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Unique substrate preference of *Ostrea denselamellosa* Lischke, 1869 (Mollusca: Ostreidae) at Haechang Bay, on the south coast of Korea

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ABSTRACT

In the present study, we observed a unique association of the flat oyster, *Ostrea denselamellosa* obtained from a muddy substrate at Haechang Bay, the south coast of Korea in the spring of 2013. Fossilized or semi-fossilized veneriid clam shells, possibly *Ruditapes philippinarum*, were found adhering to the umbonal area of the flat oyster valves. This unique association of the flat oyster shells with the fossilized clam shells suggested that the flat oyster larvae utilized the clam shells as substrate during settlement. Since availability of clam shells in the muddy subtidal environment is limited, this unique substrata for the flat oyster larvae may limit recruitment of the flat oysters in the bay.

Keywords: *Ostrea denselamellosa*, Haechang Bay, *Ruditapes philippinarum*, substrate preference, Korea

INTRODUCTION

The "flat oyster" *Ostrea denselamellosa* Lischke, 1869 is commonly occurring in small bays off the south and west coast of Korea (Min, 2004), as well as in southern Japan and China (Okutani, 2000; Lam and Morton, 2004). The flat oyster is considered to be one of the important bivalve resources in coastal shellfish fisheries, although its population density is known to be small (Lam and Morton, 2004). In Korea the flat oyster occurs on rocks and gravel on sandy-mud or muddy bottom at depths of 3-10 m (Min, 2004). The flat oyster shell is irregularly sub-circular to sub-quadrate, and concave, with the right valve flatter than the left. The valves are radially ribbed; those of the right valve are covered with fragile growth scales which are lacking on the left which may be purplish with radiating ribs (Park *et al.*, 1998). *O. denselamellosa* is viviparous, depositing its larvae directly into the water column. The time between release and the pseudo-veliger stage, when settlement occurs, is from 20-28 days (Yang *et al.*, 2003; Chen *et al.*, 2006). On the south coast, where it is commercially farmed, the bottom-culture method is employed at depths less than 20 m (Yoon, 2008).

Available hard substrate is often limited for sessile marine bivalve larvae, including the flat oyster (Ventilla, 1984; Arakawa, 1990a, b). In particular, hard substrate is crucial for benthic sessile organisms and may play a limiting factor in subtidal muddy or sandy soft bottom. Alternatively, dead shells or fossilized marine bivalve shells are often serve as substrate to the oyster larvae for settlement (Ventilla 1984; Kennedy 1986; Su *et al.*, 2007). In this study, we report a unique association of the flat oyster shells

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Fig. 1. *Ostrea densalamellosa* collected from Haechang Bay, off the south coast of Korea.

with fossilized or dead shells of a venerid clam, possibly *Ruditapes philippinarum*, from a muddy subtidal area on the south coast of Korea, where the clam shells are serve as the substrate for the flat oyster *O. denselamellosa.*

MATERIALS AND METHODS

On April 2013, *Ostrea denselamellosa* (Fig. 1) were dredged at Haechang Bay, near Yeosu, on the southern coast of Korea (Fig. 2). The flat oysters were distributed on a subtidal mudflat at a depth of 5-7 m. Upon arrival the laboratory the oysters were cleaned to remove sediments and debris deposited on the shells. Shell length as the longest axis of the right valve, was recorded to mm. Attached sessile organisms on the shell surface, mainly mollusks, were identified to species level using a dissecting microscope, according to Min *et al*. (2004) and Kim (1998).

RESULTS AND DISCUSSION

The valves of *O. denselamellosa* collected from Haechang Bay were generally quite clean, with only 18% exhibiting attached organisms. The sessile organisms (Fig. 3) attached to the shell were identified as one species of barnacle and two mollusk species. The mollusks were identified as *Crepidula onyx* Sowerby I, 1824 (Gastropoda) and *Anomia chinensis* Philippi, 1849 (Bivalvia), and the barnacle as Balanus cf. trigonus Darwin, 1854; one specimen was unidentified. Of the oysters possessing attached organisms, barnacles occurred on 67%, along with

Fig. 2. Location of the sampling site.

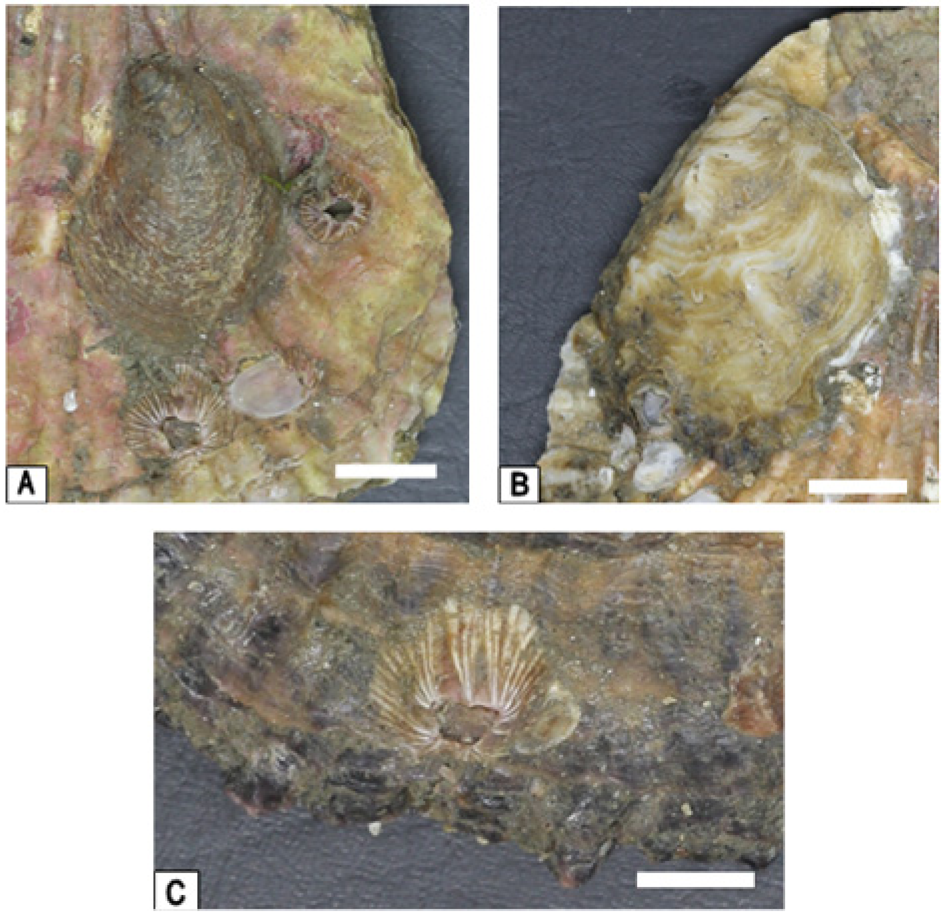

Fig. 3. Sessile animals attached to valves of *O. denselamellosa*. **A**. *Crepidula onyx* Sowerby I, 1824; **B**. *Anomia chinensis* Philippi, 1849; **C**. *Balanus* cf. *trigonus* Darwin, 1854. Scale = 1cm

three specimens of *C. onyx* and four of *A. chinensis*, respectively. Most specimens occurred individually on the oyster valves, but barnacles occurred with one *A. chinensis* and one *C. onyx* specimen. No size preference for the larvae of these species was demonstrated (Table 1).

A close examination of the left valve of the 18 specimens selected revealed that on most of them, near the umbo, a valve of a species of Veneridae was adhering (Fig. 4). These valves appeared to belong to *Ruditapes* sp., possibly *R. philippinarum* (Adams and Reeve, 1850), and some that were broken on the edge were full of a consolidated material. The valves, mainly mature specimens of about the same size, appeared to be subfossil, or near subfossil, and some retained most of their original color. According to Powell *et al*. (2008), regardless of substrate, the dominant taphonomic process is discoloration, although some specimens may experience fading without subsequent discoloration, as appears to be the case at Haechang.

According to Yang *et al*. (1999), the substrate at Haechang Bay is composed of coarse sand, sandy silt, and silty sand. It appears that *O. denselamellosa* may have employed the *Ruditapes* shells as a substrate as the larvae settled and metamorphosed, as *R. philippinarum* is very common in this area (Yang *et al*., 1999). Although this species, like most Ostreoidea, prefers a hard, stable substrate, such as rocks, the Haechang Bay area with its muddy substrate provided a severely limited choice. Silt and sand are very unstable substrata, thus with dead shells as the only

Table 1. Length of shells, and type and number of sessile species

SHELL LENGTH (MM)	BARNACLE	CREPIDULA	ANOMIA	UNIDENTIFIED
77.6	1		1	
78.3	1			
78.7	1			
79.4	1			
79.6	1			
84.1	1			
84.3			1	
85.0	1			
85.2	2			
86.9		1		
89.0	2			
89.4	1			
90.1				1
91.5			1	
92.0	1	1		
94.1			1	
102.6	1			
159.0		1		

substrate available, the oyster larvae would select the subfossil *R. philippinarum* valves as a substrate for settling. Therefore, instead of a stable substrate for settlement and growth, *O. denselamellosa* in this area has to choose a rather fragile substrate: subfossil *R. philippinarum* valves resting on a muddy substrate, a unique ecological niche.

O. denselamellosa prefers moderately deep water, 2-11 m, with high salinity (Park *et al.*, 1988) thus the water may be too turbid and saline for other oyster species. For example, *Crassostrea gigas* (Thunberg, 1793), the most common species, can tolerate a wider range of salinity but generally prefers shallower water with less saline conditions (Park *et al.*, 1988). This bathymetric preference of *O. denselamellosa* would result in little interference from other oysters, and a uniform settlement habitat with room to grow with no crowding would result in a largely uniform size and shape. Thus, *O. denselamellosa*, on a soft substrate, can become a solitary oyster species.

As for the actual method of settlement, we hypothesize that strong currents in nearby hatching areas may bring larvae to unsuitable areas, such are those with silt or mud where the settling larvae would be smothered. However, as *R. philippinarum* is very common in this part of Haechang Bay, the valves could become disarticulated after death and be exposed at the surface of the mud, forming small beds of empty valves. Wave action caused by storms could dislodge those valves throwing them into the water column where many would settle with the concave side facing upwards. Allen (1986) demonstrated that, in areas of high turbidity, there is a high frequency of "concave-up" bivalve positioning. The concave surfaces of the valves could provide a better shelter and substrate for the flat oyster larvae than the smoother "convex-up" positioning; the curved convex side of the valves facing the mud would enable them to settle further into the substrate, offering more stability. All specimens of *O. denselamellosa* in this study were attached to the concave side of the Ruditapes valves (Fig. 4).

All *Ruditapes* valves exhibited various stages of taphonomy. It appears that many of those valves may

Fig. 4. Veneriid fossil shells attached on the right valve of *O. densalamellosa*. Scale = 1cm

have become embedded in the substrate and gradually collected some of the larger, more granular material present. This became consolidated over time by cementation of the sediments, caused in part by leaching of calcium carbonate from the shells (Muckle, 1980). The taphonomic process is, in general, slow (Powell *et al*., 2008), and infauna, such as *R. philippinarum*, are usually better preserved (Lazo, 2004). Another possible explanation for the relatively fresh appearance of some of the valves is that bivalves in siliciclastic environments, with finer-grained sediments, exhibit a lesser degree of taphonomic change (Best and Kidwell, 2000; Best, 2008, Fig. 4).

Currents or wave action may have disturbed the soft substrate and exposed the valves, providing a suitable surface where the oyster larvae can settle. The settling larvae are able to creep until they find a suitable place for permanent attachment (Park *et al*., 1988). This may cause a possible patchy distribution of *O. denselamellosa*. According to Yang, *et al*. (1999) the density of this species at in Haechang Bay was only 0.25 individuals per m^2. Thus the occurrence of subfossil valves becomes a limiting factor in the occurrence and distribution of this species. Another limiting factor is that *O. denselamellosa* is a brooding species (Chen, 2010; Qi, *et al*., 2004), and would release its larvae only after they had hatched from the eggs, causing them not to spread very far.

Basically those valves were mainly mature valves of the same size, as the larvae would need a moderately stable substrate on which to settle. Chen (2010), in an experimental study on reproduction and settling, demonstrated that, of a variety of substrata offered to newly-hatched larvae, scallop shells were preferred, suggesting that medium to large bivalve shells would be a suitable substrate for attachment. In this study, the subfossil *Ruditapes* shells were the only substrate available, and they would have to be stable in the mud to enable the juveniles to grow. These old valves would be a satisfactory substrate for the juveniles but, as they grow larger and heavier, they may experience stability problems. As long as the currents in the area remain constant, with little turbidity, the oysters may have a chance to grow to adult size; strong currents which would dislodge the muddy substrate and the growing oysters could cause significant mortality. Thus, it may be said that the adult oysters in this area in Haechang Bay demonstrate the survival of the fittest, and the luckiest.

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