D-4.2.3 Influence of sedimentation and water temperature on coral communities

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Abstract

Field investigation on the distribution and community structure of hermatypic corals has been conducted at ten study sites within the vicinity of the Urasoko Bay, using the line transect and the quadrat methods. Hermatypic corals of 16 families 56 genera 229 species were identified within the Urasoko Bay. The number of species, the number of colonies, and the coral coverage increase from the coastal side to the offshore reef flat. The distribution pattern of the corals exhibited uniform or random one on the offshore reef flat and aggregated near the coastal side. The species and generic composition also differed each other in relation to their environmental conditions; the genus *Acropora* became dominant on the offshore reef flat, while the genus *Montipora* and *Porites* near the shore of the bay. It is considered that such diversity was caused by the complicated coral reef topography and by the wide ranges of environmental gradients.

Concentric environmental gradients of turbidity, transparency, salinity and the quality and quantity of sediments were observed from the coastal side to the offshore reef flat. They changed both vertically and horizontally according to ebb and flow. Bleaching caused by the high water temperature was hardly observed in 1995-1996, unlike in 1993-1994, in relation to slightly low water temperature during the summer.

Good inhabiting conditions for the survival of hermatypic corals are maintained on the offshore reef flat. In contrast, coral communities could not recover from damage by crown-of-thorns starfish because of much sedimentation in the coastal side of the bay.

Key Words Coral, Coral Reef, Sediment, Bleaching, Community

1. Introduction

In the last few decades, mass destruction of the hermatypic coral community and decrease of the coral reef organisms has been extraordinarily focused around the coastal area of many coral reefs. This problem has been considered to be predominantly caused by some reasons, such as the predators, eutrophication, high temperature, sedimentation, oil pollution, and so on [1) 2) 3)] . Mass predation of hermatypic corals by the crown-of-thorns starfish (*Acanthaster planci*) was one of the most drastic event among them [4)] . Outbreak of the crown-of-thorns starfish occurred in the Nansei Islands, southwestern of Japan, since the mid-1970s [5) 6)] , and most hermatypic corals of the Ishigaki Islands have been predated during about ten years from this era until the mid-1980s [7)] . On the other hand, the eutrophication and the sedimentation on the coastal regions as a result of dredging, land erosion and coastal engineering projects have been discussed seriously

as the artificial disturbance of the coral reefs [1) 2) 3)] . Moreover, the bleaching of the hermatypic corals caused by the high water temperature is recently reported from all over the world [8)]

In this study, out of these factors which have an influence on the survival of the hermatypic corals, the sedimentation and the high water temperature are predominantly examined. For this purpose, field investigation concerning the distribution and the community structures of the hermatypic corals was carried out over the Urasoko Bay, and the causality between the environmental factors and the coral communities was evaluated.

2. Methods

Ten study sites were selected in the Urasoko Bay (24 ° 27'N, 124 ° 13'E), northern part of the Ishigaki Island (Fig. 1). The Urasoko Bay is the compact bay which opens for the north with about 1.5km in diameter and about 2.6k m² in area. Several small revers are flowing into this bay. St.1-St.3 are situated near the outward margin of the offshore reef flat, St.4-St.5 are near the inward margin of the same reef flat, and St.6-St.10 are on the inner reef flat, in which St.8-St.10 are near the shore line.

The field survey has been carried out over five times, December 9-20th, 1994, March 14-24th, 1995, August 25th-September 15th, 1995, March 18-27th, 1996 and September 6-26th, 1996. The line transect (LITR) and the quadrat (ICCE) methods [9)] were adopted in the field investigation. The pre-survey was done by the line transect method to determine the installation place of the quadrat. The large quadrat method was also adopted for the first time in this study. In this method, only coral coverage within the 100-400 quadrats was examined continuously by the 1 m² unit for the wide area of 10 × 10m or 20 × 20m.

To examine the environmental conditions for each study site, the water temperature, the turbidity, the salinity and the amount of chlorophyll were measured in every 10cm from the bottom to the surface layers, using the multi data logging system (ALC-208). The degree of transparency was also measured with 1m water depth using the Secchi board. These measurements were done three times of 7:00 (high tide), 14:00 (ebb tide) and 19:00 (high tide) on September 10th, 1995 (the spring tide). Moreover, sediments on the surface of rocks were collected from three 25 × 25cm quadrats, using the suction pump. The grain size of the sediments was analysed according to the standard phi(ϕ) scales from 0.064 mm to 2mm, after drying out for the long time at low temperature below 60 ℃ . In September 1995 and September 1996, three sediment traps with 25mm in diameter were respectively installed in St.1 and St.10 to collect sedimnts every approximately 24hours.

3. Results

There was a general trend that the number of species, the number of colonies, and the coral coverage increased gently as they headed onto the offshore reef flat from the coastal side of the bay (Fig. 2). The coral coverage exhibited extreme high values from 76.2 to 91.2% in St.1-St.3 on the offshore reef flat, whereas stopped at low values from 3.6 to 7.5% in St.8-St.10 near the coastal side (Fig. 3). The phenomenon that the coral coverage was different remarkably between the places which were left each other by only 20-30m within the identical study site was observed in St.3 and St.4 (St.3-1 and St.3-2, St. 4-1 and St.4-2, in Fig. 3). The coral coverage was uniformly large in St.1, except for some places in which the soft corals inhabited or the small crevices were present. On the other hand, the coral colonies formed some distinct patches and such patches were separately

distributed each other in St.10. The distribution pattern exhibited uniform or random one in St.1 and aggregated one in St.10.

The hermatypic corals which were identified during this investigation in the vicinity of the Urasoko Bay came up to 16 families 56 genera 229 species. *Porites okinawaensis*, *Goniopora pendulus*, *Pavona diminuta* and *Caulastrea curvata*, were the first records from Yaeyama Islands.

A remarkable difference was revealed on the dominant species of hermatypic corals and their species composition within the quadrat of 1 × 1m (Table 1). In St.1-St.3, the genus *Acropora* such as *A. hyacinthus* and *A. digitifera* were recognized as the dominant species. The genus *Acropora* also dominated in St.4-St.6 but the species composition was fairly different from that of St.1-St.3. The genus *Montipora* such as *M. digitata* covered large part in St.6-St.8, and the species was dominant in St.7. In St.8-10, the genus *Porites* such as *P. lutea* and *P. evermanni* were recognized as the dominant species. The species belonging to the family Faviidae were observed in most study sites from the offshore reef flat to the coastal side, but their rates were uniformly low.

The grain size distribution of the sediments collected with a suction pump is shown in Figure 4. The sediments were composed mainly from the coarser particles more than 0.25m m in diameter in St.1-St.3, whereas the rate of the fine particles less than 0.125mm was very high in St.6-St.10. The contents of the particles were originated mainly from the organic materials in the former and the non-organic ones in the latter. Larger amount of macrobenthos were included in the latter sediments than in the former.

Horizontal distribution of transparency, turbidity, salinity and chlorophyll contentat high tide and ebb tide are illustrated in Figure 5. Concentric environmental gradients from the coastal side of the bay to the offshore reef flat were appeared. Water temperature, salinity and turbidity changed vertically according to ebb and flow (Fig. 6). There was not any tendency on the amount of chlorophyll.

Large amount of sediments were collected with the sediment traps in St.10 (Fig. 7). The strong northward wind and the heavy wave action were happened at the Urasoko Bay in the middle of September 1996, followed by a typhoon. The transparency at that time decreased to only 0.9m. The amount of sediments during this period increased remarkably to approximately 50 times by usual in St.10. This condition continued for about one week.

Mass bleaching had been occured all over the Yaeyama Islands in the summer in 1993 and 1994. Approximately 70 percent of coral colonies had been bleached and the influence continued until December of the year. However, in spite of the detail investigation in August to September when the water temperature became the highest, bleaching by high water temperature was hardly observed either in 1995 or in 1996.

4. Discussion

Hermatypic corals identified so far in the vicinity of the Urasoko Bay came up to 16 families 56 genera 229 species. The number would be over 250 species if uncertain and unidentified species are included. The number of species were equivalent to those of the Kabira Bay (17 families 68 genera 250 species) [10] and the Sakiyama Bay (17 families 58 genera 198 species) [11] and more than three times of the Shiraho region (11 families 33 genera 79 species) [12] [13] all of which are situated in the same Yaeyama Islands, The ecological features of the coral communities also differ in every study sites.

At first, it is considered that such diversity observed on the species and communities

of the hermatypic corals is related to the complication of the coral reef topography provided within the Urasoko Bay. It is supposed that the heterogeneous inhabiting environment exists in such complicated topography and that many kinds of hermatypic corals become possible to inhabit in such various habitats.

The second possible reason improving the diversity of species and communities is the wide range of environmental gradients. Concentric environmental gradients of the salinity, the turbidity, the transparency, and the amount of sediments were observed in the bay. The dominant species changed in order of *Porites*, *Montipora*, *Acropora* from the coastal side of the bay to the offshore reef flat, in related to these environmental gradients.

However, such diversity is not peculiar to the Urasoko Bay. It is assumed all around the Yaeyama Islands that more than 200 species appear wherever the places which has two elements described above, i.e. (1) heterogeneous inhabiting environment and (2) the wide range of environmental gradients.

It is well known that the formation of the hermatypic coral communities is related to the coral reef topography and the degree of wave exposure [14) 15)] . Tthis study clearly showed that the environment factors such as sedimentation influenced the structure of the hermatypic coral communities. Schematic diagram exhibiting the main habitats of some representative screlactinian coral communities is shown in Figure 8.

Unlike in 1993-1994, bleaching caused by the high water temperature was hardly obse rved in the summer of 1995-1996 . At the Ishigaki Island, the average water temperature (10AM) during the summer was 28-29 ℃ for 1995-1996, while it was 29-30 ℃ for 1993-1994. It is considered that such slight difference becomes a trigger for the bleaching.

The amount of sediments deposited in the sediment traps became remarkable large when the area was strucked by the typhoon. The maximum amount of sediments exceeded 1 kg per square meter in dry weight on September 21th, 1996. This value is extremely larger than those of hitherto known [2)] . The influence of the sedimentation becomes conspicuous in the cases that the soils are flowed from land area into the bay followed by a great deal of rainfall and that the already deposited sediments were diffused and moved repeatedly followed by the heavy wave action. Under these status, the corals are suffering not only direct damages to the polyps and the coenoserc but also indirect damages to the photosynthesis of the symbiotic zooxanthella. Such intermittent heavy stresses are important to restrict the distribution of coral species and their community structures.

The hermatypic corals around the Yaeyama Islands were severely damaged until mid-1980s because of the outbreak of the crown-of-thorns starfish [5) 6) 7)] . The number of individuals of the crown-of-thorns starfish have been drastically decreased at present. The coral communities have been completely recovered on the offshore reef flat, St.1-St.3, whereas there is not a tendency to recover the rich coral communities at the coastal sides of the bay, St.8-St.10.

As has seen in this study, good inhabiting conditions for the survival of corals are maintained on the offshore reef flat. In contrast with this, it becomes impossible to establish rich coral communities because of the sedimentation on the coastal side of the bay. It is evident that some environmental factors such as the sedimentation have a significant effect on the process of their recovery. Mass destruction by the crown-of-thorns starfish seems to be transient event because the change reversible , while sedimentation has fatal effects on the coral reef communities. These two phenomena are superficially similar

each other, but it should emphasize that they are quite different in contents.

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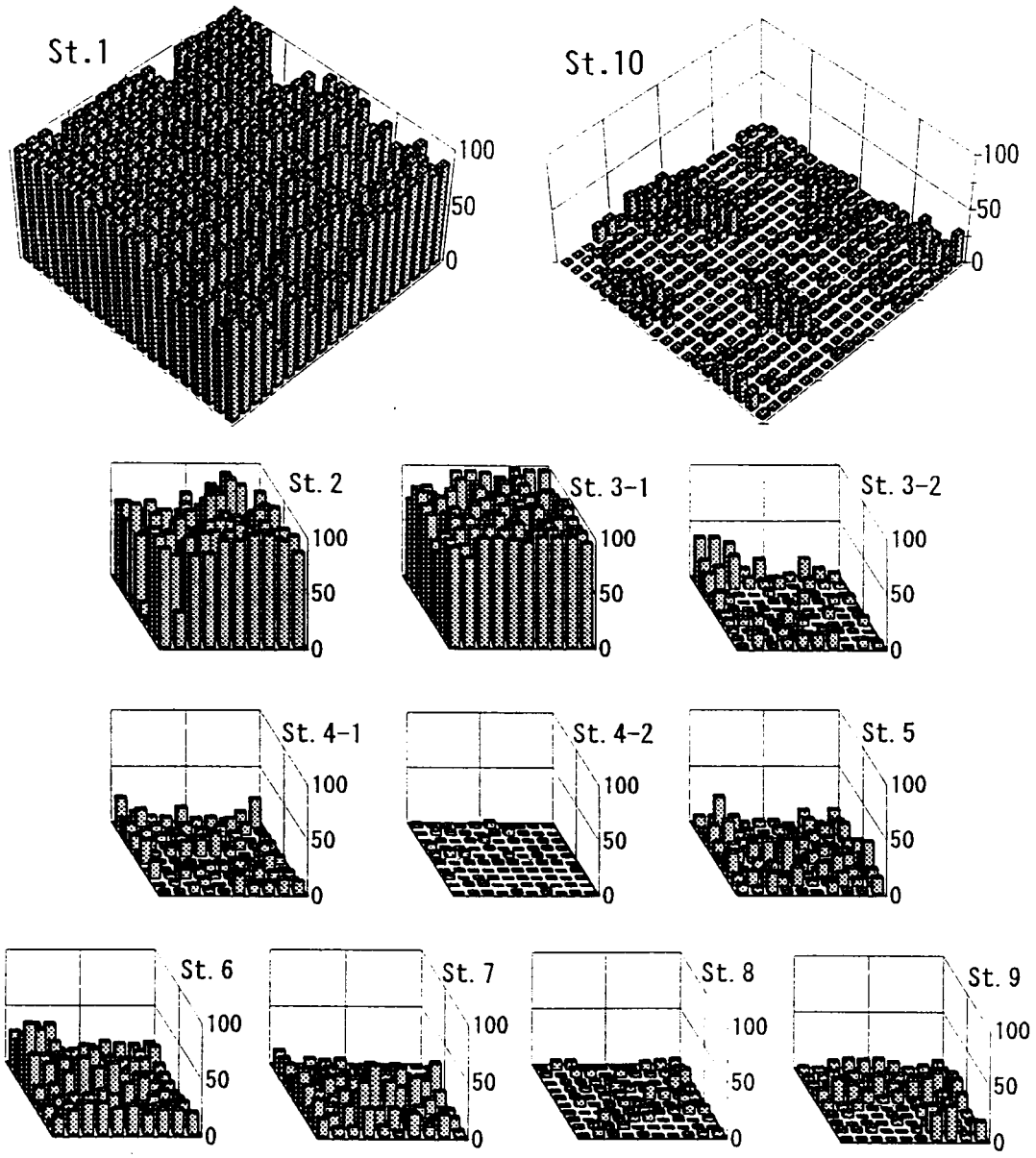

Fig.3 Coral coverage of ten study sites. Each column express the 1 × 1m quadrat. Surveyed on Aug. 28-Sep. 15, 1995

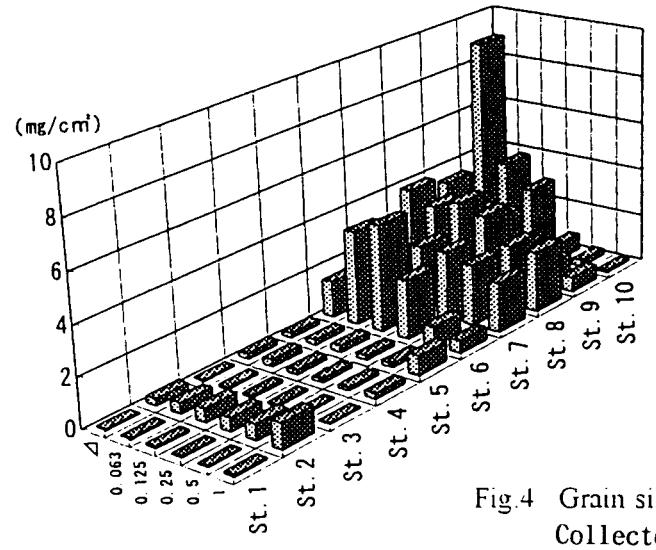

Fig.4 Grain size distribution of sediment. Collected on Aug. 25-27, 1995

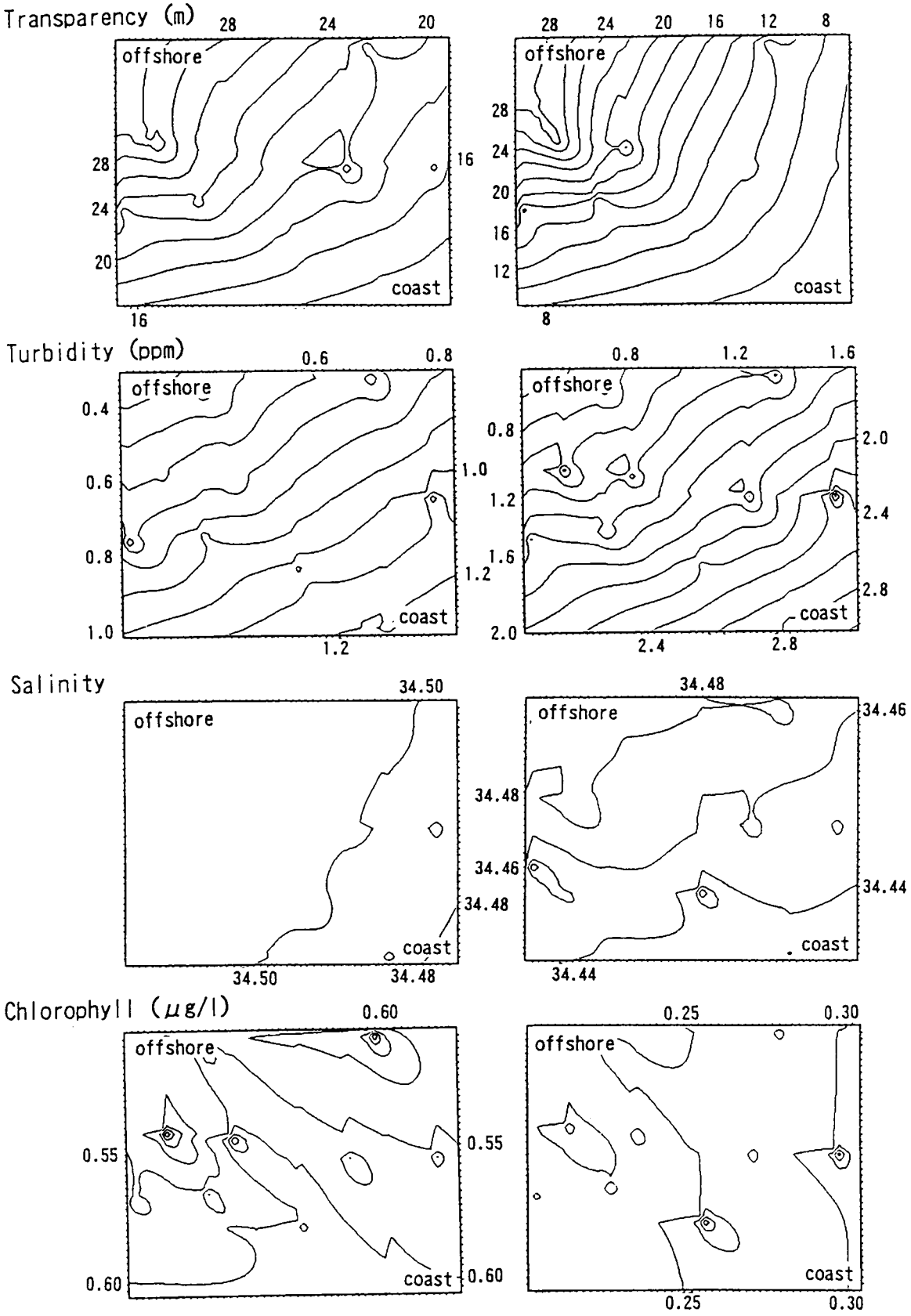

Fig.5 Horizontal distribution of main environmental factors in the Urasoko Bay. Left: flow tide Right: edd tide Measured on Sep. 10, 1995

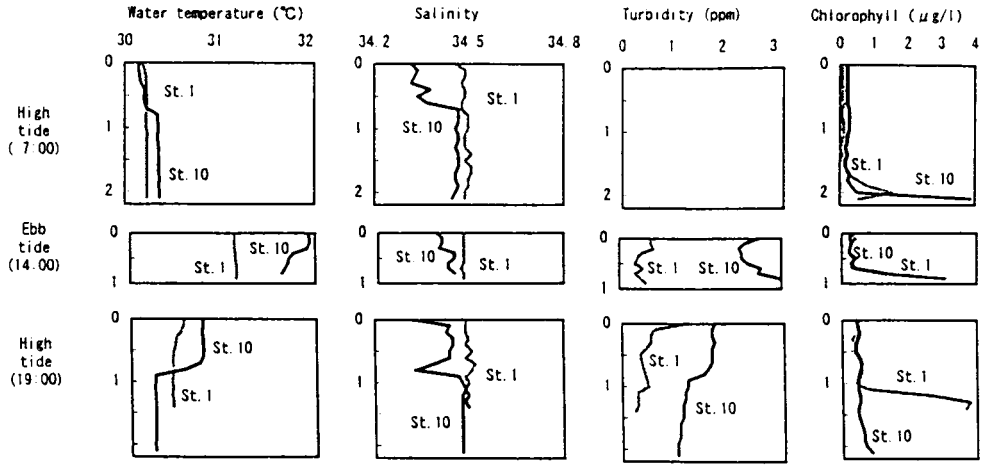

Fig.6 Vertical distribution of main environmental factors in St.1 and St.10. Measured on Sep. 10, 1995

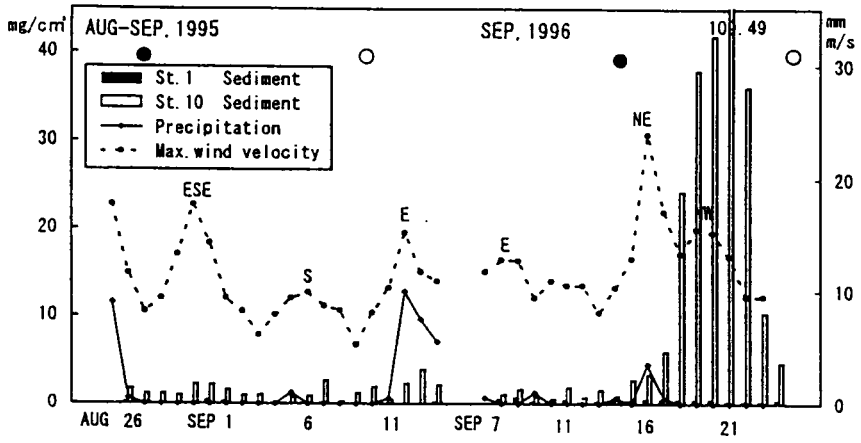

Fig.7 Daily changes of sedimentation in St.1 and St.10.

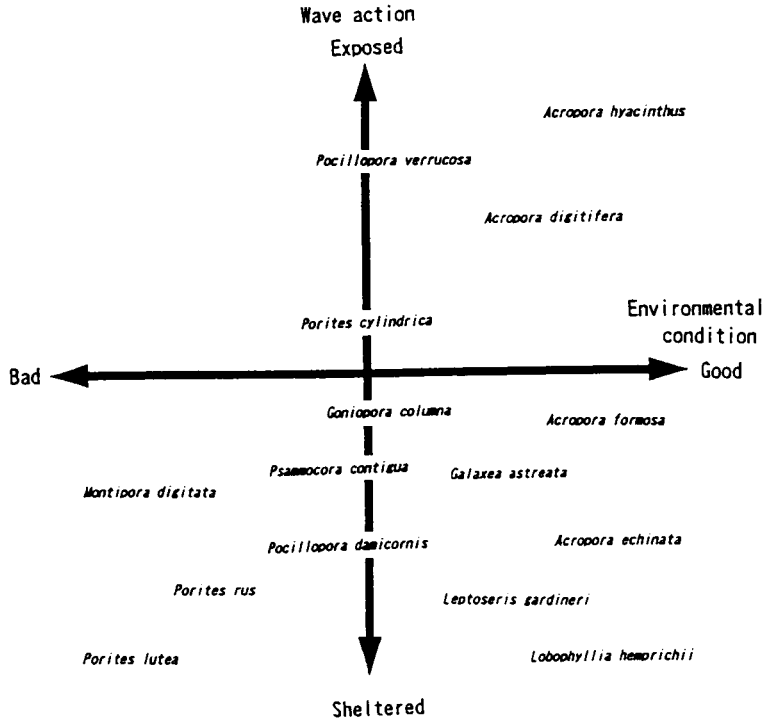

Fig.8 Schematic diagram exhibiting the habitat of representative screlactinian corals.