Abstract:

In tropical to subtropical marine areas, coral bleaching frequently occurs probably due to environmental destruction and global warming, and coastal ecosystems are degrading. JFE Group is engaged in technological development for restoring coral reefs, which have been damaged due to bleaching, etc., by combining the coral-implanting tool, which was developed by Tokyo University of Marine Science and Technology to prepare the substrate for coral larvae, and the carbonic solid of iron-steel slag " MARINE BLOCK®. " This paper reports on the healthy growth of young coral on Marine Block in the ongoing test in the actual sea.

Coral reefs are widely distributed in oceans from the tropics to the subtropics, and are extremely important as a site of primary production in ecosystems. In human life, they are a supplier of fishery and leisure resources, and at the same time, also have the vital function of protecting land areas from typhoons, tsunamis, and other natural threats. However, the coral reefs of the world are exposed to serious danger due to the inflow of sediments from land, explosive growth of *Acanthaster planci* (common name: crown-of-thorns starfish) and other predatory life forms, and rising ocean temperatures accompanying global warming.

In Japan, awareness of environmental protection is continuing to rise as these conditions become widely know(t)12(a)13((t)1f(t)1f(t)1f(t)1f3T*[3048]3((t)l6t)1f3T*[30d-13wCT*[k)12( ]TJT*[k)12(n)12(o)12(wco)12(n)12 ctnhesi

$IWHU GHYHORSLQJ IURP HJJV WR ODUYDH FRUDO ÀRDW RQ the surface for approximately 3–7 days, then settle on an DUWL¿FLDO EDVH URFN FRUDO UHHI HWF DQG EHJLQ WR JURZ $ FDVH EDVH IUDPH FRQWDLQLQJ VHWWOHPHQW GHYLFHV LV deployed (Photo 4 LQ ZDWHUV ZKHUH D FRUDO UHHI H[LVWV GXULQJ WKH FRUDO VSDZQLQJ DUHD RI 0D\ DQG coral larvae will also settle on the settlement devices during this time.

4. Research Results

4.1 Coral Larvae Settlement Test

From 2001 to 2003, an experiment was carried out to investigate the coral larvae settlement rate using Marine Blocks and ordinary concrete plates at Akajima (Aka ,VODQG LQ 2NLQDZD Photo 5 3UHIHFWXUH ,Q WKH actual sea experiment in 2002, approximately 2 times as many coral settled on the slag plates as on the concrete SODWHV LQ DOO ¿HOGV 7KHVH UHVXOWV FRQ¿UP WKDW 0DULQH %ORFN KDV KLJK ELRORJLFDO DI¿QLW\ Fig. 1

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Concrete plate (Bright color)

Marine block plate (Dark color)

Photo 5 Field test of Marine block plates and concrete plates

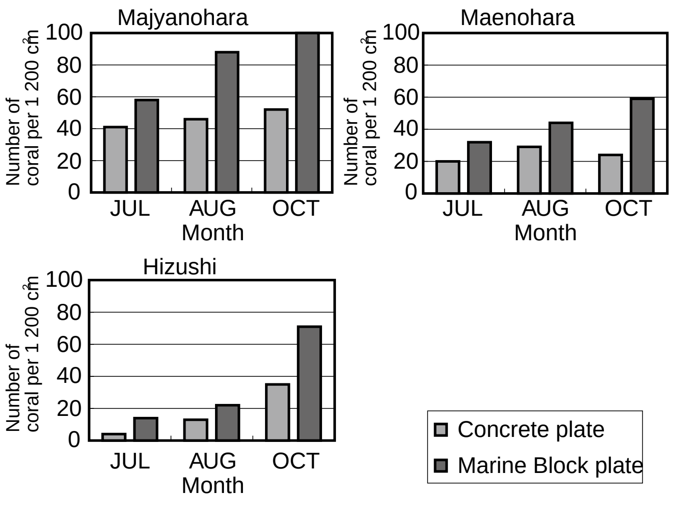


Fig.1 Numbers of implanted coral on different plate materials (2002)

4.2 Test of Transplantation of Coral to Marine Block

Based on the results of the research at Akajima, in June 2003, coral settlement devices were deployed at the Sekisei Lagoon in the Southern Ryukyu Islands with the aim of securing young coral by sexual production. ,Q $XJXVW SDUW RI WKH VHWWOHPHQW GHYLFHV ZDV WUDQVSODQWHG WR D 0DULQH %ORFN ZKLFK ZDV XVHG DV D EDVH IRU coral transplantation. All work was performed in the water. The settlement devices were installed in holes drilled in advance in the Marine Block using an underwater bond.

At the stage of June 2003, coral could not be observed with the naked eye on any of the settlement devices used in transplantation. In May 2004, settlement of coral could be observed visually on some of the settlement devices, but in all cases, these were small colonies with a size of several millimeters. In August, the condition of growth of these coral was checked, and the size exceeded 5 mm. Growth of the coral was checked again in February, and the largest had grown to a size of approximately 5 cm (Photo 6, Fig. 2

These results proved that Marine Block does not hinGHU WKH JURZWK RI FRUDO DQG FDQ

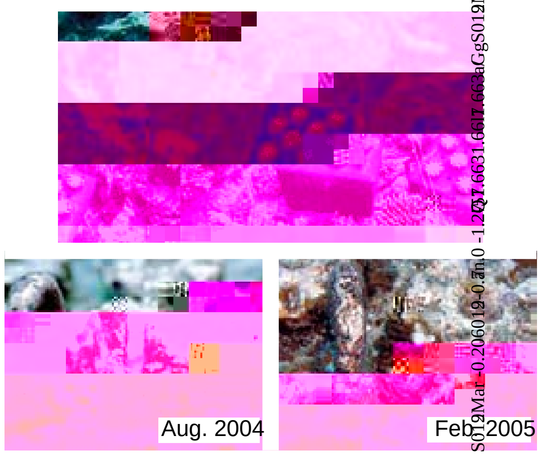
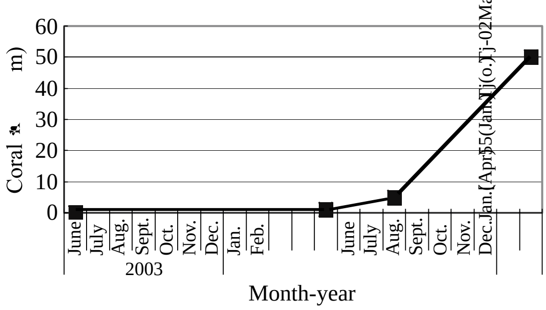


Photo 6 Overview of Marine Blocks and close views of grown coral



base for coral transplantation[3].

Beginning in 2003, the JFE Group also started development of a coral reproduction technology using Marine Block at Miyakojima. The objective of this work was to develop a technology at the actual level with the aim of practical application, based on the results of the prior research at Akajima and research carried out in parallel at Sekisei Lagoon[5].

In this technical development, the aim was to restore a former coral reef where dead coral had accumulated like debris (so-called “rock field”) using a combination of Marine Blocks and settlement devices, and to enable completion within the local waters. Restoration of coral at reefs of this type had been

and become established if they find a suitable location on a reef within 3–7 days after birth. Because larvae are dispersed and moved by tidal currents and ocean currents, it is thought that very few are able to settle and establish. Brooding type reproduction is represented by *Pocillopora sp*. In this case, larvae settle within a very close area within 1 day after release.

At present, with coral populations rapidly dwindling, use of transplantation by breaking off polyps from an adult (use of asexual reproduction) in large-scale works is not desirable. For this reason, the authors developed a coral reproduction technology utilizing sexual reproduction, beginning in 2002, and conducted coral reproduction experiments in various parts of Japan using a combination of coral settlement devices and Marine Blocks. As a result of experiments with numerous species, it was possible to create a scenario for a coral reef reproduction technology using the settlement devices and Marine Blocks. It is thought that this technology can be used in reproduction of coral reefs not only in Japan, but also around islands in tropical areas.

The settlement device provides a new settlement area to the numerous species and extremely large number of individual coral which are born as a result of simultaneous broadcast spawning and also provides grown coral for transplantation. In the design of the device, consideration was given to use in large quantity in the sea and methods of transplantation work.

A large number of individual settlement devices are stacked on a base frame, and a sea area with a high population of established larvae is selected for deployment of the devices. First, the date of broadcast spawning of the coral is predicted, and larvae of *Acropora sp*. are settled by deploying the settlement devices from a week prior to that date until the predicted date. As *Pocillopora sp*. releases its larvae from time to time thereafter, an even larger settlement can be expected. Because coral can be confirmed in the sea 1 year after establishment, in transplantation, it is possible to select and use the necessary number of settlement devices appropriately.

Coral is reproduced by fixing settlement devices to a rock base or Marine Blocks at a rate of 10 devices per 1 m^2, and then continuously taking care of the devices (a device is replaced if an individual dies, etc.). Although the devices are left in place in the sea while waiting for the coral to grow, transplantation between sea areas is easy in this stage. For example, in cases where bleaching is expected due to high water temperature, it is possible to evacuate the coral temporarily to slightly deeper water, where the temperature is lower, and in cases where the suitable area for settlement of the larvae is an area with strong waves, the coral can be moved to calmer waters after settlement.

The procedure developed for the coral reef reproduction technology using Marine Blocks and the coral settlement devices is introduced in the following.

(1) Deployment of Settlement Devices to Secure Larvae (May–June)

The settlement devices are deployed in the object waters timed to spawning of the coral. Study of the optimum location, spacing, installation method, and installation cost of the settlement devices is necessary.

(2) Placement of Settlement Devices

Settlement devices deployed in spring may be washed away by typhoons, etc. In order to avoid this risk, the settlement devices are moved to a safe location in deeper water, etc., before typhoon season. When moving the settlement devices, consideration is necessary to avoid damaging recently settled coral; in particular, it is necessary to avoid contact with the air and rapid changes in water temperature.

(3) Growth of Settled Coral (approximately for 1 year)

Coral are grown for approximately 1 year in the location to which the settlement devices were moved in summer. As a result, it is possible to obtain young coral which have survived the process of natural selection. Because coral of larger size can also be expected, the possibility of predation is reduced.

(4) Installation of Marine Blocks

Marine Blocks are sunk in the waters where the coral reef is to be reproduced. In areas with severe conditions such as high waves, a stability calculation is made, and countermeasures such as anchoring or fixing of the frames are taken. It is desirable to drill the holes for installation of the settlement devices in the Marine Blocks in advance, before the blocks are sunk.

(5) Transplantation of Settlement Devices

The settlement devices are removed from the frame, and coral which have grown on the devices are selected. After selection is completed, the devices in which the young coral are established are transplanted to the Marine Blocks. However, the number is adjusted so that the final density of the coral colony is on the order of 10 colonies per 1 m^2.

(6) Confirmation of Effect of Transplantation and Monitoring

The condition of growth of the coral on the transplanted settlement devices is observed periodically, the effects thereof are evaluated, and the necessity of movement to a new transplantation location or additional transplantation in the existing location is