F-5.1.1 Studies on structure of biodiversity in biotic community of coral reefs

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Abstract We studied on the fish community, the community of boring benthos and borehole users, and relation between fish and zoobenthos in the coral reefs of Yaeyama Islands area for analyzing the structure of biodiversity. In the fish community, we conducted diving surveys in various area and season, it is clarified the fish community in coral reef had different species composition and had high species diversity in each environment. It could be said that very high diversity of fish community had been achieved by synergy effects with various environments. Though it was not observed definite habitat segregation in the certain area, each species distributed different positions by coral form and vertical distance from coral. In the community of boring benthos and borehole users, processes of recruitment and resource partitioning by boring benthos and borehole users in the intertidal limestone bedrock were investigated. Diversity of borehole users reflected diversity of size of rock-holes bored by multiple species of borers. Results of field experiment revealed that sipunculans colonized into small holes more frequently than smooth rock surfaces, and this would suggest that boreholes are important resources for borers themselves. In relation between fish and zoobenthos, feeding habits and foraging behavior of the three young goatfishes and distribution of their prey animals were studied in seagrass area. Smaller individuals of three goatfishes fed on copepods in water column. *Parupeneus barberinoides* selected shrimps living on the surface of seagrass leaves and sandy bottom with growth, however larger *P. multifasciatus* and *P. barberinus* selected shrimps and crabs on sandy bottom. These results show that three young goatfishes divide microhabitats and their food resources with growth, and coexist in tropical seagrass area.

Key Words Fish community, Borers, Borehole users, Goatfishes, Division of resources

1.Introduction

It is necessary to clarify the structure of biodiversity in biotic community when we conserve biodiversity in coral reef. Then, we conducted surveys for understanding the reason why many species live in the coral reef and considered the interspecies relationship on habitat or food.

This sub-sub-theme consists of the following three themes.

1. Biodiversity on fish community structures
2. Diversity and distribution of borers and borehole users
3. Relation between fish and zoobenthos

These were allotted by the Coastal Biology Section, the Pelagic and Deep Sea Biology Section and the Aquatic Ecology Section of the Ishigaki Tropical Station respectively, and show the result of each theme as follows.

2. Biodiversity on fish community structures in coral reef region

(1) Purpose

It is known that there are extremely many fish species inhabited coral reef region. The current research explained many fish species distributed here from structural complexity of coral reef and existence of many species using coral as food[1]. However, the research by which seasonal change of fish distribution was investigated for a wide sea area in coral reef is very little, and the analysis of biodiversity structures based on these research results is not advanced still enough. Then, we clarify biodiversity of fish community structures according to conduct survey in various stations and seasons in Yaeyama Islands area, and in consideration of relation between species for habitat.

Change in fish species composition for micro-space was analyzed in northwest coast of Ishigaki Island chiefly in 1997 fiscal year. Geographical difference and seasonal changes of fish species composition was analyzed in Yaeyama Islands area in 1998 fiscal year. Biodiversity structures were analyzed synthesizing these results and considering interrelation between species, then we clarify the structure of fish community achieving high biodiversity in 1999 fiscal year.

(2) Research Method

Quadrate method and video method by diving survey was used as a technique to obtain fish species composition. Number of individuals by species was counted directly in quadrate method and counted on record of video. Diving surveys which were conducted by the Coastal Biology Section, Ishigaki Tropical Station included the Preliminary Survey in 1996 fiscal year, the Coral Trout Survey in 1997 fiscal year, the Station Survey and the Seasonal Survey in 1998 fiscal year, and the Station survey and the Seasonal survey in 1999 fiscal year except the Biodiversity Survey in 1997 fiscal year. We used those results for analyzing biodiversity, because those surveys were designed for having mutually compatible. That is, survey results were totaled according to area division, and calculated diversity indices and similarity indices of species composition between areas. The area division was chiefly done by geographical features and depth zone. We divided into moat, lagoon, inner bay and reef slope by geographical features, and, in addition, divided into four areas; sandy bottom belt, seagrass belt, coral belt and reef flat in moat, and divided into 2m zone, 5m zone, 10m zone and 15m zone in the area deeper than 3m. Moreover, when video record was analyzed, kind of substrate, coral form and vertical position of fish from coral were recorded.

(3) Result and discussion

Number of species occurred by survey and fiscal year were about 130 species by quadrate survey and range of 100-300 species by video survey. Small sized species inhabited among coral branch could be found by quadrate survey, and number of species occurred per survey area was more than by video survey. When all surveys were brought together, and overlapping possibility species group was excluded, number of species became 416 belong to 56 families. Number of species by family was the most abundant in Pomacentridae and Labridae, and there were not so difference in the species compositions by family among kinds of surveys and among fiscal years (Fig. 1). In relative density of fish by family, total density was the highest in the Seasonal Survey in 1999 fiscal year, which had high density in Clupeidae and Siganidae, however Pomacentridae was the most abundant in another surveys and fiscal years (Fig. 2). In the Station Survey in 1999, the total density was higher in shallower zone and the highest in reef slope. Dominant species were *Chromis viridis* in lagoon, *Chromis viridis* and larval fishes in inner bay and Clupeidae and *Pomacentrus lepidogenys* in reef slope.

To understand characteristics of fish species composition in each station, using results of the Station Survey in 1998, stations were divided into groups from similarity of fish species compositions. There is the tendency that the same group was distributed in each geographical features such as reef slope, lagoon and inner bay. Dominant species in each group were Clupeidae, Pomacentridae and *Pomacentrus lepidogenys* in reef slope, larval fishes, *Parapriacanthus ransonneti* or *Chromis viridis* in lagoon and inner bay. In the group of reef slope, we could divide stations into groups more detail, those groups distributed different depth zones, and some groups distributed in the East China Sea side or other groups in the Pacific Ocean side. Dominant species were *Pomacentrus philippinus* or Clupeidae in shallow area, *Pomacentrus lepidogenys* in deep area, *Pomacentrus lepidogenys* and Caesionidae in the East China Sea side, and Clupeidae and *Chromis xanthura* in the Pacific Ocean side. In the kind of substrate in station, substrate covered with coral and rock area dominant in reef slope, coral pebble in inner bay, and sand in lagoon. In the coral form, encrusting type was dominant in the Pacific Ocean side of reef slope, tabular type was in the East China Sea side of reef slope, and arborescent type was in inner bay and lagoon. Different fish group distributed in depending on geographical features and depth zones like above mentioned, and substrate and coral form were decided by geographical features, therefore we were able to show the distribution of each fish group was corresponded to those environments. In addition, it was smaller difference between the Pacific Ocean side and the East China Sea side and among depth zones in reef slope than difference among geographical features.

We clarified seasonal change of fish species composition using the similarity among station and depth zones of the Seasonal Survey. The same group was extending over seasons, and it could be said that difference by season was small. Difference was larger by depth zone than by season, especially large difference between moat and reef slope. In the characteristics of fish species composition by season, larval fishes abundant in reef slope in summer and autumn, and Clupeidae from sandy bottom belt to coral flat in summer.

We analyzed fish species composition by coral form for understanding fish distribution in microhabitat; there was different composition by coral form although *Chromis viridis* was dominant in moat. It is also Clupeidae, *Pomachromis richardsoni* and *Pomacentrus lepidogenys* were dominant in reef slope, however fish species compositions were different by coral form. In the species composition in vertical layers from coral, *Archamia zosterophora* distributed in the space of coral branch, and *Chromis viridis* became abundant according to part from coral in moat (Fig. 3). *Pomacentrus lepidogenys* or *Pomacentrus moluccensis* were dominant in the space of coral branch, and *Pomachromis richardsoni*, Clupeidae and Caesionidae became abundant according to part from coral in reef slope.

Number of species occurred in station and depth zone in the Station Survey in 1998 were mainly 30-40 species, however there were station and depth zone occurred 60-70 species in lagoon. When relations between area (corresponded at recording time by video) and number of species were examined, increasing rate became gradual when becoming 150 species level though number of species increased rapidly as time increasing at the beginning. When number of species according to geographical features were compared in considering this survey area, number of species was the most in reef slope, and was few in order of inner bay, lagoon and moat. According to substrate, number of species was the most in rock, continued in stone and in coral pebble, and the fewest in sand. According to coral form, number of species was the most in massive type, and continued tabular type, encrusting type and arborescent type. When relations between number of species and complexity of three-dimensional structures were examined from coral form, number of species was more abundant in simple massive type than in complex arborescent type. It was corresponding to arborescent type distributed mainly in moat where wave was week. Then, it was thought that number of species was defined strongly by geographical features than coral form. When number of species summed up together the divided environments, degree of increasing was small when year or season together. Increasing rate had risen more in the Seasonal Survey than in the Station Survey when depth zones was brought together. As for this, the reason is corresponded that diversity of environment is higher in the Seasonal Survey conducted from shoreline to reef slope than the Station Survey. In addition, we calculated several diversity indices using data of the Station Survey in 1998. When relation between these indices and number of species compared, H' and Simpson's indices were positive correlation between number of species, but J' index was almost constant in 0.5-0.6 against number of species. This showed that there were various species existence with a few number of individuals, but there was no dominant species occupied almost all in the community regardless of number of species. Average number of species in each station and depth zone was 30.3 species, average H' was 1.87, J' was 0.57 and Simpson's index was 4.82.

Moreover, data of the Seasonal Survey in 1998 fiscal year was included, and we calculated average H' in each environment. In season, spring was the highest in 2.21, and summer was the lowest in 1.74. In geographical features, reef slope was the highest in 2.02, and inner bay was the lowest in 1.75. In depth zone, the index was increased from shoreline to offshore, and reached the maximum in 1.98 in 5m depth zone, then decrease increasing depth. Therefore, H' index was corresponded with number of species.

We compared number of species occurred here with another areas. In the eastern Bering Sea, number of species in catch by Japanese trawler was 52 species[2]. In Suruga Bay, number of species in catch by small bottom trawler was 183 species[3]. In Yaeyama Islands area, we found 416 species, and number of species was far more abundant compared with the Bering Sea and Mainland coast. H' and J' indices of demersal fish community were 0.13 and 0.032 respectively in the eastern Bering Sea[2]. It was shown that diversity of fish community in the Subtropical Yaeyama Islands area was very high compared with in the Subarctic Zone and the Temperate Zone.

As mentioned above, the fish community in coral reef of Yaeyama Island area, had different species composition in each environment, and there was many species and had high species diversity in each environment. It could be said that diversity of environment was very high in the entire coral reef region. That is, geographical features, depth zone, substrate, coral form and so on were combined each other, then environment in station of survey were very differ. Thus, it could be said that very high diversity would have been achieved by synergy effects with both environment and fish community in coral reef region. Then, it could be judged that diversity of environment is very high by existence of coral reef.

Finally, to examine the reason why diversity of fish community is high in each environment, fish species were made groups from similarity of distributional pattern of fish. Group such as *Chromis viridis* and *Pomacentrus moluccensis* was species chiefly distributed in inner bay, and group such as *Pomacentrus lepidogenys* and *Pomacentrus philippinus* was species chiefly distributed in reef slope. Thus, it could be said that even species in same family had same distributional pattern, especially Pomacentridae. It is said that habitat segregation was seen in the Temperate Zone and the Frigid Zone, however habitat segregation was not so definite in the subtropical coral reef region. Especially, in the school, different species had the same food habit made the same school and moved together around coral reef area. For instance, we could observe often in Scaridae, Mullidae and Caesionidae. Therefore, in the certain station and depth zone, it is not seen definite habitat segregation between species in the same family, however, in the viewpoint of microhabitat, each species distributed different area by coral form and vertical distance from coral. That is, it seemed that fishes were effectively using the environments of coral reef. It is more advantageous in coral reef region that fishes take prey and avoid predator jointly than compete for food and retreat. Complex environments are formed with coral reef, and this seems fishes are able to segregate microhabitat.

3. Diversity and distribution of borers and borehole users at intertidal limestone bedrock in

Ishigaki Island, southern Japan

(1) Purpose

Coral reef environment is associated with limestone bedrock originated from dead corals. Limestone is subject to be drilled by boring animals e. g. bivalves and sipunculans, and the boreholes would remain even after the borers die and provide refuges for other hole users which do not have an ability of drilling but utilize vacant holes e. g. crabs and sea anemones etc. Occurrence of diverse infauna in limestone bedrock could be realized by the process of interactions between the borers and hole users. Such a mechanism termed as "Nestling chain" by Nishihira (1996)[4] should be a key process to understand biodiversity in coral reef environment. However, description of infauna in limestone bedrocks and field research including experimental approaches to examine the interspecific relationships between borers and hole-users has been quite insufficient.

Interspecific relationships between borers and borehole users are important aspects to understand mechanisms which would support diverse infauna of benthic organisms dwelling in limestone bedrock in coral reef environment. This research attempts to evaluate the resource partitioning and resource transferring processes between borers and borehole users.

(2) Research Method

Species composition and density was recorded by sampling borers and borehole users from intertidal limestones and sandstones at several reef flats in Ishigaki Island. To know the difference in size and shape of boreholes of sipunculans and the bivalve *Claudiconcha monstrosa*, the animals were collected by breaking the substrate carefully using a chisel, and diameter and depth of the holes were measured using the calipers. In the field experiment, different size of holes, 2.5, 4.5 and 8.5mm in diameter, were bored using a potable drill. After 3 months, borehole users colonized into the artificial holes were collected and compared species composition across the different size of holes. Additionally, limestone blocks were embedded in intertidal bedrock to examine initial processes of recruitment by sipunculans. Four blocks were set at field in October 1998 and collected after one year. To know potential effects of the occurrence of holes on the rate of recruitment of borers, half area of the top surface of each block was drilled with 18 holes of 2mm in diameter. Thus each block has a surface shared with the drilled area and the intact area. The collected blocks were smashed carefully and animals inhabiting inside were picked up.

(3) Results

As major borers in intertidal limestone bedrock in Ishigaki Island, 4 species of Sipunculans (*Aspidosiphon* spp.) and a bivalve *Claudiconcha monstrosa* were recorded. Diverse fauna as borehole users were recorded which are represented by 1 species of sea anemone (*Anthopleura dixoniana*), 14 species of molluscs, and 13 species of brachyuran crabs. Holes bored by sipunculans were much smaller than *Claudiconcha monstrosa* in diameter (Fig. 4) but the depth of holes were not different. Size preferences of hole users were clearly shown by the experiment drilling various sizes of artificial holes (Fig. 5). Ocypodid crabs *Ilyoplax integra* and *Macrophthalmus boteltobagoe* utilized smaller holes more frequently, but in the largest holes were most dominantly occupied by the sea anemone *Anthopleura dixoniana*. The sipunlulid *Aspidosiphon steenstrupii* colonized into the limestone blocks at the density of 4 individuals on average at the intact area, whereas 8.5 individuals recruited into the drilled area. *Claudiconcha monstrosa* also colonized into the drilled areas at the rate of 4 individuals per year.

(4) Discussion

As major borers at intertidal limestone substrate, the sipunculans *Aspidosiphon* spp. and the bivalve *Claudiconcha monstrosa* were detected. Both of them occurred at the same intertidal zone but the sizes of their boreholes were different. Size preferences to boreholes by hole users were also clearly exhibited by the experiment providing various sizes of artificial holes. Thus, it is interpreted that resource partitioning among hole users are promoted by existence of various size of holes. Occurrence of multiple species of borers results in producing various sizes of holes. It is concluded that diversity of boring animals is connected with the diversity of hole users via processes of creating various sizes of holes (Fig. 6).

4. Relation between fish and zoobenthos in tropical seagrass area

(1) Purpose

Seagrasses and associated organisms represent important communities in shallow tropical coastal environment. Tropical seagrass beds are often cited as important nursery grounds for many coral reef fishes. However, relationships between feeding habits and food in juvenile and young coral reef fishes in seagrass beds remain largely unknown.

Feeding habits and foraging behavior of the three young goatfishes, *Parupeneus barberinoides, P. multifasciatus* and *P. barberinus*, and distribution of their prey animals were studied in tropical seagrass area. This paper reports the intra- and interspecific relationships related to the utilization of food resources among three young goatfishes in tropical seagrass area.

(2) Research Method

Underwater observations of foraging behaviors and collections of specimens were made on the shallow seagrass area at the north side of Ishigaki Island, Ryukyu Islands, Japan (24°28'N, 124°13'E), between May and August in 1998. Two hundreds and seventeen individuals collected by wall nets were measured total lengths and identified their guts contents in the laboratory. In addition, prey animals living their feeding sites were collected, and later sorted and identified. Intra- and interspecific relationships among size classes and species about the utilization of feeding sites and prey animals was analyzed with multidimensional scaling.

(3) Results

Four foraging groups were made depend on the feeding sites; two size classes (30-39 mm TL and 40-49 mm TL) of *P. barberinoides* and the 50-59 mm TL size class of *P. multifasciatus* fed in the water column, two size classes (50-59 mm TL and 60-69 mm TL) of *P. barberinoides* fed on the surface of seagrass leaves and the sandy bottom, the 60-69 mm TL size class of *P. multifasciatus* and the 40-49 mm TL of *P. barberinus* fed both in the water column and on the sandy bottom, and the 70-79 mm TL size class of *P. multifasciatus* and two size classes (50-59 mm TL and 60-69 mm TL) of *P. barberinus* fed on the sandy bottom (Fig. 7).

Two size classes (30-39 mm TL and 40-49 mm TL) of *P. barberinoides*, the 50-59 mm TL size class of *P. multifasciatus* and the 40-49 mm TL size class of *P. barberinus* fed on copepods, which made swarms in the water column (Fig. 8). The 60-69 mm TL size class of *P. barberinoides* and the 60-69 mm TL size class of *P. multifasciatus* fed on shrimps, which might live both the surface of seagrass leaves and the sandy bottom. The 70-79 mm TL size class of *P. multifasciatus* mainly fed on crabs, however the same size class of *P. barberinoides* mainly fed on shrimps. Feeding habits of two size classes (30-39 mm TL and 40-49 mm TL) of *P. barberinoides* and the 40-49 mm TL size class of *P. barberinus* were similar (Fig. 9). However, similarities of feeding habits among three species decreased with growth.

(4) Discussion

Smaller individuals of three goatfishes fed on copepods in water column. *P. arberinoides* selected shrimps living on the surface of seagrass leaves and sandy bottom with growth, however larger *P. multifasciatus* and *P. barberinus* selected shrimps and crabs on sandy bottom. These results show that three young goatfishes divide microhabitats and their food resources with growth, and coexist in tropical seagrass area.

5. References

1) M. Sano, 1995. Sango syo gyorui-no tasyu kyouzon-ni kakawaru zousyou sango-no yakuwari. pp.81-118. Sango syo, seibutu-ga tsukutta ‹seibutu-no rakuen›, Heibonsha, Tokyo.
2) K. Mito, 1977. Food relationships in the demersal fish community in the Bering Sea. I. Community structure and distributional patterns of fish species. Res. Inst. N. Pac. Fish., Hokkaido Univ., Spe. Vol., 205-258.
3) S. Kobayashi, S. Tanaka and M. Kosaka, 1999. Fishes and aspect of their occurrence in catches by trawl net in Suruga Bay. Journal of the School of Marine Science and Technology, Tokai University. No. 47, 107-123.
4) M. Nishihira, 1996. Ashiba-no Seitaigaku. Heibonsha, Tokyo, 270p.

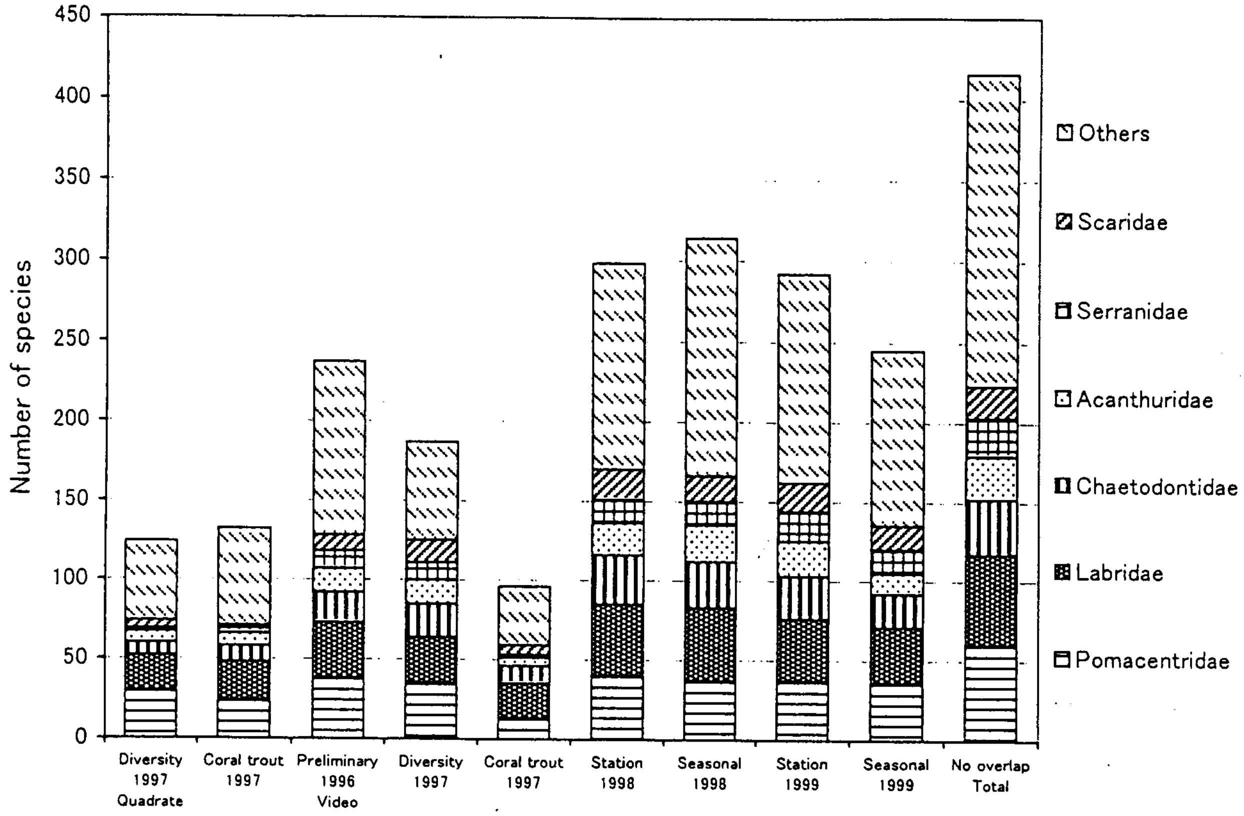

Fig. 1. Number of species occurred by family in the surveys by method, fiscal year and kind of survey.

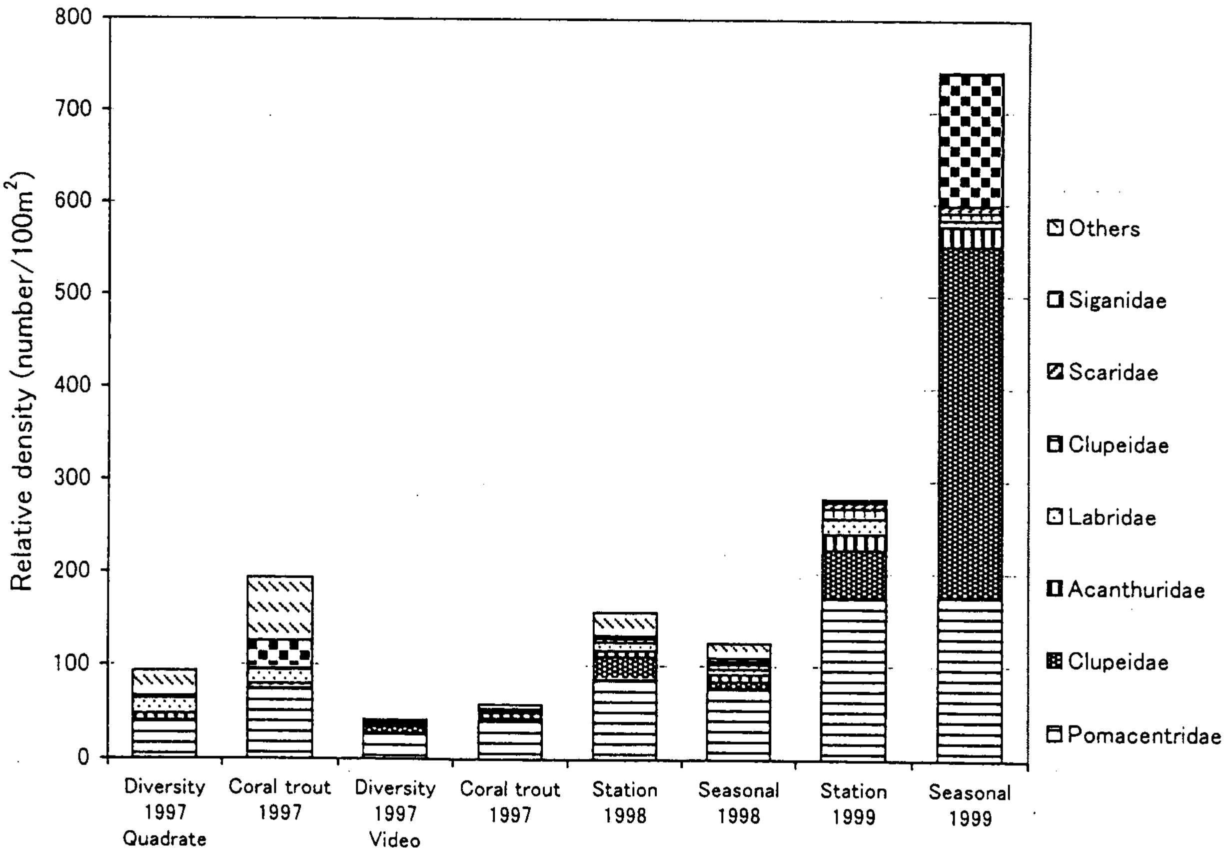

Fig. 2. Relative density by family in the surveys by method, fiscal year and kind of survey.

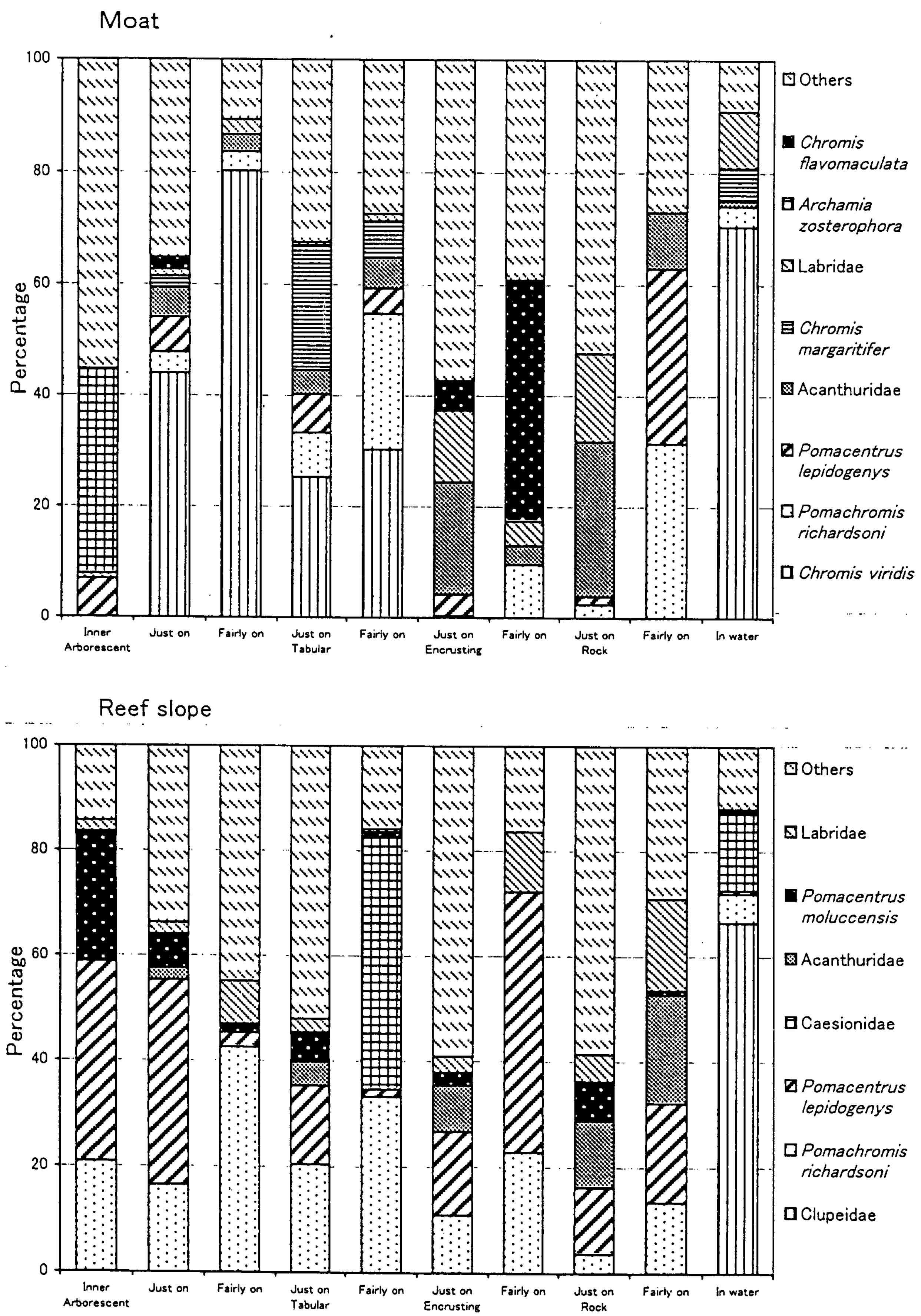

Fig. 3. Percentage in individuals by main species on vertical lyre from coral in Preliminary survey in 1996.

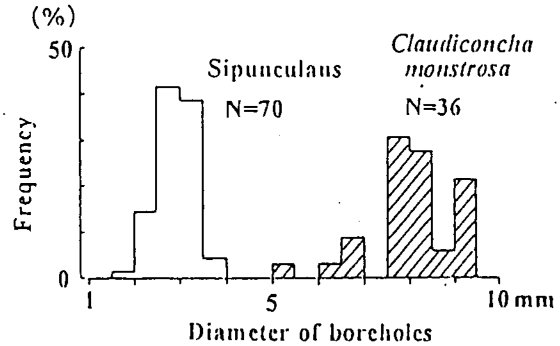

Fig. 4. Size frequency distributions of borehole-diameter bored by sipunculans (*Aspidosiphon* spp.) and the bivalve *Claudiconcha monstrosa* (hatched bars) at Ohama, Ishigaki Island.

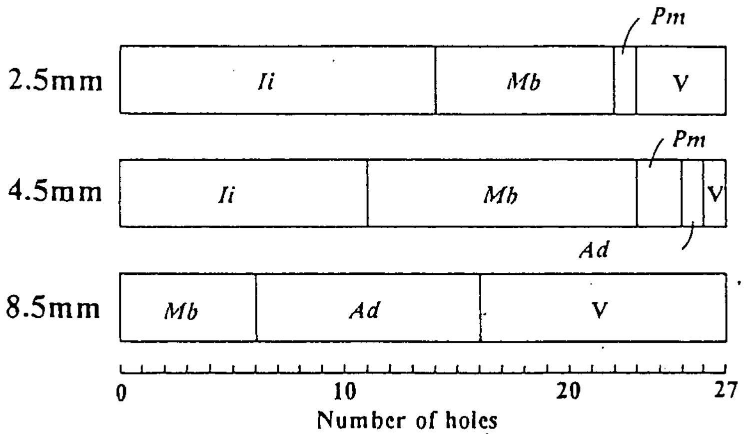

Fig. 5. Species compsition of borehole users colonized into artificial holes. Abbreviations; *Ii, Ilyoplax integra*; *Mb, Macrophthalmus boteltobagoe*; *Pm, Pachygrapsus minutus*; *Ad, Anthopleura dixoniana*; v, vacant.

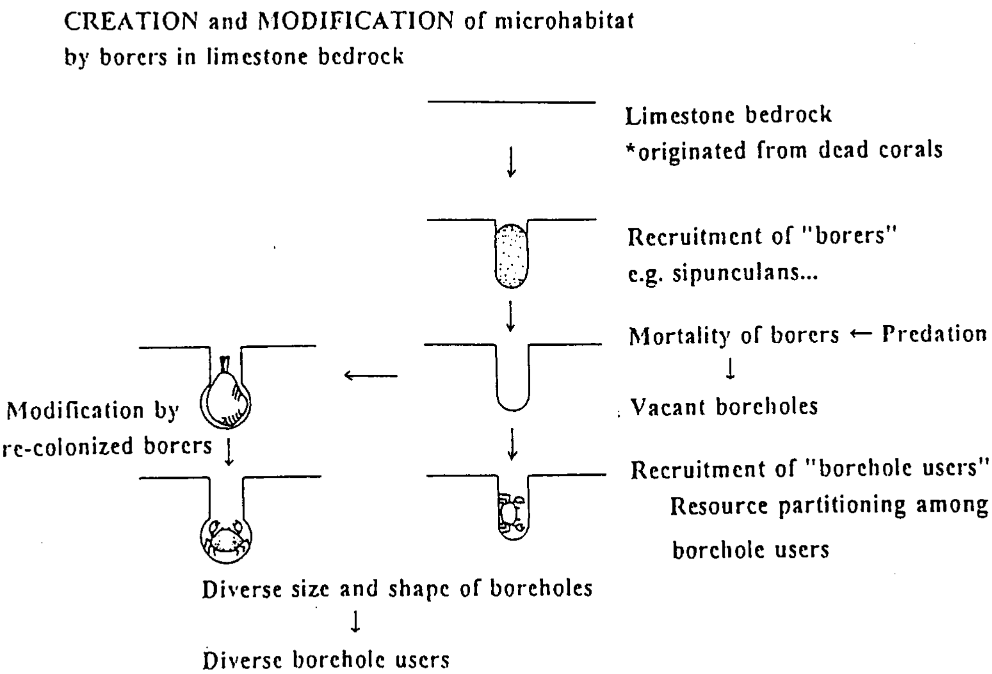

Fig. 6. Shematic model of the processes of creation and modification of microhabitat by borers, and sharing among hole-users in intertidal limestone bedrock.

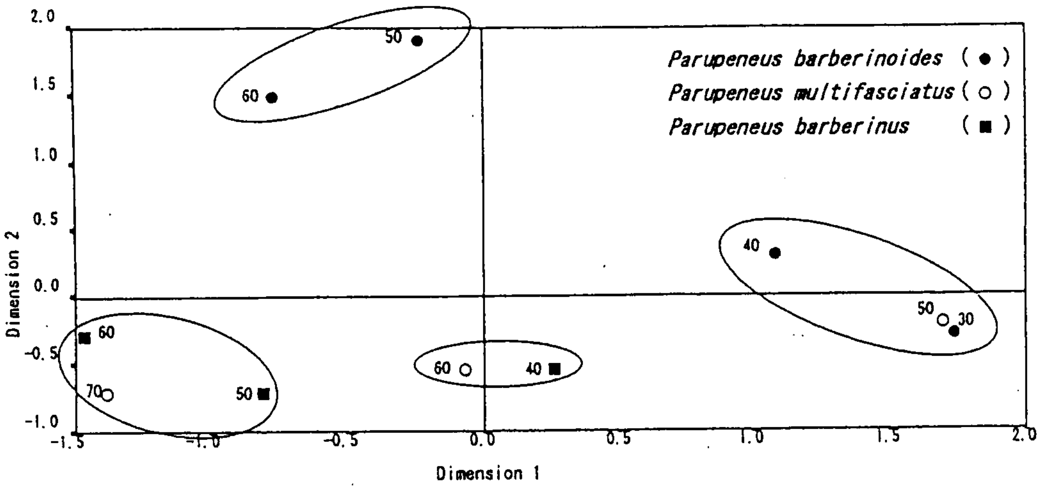

Fig.7. MDS ordination of feeding site for different size classes (mmTL) of *Parupeneus barberinoides, P. multifasciatus* and *P. barberinus* in seagrass bed.

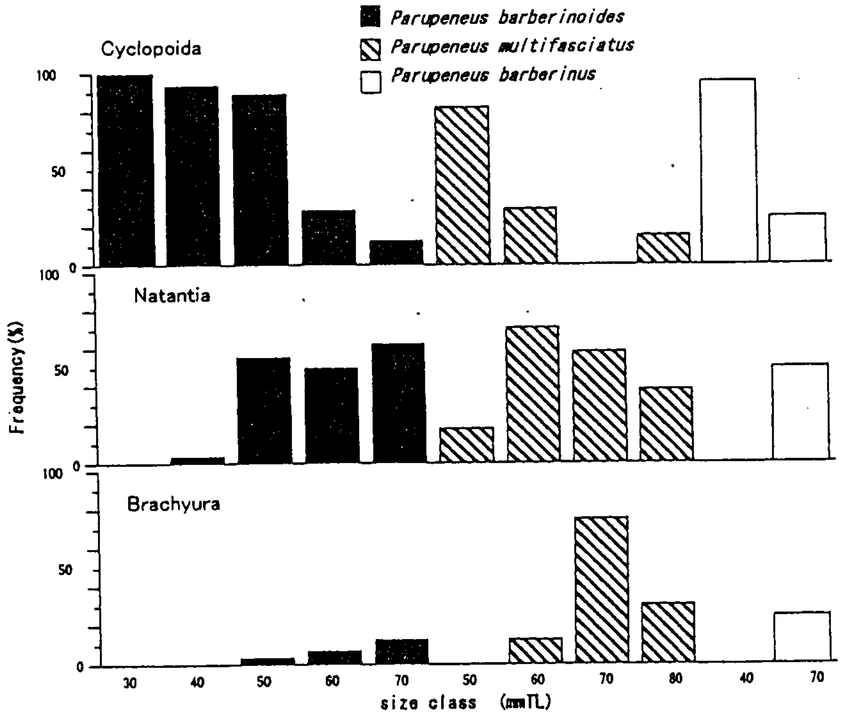

Fig.8. Frequency percentage of occurrence of main prey in different size classes.

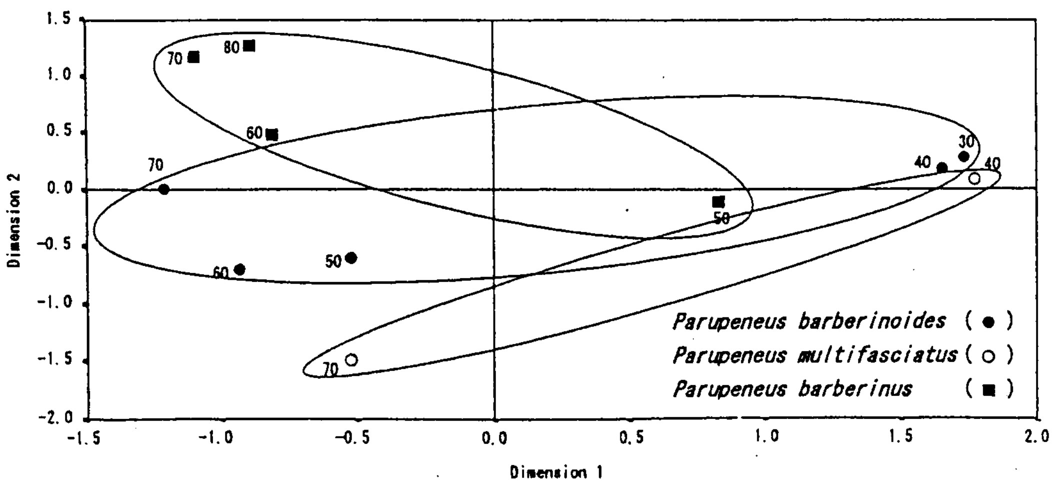

Fig.9. MDS ordination of diets for different size class (mmTL) of *Parupeneus barberinoides, P. multifasciatus and P. barberinus.*