ECOLOGICAL STUDIES ON THE MORPHOLOGICAL VARIATION OF A SESSILE BARNACLE, CHTHAMALUS CHALLENGERI I. CHANGES OF THE EXTERNAL APPEARANCE INTRODUCED BY THE POPULATION DENSITY

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By

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INTRODUCTION

Chthamalus challengeri, a sessile barnacle, is found commonly throughout tidal zone in the neighbourhood of the Marine Biological Station of Asamushi in Aomori Prefecture, and forms a distinct zone in the inter-tidal community of the rock or the cliff areas (Fig. 1).

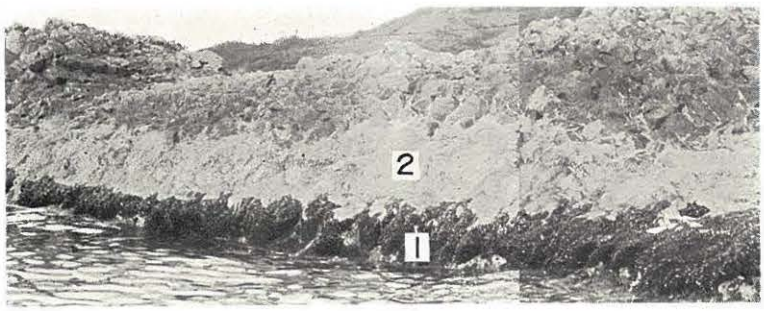


Fig. 1. The tidal zone in the neighbourhood of the Marine Biological Station of Asamushi. 1 : *Mytilus* zone, 2 : *Chthamalus* zone.

It is very interesting that there are developmental and individual variations in the external appearance of this species, viz. the pyramidal and cylindrical forms and intermediate forms between these two.

It seems that this variation in the external appearance is not introduced only by the advancement of the age, but also by the population density.

Therefore, the morphological variation of the present barnacle may afford some

1) This paper is dedicated to Professor Tadao Jimbo for his 63rd birthday.
2) Contributions from the Marine Biological Station of Asamushi, Aomori Ken, No. 258.

ecological interests with regard to the initial density, the mortality, the age distribution and the growth form.

As for the variation of the external appearance, a considerable number of works have been done (Neu 1935, Hiro 1938, Utinomi 1943, 1955, Barnes and Powell 1950 etc.) and from them it was ascertained that the ordinary barnacle has a conical form and a cylindrical or trumpet-shaped shell is formed in the course of the individual growth among the densely aggregated population. But few studies were done from the view-point of the population ecology.

The present study deals with the statistical and ecological treatments of the variation of the external appearance of *Chthamalus challengeri* with special reference to the density effect.

FIELD OBSERVATION

In the neighbourdhood of the Asamushi Marine Biological Station, the animal community of the inter-tidal zone consists of two distinct zones represented respectively by their characteristic animal, those are from the upper part downwards the *Chthamalus* zone and *Crassostrea-Mytilus* zone.

At the supra-tidal porition *Chthamalus* is found rather sparsely in clefts or depressed places of the rock but the population becomes dense nearby the high tide mark. The said zone extends downwards to the low tide mark where the population density is very thin and only a few small barnacles appear.

At the upper part of the said *Chthamalus* zone, the animal is solitary and old in age and large in size, but this conical solitary one becomes eliminated downwards and individuals have cylindrical shells which are in contact with each other, and in the lowermost part the solitary ones appear again, but are young and concial in shell shape.

MATERIAL AND METHOD

In the present investigation, the middle part of the distributing zone consisting of fully grown individuals was selected for the collection of specimens. And thus, the examined materials were obtained from various portions having respectively different population density, which was classified into five, viz. less than 1.0 individual, 1.3, 2.8, 4.0 and 5.5 individuals per 1 cm^2. Here, in the first class the animal is solitary, in the second only one or two lateral valves of the shell are adjacent to other individuals, in the third more than two valves are in contact with two or three other individuals, in the fourth most valves come in contact with the others and in the fifth all valves are in close contact with others.

Five dimensional characters were measured, namely length and breadth of the opercular portion (a and b) and of the shell base (c and d) and the shell height (h) (Fig. 2).

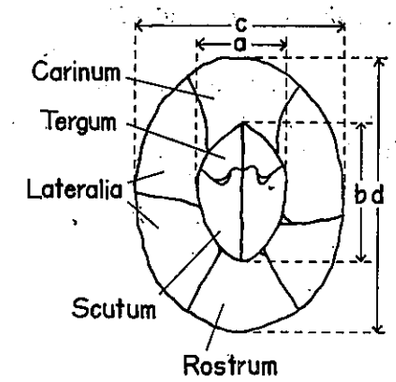


Fig. 2. Schema showing the four dimensional characters of the shell.

RESULTS AND DISCUSSIONS

From the measurements obtained from the above mentioned treatments, statistical works were done with special reference to the inter-relation among the said various characters and an attempt was made to clarify the modification of the shell size introduced by the population density.

I. *Relation between the*

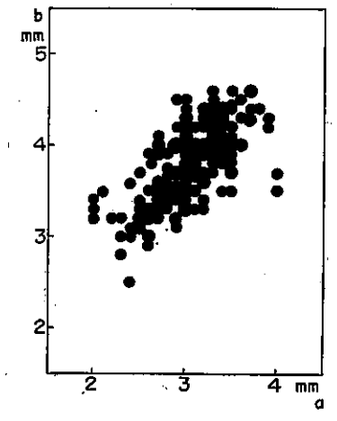


Fig. 3. Relation between the breadth (a) and the length (b) of the opercular portion.

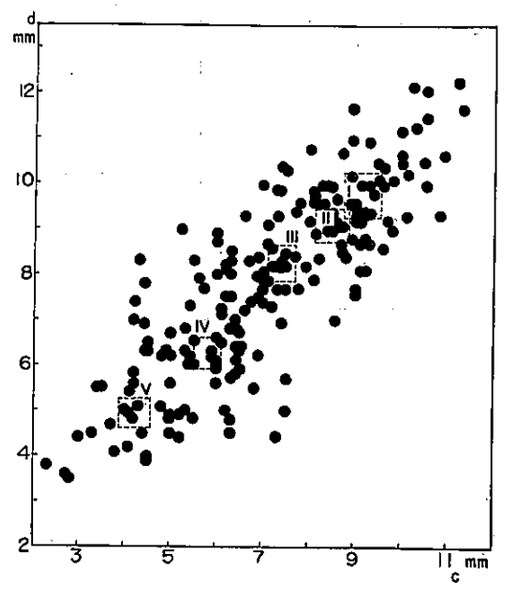


Fig. 4. Relation between the breadth (c) and the length (d) of the shell base. Roman numerals, I–V, represent the confidence intervals of mean values of measured characters in each class of various population densities.

Length and the Breadth of the Opercular Portion.

A simple parallelism is recognized between the length and the breadth of the opercular portion, and from that the confidence intervals of the mean values (in 95 per cent reliability) of the five classes overlap each other, it is considered that the variation in the shape of the opercular portion and the degree of the population density are independent of each other (Fig. 3).

II. *Relation between the Length and Breadth of the Shell Base* (*Fig.* 4).

Simple parallelism is found in the length and the breadth of the shell base. It must be noted that, though as for the opercular portion the mean values of five classes are not significantly different from one another, in this case the confidence intervals of the mean values statistically differ from each other, namely the individuals among the densely aggregated population have smaller shell bases than those among the sparse population. Therefore it may be said that the growth of the shell base, namely the spatial expansion of the shell base relates closely to the population density.

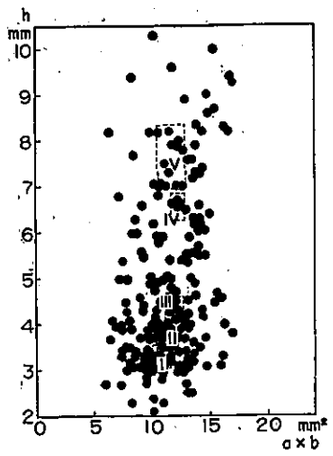


Fig. 5. Relation between the shell height (h) and the opercular size (c×d). Roman numerals represent the confidence intervals of mean values of measured characters.

III. *Relation between the Height of the Shell and the Opercular Size* (*Fig.* 5.).

As already mentioned, a and b of the opercular portion are parallel with each other having respectively the statistically equal values in each class, and therefore all individuals may have similar values of a×b.

From Fig. 5 showing the relation between the height (h) and the shell base size (a×b), it is noted that the change in the value of the shell height has no relation to the fluctuation of values of a×b, but relates to the denseness or the sparseness of the population.

It was already known that the shell base is restrained from the space expansion owing to the crowding of many individuals.

From the above, an antagonistic relation should be expected in the course of the shell growth between the shell expansion and the shell elongation. In other words, the restraining of the shell expansion may result in the shell elongation.

IV. *Relation between the Size of the Shell Base and the Shell Height* (*Figs.* 6 *and* 7).

To treat statistically the said antagonistic relation between the space expansion and the elongation of the shell height, the relation between the shell height

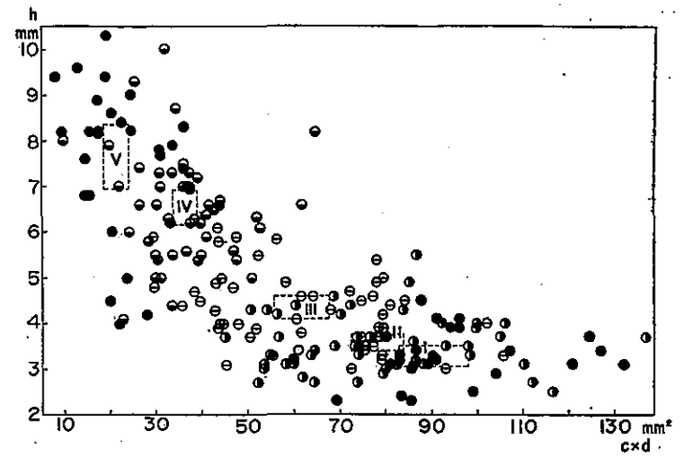


Fig. 6. Relation between the shell height (h) and the size of the shell base (c×d). Roman numerals represent the confidence intervals of mean values of measured characters.

(h) and the size of the shell base (c×d) was investigated.

As is seen in Fig. 6, among individuals of two classes having a density less than 1.3 barnacles per 1 cm², the shell height is not so variable that the confidence intervals of these two mean values overlap each other and also the mean values of the size of the shell base in these two classes are not different.

But the height increases rapidly in individuals of three classes having more than 2.8 individuals per 1 cm², and thus in general the logarithmic relation is given

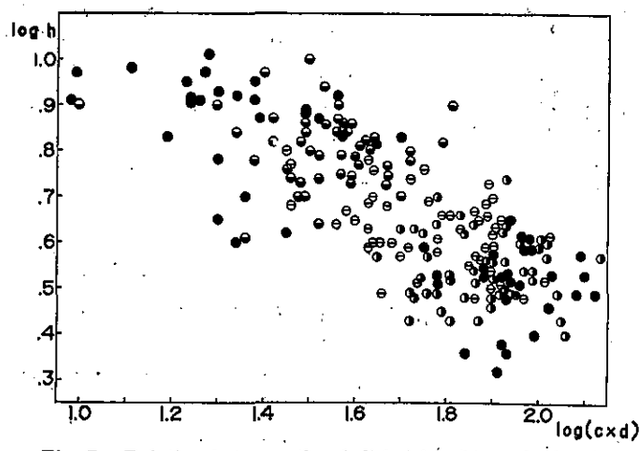


Fig. 7. Relation between the shell height (h) and the size of the shell base (c×d).

between the shell height and the shell base, namely between the shell expansion and the shell elongation.

In Fig. 7 the logarithmic value of the shell height was plotted against the shell base, and thus the expression, log h+k log (c×d)=K, is statistically given.

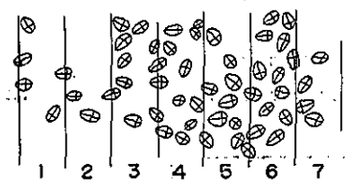
The constant k may be considered as the index of "the morphological heterogeneity of the constituents" of the barnacle population, and if the value of k is small, the given population should consist of individuals which are similar in shell size and shape, and if, on the contrary, k has large value, it may be known that the shells of constituent individuals are variable in size and shape being conical or cylindrical.

On the other hand the constant k may be also considered as the index of "the denseness and sparseness" of the population, because the variation of the shell shape, or the heterogeneity of the shell shape, is due to the density of the population.

It seems to be noteworthy that using the present "heterogeneity index" or "denseness-sparseness index" of the population the constitutional characters of a given population may be ecologically defined.

V. *Gradual Change in the Shell Shape and the Size among Colonized Barnacles.*

If the distributing zone of the present barnacle is observed in detail, some densely colonized clusters consisting of 50–100 barnacles are often recognized even in the apparently homogeneous population.



	a×b	c×d	h	vol.
1	10.8±1.5	69.8±11.3	4.2±0.9	150
2	12.4±1.0	60.8± 9.9	4.7±0.8	172
3	13.2±2.4	43.8±11.4	5.5±0.9	107
4	13.7±3.0	39.8±11.6	6.5±2.0	174
5	13.6±2.7	23.0± 7.3	9.4±2.8	172
6	13.1±2.8	19.1± 7.8	10.4±1.5	167
7	11.6±2.8	14.7± 8.7	10.8±1.4	142

Fig. 8. A cluster of *Chthamalus challengeri* shown by the opercular portions.

The marginal individuals of such colonized cluster are conical in shape, but the elongated shells appear in its central part and thus a gradual change in the dimensional characters is seen from the margin to the center of the cluster. Fig. 8 shows one of such phenomena.

The volume of the individual barnacle was also measured and it was noted that the volume of the shell increases gradually from the margin to the center, on the contrary, closely aggregated individuals in the central part decrease in their volumes.

SUMMARY

1. In the present paper, statistical treatment was done concerning the dimensional characters of the shell of barnacle, *Chthamalus challengeri*, with special reference to the morphological variation introduced by the population density.

2. The fully grown samples were obtained from the densely distributed portion of the *Chthamalus* zone in the inter-tidal community.

3. The logarithmic relation was found between the shell height and the shell base, namely the expression, log h+k log (c×d)=K is statistically given. Here, h is the shell height, c and d are respectively the length and the breadth of the shell base and k and K are constants.

4. It was known from the above that an antagonistic relation is recognized between the growth of the shell height and the shell base.

5. The constant k is considered as the index of "the morphological heterogeneity of the constituents" of the barnacle population and also as the index of "the denseness and sparseness" of the barnacle population.

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