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Seasonal Changes in *Zoanthus* spp. in the Infra-Littoral Zone at Taisho Lava Field, Sakurajima, Kagoshima, Japan

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Abstract

Changes in *Zoanthus* spp. cover and polyp number were recorded by transect survey at Taisho Lava Field, Sakurajima, Kagoshima, Japan (N31°35', E135°35') for 30 months between May 1980 to October 1982. In addition, lab experiments were conducted to investigate changes in polyps, *Zoanthus*' gonads and zooxanthellae number at different seawater temperatures. Our results indicate that *Zoanthus* polyps grow during summer and autumn, and experience a decrease in size during winter and spring. Polyps close during periods with low winter temperatures, and zooxanthellae activity and concentration also decrease, perhaps due to the winter growth in many types of algae above polyps and the appearance of diatoms on polyps themselves. In addition, volcanic ash from the nearby active volcanic cone of Sakurajima also has a negative effect on *Zoanthus* polyps.

Key Words: *Zoanthus*, seawater temperature, seasonal changes, volcanic ash, diatom

Introduction

Zoanthus spp. (Brachcnemia, Zoanthidae) are an encrusting anemone-like group that form colonies of polyps, and are found in Japan from mid-Honshu south at depths from the low tide line and below. To investigate changes in the infra-littoral zone in corals and Cnidarians at Sakurajima's Taisho study site, *Zoanthus* was selected as the subject species for an on-going transect survey, changes in the environment are easily seen in *Zoanthus* polyps, although until now research has been scarce (BABCOCK and RYLAND, 1990).

Besides *Zoanthus* spp., *Stereonephthya*, *Dendronephthya*, *Acropora*, *Favia*, *Porites*, *Pavona*, *Montipora*, and *Hydnophora* species are all readily visible at the rocky Taisho Lava Field site, located in Sakurajima, Kagoshima, Japan (HIRATA and OSAKO, 1969). Previous research has shown that these and other species are influenced not only by expected environmental factors, such as seawater temperature, but that volcanic ash-fall from the nearby Sakurajima volcanic cone also impacts the Taisho Lava Field infra-littoral environment (ONO and TSUKUHARA, 2000).

Data collected from transect surveys for this study showed that of all the species at the Taisho site, *Zoanthus* especially displayed large variability from season to season. Laboratory experiments were carried out to investigate possible reasons behind this variability. Identification of *Zoanthus* to the species level is extremely difficult (BORNEMANN, 1998),

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and therefore identification was made only to the genus level. Further research investigating what species of *Zoanthus* are present at the Taisho site is necessary.

Materials and Methods

The subject study species *Zoanthus* forms colonies consisting of many individual polyps (Fig. 1). Polyps are on average 5~7 mm in diameter across the oral disk, and have a length of 10~30 mm. Inside the polyp in the internal gastro-intestinal cavity innumerable endosymbiotic *Symbiodinium* spp. zooxanthellae are present.

Fig. 1 Colony of *Zoanthus* aff. *pacificus* in natural condition in the infra-littoral zone at Taisho Lava Fields, Sakurajima. *Zoanthus* polyps are 5~7 mm in diameter when open, and have a length of 10-30 mm, containing innumerable zooxanthellae in the gastro-intestinal cavity.

The study site at the Taisho Lava Field is located on the western shore of Sakurajima, Kagoshima (Fig. 2). The site was formed during the Taisho Eruption of Sakurajima in 1914, and the area still receives regular dustings of volcanic ash from the active Sakurajima volcano's eruptions (FUKUYAMA and ONO, 1981). The study site is in a small bay and is 20 × 50 m. Four stations (Stations 1~4) were chosen at depths of 1~3 m, and every month from May 1980 to October 1982 (30 months total) these areas were surveyed using a 50 × 50 cm transect. Coverage of *Zoanthus* and other species were noted. At the same time, samples of *Zoanthus* were collected from depths of 1~3 m near the transect stations during each survey, and stored in the laboratory at -60℃. The samples were used to examine polyp size and zooxanthellae condition.

To investigate polyp growth and shape, samples were collected during August from various places in the study site as entire portions of a colony (still connected with stolons) to prevent unwanted mortality. Individual polyps were taken from the colony sample, and

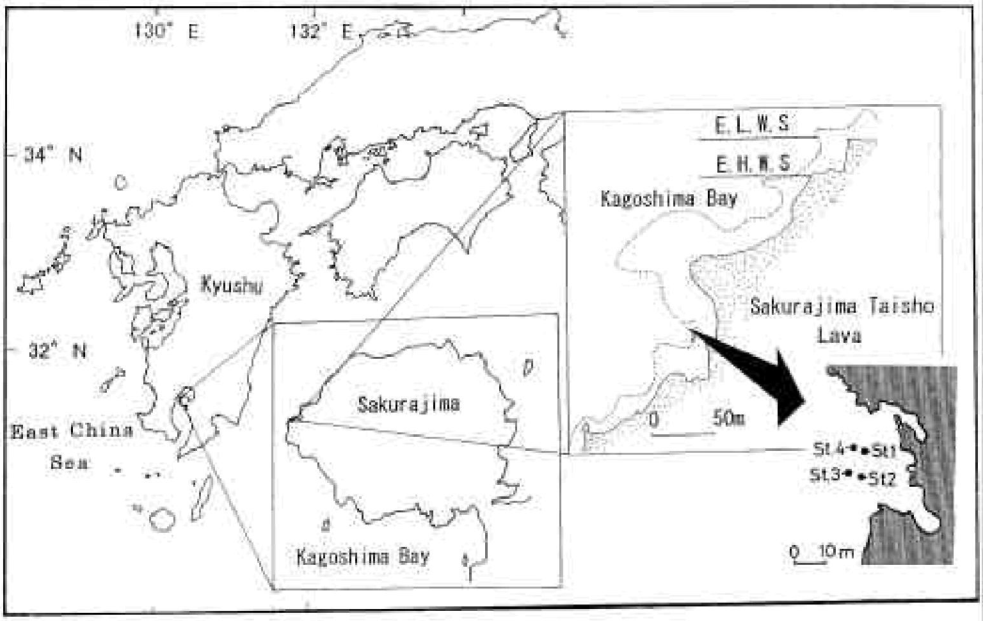

Fig. 2 Map of study site: Taisho Lava Field, Sakurajima, Kagoshima, Japan. E.L.W.S. = Extreme Low Water Spring tide line, E.H.W.S. = Extreme High Water Spring tide line, St. = Station.

the samples were placed in salt water tanks on glass plates in a laboratory under two different controlled conditions; (1) L:D = 12:12 hrs, 4000 lux, 22℃- corresponding to the study site average spring and autumn temperature, and (2) same as (1) with a temperature of 16℃, which is the average seawater temperature in winter. Ten individual polyps were placed in each temperature regime tank. Individual polyps were also examined, and oral disk diameter, length, stolon count, and polyp count were recorded. No food was given to samples before, during, and after the experiments were conducted.

Further, to investigate gonad changes, every month from March 2000 to April 2001 (every week between April and July 2000) several polyps were collected from near Station 2 and placed in Bouin's fixative solution. Samples were then mounted in paraffin and stained with Azan's staining solution. For the scanning electron microscopic study of the ultrastructural surface of the polyps samples were fixed in glutaraldehyde and OsO_4, dehydrated, dried, and coated with platinum. A Hitachi S-4100 scanning electron microscope was used.

Results

Seasonal changes in *Zoanthus* cover

Station 1 is located 10 m from shore, at a depth of 1 m. The bottom consists mainly of a large volcanic rock approximately 3 m in diameter. Compared with stations 2 and 3, station

1's water temperature and wave height, are more variable. Compared with other stations, *Zoanthus* cover at Station 1 was consistently higher throughout the course of the transect survey. Stations 2, 3, and 4 are located approximately at depths of 2.5, 3, and 3 m, and 15, 17, and 18 m from infra-littoral line, respectively. *Zoanthus* cover at Stations 2, 3, and 4 was generally below 40%..

As shown in Figure 3, *Zoanthus* cover increased between August and December, and decreased from December to August. During the last part of August in 1982 Sakurajima erupted heavily several times, resulting in extremely heavy ash-fall (5.5 kg/m^2/day) (KAGOSHIMA METEOROLOGICAL STATION: PERSONAL COMMUNICATION). At stations 2 and 3, where wave influence is low, up to 3~5 cm of ash covered *Zoanthus*. This resulted in the cover of *Zoanthus* decreasing from 45.5 % in July 1982 to 10.1% in October 1982.

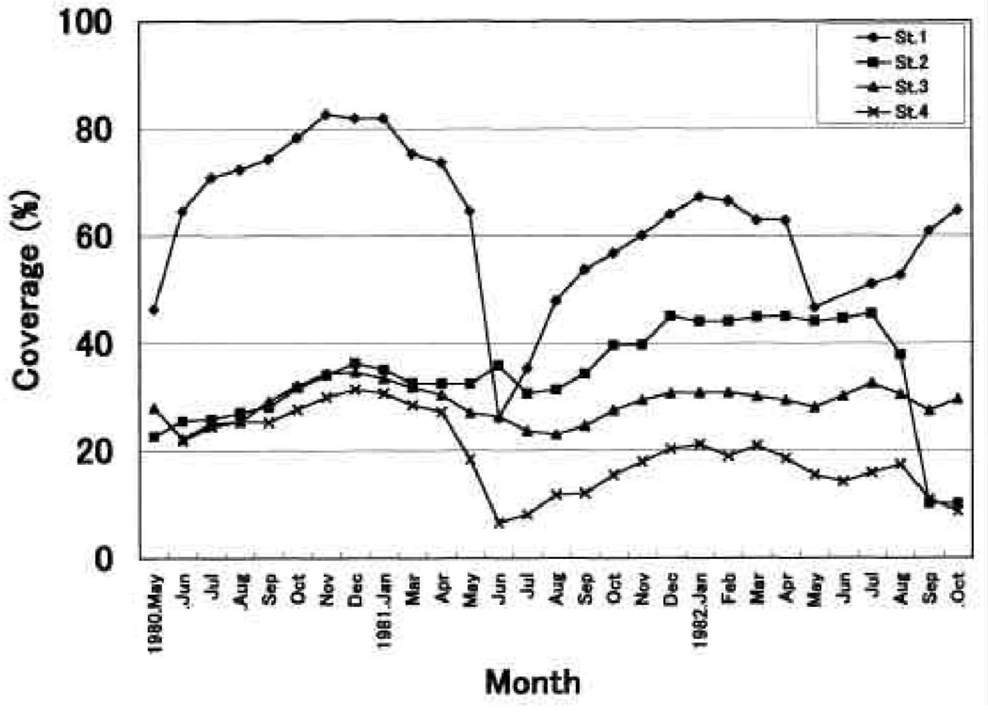

Fig. 3 Changes in *Zoanthus* cover, May 1980~Oct. 1982.

Figure 4 shows colony numbers and size data from Stations 1~4. Colony size was divided into five sizes; less than 0.25 cm^2, 0.25~6.25 cm^2, 6.25~25.0 cm^2, 25.0~100 cm^2, and over 100 cm^2. The number of small (0.25 cm^2 or less) colonies (i.e. new colonies) increased between May and September. From September to November the number of colonies less than 0.25 cm^2 decreased, and the number of colonies in the range of 0.25~6.25 cm^2 increased. From November to April the number of all colonies decreased.

The length of polyps was investigated (Fig. 5) by counting approximately 200~300 polyps per month. Small polyps with a length of less than 5 mm were very common

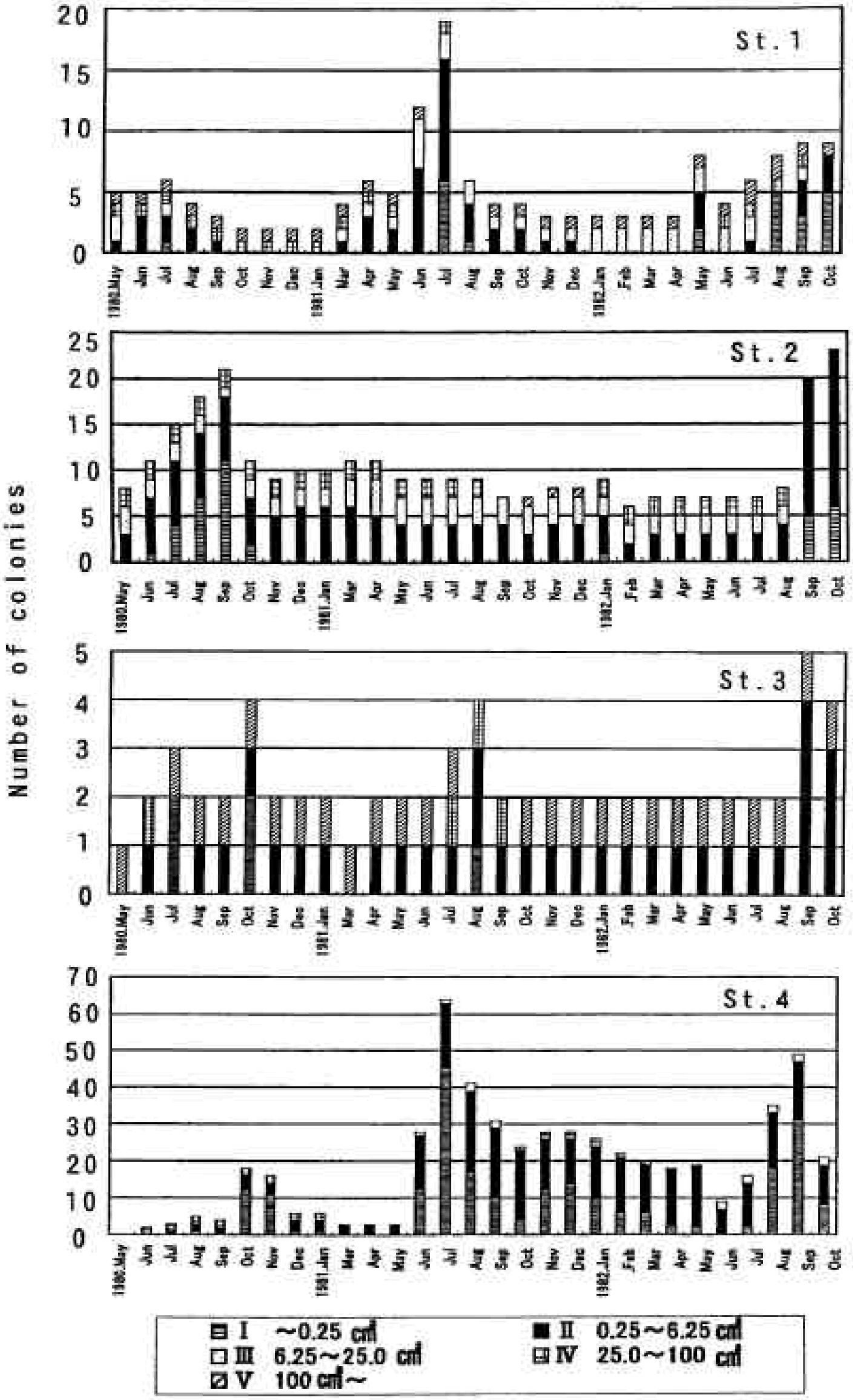

Fig. 4 Seasonal changes of *Zoanthus* colonies at Stations 1~4 by number and colony size, May 1980~Oct. 1982.

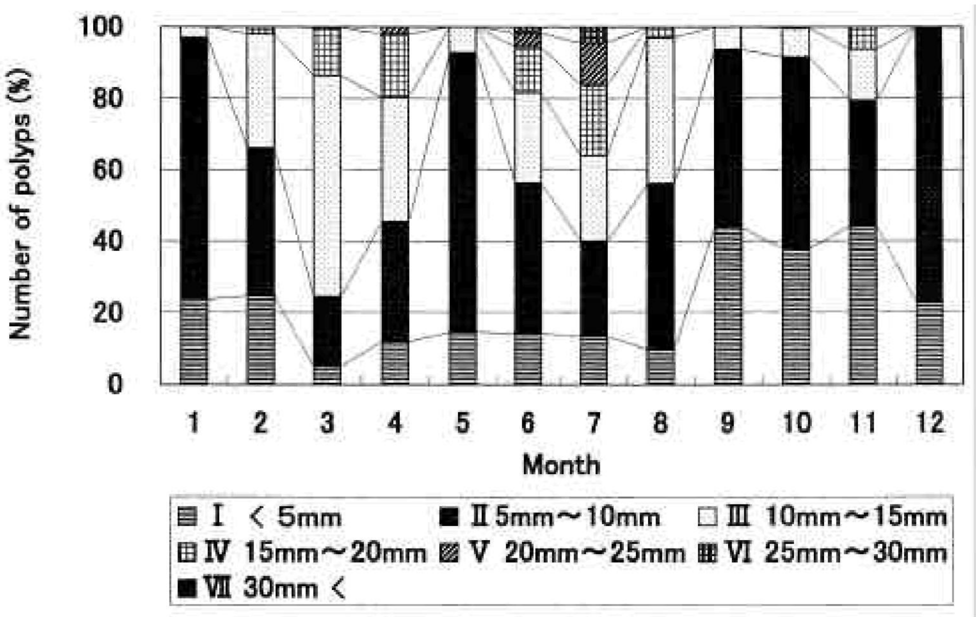

Fig. 5 Changes in *Zoanthus* polyp length (mm) by month, 1981.

between September and February.

Seasonal frequency of macro-algae and diatoms

A strong seasonal variation was seen in macro-algae and diatom (Fig. 6a, b, c) cover. *Sargassum*, *Colpomenia sinuosa*, and other species of macro-algae grow to approach 100% cover during the winter to spring period (Fig. 7). In areas above *Zoanthus* polyps this macro-algae cover appears to be especially dense. Diatoms appeared during winter and spring covering *Zoanthus* polyps.

Seasonal frequency of inactive zooxanthellae

Winter sea water temperatures at the Taisho Lava Field reach a low of approximately 15 ~16℃, and at this temperature *Zoanthus*' oral disks close, which was observed both in the field and in the lab. As seen in Figure 8, the ratio of inactive zooxanthellae generally increased from winter (January) to summer (June). This is reflected in the decreased healthiness in the zooxanthellae, and lower chlorophyll concentrations (personal data). When macro-algae cover is 100% during May (personal data), chlorophyll-less zooxanthellae account for 79% of all zooxanthellae, while in September this number decreases to 12.2% .

***Zoanthus* temperature and polyp growth experiments**

Figure 9 shows the number of stolons of Zoanthus kept in tanks at results from *Zoanthus* polyps kept in lab tanks at 16℃ and 22℃ over 10 weeks. At 16℃, no new stolons developed, and all polyps closed their oral disks. No polyps were seen to attach themselves

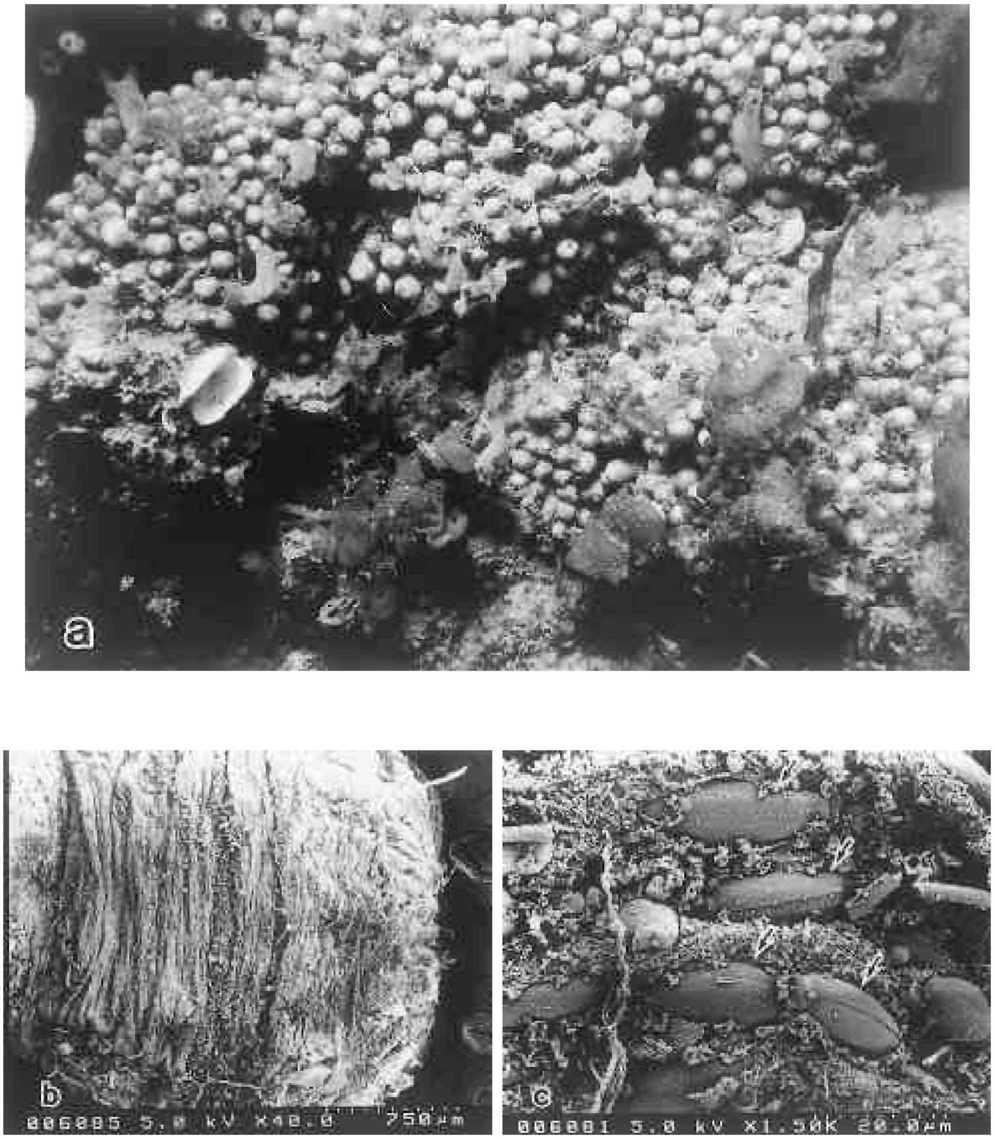

Fig. 6 *Zoanthus* polyps in winter

(a) *Zoanthus* polyps in the infra-littoral zone, February 2000. Polyps are in typical winter condition, with oral disks closed.

(b) *Zoanthus* polyp epidermis under electron microscope, February 2000. Small disk-like objects are diatoms.

(c) Detail of (b). The presence of many diatoms on the surface of the *Zoanthus* polyps is clearly evident.

Both (b) and (c) were taken with a scanning electron microscope. Scale is shown on the photographs.

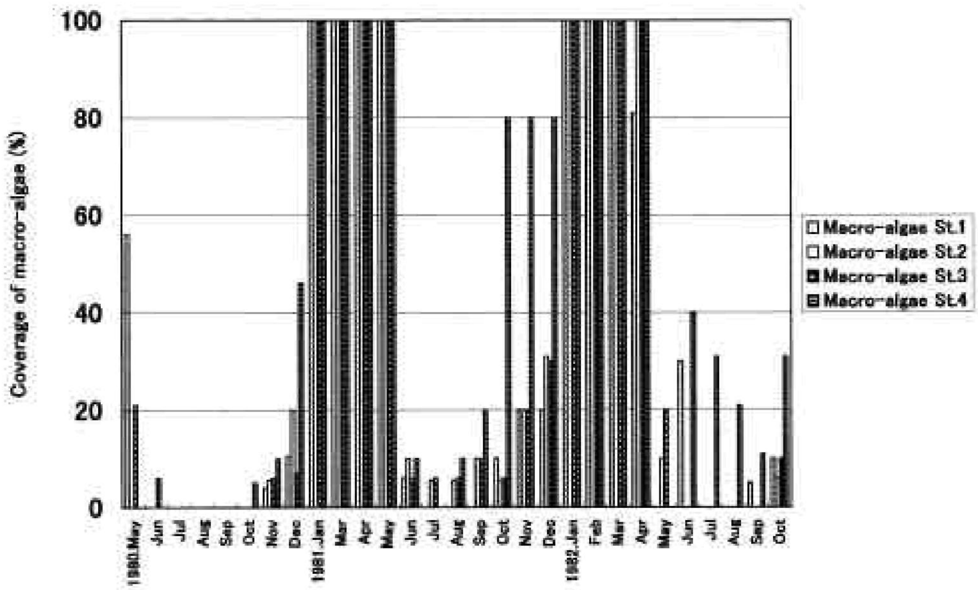

Fig. 7 Changes in macro-algae cover at Stations 1~4, May 1980 to Oct. 1982.

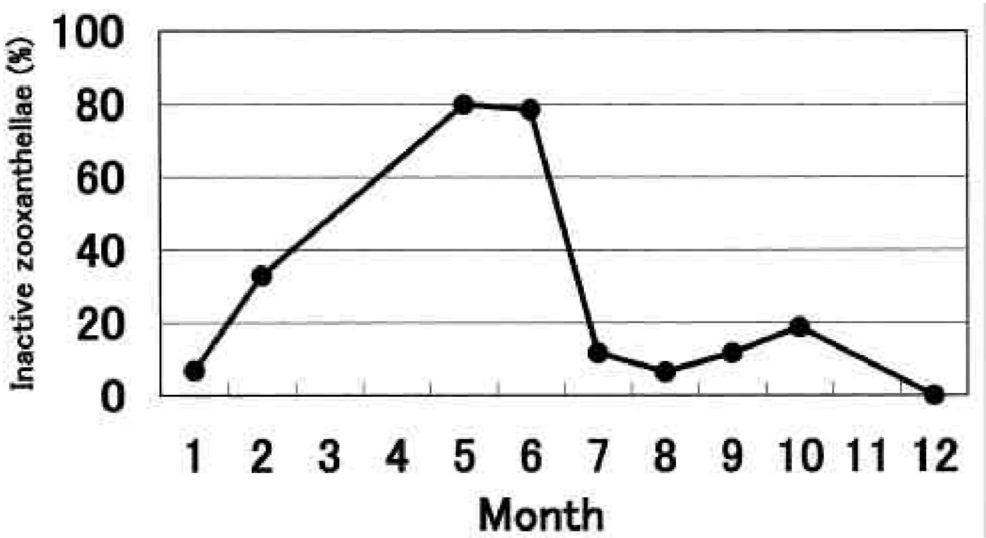

Fig. 8 Changes in inactive zooxanthellae over 1 year (1981) at the study site.

to the glass plate substrate, while at 22℃ polyps attached themselves to the substrate. In addition, at 22℃, stolons were seen to develop at 28 days from the start of the experiment, and after approximately 6 weeks all polyps showed division of the stolon. However, even after 200 days, no new formation or division of polyps was seen.

Zoanthus reproduction

Based on the monthly (and weekly from April to July 2000) cross-sections of *Zoanthus*,

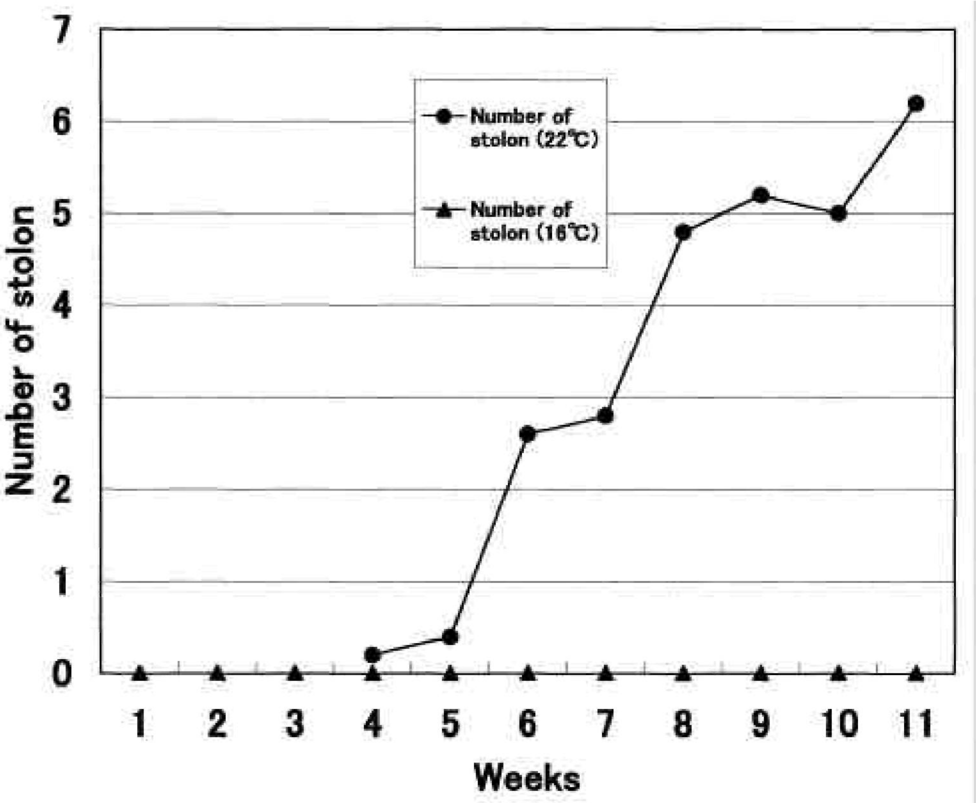

Fig. 9 Changes in *Zoanthus* stolon number L:D =12:12 hr, 4000 lux, 16℃ and 22℃, over 10 weeks.

eggs appear inside polyps from June, and grow bigger until being released during the largest tides of July (Fig. 10a). After spawning no eggs were to be seen in the cross section until the following June. Spermatogenesis began at the beginning of July, when early spermatogenia were seen to develop into spermatocytes, followed by spermatids, and finally developed into sperm (Fig. 10b). Sperm were released at the same time as the eggs during the big summer tides. After spawning, vesicles shrank until they were not visible. Based on these observations it is likely that fertilized embryos appear after the July spawning, leading to the increase in small <0.25 cm^2 polyps seen from September.

Discussion

The Effect of Light and Volcanic Ash

The growth cycle of *Zoanthus* polyps can be divided into two different phases, an expansion phase from summer to autumn, and a contraction phase from late autumn to early summer. *Sargassum*, *Colpomenia sinuosa*, and other species of macro-algae grow to approach 100% cover from winter to spring. Diatoms were seen to grow on individual *Zoanthus* polyps.

Fig. 10 *Zoanthus* polyps' gonads

(a) Ovaries of a sample polyp one week before release of eggs and sperm, July 2000. Diameter at widest point of ovaries, approximately 100~150 μm; diameter at narrowest point, 70~100 μm. Scale bar: 100 μm.

(b) Sperm bundles one week before release of eggs and sperm, July 2000. Each bundle is approximately 100 μm in diameter.

Both photos were taken with a light microscope at 100 ×. Scale bar: 100 μm.

Undoubtedly this cover influences the growth and fitness of *Zoanthus*, both on the colony and polyp level.

Based on the results, it seems safe to say that at low sea water temperatures *Zoanthus* polyps close their oral disks, decrease in size and number, and that endosymbiotic zooxanthellae decrease their activity, while macro-algae and diatom cover increase. At higher temperatures, polyps enter a state of growth and activity, characterized by an opening of oral disks, development and growth of stolons and polyps, and the appearance of small, new polyps, and spawning may occur during extreme summer tides. As well, these summer conditions correspond with a decrease in macro-algae and diatom cover. In addition, *Zoanthus*' reliance on light may be further demonstrated by the fact that very few plankton and other types of potential food sources were seen inside the gastro-intestinal cavity during the course of the experiment. In fact, it is easy to suggest that *Zoanthus* almost completely relies upon its zooxanthellae for energy. Thus, in times when light levels are not sufficient, *Zoanthus* cannot grow nor expand.

Due to the fact that the study site is located in a small bay removed somewhat from currents and other influences, volcanic ash should have a strong effect on organisms living in the infra-littoral zone of the study area (ONO *et al.*, 2002, in preparation). During the last part of August 1982 there were several large eruptions from Sakurajima volcano. 3~5 cm of ash covered *Zoanthus* and other encrusting species. In the months after the eruption dead *Zoanthus* (as well as other species) were seen at the study site. Figure 11 shows the ash-fall at sites near the Taisho field site (ANNUAL REPORT OF KAGOSHIMA PREFECTURE EMERGENCY OFFICE, 1998). Based on our observations and results, it is safe to say that volcanic ash has a harsh and debilitating effect on *Zoanthus*.

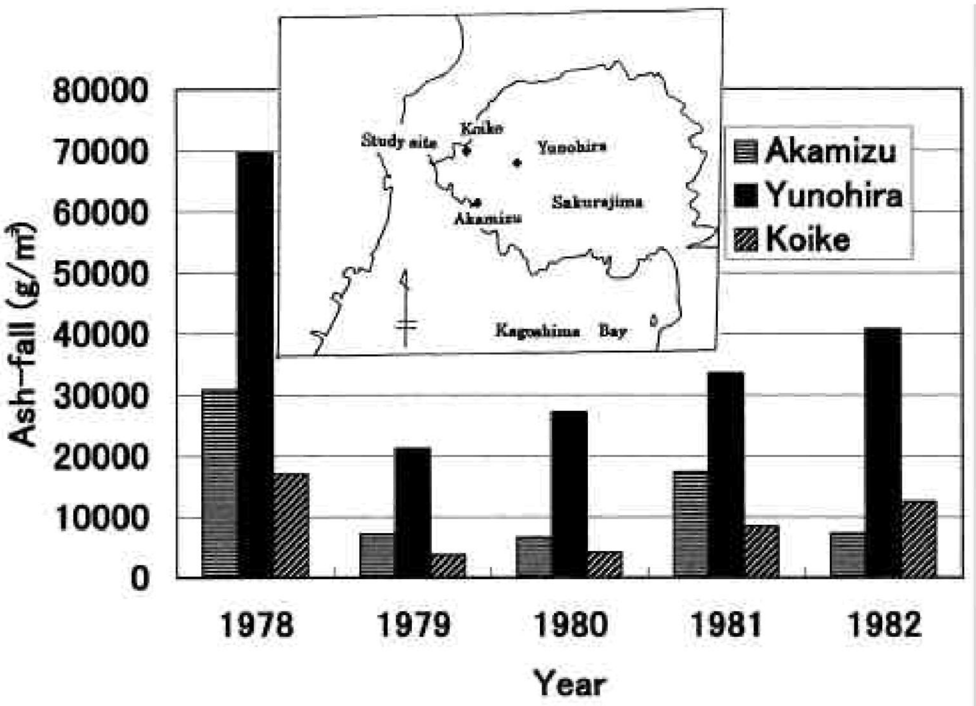

Fig. 11 Changes in volcanic ash-fall from 1978 to 1982 at three sites near the study site at Sakurajima, Kagoshima.

The Effect of Seawater Temperature

Low seawater temperatures result in the closure of polyps' oral disks, as well as the growth of macro-algae and diatoms. This causes a decrease in the activity of endosymbiotic zooxanthellae, and a stoppage and/or reversal in *Zoanthus* growth. Based on these results, one could expect to find *Zoanthus* in areas where winter sea temperatures do not go much below 16℃. This hypothesis merits further investigation.

Worldwide, widespread coral bleaching was observed in 1998, likely due high seawater temperatures (TSUCHIYA, 1999). In Japan, Okinawan coral reefs suffered heavy bleaching damage (SUGIYAMA *et al.*, 1999; YAMAZATO, 1999). As noted in separate research (ONO *et al.*, 2001) Sakurajima also showed signs of bleaching.

As worldwide temperature increases are expected in the coming years, one can expect that the frequency of coral bleaching will also become more intense, and therefore further research into the effect of temperature and the environment on *Zoanthus* and other species of encrusting corals has become more necessary than ever.

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