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Utilization and Ecological Benefits of a Sponge as a Spawning Bed by the Little Dragon Sculpin *Blepsias cirrhosus*

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Abstract It was established that the little dragon sculpin *Blepsias cirrhosus* uses the sponge species *Mycale adhaerens* as a spawning bed. The eggs were completely concealed in the sponge tissues, and caused the sponge skeleton to be partly damaged. It is conceivable that the exclusive utilization of *M. adhaerens* by *B. cirrhosus* is a consequence of the advantageous softness and thickness of the sponge which allows the fish to inject the eggs. The eggs deposited in the sponge seemed to take advantage of predator avoidance, a constant supply of oxygen, and little interference by bacteria.

The little dragon sculpin *Blepsias cirrhosus* (Pallas) inhabits the coastal and adjacent waters of the North Pacific Ocean (Hart, 1973). It has recently been determined that the incubating period of this species eexceeds 250 days (Munehara and Shimazaki, 1991) and that this is a copulating species (Munehara et al., 1991). It has also been determined that other cottid fishes such as the sunrise sculpin *Pseudoblennius cottoides*, perch sculpin *P. percoides*, Ishikawa's sculpin *Furcina ishikawae*, and the sea raven *Hemitripterus americanus* have a spawning relationship with invertebrates (Uchida, 1932; Warfel and Merriman, 1944; Shinomiya, pers. comm.). Noting the protracted incubation period of *B. cirrhosus*, it was reasonable to propose that this species may also deposit eggs in live invertebrates to ensure the exceedingly long embryonic period. The present study was undertaken to clarify what invertebrate organisms *B. cirrhosus* utilizes as a spawning bed, and how the fish and benthic organisms are associated.

Materials and methods

Collection of potentially utilized organisms. The sessile benthic organisms in which *B. cirrhosus* would most likely deposit eggs were collected from the coastal waters of Usujiri, Hokkaido, Japan (Fig. 1). The site bottom, ranged from 0 to 16 m in depth, was rocky and covered with various kinds of seaweeds.

SCUBA equipment was used for the collecting of sessile benthic organisms. Eggs thought possibly to be those of *B. cirrhosus* were found in a sponge during a preliminary examination in July 1986. Sponges and sponge-like organisms with holes of similar size to the diameter of *B. cirrhosus* eggs were collected in November 1986 and July 1987 in order to examine what kind of benthic organisms the fish used as a spawning bed. A portion of each organism was fixed in 100% ethanol for identification, and the rest was dissected to investigate for presence or absence of fish eggs.

Rearing of the eggs and larvae. The eggs deposited in the sponge were kept for identification of species. The eggs were removed from the sponge tissues by a pincette, and incubated in 1,000 m*l* glass beakers at a water temperature of about 10℃. The hatched larvae were transferred into a 10*l* transparent acrylate tank, and were fed *Artemia salina.*

Results

Specifically utilized organisms and deposited eggs

A total of 203 specimens of sponge and sponge-like organisms were collected. Specimens were classified into 11 species, consisting of five sponges, four sea squirts, one bryozoan and one zoantharian (Table 1). All of these organisms fix to the ocean substrate and are of sufficient volume to accommodate the fish eggs as a spawning bed ($>5\times5\,cm^2$), but vary in softness and thickness. The degree of softness ranged from "cream" to "cork".

Of the 11 species investigated, fish eggs were found only in the sponge *Mycale adhaerens.* Eggs were found embedded in the tissue near the gastral cavity of the sponge and usually caused some damage to the

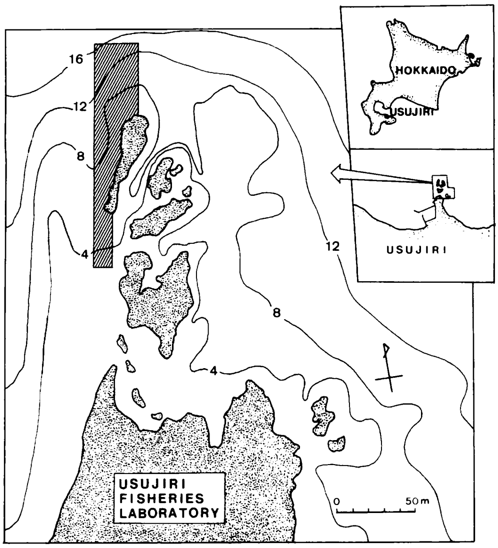

Fig. 1. Map of the southern Hokkaido coast. The area obliqued lines is studying site.

skeleton, being scarcely noticeable from the outside (Fig. 2). The eggs formed small clumps of 3–15 eggs, and sometimes more than two clumps were found near one gastral cavity. The eggs were characteristically deposited in canals for sea water taken in by the sponge for respiration and diet. Eggs were found at the same developmental stage in each clump. The deposited eggs take in oxygen for respiration from the sea water passing through the canal. All of the 29 *M. adhaerens* collected had been utilized by *B. cirrhosus* for spawning.

Besides living eggs, black discolored eggs were infrequently found (Fig. 2). These dead eggs may represent spawnings from the previous year.

Embryonic development and larvae hatched

Common characters of the eggs which were found in *M. adhaerens* were an almost spherical shape (3.0–3.2 mm in diameter), and a burnt orange color in the yolk (Fig. 2).

The development stage of the eggs which were collected in July ranged from morula stage to the embryo extending to 1/2 of the yolk circumference. The eggs possessed a large quantity of yolk, so the blastoderm or body of the embryo was very small relative to the yolk volume. In the most developed embryos, melanophores could be seen on the optic vesicles, and blood vessels ran on the yolk below the thoracic region of the embryo.

The embryos of eggs collected in November extended from 2/3 to 3/4 of the yolk circumference, and some melanophores could be seen on the peritoneal wall (Fig. 3). In the most developed embryos, melanophores were also present on the nape. Eggs collected in November were kept in an aquarium,

Table 1. Softness and thickness of the collected sessile benthic organisms, and number of specimens with fish eggs deposited.

Group Species	Softness	Thickness (cm)	Number of specimens collected	Number of specimens with deposited fish eggs
Sponges				
Mycale adhaerens	very soft	2 – 3	29	29
Phorbas intermedia	tought	1 – 3	104	0
Suberites infrafoliatus	very tough	3 – 5	4	0
Haliclona viloa	middle	0.5– 2	22	0
Agelas schmidti	soft	0.5– 1	12	0
Sea squirts				
Didemnum alhidum	middle	5 – 8 (diameter)	5	0
D. misakiense	middle	5 – 7 (diameter)	3	0
Sidneiodes snamoti	middle	1 – 2	6	0
Amaroucium glabrum	very soft	0.5– 1	8	0
Bryozoan				
Unidentified	soft	0.5– 1	4	0
Zoantharia				
Unidentified	middle	2 – 3	6	0

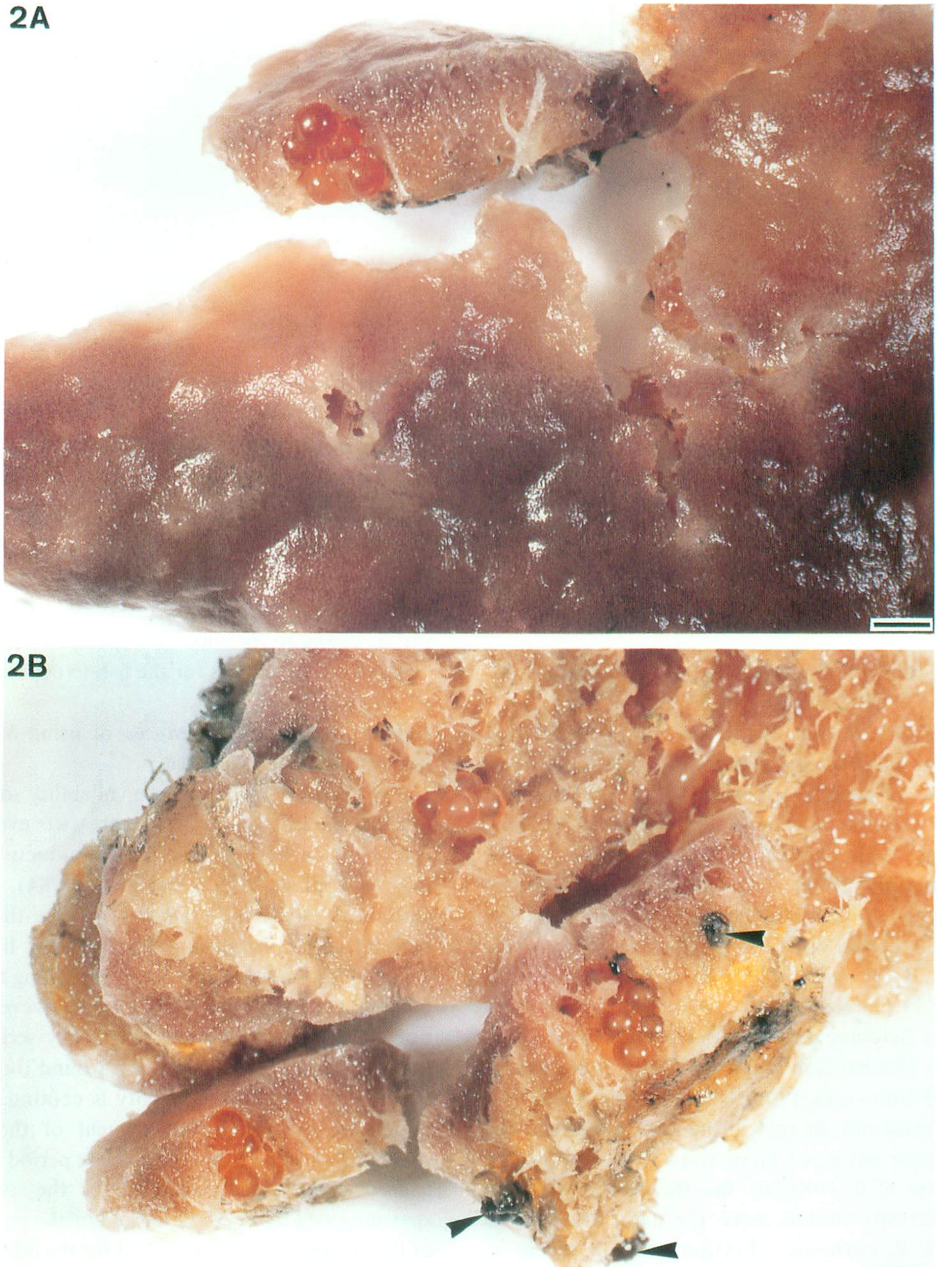

Fig. 2. *Blepsias cirrhosus* eggs deposited in a sponge *Mycale adhaerens.* A and B are the surface and the vertical sides of *Mycale adhaerens*, respectively. Arrows indicate the black discolored eggs. Bars show 10 mm.

and hatching took place from early February to early March.

The newly-hatched larvae ranged from 10.7–11.3 mm in notochord length. The body of these larvae was slender and brownish in color. The body, excepting the caudal portion, was heavily pigmented with melanophores. One specimen reached 14.4 mm in standard length three months after hatching (Fig. 4). The larva had 5 spines and 20 rays in the dorsal fin, 17 rays in the anal fin, 13 rays in the pectoral fin, 3

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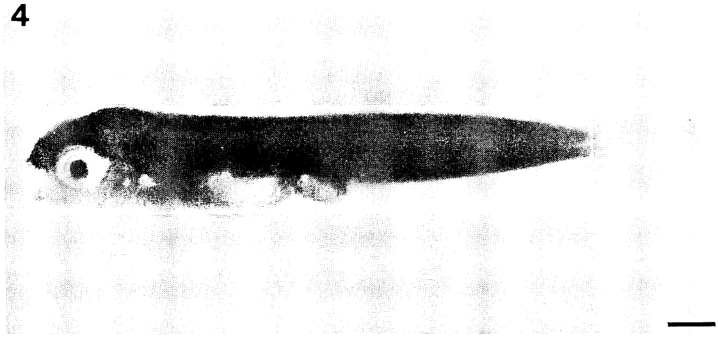

Fig. 3. An egg of *Blepsias cirrhosus* picked out from tissues of *Mycale adhaerens* collected in November. Bar shows 1 mm.

Fig. 4. The most developed larva of *Blepsias cirrhosus* obtained during this study. Bar shows 1 mm.

one spine in the pelvic fin, and 12 rays in the caudal fin.

Discussion

Identification of the eggs deposited in *Mycale adhaerens*

It was determined on the basis of the following characters that the eggs found in *M. adhaerens* were deposited by *Blepsias cirrhosus.* (1) The size and shape of the eggs and the yolk color were identical with those of known *B. cirrhosus* eggs (Munehara and Shimazaki, 1991). (2) The early embryos were exceedingly small relative to yolk volume and the incubation period was extremely protracted as in the case of *B. cirrhosus* (Munehara and Shimazaki, 1991). (3) The size and morphological characters of larvae at hatching time coincided with those of *B. cirrhosus* (Richardson, 1981; Shiogaki, 1988; Munehara and Shimazaki, 1991). (4) The spines and rays in the dorsal and the rays in the anal and pelvic fins of the most advanced larva were fewer in number than those of *B. cirrhosus*, but the pectoral fin rays which formed earliest were the same number as found in *B. cirrhosus.* Furthermore, in recent aquarium experiments, the author observed *B. cirrhosus* to deposit eggs in sponges (unpubl. data). Therefore, it was concluded that the eggs found in *M. adhaerens* were deposited by *B. cirrhosus.*

Exclusive utilization of *Mycale adhaerens* by *Blepsias cirrhosus*

Blepsias cirrhosus selectively utilizes *M. adhaerens* as a spawning bed. The eggs are injected into the sponge tissues in such a way that the sponge skeleton is partly broken. In order to accomplish injection of eggs into the tissues, the spawning bed must necessarily be softer than the eggs and far thicker than the egg diameter. *M. adhaerens* may be uniquely usable for *B. cirrhosus* because the sponge is of sufficient softness and thickness for the fish to deposit the eggs (Table 1).

Benefits to *Blepsias cirrhosus* of using *Mycale adhaerens* as a spawning bed

Egg predation and the availability of oxygen during the embryonic period are two evolutionary forces which have shaped the reproductive style of teleosts (Balon, 1975, 1984; Potts, 1984). The protection of eggs from predators may be the primary benefit for *B. cirrhosus.* On the other hand, concealment of laid eggs may result in making the supply of oxygen to the eggs inefficient. However, deposition of eggs inside sponges solves any serious problems, because the flow of water around the eggs and eventually to the gastral cavity is continually maintained by the flagellar movement of the choanocytes. The extreme long incubating period may have caused the exclusive utilization of the sponge as a spawning bed by *B. cirrhosus* and/or the convenience of the sponge as a spawning bed for the fish may have enabled the incubating period to extend in the extreme.

In addition to protection and oxygenation, *B. cirrhosus* seems to take another benefit by depositing eggs in sponges. Burkholder and Ruetzler (1969), Bergquist and Bedford (1978), Amade et al. (1982, 1987), and Thompson et al. (1985) demonstrated that some sponges have antibacterial and antifungal activities. This is probably the reason why dead eggs did not decay but were preserved in sponge tissues. As the living eggs would possibly deteriorate in the presence of dead eggs, such a property of sponges favors *B. cirrhosus* having an extremely long embryonic period.

Ecological comparison of fishes using sponges

Dependence of fish spawning on sponges is known in *H. americanus* (see Warfel and Merriman, 1944), the eighteen-spined sculpin *Myoxocephalus octodecimspinosus* (see Warfel and Merriman, 1944), the sponge blenny *Paraclinus marmoratus* (see Breder, 1939, 1941) and a nototheniid *Trematomus bernacchii* (see Moreno, 1980). The former two species attach the eggs near the base of a sponge, and the latter two utilize gastral cavity of a sponge as a nesting site. According to the ethological classification of reproductive styles (Balon, 1975, 1984), the reproductive style of *B. cirrhosus* is different from that of the above species. *P. marmoratus* and *T. bernacchii* are considered to be "guarder (hole nester)", whereas *H. americanus* and *M. octodecimspinosus* are classified as "nonguarder (cave spawner)" because these fishes utilize the branched form of a sponge as a spawning substrate. Similarly *B. cirrhosus* dose not guard the eggs, but instead injects the eggs into the tissues of sponge. Accordingly, *B. cirrhosus* is a typical "nonguarder (spawner in live invertebrates)" as are *P. cottoides*, *P. percoides*, and *F. ishikawae* which deposit their eggs into the peribranchial cavity of sea squirts (Uchida, 1932; Shinomiya, pers. comm.).

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イソバテングによる産卵床としてのカイメンの利用および生態的利点

宗原弘幸

イソバテングの産卵床を明らかにした．イソバテングの産卵場から11種類の付着性無脊椎動物を採集し，イソバテング卵の有無を調べた．その結果，本種の卵はカイメンの1種 *Mycale adhaerens* から見い出された．卵はカイメン組織内に完全に埋め込まれており，カイメンの骨格が卵の存在により部分的に損傷していた．イソバテングが産卵床として *M. adhaerens* だけを利用する理由は，魚が卵をカイメン組織内に押し込むことが可能なほどカイメン組織が柔かく，かつ十分な厚みを持っているためと推察された．このようなイソバテングの産卵習性は，本種の親魚が卵を保護しないことから，第一に卵の被食が回避されること，第二に胚への酸素供給が保証されること，第三に死卵に発生するバクテリアの繁殖を妨げることなどの利点があるものと推察された．イソバテングによるカイメンの利用の仕方は，本種が“無脊椎動物への卵寄託者 (spawner in invertebrates)”であることを示している．

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