A PROTOTYPE STUDY FOR EVALUATING ALGAL BEDS

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ABSTRACT

Algal beds are a key component of coastal ecosystems. In terms of inshore fisheries, algal beds are important as: spawning grounds for fishes; habitats for fry; and sources of small prey animals for fishes. To maintain robust fish catches, it is considered worthwhile to maintain the functions of algal beds, and even to promote the growth of more algal beds. If the value of each of the many types of algal beds can be measured using economic metrics, by using fish for example, the design of a fishery area can be planned effectively. The structure and function of algal beds however, are very complex: we lack reliable scientific knowledge about their functions and guidelines for the artificial development of algal beds. We commenced a study to evaluate the economic value of the algal beds at Oshoro Bay, Hokkaido from 2001. We described the morphological complexity of algae and species compositions of phytal animals that inhabit algae. The methods employed here, and the potential application of the data obtained from this study to the economic evaluation of algal beds, is discussed.

Keywords: Algal bed; Interstitial size; Phytal animals; Animal size

INTRODUCTION

In recent studies to evaluate the economic value of algal beds, several have focused on assessing: algal biomass, prey species abundance, or species richness. However, these values were all based on estimates using seafloor area as the unit. Therefore, evaluations of algal beds using these values lack the concept of a three-dimensional structure; and ignore various ecological functions that support algal beds. These problems were caused by the functional complexity of algal beds and only a limited ecological knowledge available to make that complexity clear.

In order to improve our knowledge for evaluating algal beds, we started a prototype study in 2001. This study focused on algal beds as sources of prey and on the interstitial spaces between algae as habitat for prey. The objectives of the first step in our study were to:

1. Characterize the morphological structure of various algae constituting the algal bed.
2. Reveal the relationships between the morphological structure of algae and the small animal fauna using the algae as habitat.

The overall goal of our study is to complete an economic evaluation of algal beds as a source of prey for fish, using a value for accumulated spatial characteristics of the algal component, which will be related to characteristics of the phytal animal fauna that are prey for fish.

In this paper, we demonstrate a new method to classify the structural characteristics of algae, and present the first results that analyze the relationship between these characteristics.

MATERIALS AND METHODS

Study site and sampling method

The samples for the analysis were collected during July 2001, July 2002, and May and June 2003, from Oshoro Bay, Hokkaido, in the northern area of the Japan Sea (Figure 1). The sampling site was a flat rocky shore, ranging from a few to ten meters in width and from thirty to sixty centimeters in depth. Arround study site, *Sargassum* species dominated the algal bed.

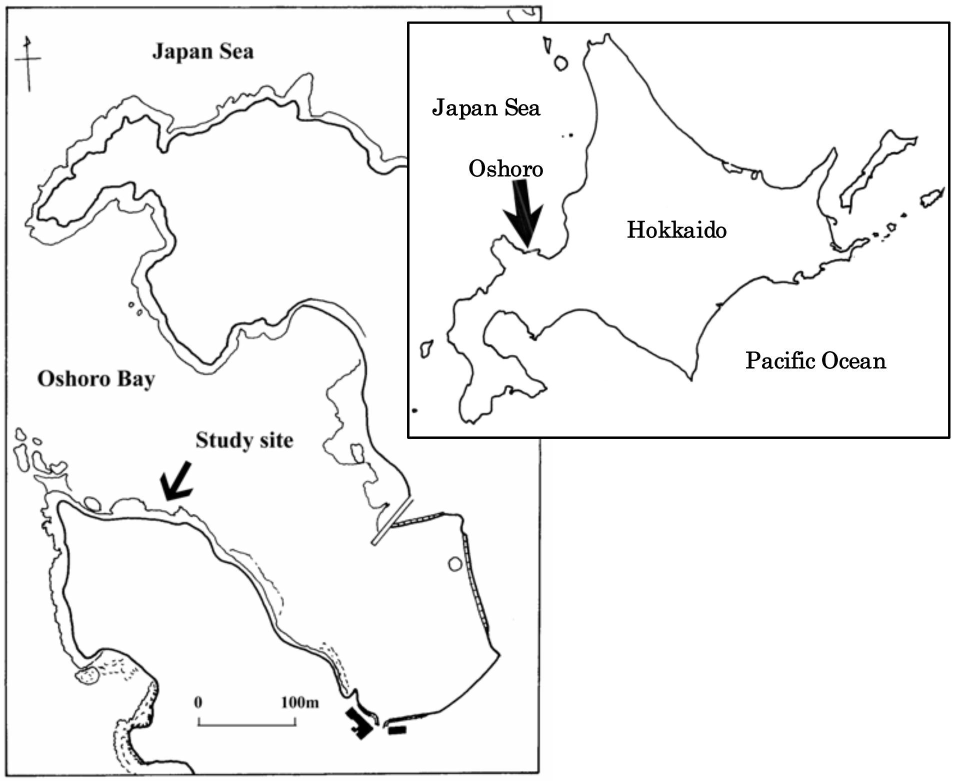

Figure 1. Study site.

Over the three-year study period, six algal species were collected for study (Table I). These species are common and abundant at this site.

The algae samples were collected from the sea floor by scraping slowly and softly; and were then washed by repeated dipping into a bucket containing seawater. In this treatment, phytal animals attached to individual alga were washed off into the seawater. After that, the seawater containing phytal animals was passed through a 0.5 mm mesh. Phytal animals retained on the mesh were collected and sorted by species. Each alga and its phytal animals were fixed in 10% formalin. Further, the fixed animals were divided into four size ranges using 0.5 mm, 1 mm, 2 mm and 4 mm mesh sizes in the laboratory, and each size-class of animal was identified separately.

After weighing each fixed alga, the algal material was analyzed for morphological characteristics using an original method we developed.

Table I: Main algal species selected for analysis.

Chlorophyceae
1. *Ulva pertusa*
Phaeophyceae
2. *Dyctiopteris divaricata*
3. *Sargassum confusum*
4. *Sargassum thunbergii*
Rhodophyceae
5. *Neodilsea yendoana*
6. *Symphyocladia latiuscula*

Method to analyze the morphological structure of algae

In order to analyze the morphological characteristics of each algal species, we developed an original method based on the size of interstitial spaces in three-dimensional algal structures. This method has made possible the analysis of interstitial space of various sizes, which occur at the junctions of single boughs and lamina and also at where many boughs overlap laminable layers. The interstitial size ratio was obtained the following steps.

1. Slowly pour agar-agar, dissolved with warm milk, around the alga in a vat, in order to fix the alga in agar-agar in its natural morphological condition (Figure 3a).
2. Slice the solidified alga (Figure 3b), to expose cross-sections (Figure 3c).
3. Take a data image of the algal cross-section using a computer equipped with a scanner (Figure 4a).
4. Open an image of the algal cross-section on the screen with image analysis software (Scion Image in this study), and paint over spaces within the algal body using the painting tool.
5. To paint initially, use a pen with a 1 mm top diameter (Figure 4b, green part). Then, paint with a pen of 2 mm top diameter (Figure 4c, pink part). The remaining green space indicates an interstitial space of 0–1 mm.
6. In the same way, paint spaces around algal body parts one by one with a 4 mm, 8 mm, 16 mm and 32 mm pen diameter (Figure 4c).
7. Calculate the ratio of each diameter space as the interstitial size ratio for each algal species.

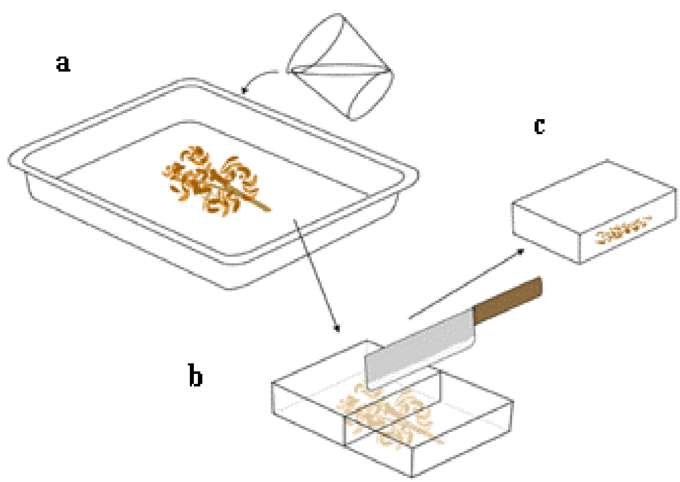

Figure 3. The treatment for immersing algae in agar-agar dissolved in milk.

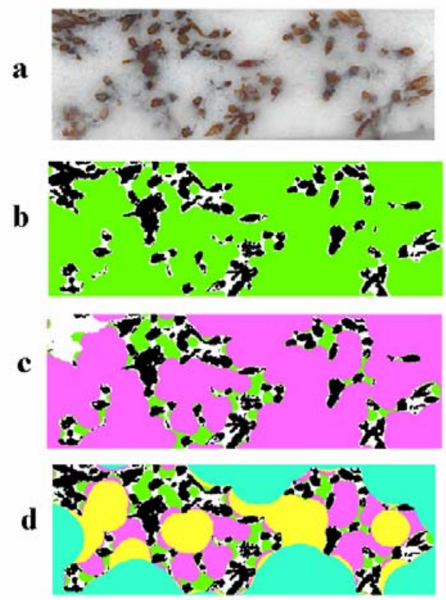

Figure 4. An example of the image analysis used to estimate the interstitial size ratio in algae. (*Sargassum confusum*)

RESULTS

Algae classified by interstitial size ratio

An image analysis was completed for the five species of algae, excluding *Ulva pertusa*. The interstitial size ratio for each alga provides a profile of the spatial complexity of each algal species. The interstitial ratio is given in Table II, and the accumulation curves for each interstitial size class is shown Figure 5.

Table II: The interstitial size ratio (%) of each algal species.

Algal species	Interstitial size ranges (mm)					
	0–1	1–2	2–4	4–8	8–16	16–32
Dyctiopteris divaricata	0.8	4.6	18.7	27.4	38.7	9.9
Sargassum confusum	2.7	4.3	27.3	58.7	2.9	4.2
Sargassum thunbergii	9.2	10.1	24.7	33.4	15.0	7.7
Neodilsea yendoana	0.1	0.3	2.5	18.2	41.5	37.5
Symphyocladia latiuscula	5.5	4.7	16.2	22.8	33.6	17.3

These curves signify three types of profile. Type 1, including *Neodilsea yendoana,* is characterized by interstitial spaces smaller than 4 mm which are very few, and ones bigger than 8 mm which are great. Further, this type indicates about 20% as having an accumulation value below 8 mm. We assume that *Ulva pertusa,* not analyzed before writing this paper, belongs to Type 1. Type 2, including *Dyctiopteris divaricata* and *Symphyocladia latiuscula,* is characterized by interstitial spaces smaller than 2 mm and bigger than 16 mm which are very few, and the bulk in the 8–16 mm interstitial size range. This type indicates about 50% as having an accumulation value below 8 mm. Type 3, including *Sargassum confusum* and *Sargassum thunbergii,* peak in the 4–8 mm size range, which indicates that over 80% have an accumulation value below 8 mm. However, the two species classified as Type 3 are different in detail. Fewer than 10% of *Sargassum confusum* have an accumulation value below 2 mm (interstitial), which is the same as Type 2; and it peaks in the 4–8 mm range, which is especially high (the ratio is about 60%).

On the other hand, about 20% of *Sargassum thunbergii* has an accumulation value at below 2 mm (interstitial), and the peak in the 4–8 mm range is not high. Thus, the accumulation curve for *Sargassum thunbergii* has a gentle slope compared to the slope of *Sargassum confusum.*

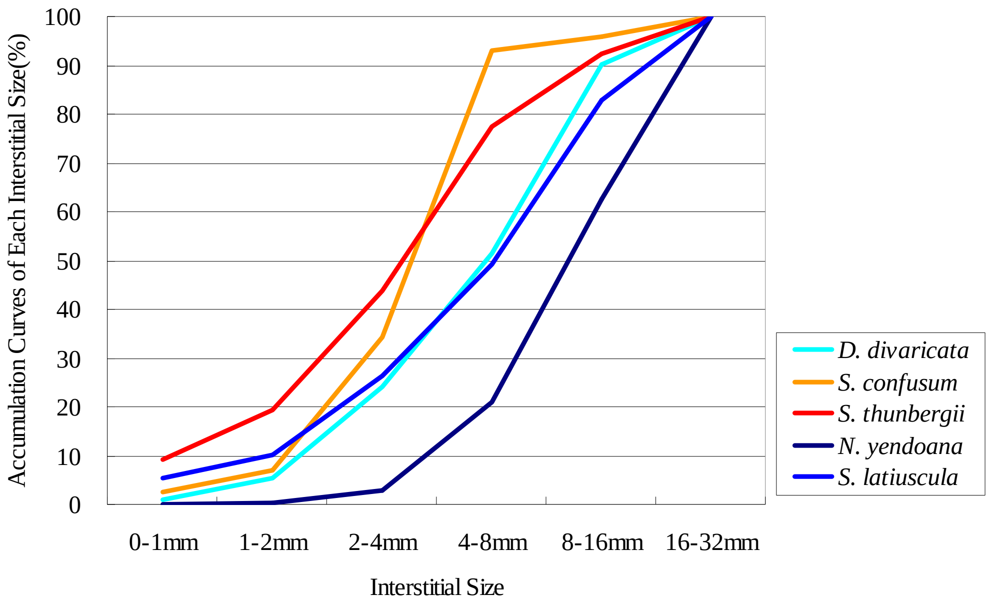

Figure 5. Accumulation curve of each interstitial size ratio.

The characteristics of phytal animal fauna

Comparisons between faunal species numbers attached on each algal species show that species numbers on *Neodilsea yendoana* and *Ulva pertusa* (Type 1 algae) are obviously fewer than on the other species, in every annual sample (Figure 6). The faunal species numbers on the other four algal species show the similar pattern to these annual fluctuations; the species numbers in July –01 is bigger than other years.

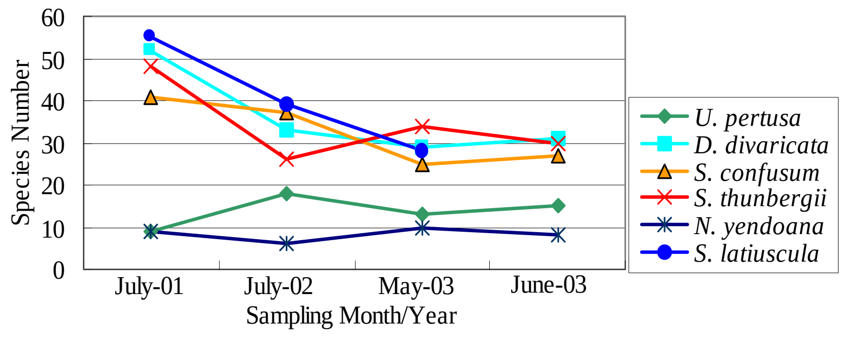

Figure 6. The annual fluctuation in faunal species numbers.

The species numbers in every size range of animals were the highest in the 0.5–1 mm size range, except for *Neodilsea yendoana* and *Ulva pertusa,* collected in May 03. This result indicates that Type 1 algal species, with little interstitial space below 1 mm (under 1%), don't support many faunal species in the 0.5–1 mm size range. Furthermore, the number of faunal species in the 0.5–1 mm size range tends to be high on *Sargassum thunbergii* and *Symphyocladia latiuscula.* These are both algal species that have more much interstitial space below 1 mm (upper 5%).

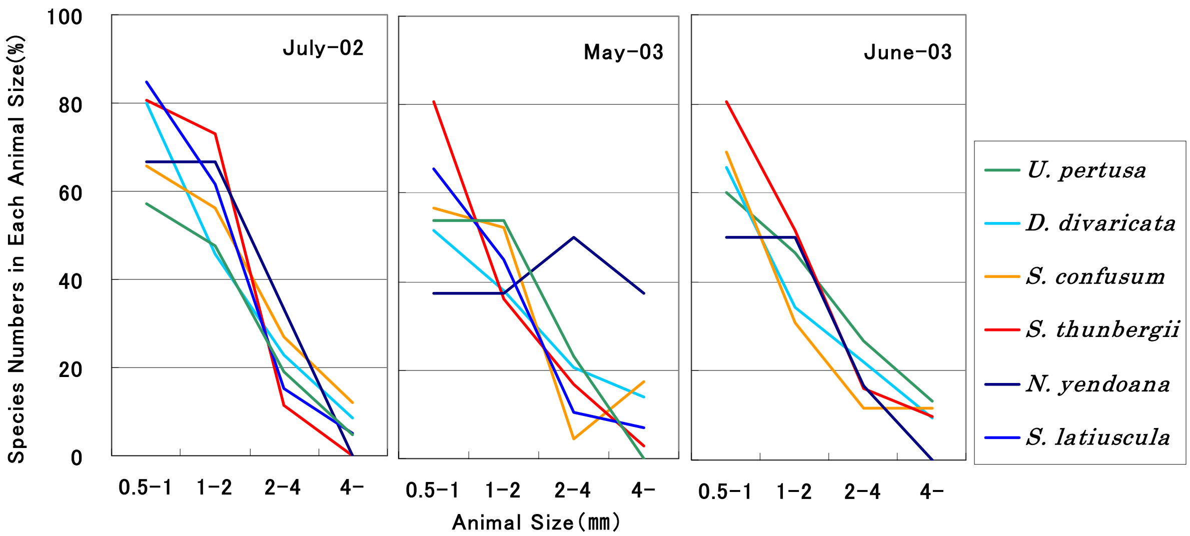

Figure 7. The ratio of faunal species numbers at each faunal size range.

In comparisons between annual numbers of individuals of phytal animals on each algal species, based on an algal weight as the unit, *Symphyocladia latiuscula* had especially high numbers. A trend is apparent that the number of individuals on *Neodilsea yendoana* and *Ulva pertusa* (Type 1 alga) are fewer than on the other species, although a trend is not clear in comparisons between species numbers (Figure 8).

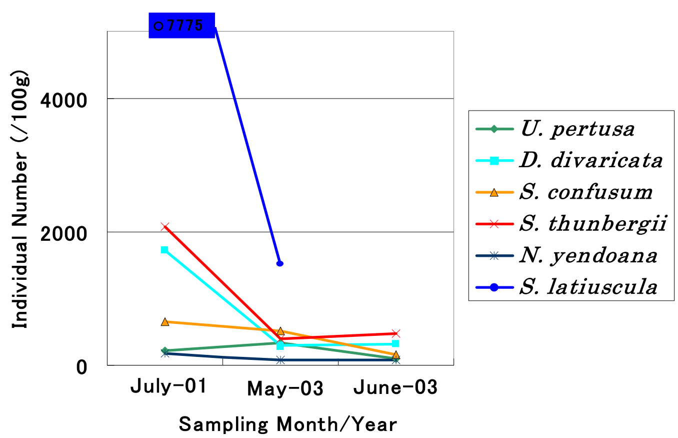

Figure 8. The annual fluctuation in individual numbers on each algal species.

According to the number of individuals in every size range, many individuals on *Symphyocladia latiuscula* and *Sargassum thunbergii* are in the 0.5–1 mm size range (upper 50%). These two algal species have a higher ratio (upper 5%), a 0–1 mm interstitial space, compared to the other algal species. Further, *Ulva pertusa* indicate a similar trend. While, the numbers of individuals on other three algal species indicate under 50% ratios in 0.5-1 mm size range. Individual numbers on annual samples of algal species fluctuate in size distribution, but commonly bulk in size below 2 mm (Figure 9). So, it is possible that some relationships would be found if we compared, in detail, the individual number of animals below 2 mm with the ratio of interstitial spaces below 2 mm, although we did not examine the relationship between individual numbers of each animal size range and the size distribution of algal interstitial space.

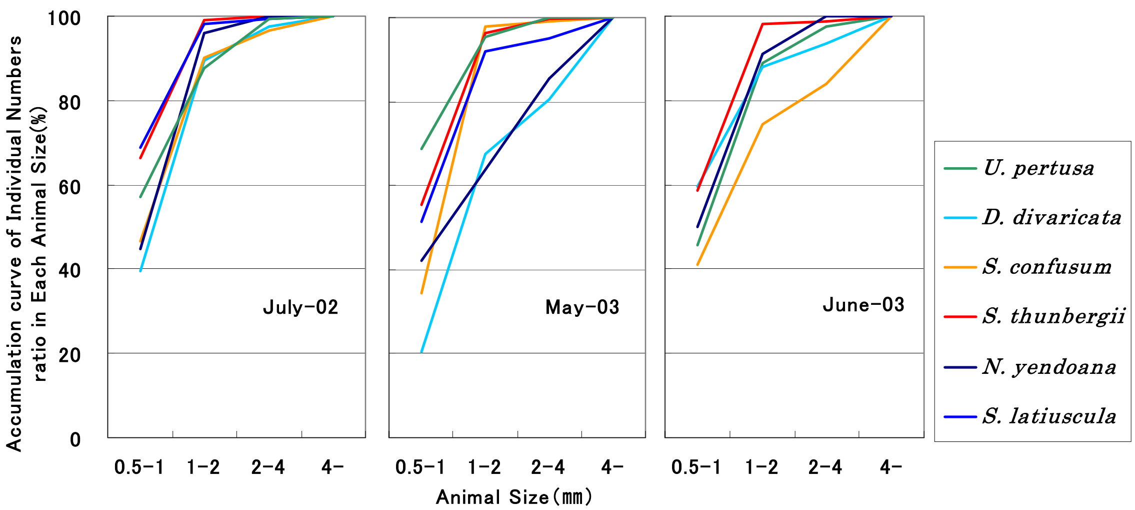

Figure 9. Accumulation curve of individual numbers ratio at each faunal size range.

The correspondence between algal species and their phytal animal fauna

The results of the correlation (Principal Component) based on a correspondence analysis are shown Figure 10 and the percentage contribution of each principal component is given in Table III. In this case, the correlations are based on whether an animal species is present (1) or absent (0) on an algal species.
In the PC1 analysis, *Dyctiopteris divaricata* and *Symphyocladia latiuscula*, (Type 2 algae) are distributed between plus 4 to 6, *Sargassum confusum* and *Sargassum thunbergii* (Type 3 algae) are distributed between plus 2 to 4, while *Neodilsea yendoana* and *Ulva pertusa*, (Type 1 algae) are distributed between minus 8 to minus 10. These results indicate that the phytal animal fauna on the same algal Type, characterized by interstitial size ratio, are similar to each other. However, the phytal animal species with a plus score in PC1 don't have common characteristics. It seems that the animal species diversity contributes to a plus score, because the algal species distributed more on the plus side are shown the high richness and abundance of phytal animal species.
In the PC2 analysis, the Type 2 algae were distributed along the minus score side. Two small animal species less than 1 mm contributed to the minus score, although the animal species contributing to the plus score side did not have any recognized characteristics.
In the PC3 analysis, each Type 2 algal species was separated into opposite scores. This minus score was characterized by sessile animals that were distributed more on hard substrate and seafloor areas. The plus score was characterized by animals that creep along algal lamina and are bigger than 4 mm in size.

Table III: The contribution (%) to each principal component.

Component	Percent	Cum. Percent
PC1	47.27	47.27
PC2	17.56	64.83
PC3	10.85	75.68

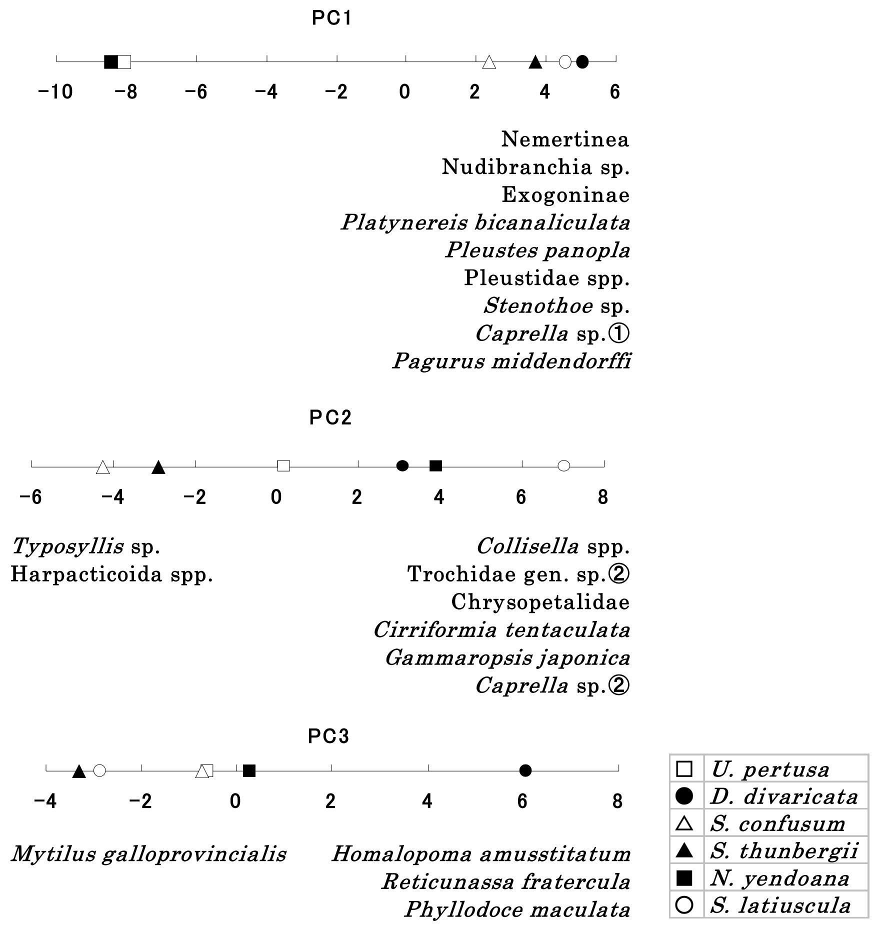

Figure 10. The Results of Correspondence Analysis.

SUMMARY AND DISCUSSION

1. Five algal species collected from Oshoro Bay were classified into three types, depending on the area of interstitial space that forms their three-dimensional structure. Then, using our original method, we could compare algal species with very different morphological characteristics. We could also conduct a spatial analysis on the interstitial space. However, we need many further examples from other algal species, or seasonal morphological changes in one species.
2. There are no relationships between algal type according to their interstitial size ratio and the number of attached phytal species and individual. However, it is clear that only Type 3 alga support low phytal animal species diversity (low density and low species number).
3. Many phytal animal species are abundant in less than 2 mm size. To examine the relationship between the interstitial distribution and individual size distribution, further, we need to conduct detailed studies on the interstitial spaces less than 2mm as same as animal size less than 2mm.
4. From the results of the Correspondence Analysis, the score for PC1 was similar for each algal type, although the contributing animal characteristics are not clear. The scores for PC2 and PC3 indicate that the contributing animals are characterized by size range or ecological characteristics, for example whether they are sessile animal or mobile animals. Thus, it seems that further ecological data are needed to better understand how algal surfaces (or the space of life) act as a substrate for phytal animals.

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