Feeding behavior of the urchin-eating urchin *Salmacis sphaeroides*

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Abstract On the shallow sandy bottom in the innermost part of the Gulf of Thailand, the regular sea urchin *Salmacis sphaeroides* feeds on two spatangoid urchins: *Brissus latecarinatus*, one of the locally dominant infaunal macrobenthic animals, and *Lovenia elongata*. Aggregations of *Salmacis* were frequently seen on the soft bottom during a survey of the macrobenthos in the Gulf, and *Brissus* individuals lacking spines were found beneath the aggregations. *Brissus* species, which are infaunal, were attacked by *Salmacis*, although the reason for their presence on top of the sandy bottom remains unknown. *Salmacis* were seen feeding first on the spines of *Brissus*, exposing the test. Occasionally, *Salmacis* carrying empty, broken tests of *Brissus* were observed, indicating that the *Brissus* organs were also eaten by *Salmacis*. The fact that *Salmacis* ate several kinds of food items such as water hyacinths originated from the nearby river system, sea pens, jellyfish, and other urchins indicates that this species is an omnivore. Cannibalism was also found both in the field and laboratory. The feeding strategy of

Salmacis has evolved to incorporate diverse food items, but *Brissus* is undoubtedly an important food source because of its high abundance.

Keywords *Salmacis sphaeroides*, *Brissus latecarinatus*, predation, Gulf of Thailand, feeding strategy

Introduction

Predation is one of the most important factors controlling community structure in natural ecosystems, and the importance of predator-prey interactions between infauna and epifauna on marine soft-bottom communities has been specifically emphasized (Schrijvers et al. 1998; Quijón and Snelgrove 2005; Beseres and Feller 2007).

We found a fact that the regular sea urchin *Salmacis sphaeroides* feeds on two spatangoid urchins: *Brissus latecarinatus*, one of the locally dominant infaunal macro-

benthic animals, and *Lovenia elongata* on the sandy bottom of the inner part of the Gulf of Thailand. Although consumption of sea urchins by some predators has been reported (Moitoza and Phillips 1979; Cowan 1983; Tegner and Levin 1983), reports of urchins preying on other urchin species are rare; in fact, this is only the second record of an urchin-eating urchin. The green urchin *Strongylocentrotus droebachiensis* preyed on the sand dollar *Echinarachnius parma* on the coast of Newfoundland, Canada (Himmerlman and Steele 1971). Here, we report the feeding habits of the urchin-eating urchin *Salmacis sphaeroides*.

Study area and methods

The surveys were conducted around the Sichang Islands, the innermost part of the Gulf of Thailand (13°09'N, 100°48'E), in 1984, 1987, 1994, and 1997. The shallow subtidal area of this region can be divided into three subzones according to the distribution pattern of macrobenthic animals and substrate characteristics (Tsuchiya et al. 1986). The shallowest zone consists of a rocky or sandy coast, the second zone is occupied by hermatypic corals dominated by the massive coral *Porites lutea* (coral zone), and the third zone is characterized by a soft bottom extending to deeper areas with conspicuous surface irregularities resulting from the feeding activity of *Brissus*. A transect line was placed perpendicular to the shoreline from the intertidal zone, and a general survey of the macrobenthic animals was conducted along the line.

Feeding activities of *Salmacis* on *Brissus* were observed both in the field and in the laboratory. In the field, a *Brissus* was dug from the sediments and put on different substrates such as sandy particles and gravels. Then, several *Salmacis* specimens were arranged to surround the *Brissus*.

Cage experiments were also conducted to observe the feeding behavior of *Salmacis*. Hemisphere type plastic cages with 5 mm mesh were used for experiments conducted in the habitat of *Brissus*. Six experimental treatments were tested. In all treatments, five individuals of *Brissus* were introduced to the cages and the behavior of *Salmacis* was monitored for one week.

Results and discussion

Sea urchins were abundant on the soft bottom. The most abundant epifaunal urchin species was *Diadema setosum*, but its distribution area was restricted to the shallower two subzones (Tsuchiya et al. 1986). A high abundance of *Brissus* was marked along the transect line within 0–50 m from the lower limit of the coral zone (70 m from the shoreline), showing a peak abundance (>100 individuals/m²) at approximately 35 m (ca. 2 m deep from the lowest low waters, LLW) (Choonhabandit and Tsuchiya 1989). The distribution area of *Salmacis* (density: 0–5 individuals/m²) overlapped considerably with that of *Brissus*, but no *Salmacis* were found in the 0–15 m region, suggesting that there may be an interspecific interaction between the two species. *Temnopleurus toreumaticus*, which is closely related to *Salmacis*, was found in the deeper area (>100 m). *Lovenia* was found mainly in the deeper zone, indicating habitat segregation with *Brissus*.

In these zones, predation on *Brissus* (Fig. 1a) by *Salmacis* was frequently observed and dead *Brissus* individuals lacking spines (Fig. 1b) or its empty shells were common on the sandy bottom surface. *Salmacis* was also feeding on *Lovenia* (Fig. 1c). Other items such as the water hyacinth (Fig. 1d) and sea pen (Fig. 1e) were also eaten.

Many potential food items are carried to this area because of its locality in the innermost part of the Gulf of Thailand. Some terrestrial and freshwater plant species are frequently carried to the Gulf and seen on the bottom. Vascular plants including *Ipomoea*, *Wedelia*, *Eichhornia*, *Leucaena*, and unidentified grasses, banana skin, dried beef, and salami were artificially placed separately at sites along the line at 5, 15, 25, and 35 m from the lower limit of the coral zone. *Salmacis* feeding was observed in all cases, suggesting that *Salmacis* is a generalist feeder and can use a diversity of food items that may show temporal variation. In addition, cannibalism among *Salmacis* was observed in the laboratory.

Six individuals of *Salmacis* were placed around a *Brissus* (ca. 10 cm in distance), and the behavior of two

Fig. 1 a) Several individuals of the sea urchin *Salmacis sphaeroides* feeding on the spatangoid *Brissus latecarinatus* (center top) in the gulf of Thailand. One individual is carrying an empty test of *Brissus* (right bottom), b) *Brissus* of which most spines were eaten by *Salmacis*, c) *Salmacis* attacking *Lovenia elongata*., d) *Salmacis* feeding on the water hyacinth carried from the nearby river system, e) *Salmacis* feeding on a sea pen, and f) Environmental heterogeneity (surface irregularity) of the habitat of *Brissus*

species were continuously monitored. One minute after setting, one *Salmacis* began to move toward the *Brissus*, in only 10 sec, reached and rode on the *Brissus*. The second *Salmacis* followed the first one showing similar behavior, reached and contacted with the first *Salmacis*. Both *Salmacis* performed spine waving, an intraspecific interaction. At the same time, another *Salmacis* also moved toward the aggregation, but voluntarily left the experimental area. The *Brissus* began to burrow into the sediment 5 min after the first *Salmacis* arrived, and half of its body was hidden in the sediment after 15 min. Other *Salmacis* joined the aggregation within 15–18 min, and two individuals left the aggregation after 20 and 24 min, respectively. After 38 min, the *Brissus* completely es-

caped into the sediment. Damage to the *Brissus* did not appear serious. We conducted similar experiments on different sediment conditions (i.e. on gravel and sandy bottoms) and observed the predation process by *Salmacis*. *Brissus* only escaped from its predators when on a sandy bottom. It could not escape from attacking predator probably because of burrowing difficulty on gravel substrates. Therefore, environmental heterogeneity resulting from the mosaic distribution of sediments (Fig. 1f) can contribute to the survival of both *Brissus* and *Salmacis*.

This was confirmed by the cage experiments in the field (Fig. 2). In Treatment 1, five *Brissus* were placed on the net installed just beneath the bottom surface, thus, all *Brissus* could not burrow and remained exposed on the

Fig. 2 Experimental design for observing of the predation on *Brissus laticarinatus* by *Salmacis sphaeroides*. Hemisphere type plastic cages, about 50 cm diameter with 5 mm mesh were used. Six treatments were prepared by installing the net in two ways: just beneath sediment surface to block *Brissus* from burrowing, and on the cage top to prevent invasion of *Salmacina* into the cage. By different combination of setting these two nets, 6 treatments were tested. Cages were set buried in the substrates in the field, as is shown here. Five *Brissus* were introduced in a cage in Treatments 1 to 4, and each 5 individuals in both sectors in Treatments 5 and 6, and the survival of *Brissus* (closed circles) and interaction with *Salmacis* (open circles with spines) were monitored

sediment surface. Another net was fit above the *Brissus*, *Salmacis* came and tried to intrude into the cage, but could not attack the *Brissus* and all *Brissus* could survive during the experimental period. When the net inside the cage in Treatment 1 was removed, *Brissus* burrowed deep into sediments and become invisible from the surface (Treatment 2, all *Brissus* survived). Some *Salmacis* were seen on and around the cage. Treatment 3 was conducted without a net both in and top of the cage. Although *Salmacis* could invade the cage, *Brissus* placed on the bottom surface burrowed into the sediments and all escaped from the predation by *Salmacis*. In Treatments 4 and 5, *Brissus* which could not burrow into sediments due to obstruction by the net, were attacked by *Salmacis* and died. When the net was set above the *Brissus* they were not attacked by *Salmacis*. Treatment 5 is a combination of treatment 3 and 4 in a cage, and Treatment 6 the combination of Treatments 1 and 2. Treatments 5 and 6 showed the same results that were found in Treatments 1 to 4. All the findings suggest that, for *Brissus*, burrowing in the sediment is only the way to escape from the predation by *Salmacis*.

The *Brissus* population can be divided into two sub-

populations by body size, with the near-shore sub-population including large specimens and the offshore sub-population including smaller individuals. The density was higher offshore (Maximum: 126 inds./m²) than near-shore (17.8 inds./m²), and the grain size distribution of the habitat also differed (Tsuchiya et al. 1989). Sediments inhabited by the near-shore population are clearly a mosaic of gravels and sand particles created by the feeding activity of *Brissus*, while the offshore area was consistently sandy. However, there is a possibility that the difference in grain size composition affects the population density; the sandy bottom may accelerate population growth, because of the easiness in escape into the sediments. On gravel substrates, *Brissus* has difficulty escaping from *Salmacis* when *Brissus* appeared on the surface, resulting in a lower density than in the deeper zone.

Tsuchiya et al. (1989) studied the recolonization process of *Brissus* in the urchin-free area (removed area) and counted a high density of ca. 50 individuals/m² 2 weeks after the depopulation. This suggests that *Brissus* continually look for their new habitat and sometimes appear on the sediment surface. This must be a good chance for *Salmacis* to prey on their food. *Brissus* ap-

pearance on the sediment surface might be a result of self-thinning of the *Brissus* population according to the intraspecific competition in the high density area. If so, the thinning effect also contributes to the survival of the other species, *Salmacis*. It is still unknown, however, why *Brissus* appears on the sediment surface in its low density zone.

A huge population of *Brissus* has been providing a considerable food source for *Salmacis*, and the coexistence of both species can be maintained by the environmental heterogeneity of the soft bottom. This heterogeneity also helps maintain the high species diversity of the infaunal community, as community structure differs among environments (Tsuchiya et al. 1989).

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