

SYNECOLOGICAL STUDY ON INTERTIDAL COMMUNITIES IV. AN ECOLOGICAL INVESTIGATION ON THE ZONATION IN MATSUSHIMA BAY CONCERNING THE SO-CALLED COVERING PHENOMENON

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IV. AN ECOLOGICAL INVESTIGATION ON THE ZONATION IN
MATSUSHIMA BAY CONCERNING THE SO-CALLED
COVERING PHENOMENON^{1),2)}

By

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At the outer coast of Matsushima Bay, the dead shells of *Chthamalus challengeri* and *Balanus amphitrite albicostatus* are found often beneath the shells of *Mytilus edulis* or of *Crassostrea gigas* beneath the shells of *M. edulis*, and it was therefore suggested that the vertical extend of zones of *C. challengeri* and *B. a. albicostatus* might be modified by the covering of *C. gigas* or *M. edulis* and the distribution of *C. gigas* by the concealing of *M. edulis* (Hoshiai 1958). On the artificially denuded rock surface at the same locality as mentioned above it was recognized that *C. challengeri* and *B. a. albicostatus* settled at first and then the barnacle zone was partly covered with *C. gigas* whose zone is frequently modified by the concealing of *M. edulis*. It was also observed that occasionally *M. edulis* covered directly the shells of barnacles and instead of the barnacles and the oyster the algal communities arrive prior to the settlement of *M. edulis* (Hoshiai 1960).

In these cases, it is noteworthy that on the said denuded rock surface *M. edulis* re-appears as the dominant species and forms a remarkable zone in a certain layer, covering the early arrivals. On the other hand, the pattern of the zonal arrangement of the sedentary organisms is not uniform throughout the bay and the zonation which lacks the *M. edulis* zone is found rather commonly, so that it may be important to compare the patterns of the zonation in the bay concernig with the afore-mentioned "covering phenomenon".

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OBSERVATIONS OF THE APPARENT ZONATION

As shown in Fig. 1, in Matsushima Bay many islands which are mainly, composed of tuff and with vertical cliffs are arranged making some separated groups. The bay may be divided into three regions by the larger islands situated at the mouth of the bay, the inner region, the channel region and the outer one. The transparency of the sea water is higher in the outer region than in the others but

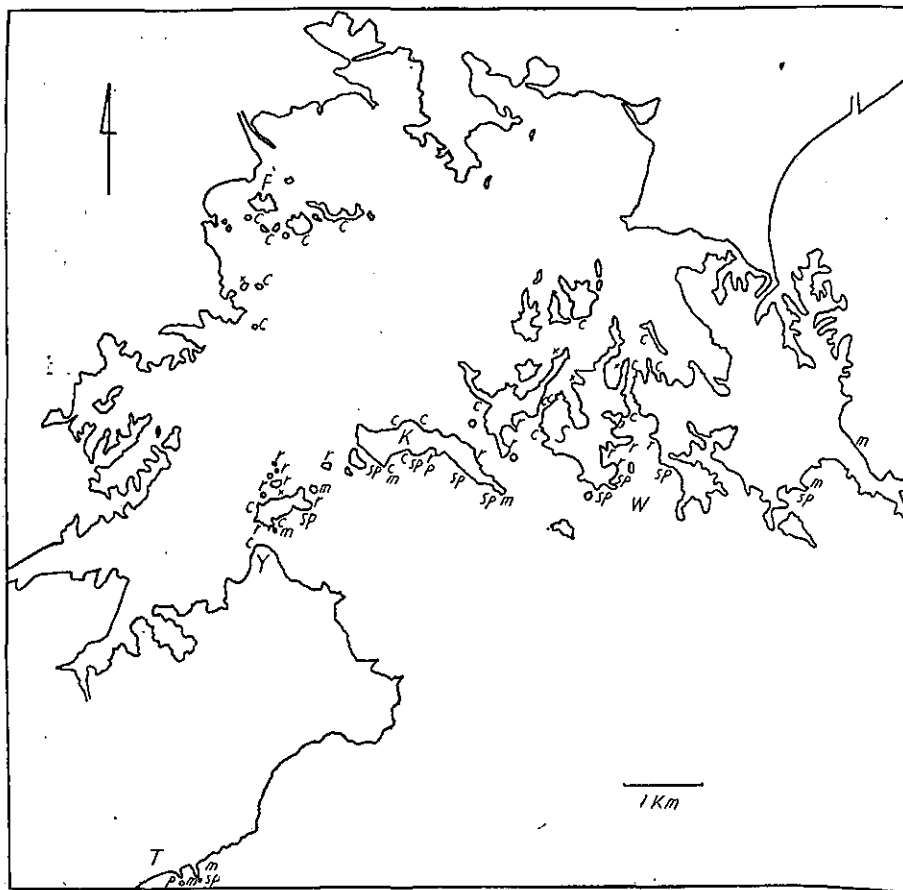


Fig. 1. The distribution map of the zonation in Matsushima Bay. The small letters, b, c, p, r, sp and m show the zonation characterized by the barnacle zone (b), the *C. gigas* (c), the *P. crosslandi* zone (p), the *R. japonica* zone (r), the sponges-algae zone (sp) and the mussel zone (m). The place where no characteristic sedentary organisms are found is shown by x. The capital letters show the name of the locality. F—Fukuurajima, K—Katsurajima, S—Sabusawajima, T—Tobigasaki, Y—Yogasaki, W—Wanigafuchi-channel.

it is not so high throughout the bay. Wave action is stronger in the outer region and becomes weaker through the channels between the said larger islands.

The observations were performed at intervals from 1956 to 1960.

The inner region: The zonation of the sessile organisms is relatively uniform.

1. The *C. gigas* zone is formed on the cliffs which dry up as well as on the rocks which remain wet during the ebb tide in summer, and at the wet part an unidentified yellowish sponge is found among the *C. gigas* shells at the lower part of the *C. gigas* zone. On such a cliff as at the end of a small cape facing the bay-mouth as surfs wash the rock surface in the day when the wind blows from the bay-mouth, either *C. challengeri* or *B. a. albicostatus* or both form an insignificant zone above the *C. gigas* zone.

2. Occasionally about the innermost part of the bay there are cliffs on which no sedentary animal zone is observed (Fig. 1).

The channel region: 1. At the coast of the narrow channels and of the said larger islands facing the inner bay the feature of the zonation is similar to that of the inner region. Many small inlets exist along the above channels. At the head of such inlets noticeable sedentary organisms are not found but at the mouth part the *C. gigas* zone appears.

2. At the middle part of the channels on the cliffs of inlets which do not dry up during the ebb tide in summer *Reniera japonica* appears as remarkable patches, and near the mouth of the inlets *C. challengeri* is distributed above the *R. japonica* zone and *Sargassum thunbergi* is found within the lower part of the *R. japonica* zone.

It is noteworthy that the simple *B. a. albicostatus* zone exists at the head of an inlet at the middle part of Wanigafuchi-channel and at its mouth a narrow *C. challengeri* zone lies above the *B. a. albicostatus* zone.

3. *C. challengeri* increases in number nearer to the outer region and also its zone extends upwards according to the increasing of the surf action. The *C. challengeri* zone and the *R. japonica* zone are found at the mouth of inlets. On the rock of the head of inlets, which dry up during the ebb tide in summer the *C. challengeri* zone or the *C. challengeri*-*B. a. albicostatus* zone and the *C. gigas* zone are arranged in order from above downwards.

4. About the broad channels the zonation which is characterized by the *R. japonica* zone is represented on the vertical cliff which does not dry up during the ebb tide in summer and although the *R. japonica* zone does not always associate with the *C. challengeri* zone, algae are found commonly in the former zone.

At the place where the cliff surface dries up during the ebb tide in summer, *C. challengeri*, *B. a. albicostatus* and *C. gigas* form respective zones, which appear on the vertical wall of the moles of Yogasaki and Sabusawajima, which are built at the location where protected from surging waves and whose surfaces dry up

during the ebb tide in summer.

The outer region: The zonation changes accompanied with minor variation of the environmental factors.

1. At the intertidal part of the cliff which does not dry up during the ebb tide even at the lowest low tide, the following zonations are distinguished.

In such a place as where the surface of the sea water violently vibrates at the cliff surface without the breaking of the swells and occasionally waves strongly splash the rock, *R. japonica* and other sponges appear as the important components of the zonation and within the upper part of the sponge zone *Ulva* sp. is found and at its lower part *Grateroupia* spp. associates commonly.

In the place where the surf washes severely the rock, the extensive *C. challengerii* and the remarkable calcareous algal zones are formed above the zone characterized by the sponges and the algae and the *Hijikia fusiforme* zone lies occasionally between the former two zones.

On the cliffs whose surface is difficult to dry owing to the heavy wave action during the ebb tide in summer the *M. edulis* zone is formed remarkably above which the *C. challengerii* zone is insignificant and at the place somewhat protected from the wave the *R. japonica* zone is found and in a more sheltered place *Pomatoreios crosslandi* forms a zone associated with calcareous algae.

2. At the sunny cliff face of a promontory where the substratum dries up during the ebb tide in summer, *C. challengerii*, *B. a. albicostatus*, *C. gigas*, *Septifer virgatus* and *M. edulis* are the prominent constituents forming a zonation. The *C. challengerii* zone and the *S. virgatus* zone below it are found on the cliff which surfs wash violently only at the flow tide but on the cliff extending from the deep bottom and washed by severe surfs the *C. challengerii* zone and the *S. virgatus*-*M. edulis* zone are arranged from the upper part downwards.

According to the decreasing of the surf action *S. virgatus*, *M. edulis* and *C. challengerii* decrease in number and *B. a. albicostatus* appears and below this barnacle zone *C. gigas* forms a zone accompanying with a small number of *M. edulis*.

OBSERVATIONS OF THE SO-CALLED "COVERING PHENOMENON"

As the pattern of the zonation differs from place to place, at every station of investigation it is necessary to know where the "covering phenomenon" is and to examine whether the "covering" is an ordinary phenomenon. Thus the constituent species are detached carefully from each zone in each region mentioned above. The results obtained from these observations are as follows:

1. At the coast along the inner region *C. gigas* settled directly on the rock surface and at the lower part of its zone *C. gigas* attached themselves to each other forming clusters under which many calcareous tubes of the living serplids but only

a few barnacles were found.

2. On the cliff of the channel region from the middle part toward the outer region beneath *R. japonica* no shells were found excepting *Spirorbis* sp. which arrived at a restricted part.

3. On the vertical wall of the moles of Yogasaki and Sabusawajima, it was observed that the dead shells of *C. challengerii* and *B. a. albicostatus* occurred beneath the *C. gigas* shells. At the upper part of this *C. gigas* zone only a few *C. challengerii* and *B. a. albicostatus* appeared scattering on the shells of *C. gigas*.

4. At the wet part of the rock in the outer region, sponges encrusted the rock face and the rhizomes of the algae with which sponges formed a zone.

5. A remarkable covering phenomenon was observed where *C. challengerii*, *B. a. albicostatus*, *C. gigas*, *S. virgatus* and *M. edulis* appear as the components forming a zonation. Beneath the shells of *S. virgatus* the dead shells of *C. challengerii* and of *C. gigas* were detected. Under the *M. edulis* shells various kinds of organisms were found, namely on the rock which surfs wash violently *C. challengerii*, *C. gigas* and *R. japonica* appeared and on the rock which waves sweep the cliff face producing the surf *H. fusiforme* and calcareous algae were found. Beneath the shells of *C. gigas*, *C. challengerii* and *B. a. albicostatus* were found and at a sheltered place the latter species increased in individual number.

Though a small number of barnacles were found on the shells of *C. gigas*, of *S. virgatus* and of *M. edulis* and the small *C. gigas* shell rarely on the valves of *S. virgatus* and of *M. edulis*, no modification of the zonation by these re-settling animals was recognized.

Relating to the "covering phenomenon" it was confirmed through the inspection of the zonations that the covering is an ordinary phenomenon which occurs in the process of the formation of the zonation where *C. challengerii*, *B. a. albicostatus*, *C. gigas*, *S. virgatus* and *M. edulis* or *C. challengerii*, *B. a. albicostatus* and *C. gigas* appear.

THE DENUDATION OF ATTACHED ORGANISMS AND THE RE-CONSTRUCTION OF THE ZONATION

Concerning the covering phenomenon, artificial denudation was attempted at the selected localities to examine its importance as one of the biotic factors playing a rôle in the zoning processes.

1. At a station of the inner region (Fukuurajima), the *C. gigas* shells were detached completely in May, 1956. No conspicuous sedentary organisms appeared till *C. gigas* settled as patches on the bare rock in the summer of 1958.

2. At the middle part of the channel region colonies of *R. japonica* were removed in May, 1956. *Watersipora cuculata* appeared successively and *R. japonica* invaded the experimental section from the adjacent parts in 1957, and this feature

of the zonation did not change till April, 1960.

3. At the part of the outer region, where the zonation was characterized by sponges and algae, after artificial denudation done in May, 1956 the rock surface was covered densely with algae within the same year, and sponges had appeared by May, 1958 and this zonation was maintained till April, 1960.

4. In May, 1956, after destroying the *M. edulis* zone which was formed on

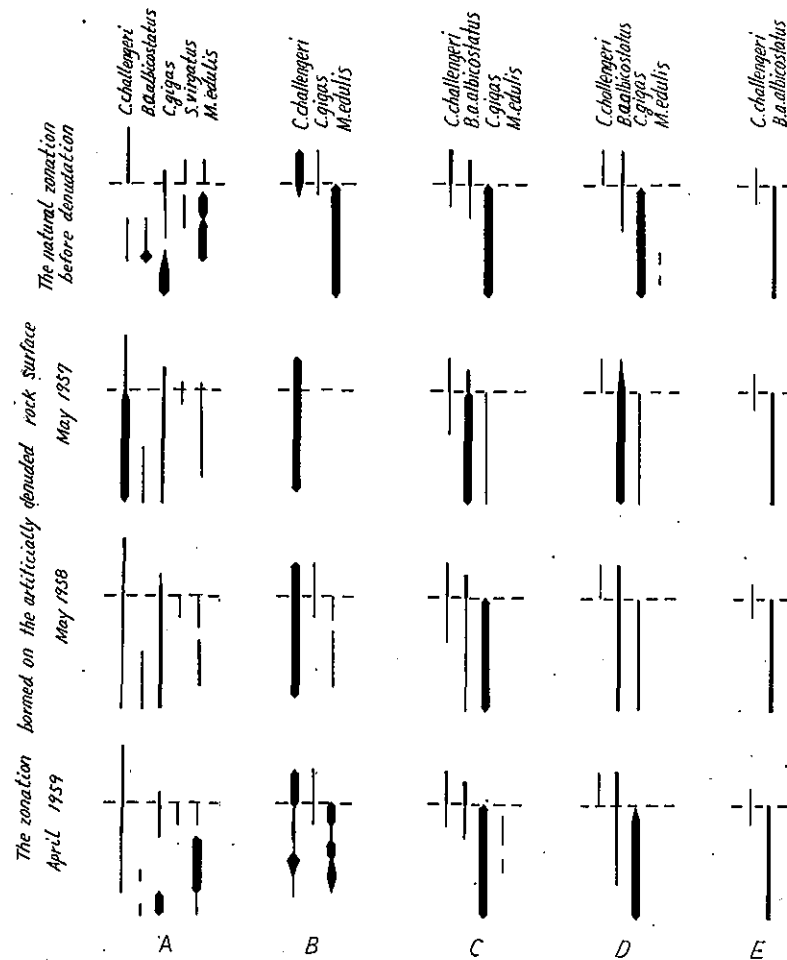


Fig. 2. The successive change of the zonation on the artificially denuded rock surfaces. The distributing range of the arrivals is represented by the vertical bars and the density of each species is relatively shown by the width of the bars. Broken line shows high water level.

A and B: Tobigasaki C: A sheltered place of Katsurajima D: The mole of Yogasaki E: The middle part of Wanigafuchi-channel

such a cliff as the rock surface which does not dry up even during the ebb tide in summer and waves violently sweep the rock face, algae appeared at first and *M. edulis* had attached to them by May, 1957.

5. At the cliff on which the *C. challengerii* and the *S. virgatus* zones were found, the rock surface artificially denuded in May, 1956 was completely covered with *C. challengerii* in June, 1956 and *S. virgatus* had appeared by May, 1958.

6. At the parts where the barnacles, the oyster and the mussels formed zones as shown in Fig. 2 A, after artificial denudation was performed in May, 1956, *C. challengerii* distributed more extensively on the bare rock in June, than in the original zonation and *B. a. albicostatus* settled at the lower part of the newly formed *C. challengerii* zone in August of the same year, and successively *C. gigas* adhered on the *C. challengerii* shells and began to conceal them and in May, 1957, *M. edulis* attached to the *C. gigas* shells. And in 1959 the general state of the newly formed zonation was considered to rather resemble that formed in May, 1956.

7. In another case (Fig. 2 B), on the rock surface artificially denuded in May, 1956, *C. challengerii* densely settled in June and *C. gigas* and *M. edulis* were found in 1958 and *M. edulis* predominated in 1959.

8. On the denuded section of a sheltered place (Fig. 2 C), *C. challengerii* appeared in June, 1956 and *B. a. albicostatus* in summer and then *C. gigas* settled and began to conceal them, and although some of *M. edulis* appeared among the *C. gigas* shells, the *C. gigas* zone was maintained till 1960.

9. On the vertical wall of the mole of Yogasaki (Fig. 2 D), the animals were removed in August, 1959, and in autumn it was found that *C. challengerii* had occupied the upper part of the intertidal area of the denuded belt and *B. a. albicostatus* settled densely below the *C. challengerii* zone and the spats of *C. gigas* could be seen among the *B. a. albicostatus* shells, thus it seemed that the barnacles predominated in the intertidal area. In 1957, *C. gigas* grew and the feature of the zonation became similar to that of the original and natural zonation, which was stable continuing till 1960.

10. At the inlet where only the barnacle zone was found, after artificial denudation was performed in May, 1956 *C. challengerii* appeared in June and a remarkable *B. a. albicostatus* zone was formed in August (Fig. 2 E). The barnacle zone continued till 1960 without modification by any other species.

The natural zonation did not change during the course of this work at any of the cliffs where the artificial denudation was performed.

CONSIDERATION

From the observations of the zonation it is known that the assemblage of the organisms varies in response to the environmental conditions as Habe (1960) and

Utinomi (1960) observed in Tanabe bay, and the pattern of the zonation changes gradually from the outer region to the inner one correlating with the strength of the wave action and the dampness of the rock surface during the ebb tide in summer.

On the other hand, the interspecific relation as well as the environmental condition should be considered judging from the "covering phenomenon" mentioned above.

The covering phenomenon is found commonly in the places where any of the barnacles, the oyster and the mussels form their zones in each of the peculiar layers respectively. As the results obtained from the artificial denudation it is recognized that the barnacle zone is narrowed by the covering of the oyster or the mussels or both, and the distribution of the oyster is modified by the concealing of the mussels at the exposed place but at the sheltered place the barnacle zone is modified only by the oyster.

If the zonation is formed through the concealing of the dominant species in a certain layer as mentioned above, in the area where mussels can not acquire the dominancy, the zonation composed of the barnacle zone and the oyster zone should be able to continue as it is and at the place where only the barnacles can survive without the invasion of other species the simple barnacle zone should be able to exist naturally. The zonation formed on the vertical wall of the mole of Yogasaki is an example of the former case and the zonation composed of the barnacle zone which is found at the middle part of Wanigafuchi-channel is one of the latter case.

SUMMARY

In Matsushima Bay the apparent intertidal zonation changes from the outer region to the inner one relating to the difference of the environmental conditions especially to the strength of the wave action and the dampness of the rock surface during the ebb tide in summer.

The mussel zone and the sponge-algae zone are characteristic in the zonation of the outer region, and accompanying the decreasing of the wave action *C. gigas*, *P. crosslandi* and *B. a. albicostatus* arrive.

The zonation of the channel region is characterized by the *R. japonica* zone and the *C. gigas* zone but at the restricted area of the middle part, the zonation which is composed of the barnacles or of both the barnacles and the oyster is seen.

The zonation of the inner region is characterized by the *C. gigas* zone.

On the other hand, it was considered that some of the said apparent zonations were formed through the so-called "covering phenomenon", that is the early arrivals are concealed by the latter ones.

In this bay the covering phenomenon was found commonly in the places where the barnacles, the oyster and the mussels inhabit.

From the artificial denudation it was commonly recognized that each of the barnacle zone and the oyster zone was modified respectively by the covering of the latter arrivals.

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