Mass coral settlement on the artificial reefs in Ishigaki Island, Okinawa, Japan: evidence of sexual recruitment in the year following the 1998 bleaching event

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INTRODUCTION

The 1998 bleaching event was the most extensive and severe one ever observed in the Ryukyu Islands, Japan. From late August to September, mass mortality of hermatypic corals, especially the genus Acropora, occurred in Urasoko Bay of Ishigaki Island (Fujioka 1999, 2002). On the outer reef flat, where the present study was conducted, the live coral coverage drastically decreased from 80.4 % (estimated) at the highest before bleaching to only 6.6 % at four months after the bleaching event (Fujioka 2002).

It was reported that in the breeding season following the bleaching event of 1998 the reproduction of corals was severely affected by the high thermal stress that had caused the mass bleaching in Okinawa (Omori et al. 2000; Hirose and Hidaka 2001) and the Great Barrier Reef (Hoegh-Guldberg 1999; Baird and Marshall 2002), and a drastic reduction in recruitment was predicted. Contrary to these predictions, an unexpectedly rapid recovery was reported to have occurred in some coral reefs (Normile 2000). However, it is not been clear whether the recovery can be attributed to new recruits or to the survival of juveniles.

In October 1998, we deployed several artificial reefs in Urasoko Bay, immediately after the bleaching event. At present, many juvenile coral colonies can be observed on these artificial reefs. This provides evidence that the sexual recruitment resulted in recovery from the mass mortality by the bleaching event of 1998.

MATERIALS AND METHODS

In October 1998, three artificial reefs were deployed at two places (one artificial reef in 4m depth and two in 12 m depth at high tide) in
Urasoko Bay, Ishigaki Island, Okinawa, Japan (the map is shown in Fujioka 2002). They were made of concrete and were table-shaped, measuring 2 m × 2 m at the top and 1.5m height with 3 m × 3 m foundation. The temperature and salinity were continuously measured near the artificial reefs at both depths. The light intensity on the upper surface of each reefs was also measured in June 2002. In July and August 2002, all the coral colonies growing on the upper horizontal and lateral (vertical) surfaces of the each one artificial reef (with the exception of 70 × 35 cm² areas of both upper and lateral surfaces of the artificial reef in shallow area, on which the experimental tiles were attached) were identified at the genus level, and the maximal diameter of the basal part was measured using a vernier caliper. The sea surface temperature images around the Ryukyu Islands were produced from the NOAA HRPT/AVHRR data received at the Ishigaki Tropical Station, Seikai National Fisheries Research Institute.

RESULTS AND DISCUSSION

The satellite images of the sea surface temperature around Ishigaki Island taken in late August 1997, 1998, and 1999 clearly indicated the high sea temperature anomaly in the summer of 1998 that caused the most extensive coral bleaching ever recorded (Fig. 1). As a result of the 1998 bleaching event, coral population in Urasoko Bay decreased drastically.

![Composite images of the sea surface temperature (8-day-maximum) around Ishigaki Island in late August 1997, 1998, and 1999. These images were produced from the NOAA HRPT/AVHRR data received at the Ishigaki Tropical Station, Seikai National Fisheries Research Institute.](image-url)
This was particularly evident in the outer reef flat, where the present study was conducted, the live coral coverage dropped to only 8.2% of that observed prior to the bleaching event, due to extinction of *Acropora* community (Fujioka 2002).

More than 3 years after the deployment, many visible coral colonies were observed on the artificial reefs (Fig. 2). Majority of the juvenile colonies found on the artificial reefs, both in shallower and deeper waters belonged to the genus *Acropora* (Table 1). The remaining juvenile colonies were identified as belonging to the genus *Pocillopora*, *Porites*, and *Goniastrea*. As shown in Table 1, juvenile colonies were observed on both the upper as well as lateral surfaces in the deeper artificial reef. However, no colonies were observed on the upper surfaces in the shallow reef. No significant differences were observed in the temperature and salinity between the shallow and deep areas, with the exception of the average light intensity during daytime, which was 2.6 times greater on the shallow reef than on the deep reef. It was demonstrated experimentally that the strong light (> 500 μmol m⁻²s⁻¹) inhibits settlement of *Acropora* larvae (Suzuki and Hayashibara submitted). Therefore, the absence of juvenile colonies on the upper surfaces of the shallow reef may be attributed to the strong sunlight. This observation is consistent with the fact that the larvae of acroporid corals tend to settle on the under surface rather than the upper surface in shallow places (e.g. Wallace 1985).

The size distribution of *Acropora* colonies on the upper surface of the deeper artificial reef showed two modes, 55 mm and 15 mm in basal diame-

![Figure 2](image-url)
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Larger size colonies exhibited 3-dimensional shape with branching, and smaller ones were relatively flat growth form. Up to 2 years, *Acropora* colonies are usually flat shape (Loya et al. 2001). Based on these informations and the time of the deployment of the artificial reefs, it was inferred that the group of large-sized colonies were 1999 settlers and they were relatively greater in number as compared to the 2000 or 2001 recruits, assuming a constant mortality rate. In fact, a maximum of 54 newly settled *Acropora* polyps had been observed in June 1999, on the 10 cm² unglazed tiles placed on the adjoining artificial reef (unpublished data).

It was noted that after the 1998 bleaching event, small *Acropora* colonies (not exceeding 3-4 cm) preferentially survived over larger colonies (Loya et al. 2001). The unexpectedly rapid recovery from the bleaching event (Normile 2000) might be attributed to the survival of juvenile colonies that had been overlooked. However, many young colonies on the artificial reefs were certainly as a result of larval recruitment.

The source of the coral larvae is unknown; however, the coral community that was source of these larvae, was also possibly subjected to great stress due to the high sea temperature anomaly prevailing throughout the Ryukyu Islands (Fig. 1). As a result, the negative influence of the high thermal stress on coral sexual reproduction, which has been observed in Okinawa (Omori et

<table>
<thead>
<tr>
<th>Place</th>
<th>Part</th>
<th>Total</th>
<th><em>Acropora</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow</td>
<td>upper surface (3.8m²)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>lateral surface (3.8m²)</td>
<td>20.8</td>
<td>20.3</td>
</tr>
<tr>
<td>Deep</td>
<td>upper surface (4m²)</td>
<td>42</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>lateral surface (4m²)</td>
<td>18.5</td>
<td>16.8</td>
</tr>
</tbody>
</table>

Fig. 3. Size distribution of *Acropora* colonies on the upper surface of the deeper artificial reef. The maximal diameter of the basal part was measured by a vernier caliper on July 1, 2002.
Mass coral settlement in the year following the bleaching (Hirose and Hidaka 2001) and the Great Barrier Reef (Hoegh-Guldberg 1999; Baird and Marshall 2002), might have been more restricted in space than expected.

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REFERENCES


Suzuki G, Hayashibara T (submitted) Inhibition of settlement and metamorphosis in Acropora (Anthozoa, Scleractinia) larvae by strong light. Proc 10th Int Coral Reef Symp


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