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Micro-crevice structure enhances coral spat survivorship

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ABSTRACT

This study examined effects of microstructure (hereafter termed “micro-crevices”) on the surface of settlement substrata, which provides refuge for minute coral spats from grazing and, hence, could enhance coral spat survivorship. Survival of coral spats settling on plain tile-surfaces or in artificially-made micro-crevices on the tile-surfaces were monitored in situ using three scleractinian coral species; *Echinophyllia aspera*, *Favites pentagona*, and *Platygyra contorta*. All coral spats settling on the plain tile-surfaces died without traces of skeleton within the first four months of the experiments while some spats that settled in the micro-crevices still survived by the end of the one-year experimental period with survival rates of up to 12%. The results demonstrated the role of micro-crevice structure enhancing coral spat survivorship in the three coral species. Hence, given grazing activity, micro-crevice structure may be a significant factor influencing development of scleractinian coral communities.

1. Introduction

In scleractinian coral species, whole colony survivorship is known to rise as colony-size increases (e.g. Hughes and Jackson, 1985; Hughes and Connell, 1987; Babcock, 1991; Nozawa et al., 2008). For coral spats with sizes less than 1 mm in diameter at settlement, very low survival rates of <2.8% have been reported for the first 7-10 months after settlement (Babcock and Mundy, 1996; Wilson and Harrison, 2005; Nozawa et al., 2006). Previous studies examined survival of coral spats settling on plain tile surfaces, however, as opposed to naturally occurring spats in the field. Such field observations are almost impossible due to the spat's microscopic size and the often complex surface structure of natural substrata. Consequently, it has been difficult for previous studies to include the effects of complex surface structure of settlement substrata, especially microstructure (hereafter termed “micro-crevices”), which provides refuge for coral spats from grazing and, hence, could enhance coral spat survivorship (Brock, 1979; Sammarco, 1980, 1982; Carleton and Sammarco, 1987).

Coral spats settling on natural substrata are often subjected to chronic grazing pressure, especially by benthic invertebrates like sea urchins that inhabit and browse on the same substrata (Sammarco, 1980, 1982). The indiscriminate nature of their feeding activity may incidentally consume microscopic coral spats settling on exposed portions of substrata while spats settling in micro-crevices may survive intact (Brock, 1979; Sammarco, 1980, 1982; Sato, 1985). If micro-crevices enhance coral spat survivorship, the survival rates estimated by the previous studies may underestimate overall survivorship of coral spats on natural substrata. Accordingly, this study examined the effects of micro-crevice structure on coral spat survivorship in three scleractinian coral species by monitoring survival of coral spats in situ settling on plain surfaces of settlement tiles or in artificially-made micro-crevices on the tile surfaces over a one-year experimental period.

2. Materials and methods

This study was conducted from August 2006 to October 2007 in a small bay in front of the Biological Institute on Kuroshio (BIK) located at Nishidomari, Otsuki, Kochi, southwestern Japan (132°44′E, 32°46′N). The site was in a region under the influence of the Kuroshio Current where there are well-developed scleractinian coral assemblages (cf. The Japanese Coral Reef Society and Ministry of the Environment, 2004). A total of 127 scleractinian coral species have been reported from the region (Veron, 1993; Nishihira and Veron, 1995).

Three broadcast spawning scleractinian coral species were used in this study; *Echinophyllia aspera*, *Favites pentagona*, and *Platygyra contorta*. Gametes of each species were collected by placing inverted plastic containers with fishing sinkers directly on spawning colonies in the field. Gametes were obtained from spawning of ten colonies of *F. pentagona* on August 15, 2006, and from three colonies of *E. aspera* and seven colonies of *P. contorta* both collected on August 16, 2006. Collected gametes were transferred to a laboratory at BIK within one hour after spawning. For each species gametes from different colonies were mixed to fertilize in a container for about 30 minutes, and then fertilized eggs were removed to a 100 L columnar container with fresh

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seawater for further development. The fertilized eggs were maintained in the containers until most became motile larvae at two days after spawning.

Larvae of each species were placed into five settlement containers (11 cm × 10 cm × 5 cm), each of which was covered with four settlement tiles at the bottom. The settlement tiles (10 cm × 9 cm × 0.5 cm) were made of slate board with plain surfaces, and the upper surface of each settlement tile (experimental surface) in the settlement containers had 70 artificial micro-crevices (5 mm in diameter, 3-4 mm in depth) drilled at intervals of 5 mm (Fig. 1). Two holes were drilled through the center and the corner of each tile for fixing and labeling, respectively. Larvae were maintained in the settlement containers for two to three weeks with running seawater under reduced natural light at BIK. The top edge of each container was surrounded by a plankton-mesh belt (100 µm) glued to the edge to prevent larvae from being taken away by the flow of running seawater during the settlement period.

Positions of all coral spats settling in the micro-crevices or on the plain sections of the experimental surfaces were mapped under a dissecting microscope (magnifications; 10-15) before being transferred to the field. Tiles were placed at approximately five meters depth and two meters above the sandy sea floor in the field. Each tile was fixed on rocky substrata, facing the experimental surface with coral spats seaward, by a stainless bolt and a stainless nut (Fig. 1). The stainless bolt had been anchored to the rocky substrata in advance by being half-embedded in a hole drilled in the rocky substrata and glued in place with underwater epoxy. Two tile-angles, i.e. vertical and horizontal (the experimental surface with coral spats upward), were employed to consider sedimentation which may negate the effects of micro-crevices on coral spat survivorship (Sammarco, 1980; Sato, 1985) (Fig. 1). For each species ten tiles were fixed with each tile angle, except the horizontal tiles of *P. contorta* (eight tiles), using vertical or horizontal surfaces of rocks. Tiles were deployed randomly at intervals of ca. 10 cm irrespective of species or tile-angle conditions.

The experiments were continued for 392 days with *E. aspera* and for 372 days with *F. pentagona* and *P. contorta*. During the experimental period, tiles were retrieved approximately monthly to examine survival of each coral spat under a dissecting microscope (magnifications; 10-15) at BIK, and were returned to the field usually within 24 hours to minimize the influence of monthly examinations. At BIK, retrieved tiles were kept in a large container with running seawater under reduced natural light, and examinations were made by placing each tile in a tray of seawater. In order to minimize the influence of microenvironment surrounding each tile, positions of tiles that were determined by positions of the bolts were interchanged haphazardly when tiles were re-fixed after examination.

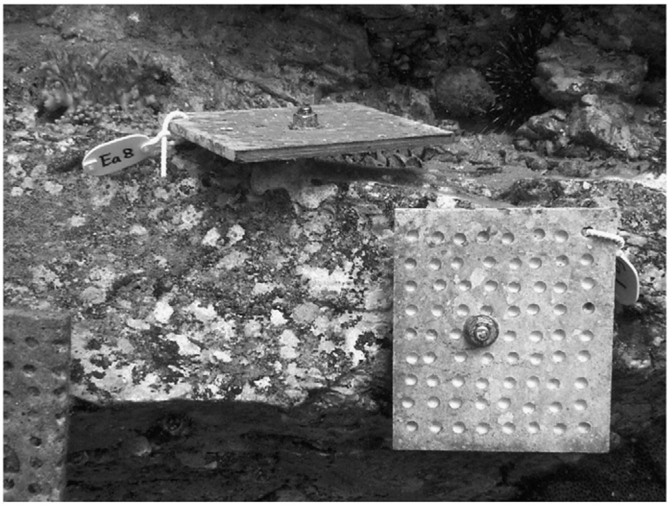

Fig. 1. Experimental setup. Settlement tiles were fixed on rocky substrata vertically or horizontally, facing the experimental surface with artificially-made micro-crevices and coral spats seaward.

Spat size was measured by acquiring photographic images under a dissecting microscope with a calibrated eyepiece micrometer. At the start of the experiments, several spats were randomly chosen on each settlement tile and photographed from above. At the end of the experiments, all surviving spats were photographed from above. Spat size (projected area of living tissue) was determined from the photographs using Scion Image software (Scion Corporation, MD, USA).

Survival rates of coral spats were estimated using the Kaplan-Meier (K-M) method which has the advantage of taking into account censored data (Machin et al., 2006). In the K-M estimate, survival of each coral spat was assumed to be independent from each other. Coral spats that fused and became chimeras in the course of the experiments (<12.8% of totals) or that still survived at the end of the experimental period were considered as censored data. A log-rank test was used to compare the estimated K-M survival curves between the two tile-angle conditions in each species. A Kolmogorov-Smirnov test was used to compare the size of surviving spats at the end of the experiment between the two tile-angle conditions in each species. Size data of all surviving spats were pooled in each tile-angle condition prior to the analysis. Statistica (version 5) software (StatSoft Inc., OK, USA) was used for the statistical analyses.

3. Results

Totals of 3788 spats of *E. aspera*, 707 spats of *F. pentagona* and 1192 spats of *P. contorta* were examined in this study. The spat sizes at the start of the experiment were 0.28 ± 0.08 mm^2 (mean ± SD) ($n = 112$) in *E. aspera*, 0.19 ± 0.05 mm^2 ($n = 104$) in *F. pentagona* and 0.18 ± 0.05 mm^2 ($n = 61$) in *P. contorta*. Although more coral spats occurred in the micro-crevices than on the plain tile surfaces in this experiment (Fig. 2), this settlement pattern was not seen in another experiment using similar settlement tiles with coral spats of the same species, which settled more evenly in micro-crevices and on plain tile surfaces (Y.N. unpublished data).

Survival rates of spats showed a striking difference between those settling on the plain tile surfaces and in the micro-crevices (Fig. 2). Though small in number, survival rates of coral spats settling on the plain tile surfaces decreased drastically and reached zero within the first to fourth month of the experiments in all three coral species while those settling in the micro-crevices remained at 1.5-12% by the end of the one-year experimental period. Coral spats settling on the plain tile surfaces were usually observed to be physically damaged, having lost a portion of tissue and skeleton, and died without traces of skeleton, as also observed in Sato (1985). In contrast, many spats in the micro-crevices survived intact and left skeletons with fine structure when (if) they died. Few sessile invertebrates were also seen on the plain tile surfaces, except in the micro-crevices, throughout the experimental period. These observations may be primarily attributed to grazing activity of sea urchins as there were numerous scratch marks arranged in a radial manner left on the plain tile surfaces but none in the micro-crevices.

The horizontal tile condition created a higher sedimentation environment where the micro-crevices on the tile surfaces were usually filled with fine sediment while the vertical tile condition created a lower light environment and resulted in higher interspecific competition for space as more invertebrates and algae recruited to and inhabited the micro-crevices. As a result, survival rates of coral spats in the micro-crevices were significantly higher in the vertical tile condition than in the horizontal tile condition in *E. aspera* ($p < 0.001$) and *F. pentagona* ($p < 0.001$) but this was reversed in *P. contorta* ($p < 0.001$) (Fig. 2). Survival rates of coral spats at the end of the experiments were; 10.7% (vertical) and 1.5% (horizontal) in *E. aspera*, 7.3% (vertical) and 1.5% (horizontal) in *F. pentagona*, and 5.0% (vertical) and 12.0% (horizontal) in *P. contorta*.