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Burrow morphology of the goby *Taenioides cirratus*

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The morphology of burrows constructed by the eel goby *Taenioides cirratus* was studied using resin castings of burrows *in situ* as well as aquarium observations. Burrows had several openings, one of which was associated with a crateriform mound. The structure of the burrows consisted of the mound, gently sloping interconnected tunnels, and many short cul-de-sac side branches. The presence of the mound suggests that the fish actively process sediment.

Taenioides cirratus (Blyth) is a gobiid fish with reduced eyes that is distributed in the Indo-west Pacific, where it occurs in shallow muddy estuaries and lives in burrows (Nayar, 1951). Little is known about the ecology of this species, probably due to its fossorial lifestyle. The burrow structures of several fish have been studied, because the characteristics of these burrows may reflect the general ecology of animals that would otherwise be difficult to examine (Atkinson & Taylor, 1991). However, the burrows constructed by *T. cirratus* have only been described cursorily (Nayar, 1951). In the present study, the morphology of *T. cirratus* burrows is described based on an analysis of resin casts taken *in situ* and aquarium observations, and the ecology of this species is discussed.

In situ investigations of the morphology of *T. cirratus* burrows were carried out on a tidal flat at the mouth of the Hidaka River, Wakayama, Japan (33°52′N 135°09′E), in September 1996. Many conspicuous mounds (up to 3 mounds m^{-2}) were observed on lower intertidal muddy flats (Figure 1A). The mounds were as large as 20 cm in diameter and 4 cm high with a shallow hollow in the centre (Figure 1B). A mound consisted primarily of mud particles, but the centre contained coarse sand. Burrow casts were made using polyester resin (U-PiCA, Japan U-PiCA Company Ltd), which was mixed with a peroxide catalyst (2% by volume) and was poured into the burrows. The burrow entrance was enlarged by removing coarse sediment from the mound, and mud was piled around it to prevent resin from spilling over onto the mud surface. After one or two days, the hardened casts were carefully removed from the sediment.

Two nearly complete burrow casts were recovered (Table 1). One individual *T. cirratus* was embedded in each cast, but no other macro-organisms were found in the casts. The morphology of the casts was quite different from that of other burrowing macrofauna in the field (*Laomedia astacina*, *Ilyoplax pusilla*, and *Macrophthalmus japonica*). Thus, there is confidence that the collected casts were of *T. cirratus* burrows. Each burrow had three or four openings, one of which was associated with the mound and was blocked by coarse sand. The structure of the burrow consisted of the mound, several gently sloping tunnels, and many short cul-de-sac side branches (Figure 1C–E). Interconnected tunnels leading to the surface descended to about 30 cm. Tunnels were sub-circular in cross section and had rough roofs and smooth floors.

To further investigate the morphology of *T. cirratus* burrows, aquarium observations were conducted at the Seto Marine Biological Laboratory in April 1998. Specimens of *T. cirratus* were collected from a tidal flat at the mouth of the Tonda River, Wakayama, Japan (33°38′N 135°24′E), by using a shovel to dig up sediment in areas where mound density was high (similar to Figure 1B). Two *T. cirratus* were then individually maintained in two narrow, sediment-filled aquaria that measured 40×2.5×40 cm (length × depth × height) in a 500-l tank.

One fish (body length: 130 mm) successfully constructed a burrow within two days. The burrow system was similar to that of the resin casts collected in the field: it was composed of a gently sloping tunnel connected with a mound (Figure 1F) and branched tunnels, one of which connected to the surface. The fish occasionally excavated sediment by mouth (Figure 1G). Muddy sediment was washed out from the burrow through the mound with a strong backward current created by undulating motions of the fish. Ejection of muddy water from the mound was also observed in the field. In addition to mud, the guts of five specimens of *T. cirratus* collected from the Tonda River contained the mud-shrimp *Upogebia yokoyai* which is abundant at the flat (three fish) and an annelid (one fish).

A shallow, elongate, and branched burrow system with many openings may be a common structure among the burrows made by *Taenioides* species, i.e. *Taenioides* sp., *T. cirratus*, and *T. rubicundus* (see Atkinson & Taylor, 1991 for references); however, the crateriform mound is described for the first time in this study. The presence of the mound indicates that the fish actively processes the sediment, as has been suggested for thalassinidean shrimp (Nickell & Atkinson, 1995). Carnivory and deposit-feeding have been suggested as foraging strategies in *T. cirratus* (Nayar, 1951; Geevarghese, 1983). Considering that upogebiids, one of the prey items of the goby, rarely leave their Y-shaped burrows (Nickell & Atkinson, 1995) and that the diameter of the burrow of *U. yokoyai* at the flat is too small for the goby to enter in (unpublished observation), *T. cirratus* may have foraged on these shrimp underground. A highly branched burrow system may facilitate underground predation in addition to deposit-feeding. Multiple burrow openings, however, may also suggest the possibility of surface foraging around the openings, as is the case in the mud-shrimp *Jaxea nocturna* (Nickell & Atkinson, 1995). In contrast to the mounds made by the goby *Valenciennea longipinnis*, which are constructed by piling coral debris to promote water-

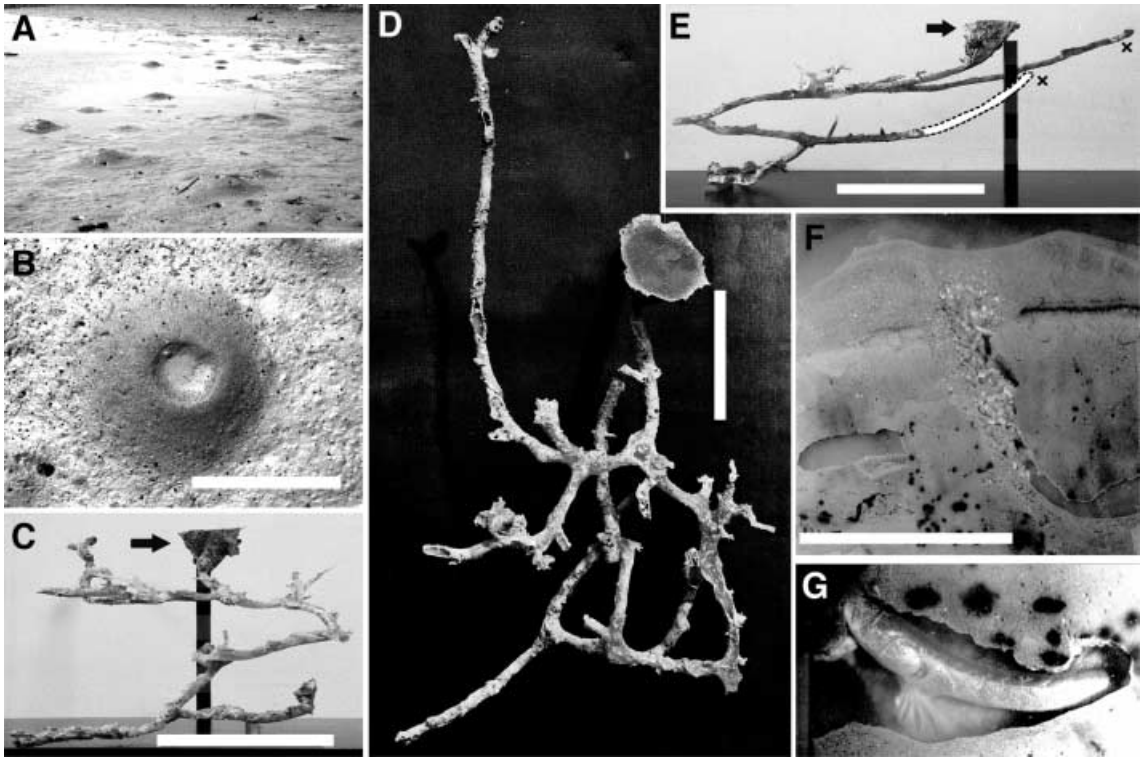

Figure 1. (A) Surface features of a tidal flat at the mouth of the Hidaka River, Wakayama Prefecture, Japan; (B) close-up of the sediment showing a crateriform mound; (C) side view of the polyester resin cast (no. 1) of a *Taenioides cirratus* burrow. The arrow indicates the burrow opening connected to the mound; this opening was enlarged conically for the process of resin casting; (D) view of the same cast as seen from above; (E) another side view of the same cast. Black dashes outline the part of the burrow in which the *T. cirratus* was embedded. The arrow indicates the burrow opening connected to the mound and the Xs indicate the openings without mounds; (F) mound and burrow constructed against the wall of an aquarium. The black horizontal line indicates the initial mud surface; (G) burrowing activity of *T. cirratus* in an aquarium. Scale bars: B,F, 10 cm; C–E, 25 cm.

Table 1. *Morphometric data for burrow casts of* Taenioides cirratus.

Cast no.	Body length of the embedded fish (mm)	Mound diameter (cm)	Horizontal extension (cm)	Depth (cm)	Total length (cm)	No. of surface openings	Mean tunnel width (mm)	Mean tunnel height (mm)
1	190	15	140 × 70	30	330	3	19	14
2	210	18	110 × 65	20+	420+	4	21	17

exchange in the burrow (Takegaki & Nakazono, 2000), mounds made by *T. cirratus* are a byproduct of burrowing activity caused by settlement of sediment vented in suspension. A more comprehensive collection of resin casts together with quantified laboratory and field observations will be needed to provide a better understanding of the ecology of the eel goby.

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