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20A Restoration of coral reefs

Experimental transplantation of corals using sexual reproduction in Manado, Indonesia

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Abstract. We conducted a survey of the coral community structure and recruitment of *Acropora* in six sites around Manado, Indonesia, in 2007 and 2008. We found that the population of *Acropora* corals as well as recruitment of juvenile coral was extremely low. To examine the future of *Acropora* corals around Manado, we assessed the reproduction potential of *Acropora* at two sites of Bunaken Island. As a result, spawning was estimated to occur several times in 2007. Anyway, *Isopora* corals could not be separated from *Acropora* (hereafter referred to as Acroporidae). The number of Acroporidae that settled on Coral Settlement Devices (CSDs) and Marine Block (MB) plates was very low. The spawning peaks of *Acropora* were estimated to be between February and June, and around October. The spawning around October was lower than that observed between February and June. We attempted to apply a coral restoration method using sexual reproduction developed and successfully applied in Japan's largest coral reef, Sekisei Lagoon, to prevent the extinction of *Acropora*. For the experiments, we used CSDs to settle and raise corals *in situ* for transplantation and MB plates as artificial substratum on sandy bottom areas. Cases containing CSDs were deployed at the breakwater of Manado coast in May 2009 and transported to Bunaken Island in August to prevent biofouling and sedimentation. Ten MBs were placed on a sandy bottom at 7-m depth in Likupang in November 2010. Two hundred and four CSDs with 203 growing corals were transplanted onto the MBs and monitored periodically.

Key words: CSD, marine block, coral transplantation, sexual reproduction

Introduction

Coral reefs around the world have been rapidly degrading due to overfishing, coastal development, and runoff from terrestrial areas. Moreover, since 1997/1998, coral bleaching caused by global warming has become one of the greatest threats to reefs (Hughes 1994; Hoegh-Guldberg 1999; Jackson et al. 2001; Carpenter et al. 2008). Sekisei Lagoon, the largest coral reef in Japan, suffered bleaching in 1998, 2001, 2003, and 2007 (Okamoto et al. 2007; Sato 2008). As a result, the dominant *Acropora* corals decreased drastically. To protect *Acropora* from extinction, we have been examining a new type of coral-restoration technology since 1999 (Okamoto et al. 2005; Okamoto et al. 2008；Okamoto et al. 2010).

We developed a ceramic coral settlement device (CSD) in 2002. A CSD contained within a polypropylene case is fixed to the sea bottom 1 week before mass spawning. Settled corals were raised *in situ* for approximately a year and a half (corals grew to approximately 1.5 cm in diameter). These corals were transplanted to coral reefs or onto marine blocks (MBs) on a sandy bottom. CSDs have been improved by applying the results of *in situ* examination with regard to materials, shapes, and arrangement within a case. A small CSD case makes the following features easy: underwater handling, deployment at the settlement site, and transportation to the nursery and restoration site. The CSD case is readily transportable between the sea and the water tank onboard a ship in a small plastic bucket filled with seawater.

During a visit to the Bunaken National Park in 2003, we were surprised to learn that *Acropora* corals on the reef crest had very low cover and that the number of juvenile *Acropora* was extremely small (only a few juvenile specimens during a 30-min survey), and this condition of the corals continued till 2007. Therefore, we planned to apply our technology at Manado and Bunaken National Park as a representative of coral reef in the Coral Triangle. Since February 2007, we have obtained basic information regarding *Acropora* to apply CSDs: time of spawning, recruitment, and early growth. We

started our small-scale coral restoration study in 2009, and the results are reported here.

Material and Methods

Two types of CSDs were used: (1) type-06 ceramic CSDs (diameter, 40 mm; height, 25 mm; Fig. 2) to examine the recruitment of *Acropora*, and (2) type-07 slag–ceramic CSDs (diameter, 43 mm; height, 26 mm; Fig. 3) for transplantation studies. These CSDs were set in a polypropylene case (27 × 12 cm, 21 cm in height) (Fig. 4). A total of 120 type-06 ceramic CSDs or 100 type-07 slag–ceramic CSDs in a case were employed. The CSDs were composed of a disk, a spacer, and a leg. On the underside of the disk, eight grooves are placed radially. On the upper side of the disk, a hollow was prepared to insert the leg of the CSD above it during pilling. This led to the formation of an 8-mm-high vertical space between discs.

Two types of MBs were used: (1) MB plate to examine the growth of *Acropora* (25 × 25 cm, 4 cm in width); 96 holes, 10 mm or 6 mm in diameter and 15-mm deep, were drilled at each side. (2) MB plate for transplantation as an artificial substratum (1 × 1 m, 0.5 m in height; weight: 1 ton). MB plates were made from fine slag produced during steel manufacture by combining the calcium oxide contained within the slag with carbon dioxide separated from smoke emitted by industrial processes. The slag was then coated and hardened with calcium carbonate (Roeroe 2009)

Preparation for the experiment

Preliminary dives were conducted in 2007 around Manado, North Sulawesi, and Bunaken National Park. Two locations at the southern coral reef of Bunaken Island were selected as the study sites (1°36.7′ N, 124°44.4′ E, depth = 5 m; 1°36.3′ N, 124°46.1′ E, depth = 8 m; Fig. 1B). Four type-06 CSD cases and one MB plate were deployed on stainless-steel racks fixed at the bottom of the two sites in February, April, July, and September 2007. CSD cases deployed in February and April were collected in July 2007, and those deployed in July and September was collected in February 2008. CSDs were dried and transported to a laboratory to enumerate the settled juvenile Acroporidae corals. MB plates were left at the site to observe growing corals. Five MB plates were sampled in April 2008, and four of them were deployed again after cleaning the holes. In total, 1,920 CSDs were collected from the two sites. A total of 406 colonies of Acroporidae settled on CSDs. In April 2008, one Acroporidae (10.7 mm in diameter) was observed growing on the MB plate deployed in July 2007. In October 2010, it had grown to a diameter of 98.2 mm. In April 2009, 18 new Acroporidae were found on seven MB plates. The size of corals observed between February and May was 5.1–31.8 mm. We assumed that these corals had spawned during the previous year (Minlee Y., unpublished data, 2011).

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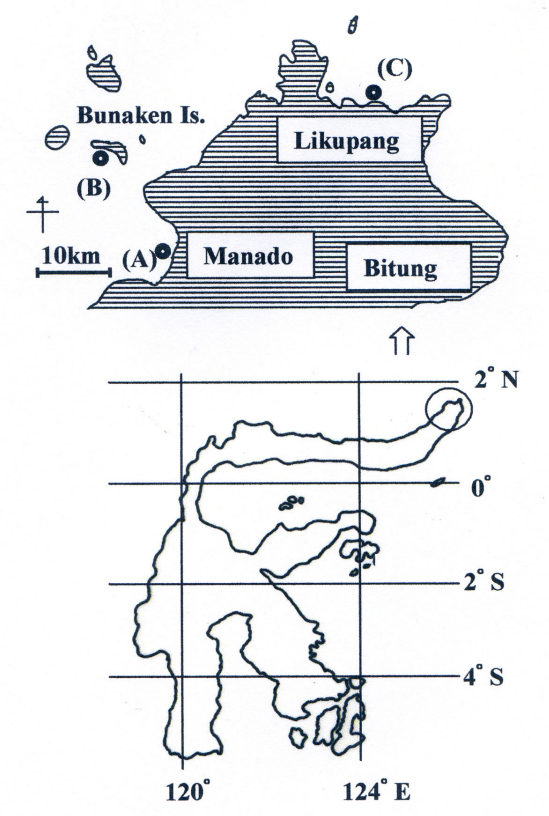

Figure 1: Experimental sites. Manado and Likupang are located at the north-east of Sulawesi Island.

Figure 2: Type-06 ceramic CSD.

Figure 3: Type-07 slag–ceramic CSD.

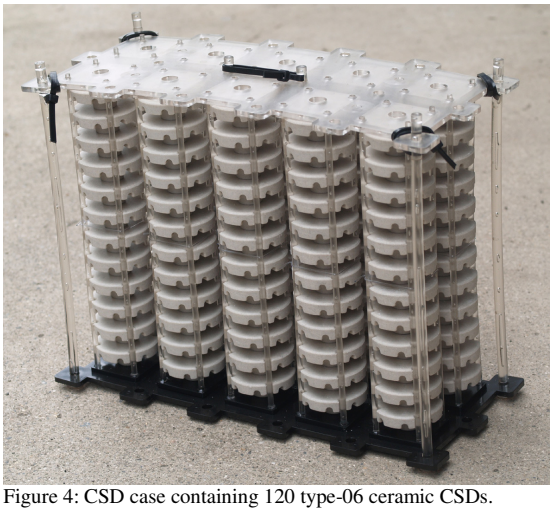
Figure 4: CSD case containing 120 type-06 ceramic CSDs.

Coral restoration

Three sites were selected for the first coral transplantation experiment (Fig. 1): (A) larvae settlement site, (B) nursery site, and (C) restoration site.

The settlement site (1°29.16′ N, 124°49.98′ E) was located on the coast of the Manado Reclamation Area established in 2000. The sandy bottom was covered to a height of 6 m with 1–2-m rocks. On the rocks, we observed many *Acropora* corals, mainly *Acropora tenuis*, *A. humilis*, and *A. hyacinthus*. Unlike the other study sites, *Acropora* corals formed a significant proportion (approximately 50%) of the coral coverage) here. We also observed many juvenile *Acropora* corals on the rocks.

The nursery site (1°36.7′ N, 124°44.4′ E) was located on the southward fringing reef of Bunaken Island. The reef crest was covered with rubble of foliose coral, and the coral coverage was very poor. The depth of this site increased gradually till the depth of 6 m, beyond which there was a steep slope. The area 5–6 m depth had high coral coverage of 80–100%. It was dominated by *Turbinaria peltata*, followed by large communities of branching and massive *Porites*, *Cyphastrea decadia*, and *Isopora brueggemanni*. A large community of *Echinopora lamellosa* was found at a depth of 10 m on the reef slope. *Leptoseris* corals and *Isopora palifera* were also abundant.

The restoration site (1°40.8′ N, 125°04.6′ E) was located at a depth of 7–8 m on a sandy bottom at the Likupang Marine Station of Sam Ratulangi University. Small patch reefs are distributed around the site, so coral coverage was <5%.

Coral larvae were settled by deploying 24 type-07 slag–ceramic cases at the breakwater of Manado coast (A) on April 22, 2009. Twenty-one cases were transported to the southward coral reef at Bunaken Island (B) on August 20, 2009 to avoid biofouling and sedimentation on CSDs. Ten MBs were set at the bottom of Likupang (C) on November 15–16, 2011. CSD cases were transported from Bunaken Island (B) to Likupang (C) on November 16, 2011. CSDs were separated from the cases, and CSDs with corals were selected for transplantation *in situ*. In total, 204 CSDs were fixed onto 10 MBs (96 CSDs on one MB, and 108 CSDs on nine MBs) on November 17, 2010. To fix CSDs onto MBs, small holes (diameter, 8 mm; depth, 10 mm) were drilled on the upper surface before deployment. Underwater cement was filled in the holes, and the leg of the CSD was inserted into the holes. Corals growing on each CSD were observed and recorded (Nikon D700 with a 28-mm F2.8 lens in Sea & Sea Housing; Nikon D60 with a 60-mm F2.8 lens in Sea & Sea Housing with a strobe). Corals were monitored on September 17, 2011 and April 3, 2012.

Results

The number of growing corals transplanted at Likupang is shown in Table 1. When transplanted on MBs, 203 corals were observed on 204 CSDs. Majority of the corals were *Pavona* and *Porites*. Twenty *Acropora* colonies were observed. The size of *Acropora* corals transplanted at Likupang in November 2010 was <3 cm in maximum diameter. In September 2011, 13 of 204 CSDs were lost from MBs and 114 corals were growing on 191 CSDs. In April 2012, another CSD was lost and 89 corals were growing on 190 CSDs (including 4 new recruitment colonies). The growth of corals was different between genera: *Pocillopora* and *Acropora* grew well, but *Montipora*, *Porites*, and *Pavona* did not. On April 2012, we observed that 15 of 19 *Pocillopora* colonies grew to >9 cm in maximum diameter (9.0–13.5 cm; mean, 11.1 ± 1.92 cm), 4 *Acropora* of 7 colonies grew to >13 cm in diameter (13.9–15.2 cm; mean, 14.5 ± 0.54 cm).

Discussion

There is a dearth of information regarding the mass spawning of *Acropora* in tropical countries (Turac et al. 2003; DeVantier et al. 2006; Mangubhai et al. 2008). The *Acropora* community is decreasing drastically around the Manado area. In fact, mass spawning on a large scale may not occur. The results of coral settlement on CSDs at Breakwater on the Manado coast (Table 1), where recruitment of *Acropora* looked good, showed the difficulty of settling sufficient *Acropora* on CSDs. Twenty colonies on 21 CSD cases (2,100 CSDs) of juvenile *Acropora* were used for transplantation in September 2010. The major corals obtained were *Porites* and *Pavona.* This demonstrated the degraded coral

conditions around Manado (including Bunaken National Park).

	Nov. 2010	Sep. 2011	Apr. 2012
No. of CSDs	204	191	190
No. of corals	203	114	85 (+4)
Pocillopora	12	19	17 (+2)
Montipora	11	13	6
Acropora	20	5	7
Porites	31	25	14
Pavona	75	44	31 (+1)
Faviidae	2	8	10 (+1)
Unknown	52	-	-

Table 1: Number of corals after transplantation.
Number in parentheses shows new recruitment on CSDs.

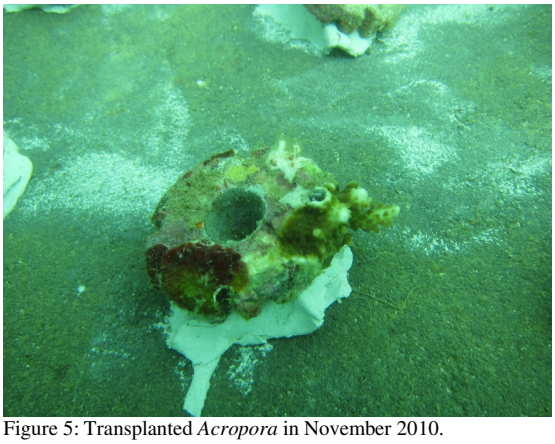

Figure 5: Transplanted *Acropora* in November 2010.

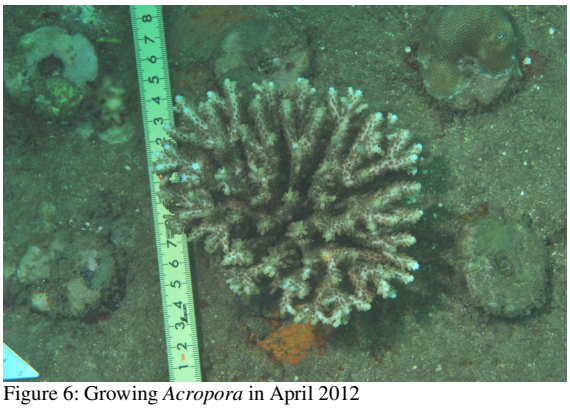

Figure 6: Growing *Acropora* in April 2012

Natural *Acropora* was not observed at Likupang. The mortality of transplanted *Acropora* was low (7/20 colonies), and the growth of survived *Acropora* was good. This site is affected by runoff from rivers in the rainy season. Hence, *Montipora*, *Pavona,* and *Porites* did not grow well. This finding suggested that the seawater at Likupang is not eutrophied like that at the Manado coast. This is because few agricultural activities are conducted around the river and few people live there. This suggests that transplantation of *Acropora* at this site may be useful.

Acknowledgement

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