Advances in Coral Husbandry in Public Aquariums. Public Aquarium Husbandry Series, vol. 2. R.J. Leewis and M. Janse (eds.), pp. 401-406

Chapter 44

Coral reefs at risk: the role of Japanese science and technology for restoration

Makoto Omori

Akajima Marine Science Laboratory,179 Aka, Zamamison, Okinawa, 901-3311, Japan
makomori@amsl.or.jp

ABSTRACT
This paper briefly describes the status of the coral reefs of Japan and reviews present research activity on coral reefs restoration at Akajima Marine Science Laboratory in Okinawa. With respect to the latter, effort has been given to develop techniques for mass culture of *Acropora* spp. from eggs. In late 2006, 18 months after the fertilization, colonies of *Acropora tenuis* on the tiles have grown to average 5.8 cm in diameter in cages suspended in the sea. 2,000 clusters of them were transplanted onto the bommies near Akajima Island.

INTRODUCTION: STATUS OF CORAL REEFS OF JAPAN

Although coral reefs constitute about 0.17 % of the world ocean area (Smith, 1978), their ecosystem is said to provide wealth worth 375 billion US dollars per year in goods and services to the world (Wilkinson, 2002). Coral reefs support diverse marine life, contribute to local fishing and tourist industries and, acting as natural seawalls, they protect people from high tidal waves and storm surges. However, corals are dying fast from bleaching and as a result of human activities such as pollutant discharges and coastal development. An estimated 30 % of the world's coral reefs are already severely damaged, and close to 60 % may be lost by 2030 (Wilkinson, 2002). Some scientists are concerned that if global warming and ocean acidification continue, almost all coral reefs on the planet will go extinct by the year 2100 (Hoegh-Guldberg *et al.*, 2007).

Japan is one of a few developed nations that have coral reefs in their waters. The distribution of major coral reefs in Japan is restricted mainly to the Ryukyu Islands and the Ogasawara Islands, both ranging between 24 °N and 30 °N (Omori, 2002). This range is the northern limit of the world coral reef distribution. Some hermatypic coral communities are distributed further north than 30 °N. These high-latitude coral communities along the Pacific coast can be seen from Tokara Island up to Tateyama, the entrance of Tokyo Bay (35 °N), owing to the influence of the warm Kuroshio Current (Figure 1). These coral communities do not develop coral reefs but have a similar function and characteristics as coral communities on coral reefs.

DETERIORATION OF RYUKYU ISLANDS CORAL REEFS

Up until 40 years ago, coral reefs around the Ryukyu Islands provided habitats for such large fish as groupers and parrotfish, lobsters, sea cucumbers and turban shells that were used for buttons and inlays. These fish and shells are easy targets for fishermen. As fishermen utilize advanced fishing techniques and expand their fishing in scale, they may over-fish. Owing to the intensive soil erosion that accompanies land development projects, coral reefs have been repeatedly damaged by silt. Outbreak of the large coral-eating crown-of-thorns starfish *Acanthaster planci* (Linnaeus,1758) in the 1970s wiped out almost all of the corals on the reefs off Okinawa Island of the Ryukyu Islands by the end of the 1970s (Yokochi, 2004). Chronic outbreaks during which recovering coral communities were affected again and again, have lasted for more than 20 years. However, the outbreaks have extended to surrounding

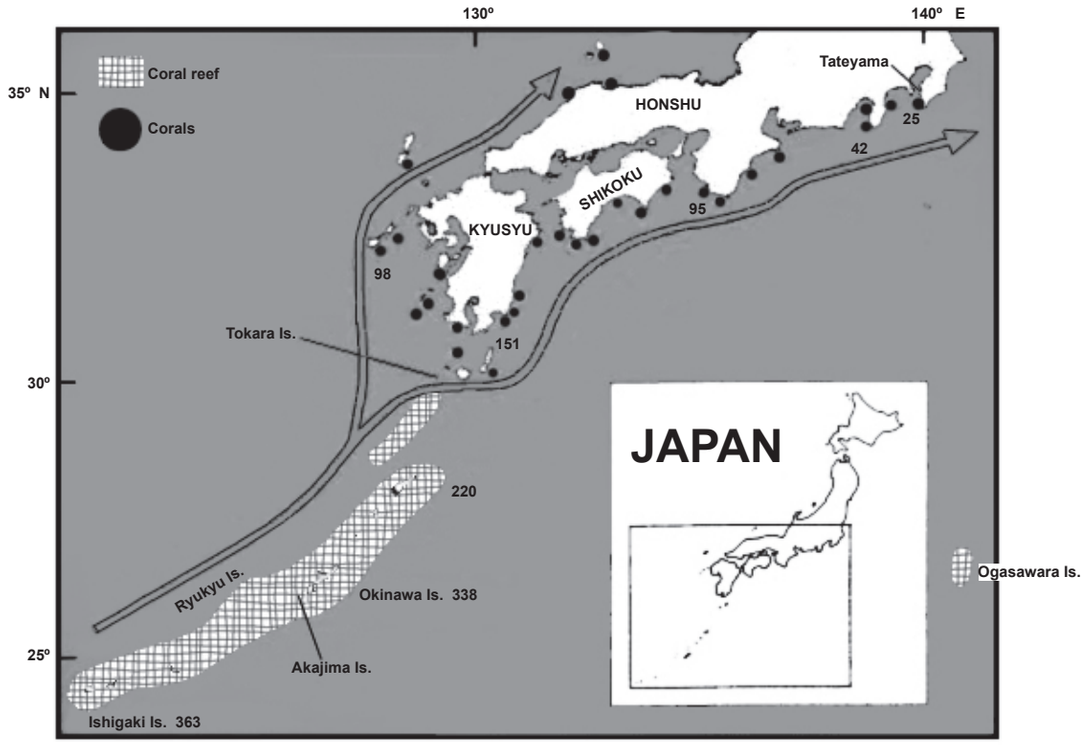

Figure 1. Regional distribution of hermatypic corals of Japan. Number means total species complement by Veron (1992). (Courtesy of Akajima Marine Science Laboratory)

islands and are still causing serious damage from around 2000. The worldwide large-scale coral bleaching event that occurred from 1997 to 1998 has also deteriorated coral communities in the Ryukyu Islands (Nakano, 2004).

DEVELOPMENT OF CORAL MASS CULTURING TECHNIQUES AT AKAJIMA MARINE SCIENCE LABORATORY AS A TOOL FOR REEF RESTORATION.

What can Japanese science and technology do to stop corals from dying? Japan, being blessed with coral reefs, should play a more important role for the conservation of coral reefs in the world. Driven by such aspiration, Mr. S. Hosaka established the Akajima Marine Science Laboratory on Akajima Island in Okinawa. The present author assisted in his endeavour.

It is a privately funded, small research institute on corals and coral reefs. The laboratory won international recognition by research on the reproduction and evolution of corals (e.g. Hayashibara *et al.*, 1993; Hatta *et al.,* 1999). Based on the knowledge acquired in the process, the laboratory is now developing techniques for mass culture of *Acropora* corals that help the restoration of coral reefs (Hatta *et al.,* 2004).

Acquiring eggs, sperm and embryos

Mass spawning of *Acropora* corals starts in Okinawa near the time of the full moon on early summer nights (Hayashibara *et al.*, 1993). Aggregates of fertilized eggs of corals drift in the surface waters following the mass spawning. In coral mass culture, the eggs and embryos may be collected from the surface aggregates. Alternatively, fertilization can be induced in the laboratory by means of gently mixing of sperm/egg bundles from more than three donor colonies of the same species.

Production of planula larvae

The embryos are then bred in large water tanks on land or in floating ponds in the sea. They stay in the surface water and grow into planula larvae. Within five to six days after fertilization the planulae swim down to the bottom to look for a suitable place to settle. After repeated trials, we were able to produce about 430 thousand larvae that were competent to settle (134 planulae per one liter of water) in a 2 by 2 m floating pond (1 m deep) shown in Figure 2 (Omori *et al.*, 2007).

Settlement

Planulae follow special chemical signals emitted by certain bacteria and crustose coralline algae on the substratum (Morse *et al.*, 1996; Heyward

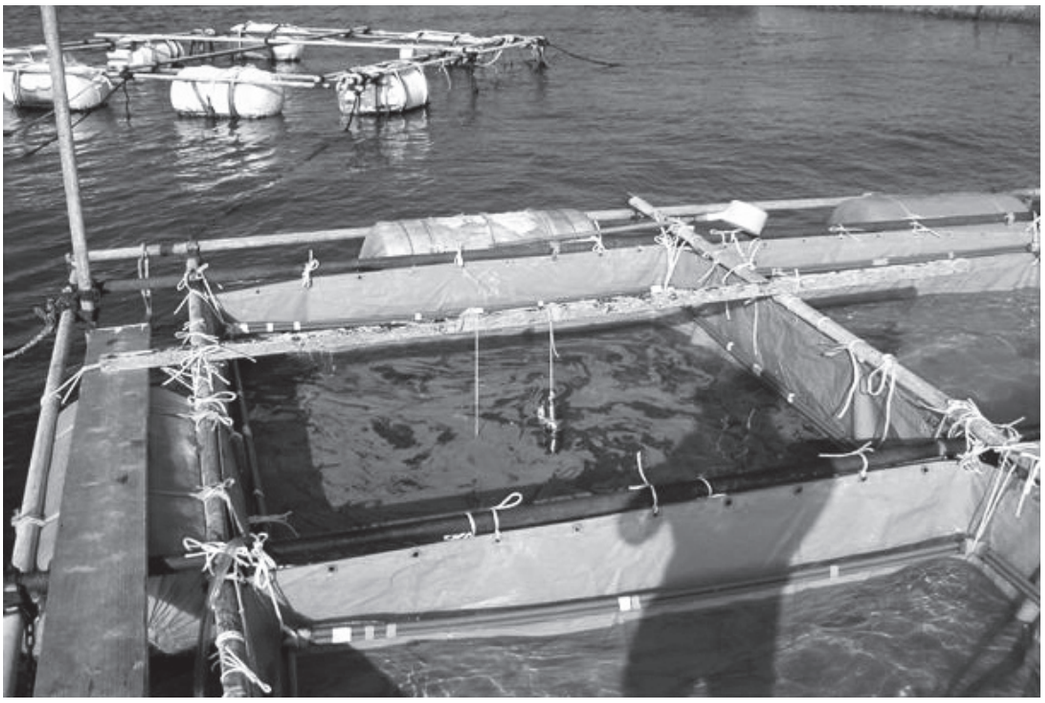

Figure 2. Cultivation of embryos and planula larvae in floating ponds. One pond contains 3.2 tons of seawater. The larvae commence settlement 5-6 days after fertilization. (Courtesy of Akajima Marine Science Laboratory)

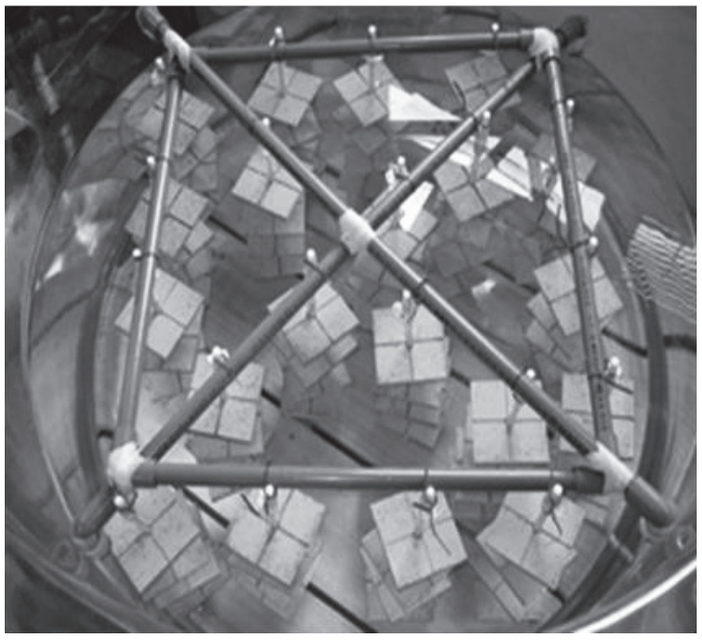

Figure 3. Reseeding of planula larvae on pre-conditioned tiles. Juvenile corals on the tiles are cultured in cages together with juvenile top shells. (Courtesy of Akajima Marine Science Laboratory)

and Negri, 1999). In other words, the planulae neither settle nor metamorphose to polyps (juvenile corals) on substratum where these organisms are not around. When more than 80 % of planulae are competent to settle, larval reseeding takes place in a large water tank (500-1,000 L) in the laboratory or in a mesh enclosure in the sea. The larvae may well settle onto substratum after two nights with the larval density of about 500 inds.L^{-1}. It is possible to induce up to 700 polyps to settle on a tile (10 x 10 cm) made of concrete or unglazed potter's clay when it is placed beforehand in the sea over one month to develop a biofilm and coralline algae on the surface (Figure 3).

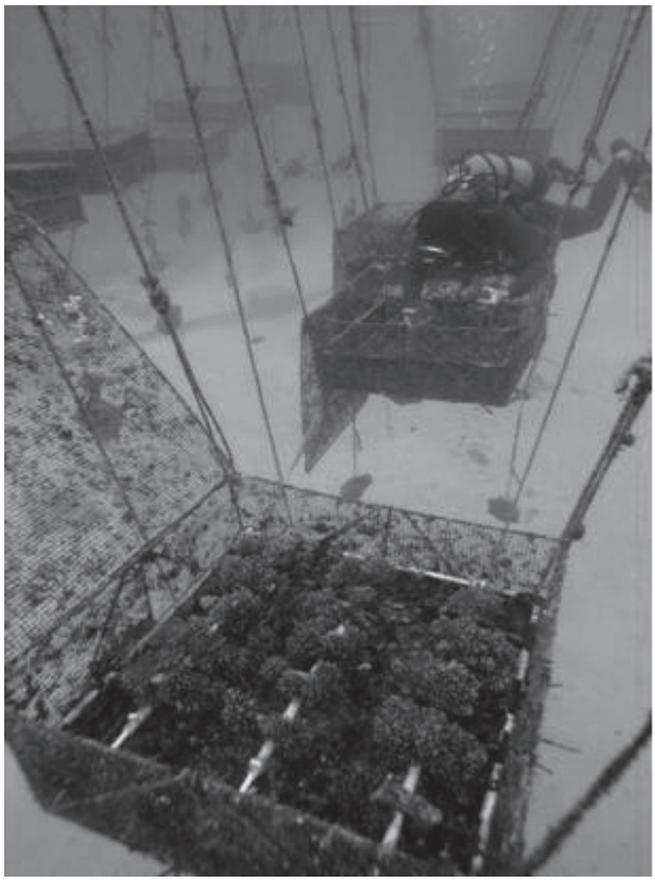

Figure 4. Cultivation of corals in cages suspended to 3 m depth in the sea (Courtesy of Mr. H. Kobayashi, Asahi Shimbun).

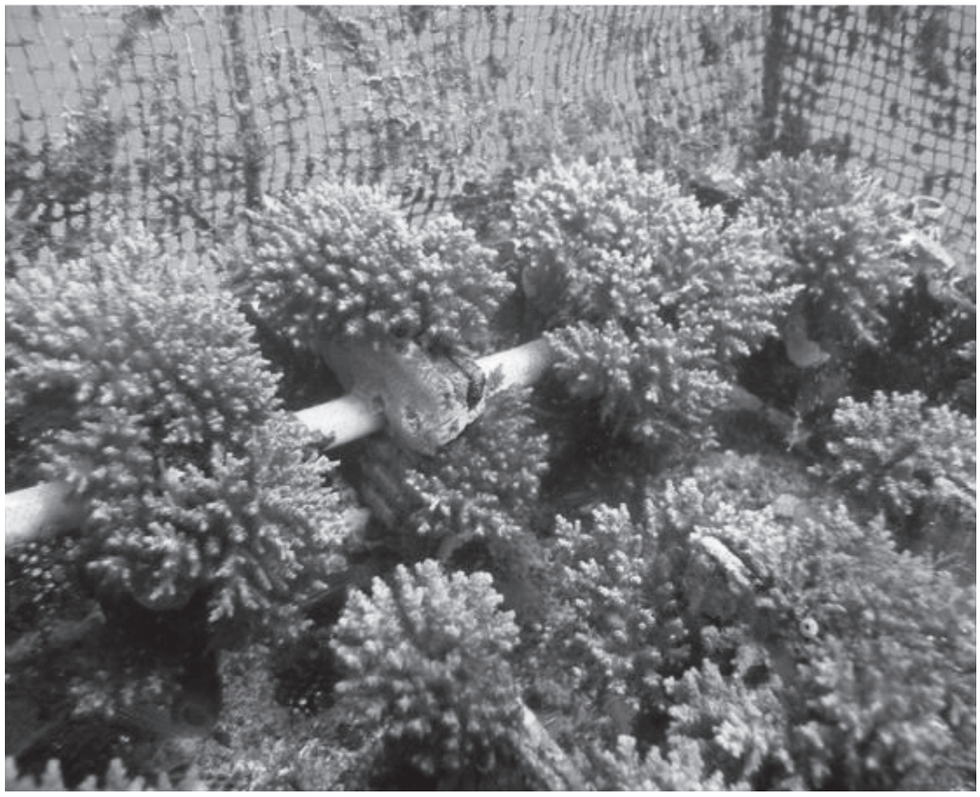

Figure 5. Acropora tenuis, 1.5 years old in cage. They have grown to an average 5.8 cm (SD 2.2 cm, largest 10.5 cm). (Courtesy of Akajima Marine Science Laboratory)

Growth and survival

The polyps, each measuring about one millimeter in diameter, multiply by producing their clones to form a large colony on the tile. Juvenile corals were cultured in cages suspended 1.5 to 3.0 m depths in the sea (Figure 4). However, when seaweeds propagated on the tile and deprived juvenile corals of sunlight, the corals died resulting in low overall rates of survival. The decision was taken to release algae-eating juvenile top-shell snail *Trochus niloticus* (Linnaeus, 1767) into the cage. This mixed culture of *Acropora* corals and top-shell snails in the same cage has dramatically reduced the odds against coral farming (Omori, 2005).

The survival rate of 1-year-old juvenile colonies may be only 1 to 3 %, but it is sufficient if, 10 colonies out of 700 polyps remained on a tile. Beside seaweeds, various organisms such as sponges and colonial tunicates may invade the tiles causing significant depth of juvenile corals during the cage culture in the sea. However, the mortality would be reduced if the corals were cultured in tanks on land with running water and frequent attention. In late 2006, 18 months after the fertilization, colonies of *Acropora tenuis* (Dana, 1846) on the tiles have grown to an average 5.8 cm in diameter (Figure 5). We transplanted 2,000 clusters of them onto the bommies near Akajima Island using epoxy cement and concrete nails. Six months later in June 2007, 89 % of the colonies were alive. In June 2008, these 3 years old colonies had grown to 15-20 cm in diameter.

CONCLUSION

It is humbling to compare the relative scale of coral reef restoration attempts to date (hectares) to the scale of reef degradation (many thousands of km^2) (Edwards and Gomez, 2007).

Nevertheless, the new techniques have shown possibility to assist local restoration and enhanced public enthusiasm for coral reef conservation. Science and technology for coral mass culture will develop even further, and I hope their fruits may help large-scale restoration of coral reefs someday before long.

ACKNOWLEDGEMENT

I am grateful to the Nippon Foundation for a long-term financial support for achievement of the coral culture technique.

REFERENCES

Edwards, A., and E. Gomez, 2007. Reef Restoration Concepts & Guidelines: making sensible management choices in the face of uncertainty. Coral Reef Targeted Research & Capacity Building for Management Programme. St Lucia, Australia. IV+38 pp.

Hatta, M., H. Fukami, W. Wang, M. Omori, K. Shimoike, T. Hayashibara, Y. Ina, and T. Sugiyama, 1999. Reproductive and genetic evidence for a reticulate evolutionary history of mass-spawning corals. Molecular Biology and Evolution, 16:1607-1613.

Hatta, M., K. Iwao, H. Taniguchi, and M. Omori, 2004. Seed production. In: Omori, M. and S. Fujiwara (eds.), 2004. Manual for restoration and remediation of coral reefs. Nature Conservation Bureau, Ministry of the Environment, Japan: 14-28.

Hayashibara, T., K. Shimoike, T. Kimura, S. Hosaka, A. Heyward, P. Harrison, K. Kudo, and M. Omori, 1993. Patterns of coral spawning at Akajima Island, Okinawa, Japan. Marine Ecology Progress Series, 101: 253–262.

Heyward, A. J., and A. P. Negri, 1999. Natural inducers for coral larval metamorphosis. Coral Reefs 18: 273-279.

Hoegh-Guldberg, O., P.J. Mumby, A.J. Hooten, R.S. Steneck, P. Greenfield, E. Gomez, C.D. Harvell, P.F. Sale, A.J. Edwards, K. Caldeira, N. Knowlton, C.M. Eakin, R. Iglesias-Prieto, N. Muthinga, R.H. Bradburry, A. Duni, and M.E. Hatziolos, 2007. Coral reefs under rapid climate change and ocean acidification. Science, 318:1737-1742.

Morse, A.N.C., K. Iwao, M. Baba, K. Shimoike, T. Hayashibara, and M. Omori, 1996. An ancient chemosensory mechanism brings new life to coral reefs. Biological Bulletin, 191:149-154.

Nakano, Y., 2004. Global environmental change and coral bleaching. In: M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano (eds.) 2004. Coral Reefs of Japan. Ministry of the Environment and Japanese Coral Reef Society: 42-48.

Omori, M., 2002. Coral reefs and coral reef studies in Japan.In: M. Kasim Moosa, S. Soemodihardjo, A. Soegiarto, K. Romimohtarto, A. Nontji, Soekarno, and Suharsono (eds.) 2002. Proceedings of the Ninth International Coral Reef Symposium, Ministry of Environment, Indonesian Institute of Sciences, and International Society of Reef Studies: 41-42.

Omori, M., 2005. Success of mass culture of *Acropora* corals from egg to colony in open water. Coral Reefs, 24:563.

Omori, M., S. Shibata, M. Yokogawa, T. Aota, A. Watanuki and K. Iwao, 2007. Achievement of coral reef restoration techniques: Survivorship and vertical distribution of coral embryos and planula larvae in floating rearing pond. Galaxia, Journal of the Japanese Coral Reef Society, 8:77-81.

Smith, S.V., 1978. Coral-reef area and the contributions of reefs to processes and resources of the world's oceans. Nature, 273:225-226.

Veron, J.E.N., 1992. Conservation of biodiversity: a critical time for the hermatypic corals of Japan. Coral Reefs, 11:13-21.

Wilkinson, C., (ed.) 2002. Status of Coral Reefs of the World: 2002. Australian Institute of Marine Science, Townsville: 378 pp.

Yokochi, H., 2004. Predation damage to corals. In: M. Tsuchiya, K. Nadaoka, H. Kayanne, and H. Yamano (eds.) 2004. Coral Reefs of Japan. Ministry of the Environment and Japanese Coral Reef Society: 49-55.