水研センター研報，第32号，61－67，平成22年
Bull. Fish. Res. Agen. No. 32, 61-67, 2010

Different effects on seaweed succession after sea urchin removal at several coastal waters in Tosa Bay, southern Japan

Seiya TAINO [*1]

Abstract : The effectiveness of sea urchin removal for the purpose of regenerating the seaweed bed was studied at several study areas in Tosa Bay. Marine algal succession and density of invaded sea urchins after sea urchin removal were examined at five stations (Kamikawaguchi, Kutsuu, Ikenoura, Tei and Sakamoto). Large perennial algae superseded coralline algae at Kamikawaguchi, Kutsuu and Ikenoura, since the inhibiting factor was removed by sea urchin removal by scuba diving. Furthermore, spores and embryos, tided from near seaweed beds to study area, accelerated regeneration of seaweed bed. On the other hand, seaweed beds have not regenerated after sea urchin removal by SCUBA diving at Tei and Sakamoto, In these stations, it appears that both the feeding activity of sea urchin and the browsing activity of herbivorous fishes inhibited marine algal succession. Fishermen and students removed sea urchins by skin diving at Kamikawaguchi and Kutsuu in 2007. It should be noted that even the skin diving removal of sea urchin have an effect on regeneration of seaweed bed.

Key words : Isoyake, sea urchin removal, *Anthocidaris crassisspina*, *Echinometra* spp., *Sargassum micracanthum*, *Sargassum siliquastrum*, *Ecklonia cava*

The first step to recovery of seaweed bed

The barren grounds 'Isoyake' exist along the coasts of Kochi Prefecture, Japan. In the Isoyake areas in Kochi Prefecture, *Anthocidaris crassisspina*, *Echinometra* spp. and *Echinostrephus molaris* dominate on bedrock and boulders.

The first approach of sea urchin removal in Kochi Prefecture started at Kamikawaguchi in 2002 (Fig. 1). The experimental area was a hectare in area. It took nine days and twenty-seven divers cumulatively to remove all sea urchins in the experimental area. Sea urchins were crushed in the water by using iron sticks, because there were no edible sea urchins. The estimated number of removed sea urchins was approximately 74,000 individuals. The coverages of large perennial algae (*Sargassum micracanthum, S. siliquastrum* and *Ecklonia cava*) were examined at thirteen stations by using a quadrat from December 2002 to February 2008. Also the density of invaded sea urchins after sea urchin removal were studied at four stations (St.1, 2, 3 and St.4 or St.4') by quadrat sampling from December 2002 to February 2008 (Fig. 2). According to field surveys at Kamikawaguchi, the deviation of *Echinometra* spp. which assumed the density of *Echinometra* spp. in preliminary survey was 0 have ranged from -9.3 to 0.3 ind. / m^2 in St.1 and St.2 during survey period. On the contrary, the density of *Echinometra* spp. in St.3 frequently exceeded that before removal (Fig. 2). *S. micracanthum*, *S. siliquastrum* and *E. cava* grew in shallow water superseded coralline algae within a year of the sea urchin removal. After six years, the coverage of *E. cava* became higher than that of *S. micracanthum* and *S. siliquastrum* (Fig. 3).

The second sea urchin removal carried out at Ikenoura (Fig. 1) in 2006 (Taino *et al.,* 2008). The experimental area was half of a hectare in area. It took seven days and forty-two divers cumulatively to remove all sea urchins in the experimental area.

2010年７月１日受理（Received on July 1. 2010）
*1 Kochi Prefectural Fisheries Experimental Station 1153-23 Haigata, Uranouchi, Susaki, Kochi 785-0617, Japan

The number of removed sea urchins was 150,034 individuals. Sea urchins were crushed by the same way as above. The density of invaded sea urchins after sea urchin removal were studied at four stations (St.1, 2, 3 and St.4) by quadrat sampling from June 2006 to March 2008. The deviation of *A. crassisspina* and *E. molaris* described above have been negative value within experimental area (St.1, St.2 and St.3) during the survey period. On the contrary, the density of *Echinometra* spp. occasionally exceeded a reference value (Fig. 4). The coverages of large perennial algae, *S. micracanthum,*

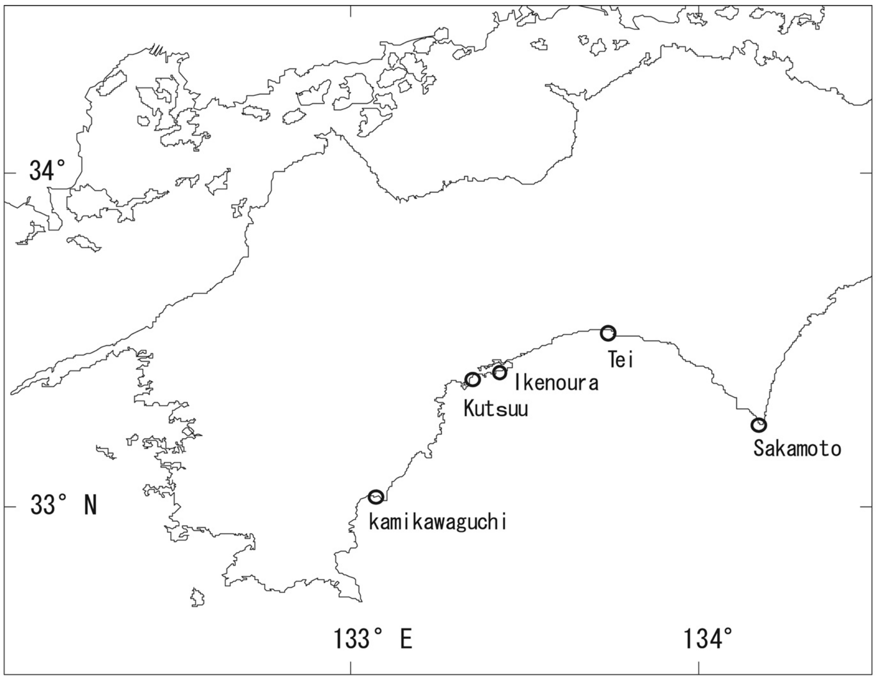

Fig. 1. Map showing five study sites of sea urchin removal along the coast of Tosa Bay, Kochi.

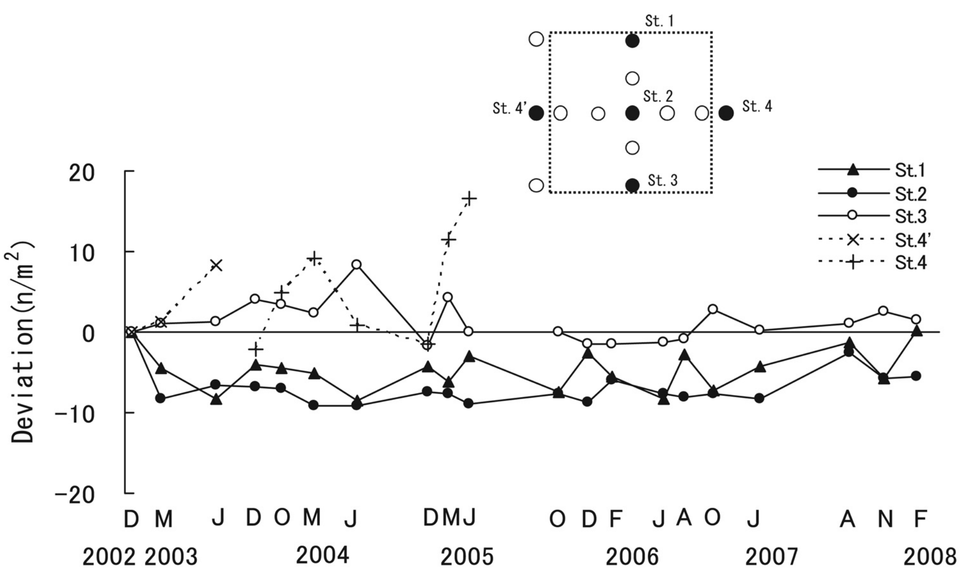

Fig. 2. Seasonal variations of the deviation of *Echinometra* spp. at St.1-3 (December 2002 to February 2008) and St.4 (December 2002 to July 2003) and St.4' (December 2003 to July 2005) in Kamikawaguchi. Simplified drawing on top showing the stations of coverage observation (open and solid circles) and quadrat sampling (solid circles).

were examined at twenty-eight stations (Fig. 5) by using a quadrat from June 2006 and December 2007. Our observations show that the shallow water. *micracanthum* population existed before sea urchin removal colonized the Isoyake area in December 2007.

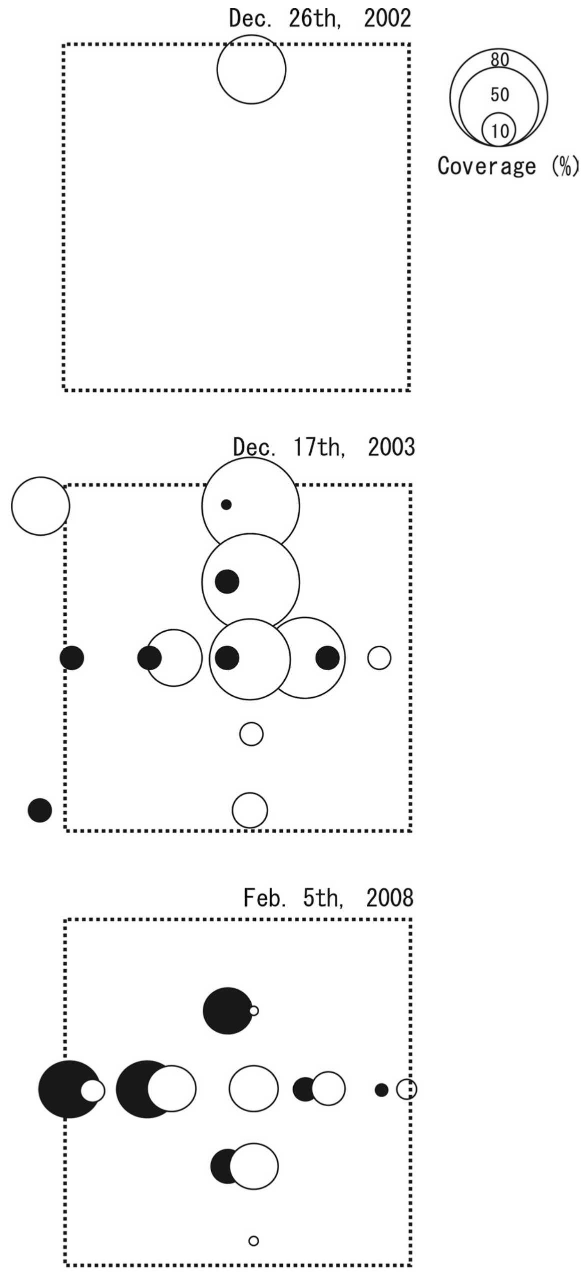

Fig. 3. Changes in the coverage of *Sargassum micracanthum, S. siliquastrum* (open circles) and *Ecklonia cava* (solid circles) at Kamikawaguchi.

Difficult situations which show few signs of a recovery of seaweed bed

The third experimental site, Tei, is located in the central part of Tosa Bay (Fig. 1). Extensive *E. cava* population has been existed from 1980's to early 1990's. A large number of researches (Ohno and Ishikawa, 1982; Serisawa *et al.,* 2001; Serisawa *et al.,* 2002a; Serisawa *et al.,* 2002b; Tominaga *et al.,* 2004) were done in this area. The unbelievable fact that the *E. cava* population disappeared during 1999 to 2000 at Tei was reported in 2000 and 2004 (Serisawa *et al.,* 2000; Serisawa *et al.*, 2004). The approach of regeneration of seaweed bed started in July 2005. There were two experimental areas which was 49,000m^2 in area respectively. It took twenty-nine days and one hundred and twenty divers cumulatively to remove all sea urchins in two experimental areas. The method of removal was same as Kamikawaguchi and Ikenoura. The number of removed sea urchins was 304,356 individuals. Same surveys as above were carried out at Tei from July 2005 to February 2008. The density of *Echinometra* spp. has been at a low level within experimental area during survey period. On the contrary, the density of *A. crassisspina* exceeded a reference value obtained before removal. At these experimental areas, the Gelidiaceae community, which was observed before the removal of sea urchins, broadened. Otherwise, large perennial algae have never appeared during survey period. Now we are trying a spore bag method (Serisawa *et al.,* 2005) to regenerate large perennial algae (e.g., *Sargassum* and *Ecklonia*).

Forth study site, Sakamoto, is located in the eastern part of Tosa Bay (Fig. 1). The experimental area was a hectare in area. It took six days and forty-three divers cumulatively to remove all sea urchins in the experimental area. The number of removed sea urchins was 227,262 individuals. Sea urchins were crushed by the same way as above. Same surveys described above were carried out at Sakamoto from August 2006 to February 2008. After sea urchin removal, small annual and small perennials, increased here, but large perennials never appeared. In this station, only *Dictyopteris undulata* colonized in November 2007. There are many herbivorous fishes in this experimental area, and there were many white spots which were traces of scraping by *Scaridae* fishes. It appears that both the feeding activity of sea urchin and the browsing activity of herbivorous fishes inhibited marine algal succession.

New approach of cooperative activity with fishermen, students and volunteers

Fishermen and students removed sea urchins by skin diving at Kutsuu in June and October 2007 (Fig. 1, 6). After six months, many juveniles of *Sargassum yamamotoi* has been appeared, and then they grew up in April 2008.

Thirty fishermen removed sea urchins by skin diving at Kamikawaguchi in August 2007 (Fig. 1). The experimental area was a hectare in area. The sea urchin removal carried out during three days and eighty-two divers engaged cumulatively in removal of sea urchins in the experimental area. The sea urchins were crushed in the water. The number of removed sea urchins was estimated approximately 68,000 individuals which were 40% of their total composition in the experimental area. After seven months, many juveniles of *Sargassum* spp. appeared in the experimental area. It should be noted that even the skin diving removal of sea urchin have an effect on regeneration of seaweed bed.

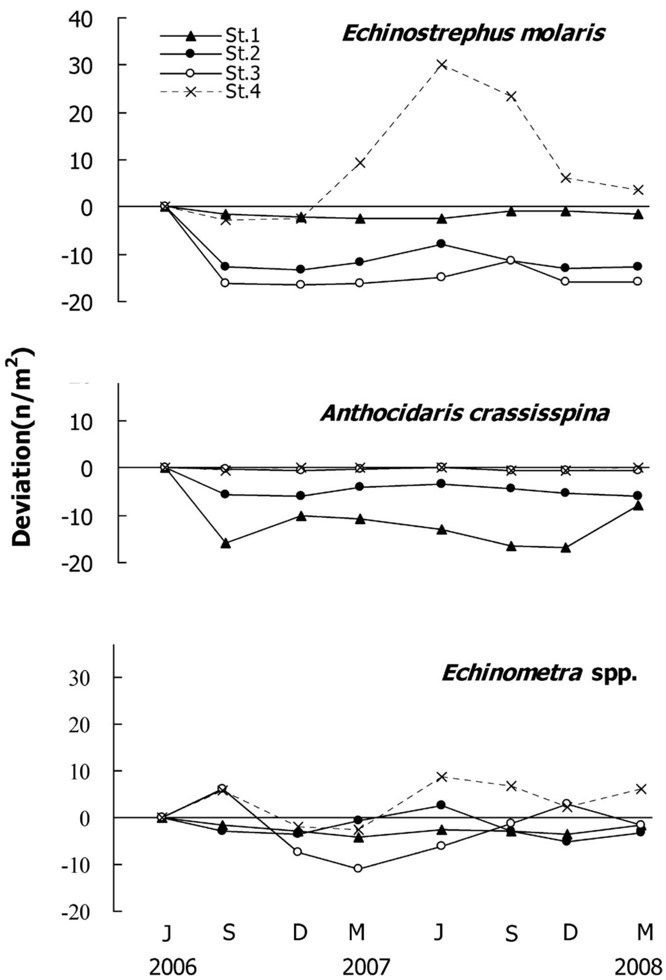

Fig. 4. Seasonal variations of the deviation of *Anthocidaris crassisspina, Echinostrephus molaris* and *Echinometra* spp. at Ikenoura from June 2006 to March 2008.

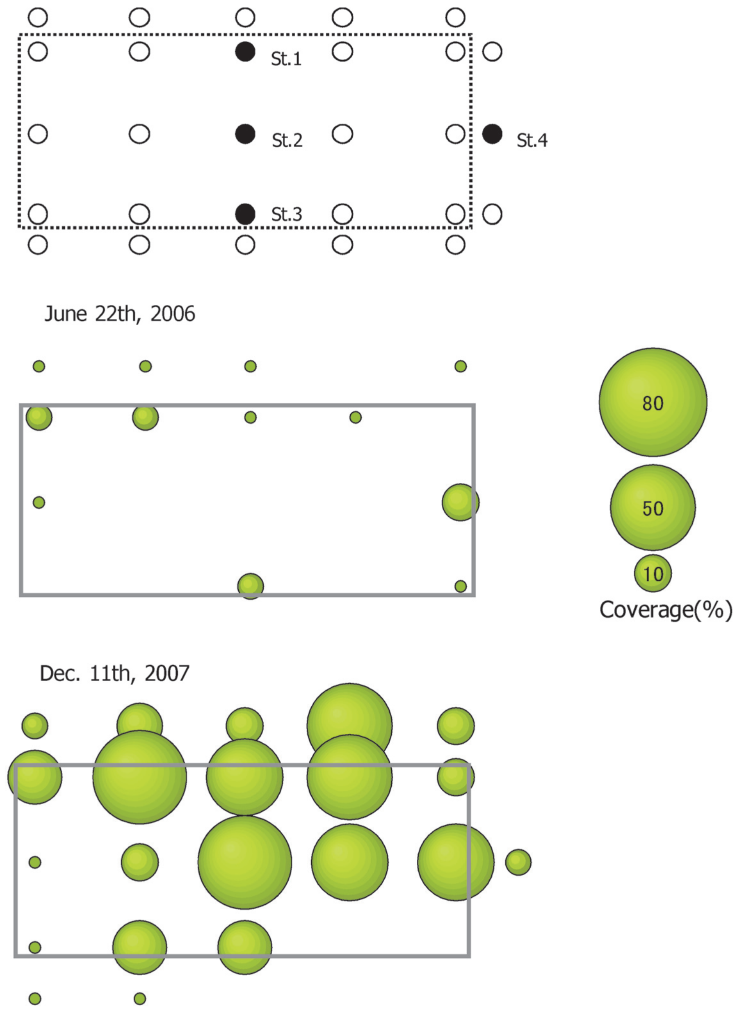

Fig. 5. Changes in the coverage of *Sargassum micracanthum* at Ikenoura. Simplified drawing on top showing the stations of coverage observation (open and solid circles) and quadrat sampling (solid circles).

The case examples of marine afforestation by sea urchin removal were reported in Hokkaido (Agatsuma *et al.*, 1997; Kuwahara *et al.*, 2001; Kawai *et al.*, 2003; Kawai and Tajima, 2003) and Nagasaki Prefecture (Yotsui and Maesako, 1993). At Kamikawaguchi, after two weeks from removal of sea urchins, rocky bottoms were covered by attached diatoms in experimental area. In the next March, *Colpomenia sinuosa* and juvenile thalli of *Sargassum* spp. appeared densely on rocky bottoms. Maximum biomass of *Sargassum* bed (5.2 kg wet wt / m^2) was recorded in December 2003. Thus, attached diatoms, small annual algae and large perennial algae colonized in the Isoyake area, successively. In this report, we carried out sea urchin removal at five experimental areas. And now there are five kinds of result. Sea urchin removal is most effective method to regenerate seaweed bed at Kamikawaguchi, Kutsuu and Ikenoura. Although at Tei and Sakamoto, we must develop strategies for the browsing activity of herbivorous fishes in addition to the feeding activity of sea urchin. Furthermore, I would like to go on to develop the management of cooperative activity with fishermen, students and volunteers.

Fig. 6. Photographs showing the cooperative activity with fishermen, students and volunteers. Meeting with students before sea urchin removal at Kutsuu (A), Skin diving removal of sea urchin at Kutsuu (B), Student crushed sea urchins in the water by using iron stick at Kutsuu(C), Commemorative photograph of the first cooperative activity of afforestation at Kutsuu(D).

References

Agatsuma Y., Matsuyama K., Nakata A., Kawai T. and Nishikawa N. 1997: Marine algal succession on coralline flats after removal of sea urchins in Suttsu Bay on the Japan sea coast of Hokkaido, Japan. Nippon Suisan Gakkaishi, **63**, 672-680. (in Japanese)

Kuwahara H., Kawai T. and Kaneta T. 2001: Mechanisms for Kelp (Laminaria religiosa) forest development on the barren ground, along the southwest coast of Hokkaido, Japan. Fisheries Engineering, **38**, 159-165. (in Japanese)

Kawai T., Kaneta T. and Kuwahara H. 2003: Optimum removed timing of the sea urchin and mean benthic velocity for afforestation of the kelp in Isoyake area using fence. Fisheries Engineering, **39**, 213-218. (in Japanese)

Kawai T. and Tajima K. 2003: Maintain and utilization of the *Sargassum confusum* population among the coast of southwestern Hokkaido, Japan. Fisheries Engineering, **40**, 1-6. (in Japanese)

Ohno M. and Ishikawa M. 1982: Physiological ecology of brown alga, *Ecklonia* on the coast of Tosa Bay, southern Japan. I . Seasonal variation of *Eckolonia* bed. Rep. Usa Mar. Biol. Inst. Kochi Univ., **4**, 59-73. (in Japanese)

Serisawa Y., Imoto Z., and Ohno M. 2000: The occurrence of a large barren-ground 'Isoyake' off the Tei coast in Tosa Bay, southern Japan. Bull. Mar. Sci. Fish. Kochi Univ., **20**, 29-33.

Serisawa Y., Yokohama Y., Aruga Y. and Tanaka J. 2001: Photosynthesis and respiration in bladelets of *Ecklonia cava* Kjellman (Laminariales, Phaeophyta) in two localities with different temperature conditions. Phycological Research, **49**, 1-11.

Serisawa Y., Akino H., Matsuyama K., Ohno M., Tanaka J. and Yokohama Y. 2002a: Morphometric study of *Ecklonia cava* (Laminariales, Phaeophyta) sporophytes in two localities with different temperature conditions. Phycological Research, **50**, 193-199.

Serisawa Y., Ueshima T., Matsuyama K., Taino S., Imoto Z., and Ohno M. 2002b: Relationship between age and Morphology of *Ecklonia cava* (Laminariales, Phaeophyta) sporophytes growing off Tei, Kochi Prefecture, Japan. SUISANZOUSHOKU, **50**, 163-169. (in Japanese)

Serisawa Y., Imoto Z., Ishikawa T. and Ohno M. 2004: Decline of the *Ecklonia cava* population associated with increased seawater temperatures in Tosa Bay, southern Japan. Fish. Sci., **70**, 189-191.

Serisawa Y., Imoto Z., Taino S., Choi C. G., Ishikawa T., Ohno M. and Hiraoka M. 2005: Marine afforestation of *Ecklonia cava* by using a spore bag method at an ISOYAKE area in Tosa Bay, southern Japan. Jpn. J. Phycol., **53**, 19-24. (in Japanese)

Taino S., Hayashi Y. and Ueno Y. 2008: Establishment of methodology of marine afforestation aspiring for 'Satoumi'. Annual rep. Kochi Pref. Fish. Exp. Stn., **104**, 100-108. (in Japanese)

Tominaga H., Serisawa Y. and Ohno M. 2004: Seasonal changes in net production of the bladelets and size of the proximal blade of *Ecklonia cava* in Tosa Bay, Kochi Prefecture. Jpn. J. Phycol., **52**, 13-19. (in Japanese)

Yotsui T. and Maesako N. 1993: Restoration experiments of *Eisenia bicyclis* beds on barren grounds at Tsusima Islands. SUISANZOSHOKU, **41**, 67-70. (in Japanese)