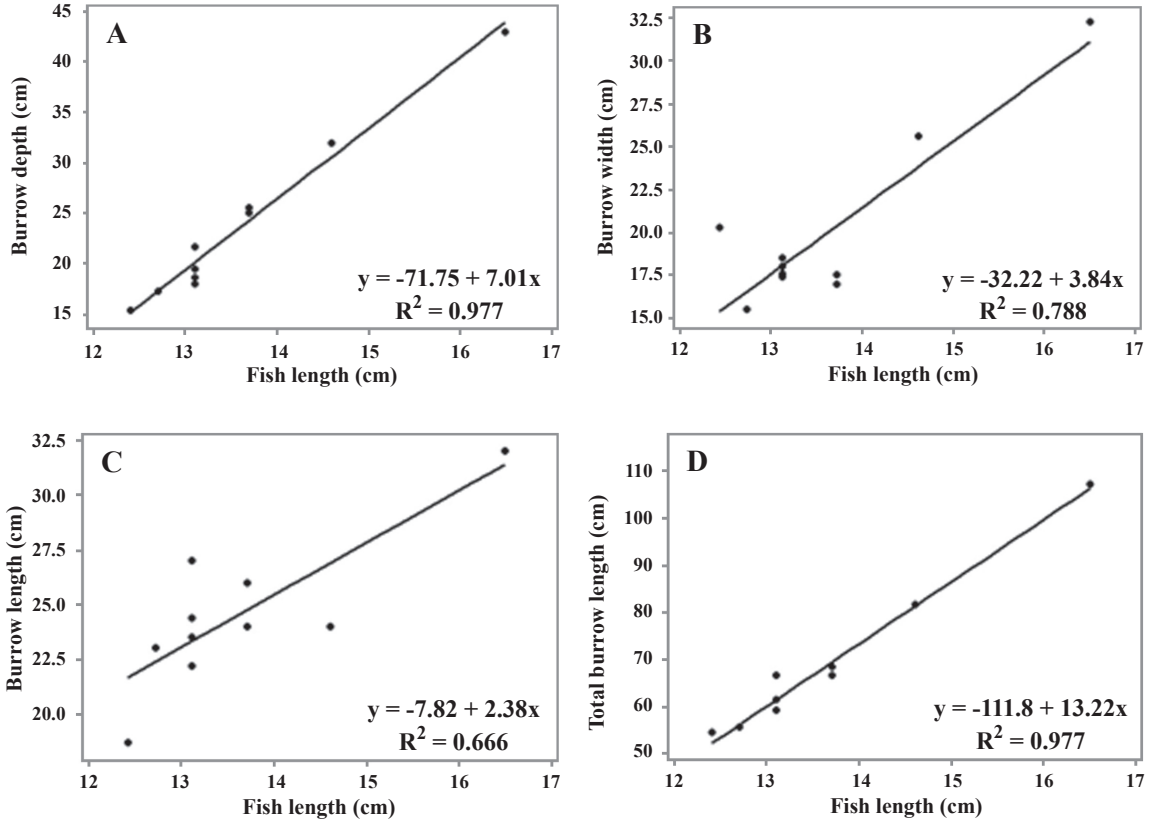

Figure 5. Relationships between fish length and the burrow depth (A), width (B), length (C), and total burrow length (D) (n = 10 in all cases)

Burrow utilization

Field observations revealed that the mudskipper, *B. boddarti* would quickly enter its burrows tail first when they saw fishermen and fiddler crabs, which indicated that the fish used the burrows as places for foraging prey, living, and taking refuge from predators. During the field observation, even though the endoscope camera could not show any evidence related to egg-tending because of the high sedimentation rate in the burrows, fish with stage V gonads (Vesey & Langford,1985) were caught by hand, suggesting that the fish might use its burrows as a place for reproduction.

DISCUSSION

Burrowing morphology

Finding of the I- and U-shaped burrows of *B. boddarti* was different from those of the related *Pseudapocryptes elongatus* (Y-shaped) residing in the same habitat (Dinh, 2008), and other gobiid fishes such as *Taenioides cirratu*s (Itani and Uchino, 2003) and *Odontamblyopus lacepedii* (Gonzales *et al*., 2008) (unclear burrow shape) distributed in the muddy flats. The I and U shapes of burrows of this mudskipper species might help it to escape from predators including fishermen. There was no mound at the burrow opening of *B. boddarti* which was similar to gobiid fish, *Pseudapocryptes elongatus* (Dinh, 2008), whereas burrow opening of *Taenioides cirratus* (Itani and Uchino, 2003) and *Odontamblyopus lacepedii* (Gonzales *et al*., 2008) had mounds. It seems that *B. boddarti* effectively used the sedimentary habitat with various burrow shapes, tunnels and openings to escape from predators by using bulbous chambers to change directions when it moves in or out of its burrow.

It was apparent that the burrows of *B. boddarti* had less branches compared to other mudflat dwellers such as *Odontamblyopus lacepedii* (Gonzales *et al*., 2008), *Taenioides cirratus* (Itani and Uchino, 2003) and *Pseudapocryptes elongatus* (Dinh, 2008) (Table 1). The burrow depth of *B. boddarti* is about half of that of *P. elongatus* (Dinh, 2008) and *Odontamblyopus lacepedii* (Gonzales *et al*., 2008), but similar to that of *Taenioides cirratus* (Itani and Uchino, 2003) (Table 1). The burrow width and length of *B. boddarti* were less than that of

Table 1. Morphometric measurement of burrows created by *Boleophthalmus boddarti* and other burrow-building fish species

No. of casts	No. of openings	Mound	Burrow depth (cm)	Burrow width (cm)	Burrow length (cm)	Total burrow length (cm)	Species	Location*	Sources
2	3.5±0.7	Yes	25.0±7.1	67.5±3.54	125.0±21.21	375.0±63.6	*Taenioides cirratus*	(1)	Gonzales *et al.* (2008)
9	3.8±2.0	Yes	41.1±23.7	107.2±58.2	140.11±3.7	1326.1±1093.5	*Odontamblyopus lacepedii*	(2)	Itani and Uchino (2003)
7	2.1±0.7	No	42.6±11.9	27.1±8.8	39.4±22.0	82.6±31.8	*Pseudapocryptes elongates*	(3)	Dinh (2008)
10	1.8±0.4	No	23.6±8.4	19.9±5.1	24.5±3.5	68.1±15.9	*Boleophthalmus boddarti*	(4)	This study

*(1): Hidaka River, Japan, (2): Saga Prefecture, Japan, (3): Bac Lieu, Vietnam, (4): Soc Trang, Vietnam

Odontamblyopus lacepedii (Gonzales *et al*., 2008), *Taenioides cirratus* (Itani and Uchino,2003) and *P. elongatus* (Dinh, 2008) (Table 1). The total length of burrows of *B. boddarti* was similar to the related species, *Pseudapocryptes elongatus* (Dinh, 2008), whereas it was less than that of *Odontamblyopus lacepedii* (Gonzales *et al*., 2008) and *Taenioides cirratus* (Itani and Uchino, 2003). It could be because *Pseudapocryptes elongatus* (Dinh, 2008) and *B. boddarti* were distributed in the same habitat, whereas *Odontamblyopus lacepedii* (Gonzales *et al*., 2008) and *Taenioides cirratus* (Itani and Uchino, 2003) are found in Japan where the sediments might differ from those in the Mekong Delta. The strong relationship between fish size and burrow dimensions of *B. boddarti*, suggested that large fish could use a burrow more effectively than small fish for predator avoidance and foraging prey. This also occurred in the air-breathing eel goby, *Odontamblyopus lacepedii* (Gonzales *et al*., 2008).

Burrow utilization

The mudskipper, *B. boddarti* usually enters head first, implying that chambers are used as a place for feeding, which is similar to tilefish, *Lopholatilus chamaeleonticeps* (Able *et al*., 1982). *B. boddarti* also used its burrow as a place for living and refuge to escape from predators, which was similar to the goby, *Taenioides cirratus* (Itani and Uchino, 2003) and eel goby, *Odontamblyopus lacepedii* (Gonzales *et al*., 2008). *B. boddarti* also used burrows for spawning which was similar to the monogamous goby *Valenciennea longipinnis* (Takegaki and Nakazono, 1999; Takegaki, 2001), goby *Zosterisessor ophiocephalus* (Mazzoldi *et al*., 2000), *Periophthalmodon schlosseri* (Ishimatsu *et al*., 2009) and mudskipper *Periophthalmus modestus* (Ishimatsu *et al*., 2007).

CONCLUSION

The burrow structure of *B. boddarti* comprised of "I" and "U" shapes, and had one to two openings with "footmarks", bulbous chambers and slightly inclining tunnels connecting to bulbous chambers and some short cul-de-sac side branches. Burrow depth, width, length and total length were 18-32 cm, 17-32.3 cm, 22.2-32 cm and 59.1-207.3 cm, respectively. There was no mound at the burrow openings. This study reported that burrow structural dimensions have a strong relationship with fish size, and the blue-spotted mudskipper used burrows as a place for feeding, living, protection and spawning.

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LITERATURE CITED

Able K.W., C.B. Grimes, R.A. Cooper, J.R. Uzmann. 1982. Burrow construction and behavior of tilefish, *Lopholatilus chamaeleonticeps*, in Hudson Submarine Canyon. **Environmemtal Biology of Fishes** 7 (3):199–205.

Atkinson R.J.A., C.J. Chapman. 1984. Resin casting: a technique for investigating burrows in sublittoral sediments. **Progress in Underwater Science** 10, 109-115.

Atkinson R.J.A., A.C. Taylor. **Burrows and burrowing behaviour of fish.** In: Meadows P.S., A. Meadows (eds) The environmental impact of burrowing animals and animal burrows, Zooological Society of London, 1991. Clarendon Press-Oxford, pp 133-155.

Bhatt N.Y., S.J. Patel, D.A. Patel, H.P. Patel. 2009. Burrowing activities of goby fish in the recent intertidal mud flats along the Navinal coast, Kachchh, Western India. **Journal of the Geological Sociaty of India** 74 (4):515-530.

Clayton D.A. 1993. **Mudskippers. Oceanography and Marine Biology: an annual review** 31:507-577.

Dinh T.D. 2008. **Some aspects of biology and population dynamics of the Goby *Pseudapocryptes elongatus* (Cuvier, 1816) in the Mekong Delta.** PhD, Universiti Malaysia Teregganu, Malaysia.

Dinh T.D., S. Koichi, N.T. Phuong, H.P. Hung, T.X. Loi, M.V. Hieu, U. Kenzo. 2013. **Fishes of Mekong Delta, Vietnam.** Can Tho University publisher, Can Tho.

Froese R., D. Pauly (2013) **FishBase.** World Wide Web Electronic Publication. www.fishbase.org. Accessed 19/07/2013.

Gonzales T.T., M. Katoh, A. Ishimatsu. 2008. Intertidal burrows of the air-breathing eel goby, *Odontamblyopus lacepedii* (Gobiidae: Amblyopinae). **Ichthyological Research** 55 (3):303-306.

Ishimatsu A., Y. Hishida, T. Takita, T. Kanda, S. Oikawa, T. Takeda, K.K. Huat. 1998. Mudskippers store air in their burrows. **Nature** 391 (6664):237-238.

Ishimatsu A., T. Takeda, Y. Tsuhako, T.T. Gonzales, K.H. Khoo. 2009. Direct evidence for aerial egg deposition in the burrows of the Malaysian mudskipper, *Periophthalmodon schlosseri*. **Ichthyological Research** 56 (4):417-420.

Ishimatsu A., Y. Yoshida, N. Itoki, T. Takeda, H.J. Lee, J.B. Graham. 2007. Mudskippers brood their eggs in air but submerge them for hatching. **The Journal of Experimental Biology** 210 (22):3946-3954.

Itani G., T. Uchino. 2003. Burrow morphology of the goby *Taenioides cirratus*. **Journal of the Marine Biological Association *of the* United Kingdom** 83 (4):881-882.

Mazzoldi C., M. Scaggiante, E. Ambrosin, M.B. Rasotto. 2000. Mating system and alternative male mating tactics in the grass goby *Zosterisessor ophiocephalus* (Teleostei: Gobiidae). **Marine Biology** 137 (5):1041-1048.

Ravi V. 2013. Food and Feeding Habits of the Mudskipper, *Boleophthalmus boddarti* (Pallas, 1770) from Pichavaram Mangroves, Southeast Coast of India. **International Journal of Marine Science** 3 (12):98-104.

Takegaki T. 2001. Environmental factors affecting the spawning burrow selection by the gobiid *Valenciennea longipinnis*. **Journal of Fish Biology** 58 (1):222-229.

Takegaki T., A. Nakazono. 1999. Reproductive behavior and mate fidelity in the monogamous goby, *Valenciennea longipinnis.* **Ichthyological Research** 46 (2):115-123.

Vesey G. & T.E. Langford. 1985. The biology of the black goby, *Gobius niger* L. in an English south coast bay. **Journal of fish biology,** vol. 27, no. 4, 417-29.