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SURVIVAL AND GROWTH OF TRANSPLANTED CORAL FRAGMENTS IN A HIGH-LATITUDE CORAL COMMUNITY (32° N) IN KOCHI, JAPAN

By

Katsutoshi MIYAZAKI [1], Shashank KESHAVMURTHY [2], and Kimio FUKAMI [2]

Abstract

Survival and growth of transplanted fragments of the reef coral species *Acropora hyacinthus* and *Acropora muricata* was observed over a period of 3 years from November 1999 to November 2002 in a high-latitude coral community in Shirigai National Marine Park, Otsuki, Kochi Prefecture, Japan. A total of 36 coral fragments (a total area of 4.4 m^2) (thirty one *A. hyacinthus* fragments and five *A. muricata* fragments) were transplanted into 3 separate blocks at 3-4 m depth with each block consisting of approximately equal number of coral fragments in each species. Out of 36 coral fragments transplanted, all *A. muricata* fragments died before the first survey (one year after the transplantation) and only 29 *A. hyacinthus* fragments survived the initial relocation. The results showed an increase in the coral cover to 48% of the total area form the initial 8.9% in case of *A. hyacinthus*. There was a horizontal increase in the coral size resulting in the accretion of the coral skeleton with the neighboring coral fragments. Transplanted fragments grew rapidly (6.9 -15.8 cm) in the warmer (17-25 ºC) months compared to the slower growth (0.9-4.8 cm) in the colder (below 17 ºC) months. This is the first study that documented the survival and growth of transplanted coral fragments over time in a high-latitude coral community.

Introduction

Over past several decades, there has been a decline in the coral reefs (Wilkinson 1993; 1999; Rinkevich 1995) as a result of various natural (tropical cyclones, volcanic activity, catastrophic low tides) and anthropogenic (e.g. coral mining, dredging, sewage, dynamite fishing, chemical pollution, oil spills, ship groundings and sediment, fertilizer and pesticide run-off as a result of changing land use) factors (Brown and Howard 1985,;Clark and Edwards 1995; Rinkevich 1995). Studies in the recent years have aimed at the conservation of coral reefs. Various methods like coral rearing and coral transplantation has been attempted. Some of the transplantation studies carried out till today are, dynamite fishing related reef recovery (Auberson 1982; Yap *et al.* 1992); replacement of corals killed by thermal effluent (Brikeland *et al*. 1979); recovery of reef following ship groundings (Japp 1999) and recovery of reef due to damage by Crown-of-thorns starfish (Harriott and Fisk 1988b). Such measures help conserve the reefs that are facing a threat to their existence and are a form of sustainable exploitation. Hence the primary objective of the coral transplantation method is to improve the condition of the reef in terms of live coral cover.

Coral transplantation involves the introduction of fragments in areas devoid of any coral presence and/or areas rendered unsuitable for planular settlement (Heyward and Collins 1985). For a successful coral transplantation, selection of proper area to be used for transplantation is

1. Otsuki Park Volunteer, Shirigai Marine Park, Otsuki, Japan
2. Graduate School of Kuroshio Science, Kochi University, Monobe, Nankoku, Japan.
Present address: Biodiversity Research Center, Academia Sinica (BRCAS),
128 Academia Road Sec. 2, Nankang, Taipei 115 Taiwan, ROC.
e-mail: shashank@gate.sinica.edu.tw

necessary. It has been mentioned that the transplantation might not be suitable in an area where the coral recruitment has failed over the years. This is because the transplanted corals may not recruit. Also studies have shown significant effects of environmental factors (eg. light, temperature, sedimentation and water movement) on growth and / or survival of coral transplants. (Meesters *et al*. 1994; Yap and Gomez 1984; Yap and Gomez 1985; Rice and Hunter 1992; Montebon and Yap 1995). Choice of a particular habitat for coral transplantation is therefore a critical aspect of coral transplantation studies.

One more problem in coral transplantation is the selection of species to be transplanted. Studies have shown that different coral species show different growth and survival after transplantation due to the differences in their life history strategies (Yap *et al*. 1992). Till now only selected species has been used in the transplantation studies. But information on the suitability of a particular coral species for transplantation and their responses to relocation needs to be established by more research. Edwards and Clark (1998) have argued that there has been too much focus on transplanting fast growing branching corals over slow growing massive corals. They further mention that fast growing branching corals although recruit fast, are not able to survive the effect of transplantation and relocation. Another factor to be considered in the coral transplantation efforts is the size of coral colonies or fragments. In the previous studies, it has been shown that the size of the coral plays an important role in the survival of transplanted fragments (Hughes and Jackson 1985; Harriott and Fisk 1988; Bowden-Kerby 1996). However, the relationship between colony size and growth was shown to be significant for some species, but not in others (Clark and Edwards 1995).

In this work attempt was made to relocate and transplant fragments of two dominant coral species *Acropora hyacinthus* and *Acropora muricata* in a high-latitude coral community. The study area forms a part of National Marine Park and is being monitored by the Otsuki Park Volunteers. In certain parts of this study area, coral cover had considerably decreased due to extensive grazing by *Drupella* sp. over the years. Also part of the marine park was prone to sedimentation due to the runoff from the adjacent mountains as a result of frequent heavy precipitation.

Following aspects were addressed in this study; (1) to revive the lost coral colonies in the Shirigai Marine Park, Kochi, Japan; (2) to relocate the coral colonies from an area prone to constant sedimentation; (3) to see if there is any effect on the initial size of the coral fragment on the survival after transplantation and (4) to see the effect of seawater temperature on the growth of coral transplants.

Material and Methods

Site description: The transplantation study was carried out in the Shirigai Marine Park situated in the Otsuki town (N 32^{o} 46' 45" and E 132^{o} 43' 59"), Kochi Prefecture, Japan (Fig. 1). The fragments obtained for transplantation (Location A; prone to sedimentation) and the site to which the corals were transplanted (Location B; corals lost due to grazing by *Drupella* sp.) were located at the same marine park.

Coral collection: Coral fragments of *Acropora hyacinthus* and *Acropora muricata* between 7 cm^2 to 17 cm^2 were collected from location A (Fig. 1). In all 36 fragments (31- *A. hyacinthus* and 5- *A. muricata*) were collected in October 1999 for the transplantation. The coral fragments were transplanted into 3 blocks (Block A – 1.8 X 0.6 m^2, Block B- 2.3 X 1 m^2 and Block C 0.7 X 1.5m^2 area) totaling an area of 4.4 m^2 at location B (Fig. 1) into 3 different depths with Block A at 3m, Block B at 3.5 m and Block C at 3.5 - 4 m depth respectively. Coral fragments were fixed by SCUBA on to the substrate (dead coral surface) using cementing putty (Fig. 2 A and B).

The coral fragments were monitored occasionally for the condition and increase in the growth by measuring the size underwater. Increase in the size of all the fragments in the 3

blocks were pooled to get the total increase in the percent cover of coral during the monitoring period. The condition of the coral transplants over time in location B was monitored till 2007 by photographing the 3 blocks to see the health condition of coral colonies. Seawater temperature at the site was recorded by a hand-held temperature recorder.

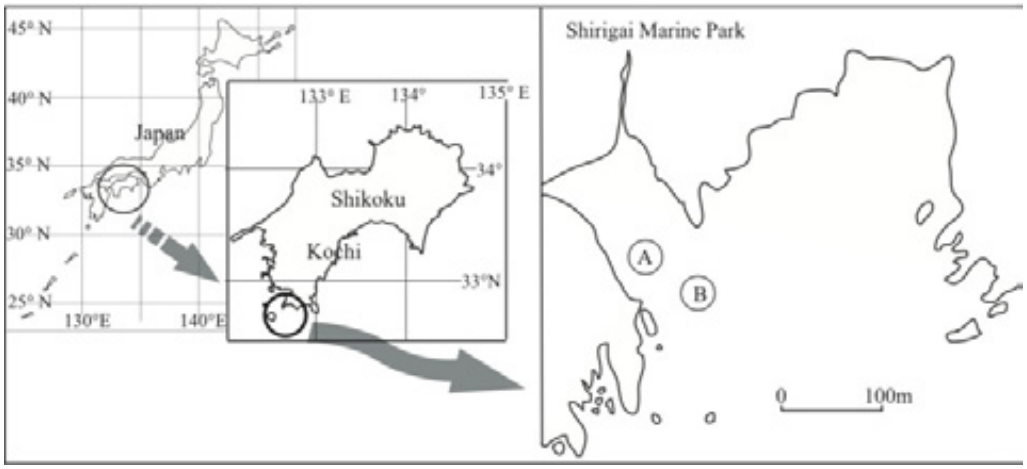

Fig. 1. Map of the study area showing the location of the transplantation site at the Shirigai Marine Park, Otsuki, Kochi Prefecture. A- site from where the donor fragments were obtained and B- site into which the coal fragments were transplanted.

Results

Results showed an increase in the growth of *A. hyacinthus* transplanted fragments during the 3-year monitoring. However, all the transplanted fragments of coral *A. muricata* failed to survive and died within 1-year of relocation. *A. hyacinthus* fragments were healthy and showed considerable skeletal accretion (Fig. 2 C and D). Initial and final size of each fragment in the separate blocks is shown in Table 1. At the end of 3-year period, the coral cover in the transplanted area of 4.4 m^2 increased to 48% from the initial cover of 8.9% (Table 1). The average growth of coral fragments was 6.9 cm at the end of 3-year.

Results also showed that the coral fragments grew rapidly (6.9-15.8 cm) between May and October when the seawater temperature was between 17-25 ºC (Fig. 3). Whereas the growth was rather slow (0.9-4.8 cm) in the months when the seawater temperature was below 17 ºC (Fig. 3). Corals showed growth at all three depths and the size of the fragments did not show any difference in the growth rate of corals (Table 1).

In 2001, location A experienced heavy sediment input due to high precipitation (110-577 mm) between 6^{th}-7^{th} of September that resulted in the accumulation of 20-40 cm sediment directly on to the coral colonies (Fig. 4 A-D). This resulted in the death of the coral communities in this area.

Plate 1 and 2 show the time series photographs of coral fragments in 3 separate blocks from 1999-2007 wherein the increases in the growth of transplanted coral fragments can be clearly seen over a 7-year period.

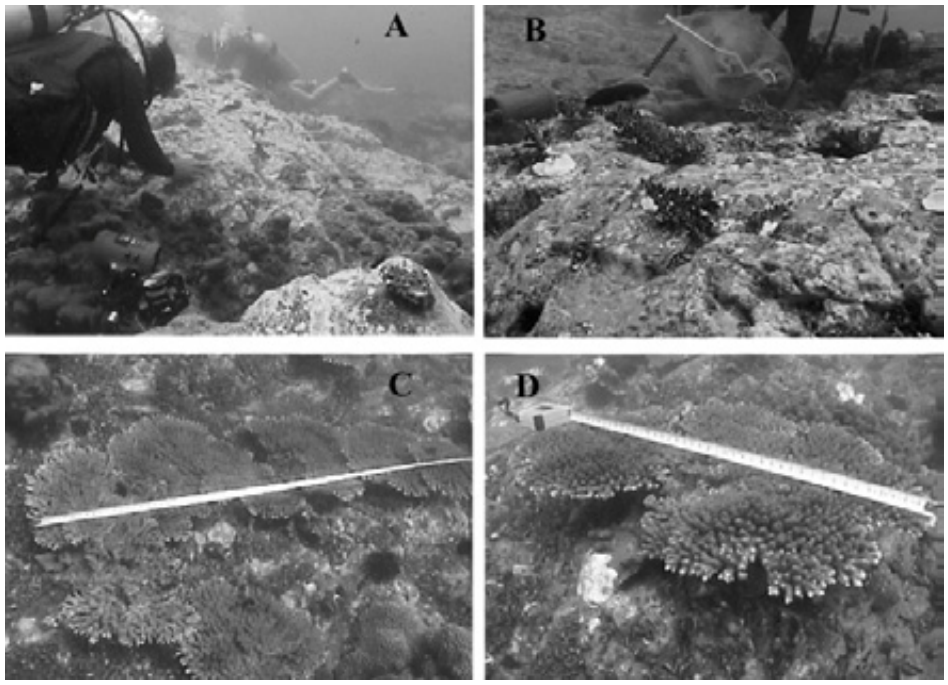

Fig. 2. Photographs showing; A, B - the attachment of coral fragments on the substrate and C, D-horizontal growth and accretion of coral fragments.

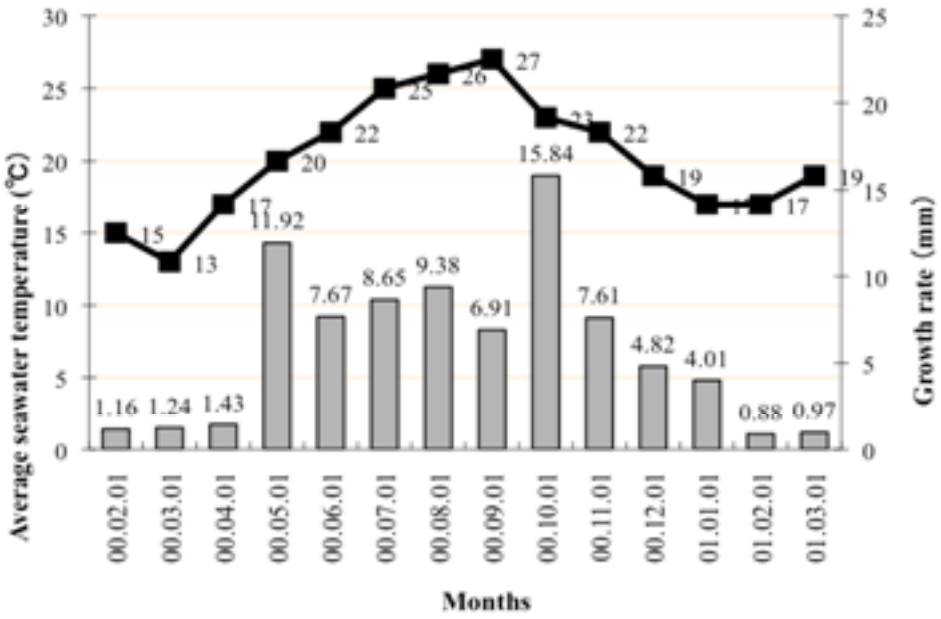

Fig. 3. Influence of sweater temperature on the growth rate of the coral fragments observed between February 2000-March 2001.

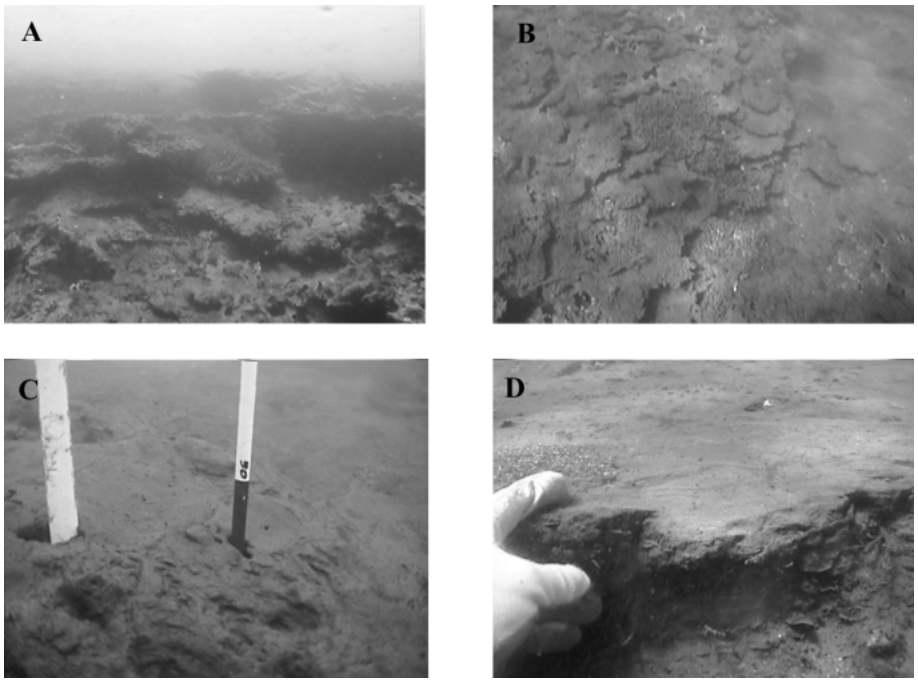

Fig. 4. Photographs showing the input of sediments onto the coral colonies at location A in September 2001.

Table 1. Yearly increase in the size and area of the coral fragments in the transplanted area of 3 blocks. The table shows the year, fragment number and area of the fragment. Transplantation was carried out in 1999 and the monitoring for the coral growth was carried out till 2001.

Block A

Year	No.	Area (cm^2)
1999	1	226.9
	2	60.4
	3	86.3
	4	87.9
	5	176.7
	6	102.1
	7	38.4
	8	84.8
	9	117.8
	10	77.7
	11	51.8
2000	1	373.9
	2	268.6
	3	343.2
	4	186.9
	5	282.7
	6	238.8
	7	164.9
	8	164.9
	9	141.4
	10	204.2
	11	200.3
2001	1	*
	2	3,714.9
	3	*
	4	*
	5	*
	6	*
	7	1,319.5
	8	
	9	176.7
	10	656.6
	11	1,869.3

Block B

Year	No.	Area (cm^2)
1999	1	110.0
	2	117.8
	3	127.2
	4	117.8
	5	180.6
	6	466.5
	7	255.3
	8	133.5
	9	274.9
	10	66.0
	11	43.2
2000	1	307.1
	2	183.8
	3	360.5
	4	251.3
	5	471.2
	6	628.3
	7	365.2
	8	307.1
	9	471.2
	10	183.8
	11	169.6
2001	1	988.0
	2	2,591.8
	3	*
	4	*
	5	1,924.2
	6	1,665.0
	7	*
	8	596.9
	9	1,036.7
	10	*
	11	*

Block C

Year	No.	Area (cm^2)
1999	1	235.6
	2	94.2
	3	102.1
	4	157.1
	5	19.6
	6	117.8
	7	219.9
2000	1	408.4
	2	141.4
	3	263.9
	4	294.5
	5	204.2
	6	204.2
	7	325.2
2001	1	1013.2
	2	1207.2
	3	722.6
	4	*
	5	1492.3
	6	*
	7	659.7

(*) = the size of th coral fragment could not be determined due to horizontal growth and accretion

Discussion

Coral conservation studies through relocation and transplantation has been emerging in recent years due to increased loss in the coral cover in the reefs. The goal of the transplantation technique is to speed up the recovery of degrading reefs. However, the drawbacks of such studies are the use of coral material from unaffected donor reef areas for transplanting into impacted areas. Since, the transplantation techniques are not always completely successful, it may result in loss of donor corals as well as failure in the transplantation technique.

In the present study an attempt was made to revive the coral cover lost in one area of

the park by transplanting the coral fragments from an adjacent area prone to constant sedimentation. The results showed the success of the transplantation with the transplanted corals in good condition even after 7-years after transplantation (Plate 1). The area prone to sedimentation lost the coral cover completely after 1-year of relocation into the adjacent area (location A, Fig. 4). On the contrary, the coral fragments that were relocated have shown increasing growth over the years, with the coral cover slowly increasing (Plate 1). Also, there has been considerably less occurrence of *Drupella* sp. (unpublished data) in this area compared to pre-transplantation period.

Similarly, initial size of the coral fragments did not affect the growth, on the contrary to the study carried out by Harriot and Fisk (1988a) in which small fragments experienced higher mortality rates than larger ones. Yap *et al.* (1998) also have shown that there was no significant difference in the mortality between large and small fragments in case of *Porites cylindrica* and *P. rus* in their transplantation experiment.

One another important aspect of this study was the seasonality in the growth of the transplants. The results showed higher growth rate of corals during the warmer period and low growth rates during the cooler period. Previous study (Yap and Gomez 1984) has shown that the seawater temperature negatively affected the growth of the transplants of the coral *Acropora pulchra* at a study site in the Northern Philippines, and has shown high growth rates during the cooler times of the year and low growth rates during the warmer periods. Other similar studies (Jokiel and Coles 1977; Clausen 1971) have shown that the optimum temperatures for the growth of *Pocillopora damicornis*, *Montipora verrucosa* and *Fungia scutaria*, is 26 ºC and 27 ºC for *P. damicornis*. Possible explanation for this is that the tropical coral reefs are exposed to summer seawater temperature that is normally between 28-30 ºC and winter seawater temperature is between 25-28 ºC. This is not the case with the high-latitude coral communities that are exposed to a summer seawater temperature between 25-29 ºC and a winter seawater temperature between 14-18 ºC. This change in the temperature patterns makes to the difference in the growth response of corals.

From the observation of this study it is concluded that successful coral transplantation and relocation depends on the site and the species. Also, the effect of size and environmental parameters like seawater temperature is species specific.

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Explanation of Plate 1

Time-series photographs of the growth of the coral fragments from 1999 – 2007 in blocks A, B and C at the transplanted site.

PLATE 1