北 大 水 産 彙 報
24 (4), 133–138. 1974.

Phytosociological Study of the Intertidal Marine Algae III. Effect of wave action on algal zonation

Susumu ATOBE* and Yuzuru SAITO*

Abstract

Algal zonations were surveyed along two groups of three transects on exposed, intermediate and sheltered natural rocky slopes at Tachimachi and Anama; both are on the coastline of Hakodate Hill, Hokkaido. As a result, the growing belts for eleven species, of which one is a benthic animal, were higher along the exposed transects than along the sheltered transects. We determined the frequency of submergences caused by wave action at several levels along the transects, and found that the submergences were more frequent along the exposed transects. Although it is not clear whether the length of submerged period or its frequency is important to intertidal organisms, we concluded that the suitable belt for certain algal species is elevated by the strong wave action.

Introduction

Previously, we[2] pointed out that tide factors in combination with wave action are the main regulating factors of algal zonation. This conclusion was based on analysis of algal communities on the gentle natural rocky slope in Usujiri Benten-Jima, Hokkaido. Since then, we have tried to clarify the effect of wave action on algal zonation. In the present study we have related algal zonation to wave action at Tachimachi and Anama, in Hakodate, Hokkaido (Fig. 1). This was done by comparing sites with different wave action but otherwise being similar.

We are grateful to Dr. L.D. Druehl of Simon Fraser University for discussion on this manuscript, and to our colleagues, Messrs. K. Matsuyama, K. Murata and Y. Sanada for their assistance during the field work.

Method

We used two groups of transects on natural rocky slopes which had no prominent projections. Both groups, one at Tachimachi and the other at Anama, consist of three transects in wave exposed, intermediate and sheltered conditions. These transects were remote from freshwater streams, and faced, at least those in one group, approximately the same direction. The slope pitch was nearly the same, between 26° (Transect 2) and 36° (Transect 3) at Tachimachi, and between 20° (Transect 6) and 27° (Transect 5) at Anama (Fig. 2). Because of their close

* *Laboratory of Marine Botany, Faculty of Fisheries, Hokkaido University*
(北海道大学水産学部水産植物学講座)

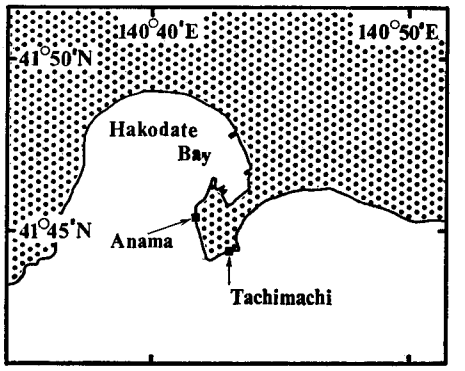

Fig. 1. A map showing location of Tachimachi and Anama.

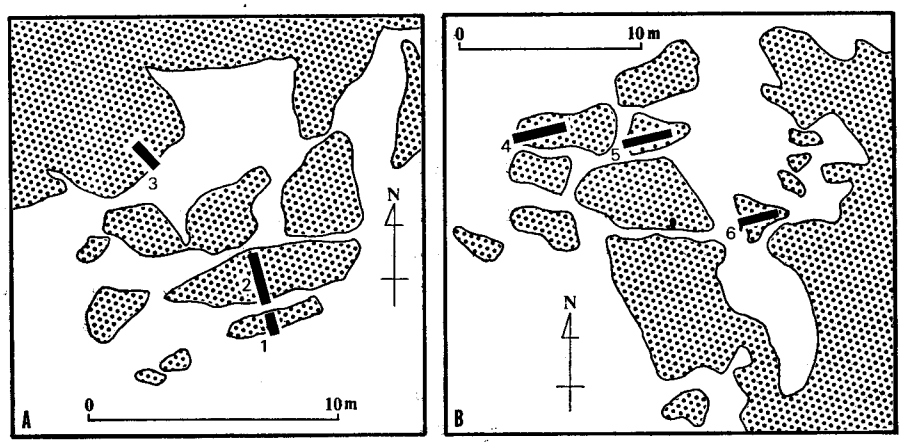

Fig. 2. A map showing topography of Tachimachi site and Transects 1–3 (A), and Anama site and Transects 4–6 (B).

proximity, we believe the only significant physical difference between the three transects at both sites is wave exposure.

To determine vertical position and abundance of algae, we used methods previously described[2] with some modification. A 50×50 cm quadrat divided into twenty-five small areas (10×10 cm) was used for observation. Algal coverages were successively observed throughout the intertidal zone, so that a belt transect with 50 cm width was studied. Ten 10×10 cm areas (in 50×20 cm) were combined as one station, and the mean coverage of the ten small areas was used as the coverage for that station. Although the intertidal algal communities in the Hakodate area usually consist of about thirty species, those species with less than 5% coverage were eliminated.

Observations were carried out on the following dates:

Tachimachi	Transect 1: 22 June 1971
	Transect 2: 29 May 1972
	Transect 3: 22 June 1971
Anama	Transect 4: 15 April 1972
	Transect 5: 15 April 1972
	Transect 6: 14 April 1972

We also determined the relative influence of waves on the six transects by observing the extent of the wave wash above the predicted tide level. Simultaneous observations were made at the Tachimachi site from 16:07 to 16:17, 27 January 1973 when the predicted tide was 32 cm above datum, and at Anama, 15:49 to 15:59, 11 February 1973 when the predicted tide was 23 cm above datum. During both observational periods the sea was moderately calm.

Results

Percent coverage for each species along each transect is shown in Figs. 3 and 4. At Tachimachi site *Corallina pilulifera*, *Analipus japonicus* and *Symphyocladia latiuscula* occur on all three transects. *Corallina pilulifera* appears in all stations along Transect 1 (31–114 cm), and is especially abundant above 62 cm level with a coverage of 45–75%. Its upper limit results from lack of suitable substrata above 114 cm level. The dense belt for this species along the other two transects are vertically depressed; between the 37 and 73 cm levels along Transect 2 (36–75%), and between the –2 and 37 cm level along Transect 3 (42–45%). *Analipus japonicus* is distributed above the 93 cm level along Transect 1, but it is restricted between the 55 and 82 cm levels along Transect 2, and between 24 and 50 cm along Transect 3. *Symphyocladia latiuscula* occurs up to the 73 cm level along Transect 1. This species, however is restricted to below the 46 cm level along Transect 2 and below the 24 cm level along Transect 3. Furthermore, the vertical limits of all the species which appear along two transects only are lower along the sheltered transects, i.e. *Chthamalus challengeri*, *Alaria crassifolia*, *Leathesia difformis*, *Callilarthron yessoense* and *Neodilsea yendoana*.

The three transects at Anama (Fig. 4) were too vertically restricted to clarify the upper extremes of distribution for some species. There are however similarities to those at Tachimachi site. *Corallina pilulifera* occurs at all elevations along Transect 4 (5–79 cm), and its dense belt is located between the 31 and 66 cm levels with coverage of 32–56%. This species forms less than 5% coverage above the 70 cm level along Transect 5, and above the 31 cm level along Transect 6. Dense populations of this species are seen below the 47 cm level through 23 cm along Transect 5 (30–42%), and below the 25 cm level along Transect 6 (39–56%). *Hizikia fusiforme* appears between the 31 and 59 cm levels along both Transects

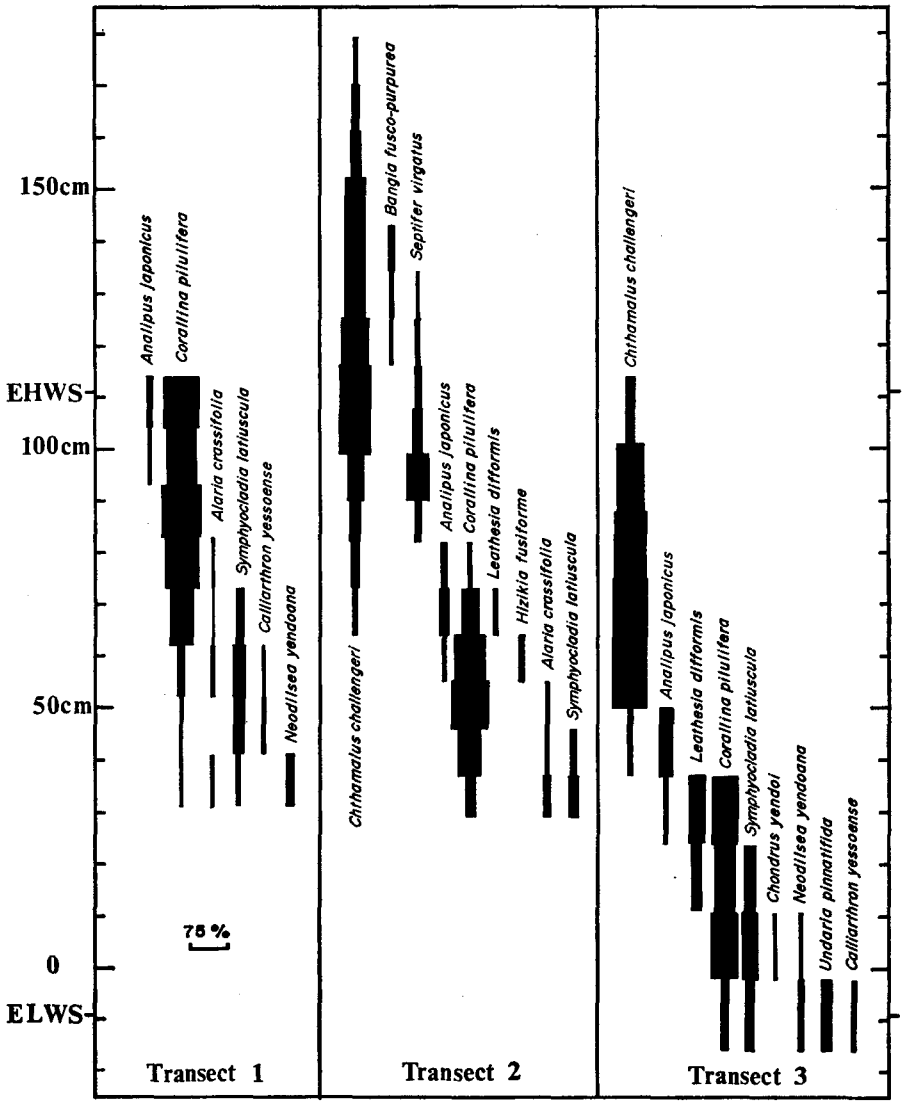

Fig. 3. Vertical distribution of major species of marine algae at Tachimachi shown in percent coverage, as observed on 22–VI–1971 (Transects 1 and 3) and 29–V–1972 (Transect 2).

4 and 5, and its belt along Transect 6 is much lower; below 25 cm level. The upper limits of *Chthamalus challengeri* and *Analipus japonicus* cannot be clarified along Transects 4 and 5, because of the lack of the higher elevations. But both species seem to grow at lower elevations along Transect 6, than they do along Transects 4 and 5. Of the species which occur on two transects only, we cannot

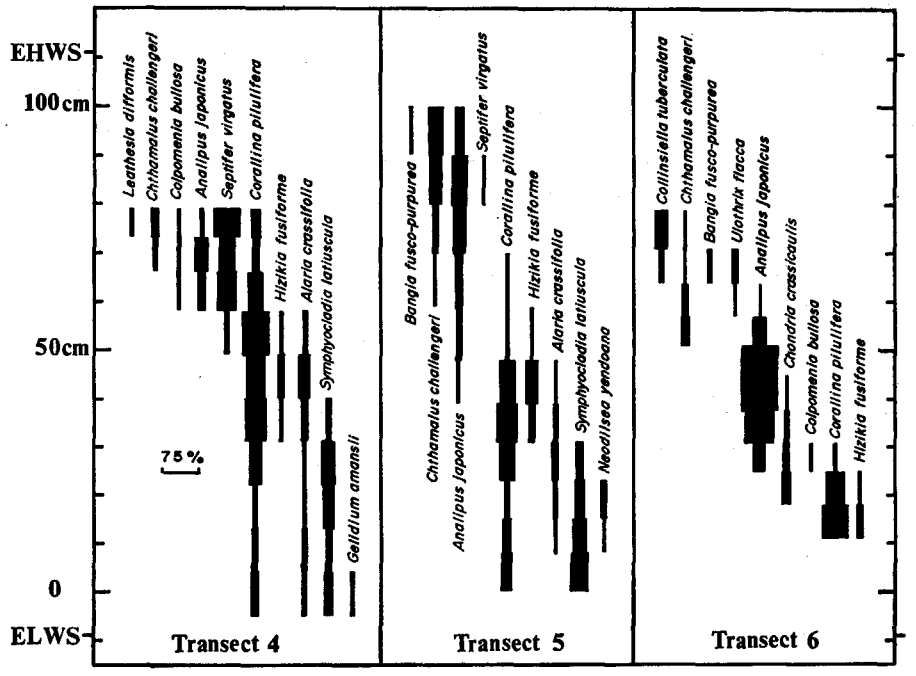

Fig. 4. Vertical distribution of major species of marine algae at Anama shown in percent coverage, as observed on 15–IV–1972 (Transects 4 and 5) and 14–IV–1972 (Transect 6).

Table 1. *Extent of wave wash, as counted during ten minutes periods at different levels along the transects. Tachimachi, 16:07–16:17, 27–I–1973, sea level was about 32 cm above datum. Anama, 15: 49–15: 59, 11–II–1973, sea level was about 23 cm above datum. Sea was moderately calm for the winter season.*

Transect \ Elevation in cm		114	70-80	50
Tachimachi	1	36	n.o.	n.o.
	2	15	66	102
	3	0	6	43
Anama	4		72	116
	5		36	84
	6		0	4

n.o.: No observation

define the upper limit of *Septifer virgatus* because of low elevation of the transect. The growing belts for *Colpomenia bullosa, Alaria crassifolia, Bangia fusco-purpurea* and *Symphyocladia latiuscula* are clearly lower along inner (more sheltered) transects.

The results of our observations of wave wash are shown in Table 1.

Discussion

The effect of wave action on algal zonation has been noticed by several authors. Lawson,[1] for example, attached importance to the wave action on the Gold Coast, Africa, and described algal zonations for four wave exposure conditions: exposed, moderately exposed, moderately sheltered and sheltered. We tried to clarify the relationship between individual species distribution and wave conditions. We found that the growing belts for eleven species including one benthic animal, viz. *Leathesia difformis, Analipus japonicus, Colpomenia bullosa, Alaria crassifolia, Hizikia fusiforme, Bangia fusco-purpurea, Neodilsea yendoana, Corallina pilulifera, Calliarthron yessoense, Symphyocladia latiuscula* and the barnacle *Chthamalus challengeri*, exist at higher elevations along the outer more exposed Transects 1 and 4, and lower elevations along the inner more sheltered Transects 3 and 6. Along Transects 2 and 5 located between the above transects, the growing belts for these species seem to be at intermediate vertical positions. The reason for above described vertical elevation of habitat from the inner to the outer transects must be wave action, since the tide factors along the transects are the same, at least within each group.

Strong wave action moistens plants exposed to the dessication by air and sun. This is accomplished by water wash and spray. We compared the number of submergences occurring during the same period at each site. From these observations which clearly show wave action to be significantly different between the exposed and sheltered transects, we concluded that the suitable growing belt for certain species of marine algae is elevated by the strong wave action.

References

1) Lawson, G.W. (1956). Rocky shore zonation on the Gold Cost. *Jour. Ecol.* **44**, 153–170.

2) Saito, Y. and Atobe, S. (1970). Phytosociological study of the intertidal marine algae, I. Usujiri Benten-Jima, Hokkaido. *Bull. Fac. Fish., Hokkaido Univ.* **21**,37–69.