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ON THE RELATION BETWEEN THE STABILITY AND THE LENGTH FREQUENCY MODE OF MUSSEL (*Mytilus galloprovincialis Lamarck*) POPULATION.

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INTRODUCTION

Mussel populations settled on concrete walls never survive beyond a few years. After an initial period of exuberance the populations die out completely, not a single individual cannot be found. Usually spat in a few number recruit and grow among the older individuals, as will be shown in my unpublished paper. If by a chance the younger members succeed in gaining a foothold in such a bed, the bed itself die out. Even if no invasion by spat do take place, in neither case, the bed can survive indefinitely.

The foregoing facts related to mussel beds growing on flat concrete walls provided semi-experimental conditions where similar samples could be collected at any different points. Even though fundamental laws will hold for all populations, still more complex behavior may be expected from populations growing in situations as intricated as piled up tetrapod. On these uneven surfaces and due to differences in microgeographic conditions, uneven beds are formed by necessity.

The present paper deals with the stability of populations growing on tetrapod by means of length frequency distribution analysis with proper consideration to the existing complex phenomena at work. Unfortunately little is known as yet on the nature of the relations between population fluctuation and length frequency which is the result of intraspecific competition and predation.

If fluctuations in a given population are just treated without giving proper consideration to the differences in size among individuals of the population, we may fail to gain a true picture of the conditions existing in the population and so may be led to a hasty conclusion liking fluctuations directly to the enviroment. In a mono-specific population main, contradictions may exist between different size groups.

Field stations for the present research were provided by the piled up tetrapods existing outside the oil depot and the yacht harbor at the east end of the Suma coast facing Osaka Bay. In this area, every where along the coast at the lower level of the intertidal zone is densely inhabited by populations of *Mytilus galloprovincialis Linne.* The occurrence in this area of such a dense population should be ascribed to the existence of a favourable current moving parallel to the coast. Along the inner coastline of the bay both stations are exposed to the surf. This must be considered as a favorable condition for the settlement and growth of the mussels. Outside the oil depot (for about a four kilometers) and the yacht harbor (for about 300 meters) the coast is protected to the oncoming waves by a wall of concrete tetrapods. This latter area is especially rich in food stuff due to its being near the mouth of a small river.

The piled-up tetrapod form a very complex cave-like holow structures. Since current cannot flow well into these caves, mussel growth is very poor in here. In general a density decrease in bed depth as one goes from the outermost teptrapod to the innermost.

In favorable enviroments the mussels were generally distributed in shallow water of the sublittoral and intertidal zone where the water level was 0.7m above and 1.0m below MLWS. Small colonies may be seen, though rarely, at higher or lower levels. Determination of sampling points reflecting the nature of the population was a difficult task. Collection of samples was made from the low tidal belt of the outermost tetrapods. In each case samples were chosen that represented dense, medium and poor bed conditions.

With regard to the tetrapod outside the yacht harbor, collections were made on eight different occasions throughout the life span of the population, taking several samples each time. Dates are indicated in Table 1. With regard to the tetrapod around the oil depotsamples were collected on nine different ocasions, until the end of the bed, starting one year after its settlement. (Table 2).

FREQUENCY DISTRIBUTION OF THE YACHT HARBOR POPULATION

The yacht harbor bed were formed in 1969 and in 1971 had completely disappeared. The life span of this population was characteristically short, and suffered a sudden depletion twice, one during the autumn and winter of 1969 and another during the autumn of 1970. Length frequences of samples from this population are plotted in Fig. 1. It shows the various changes that took place during the population life span.

Table 1 Sample collection date and remark on tetrapod outside the yacht harbor

Date of collection	Remarks
June 4, 1969	Soon after spat fall, 100 per cent coverage
July 10, 1969	More than 80 per cent coverage
Aug. 14, 1969	ditto
Dec. 10, 1969	Intensively decreasing
May 5, 1970	Patchy bed surviving
July 20, 1970	ditto
Sept. 15, 1970	Great destruction
Apr. 21, 1971	Almost disappeared

Table 2 Sample collection date and remarks on tetrapod around the oil depot.

Date of collection	Remarks
June 30, 1969	One year after spatfall, great exuberance
Sept. 23, 1969	More than 50 per cent coverage, great exuberance
Dec. 10, 1969	ditto
Apr. 10, 1970	ditto
June 21, 1970	Decreasing
Sept. 13, 1970	dit o
Apr. 27, 1971	Almost disappeared

During the first lap of the life up to Dec. 1969, the frequency distributions of samples collected on the same occassion were quite similar and did change in the same way. By May 1970, however, the modes of the histograms showed some variations. In Dec. 1969, at the time the beds were undergoing their first depletion, histogram plots showed an overwhelming predominance of the smaller members. In statistics this type of frequency distribution is called "L-shape distribution". It is quite an interesting thing that this type of distribution is obtained before the poulation failing, that is to say, when it is unstable. In Dec. 1969 the tail of the mode showed an upward shift while by May of 1970 it did skew downwards. The shift between these two steps of the histograms meant either that the younger members were eliminated during this period or that only that part of the bed remained which had eliminated the younger members. In July 1970 the distribution showed several modes within a basic bimodal form. This indicated that a number of younger mussels were recruited into previously formed older beds, and that the recruitment and growth of the young mussels was not uniform from place to place.

If the recruitment and growth of the young mussels had been uniform, thehis tograms would have been expected to show the same form. In September 1970 the histograms also show a similar trend. The samples at this time were taken just before the second great depletion that took place between Autum and Winter. As result of this second bed failure the figures for April 1971 look as if only very few younger mussels remained. This may be the resulteither of the disappearance of younger individuals from the population or of the survival of only those bed parts where the younger individuals had been utterly killed.

FREQUENCY DISTRIBUTION IN THE POPULATION AROUND THE OIL DEPOT.

The population around the oil depot emerged in 1968 and subsequently suffered a gradual decline that led to its complete disappearance by August 1971. This bed did not undergo a sudden and rapid failure. The samples represented in the original histograms were collected in June 1969, one year after the settlement of the population. This histogr-

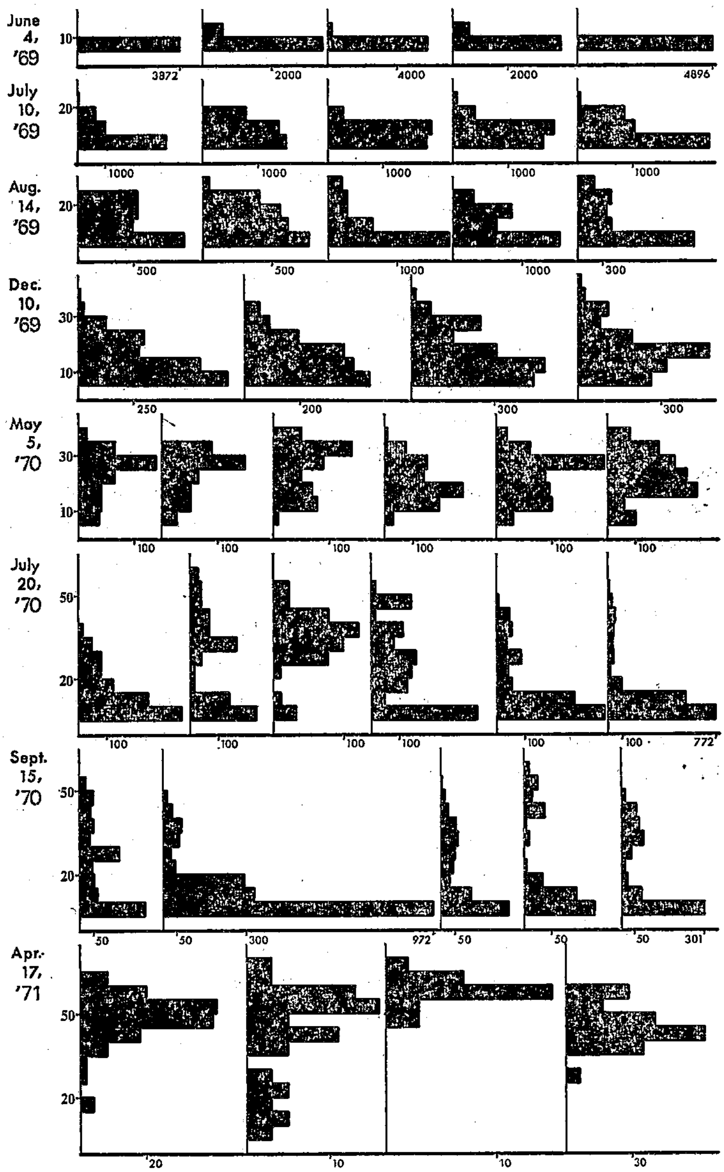

Fig. 1

Fig. 1 The variation of length frequency distributions of the mussel population settled on the tetrapod pilled outside the yacht harbor. Vertical axis represent the length in mm. Horizontal axis represent the number of individuals in 400 cm^2. The different graphs on the same horizontal line reffer to samples collected at same time. There is however no direct relation between them because samples were collected in different spots.

Fig. 3 The successive change of the position of peaks represented by the length frequency distribution of the yacht harbor population. Black marks represent main peak position and white ones, sub-peak position.

Fig. 4. The succes ive change of the position of peaks represented by the length frequency distribution of the oil depot population. Other explanations as in Fig. 3.

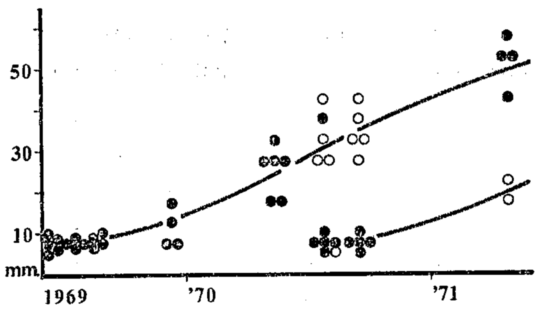

Fig. 3

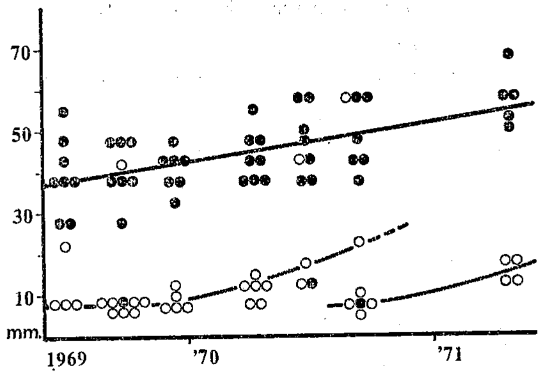

Fig. 4

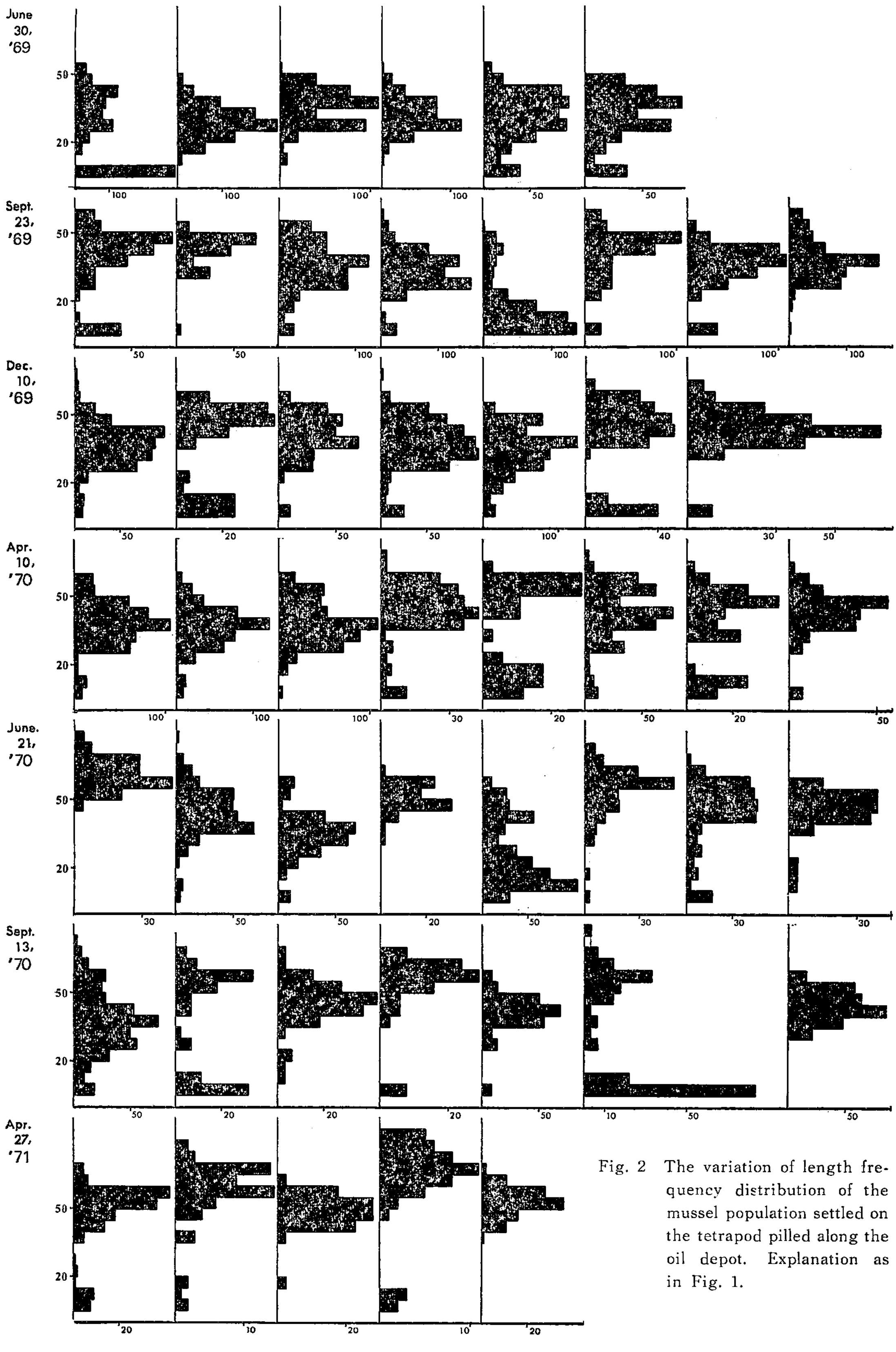

Fig. 2 The variation of length frequency distribution of the mussel population settled on the tetrapod pilled along the oil depot. Explanation as in Fig. 1.

ams of the original step displayed several modes. This variety of modes were due to differences in mean length and deviation from older age groups. By this time the younger mussels had not yet been recruited into the bed in such great numbers so as to attract our attention. Slight differences among the places where the samples were collected might have caused these apparent differences in forms of the populations. This variety in the population is evident in the whole series of steps of graphs, including the final one. The histograms of September 1969 show that the recruited younger mussels had grown in the bed to a soybean size. However, they have not caught up in growth with the older ones. The clear cut gulf between the two well defined age groups is evident in the histograms of December 1969 and and April 1970. The younger mussels had almost completely dissappeared by June 1970. They must have been killed out during the Spring. In September 1970 younger members age O_+ entered into the bed tried to grow in there. Only traces of age 1_+ were found at this time. Samples of this period must consist of three different age groups though trimodal histograms are not clearly recognized. The fina' stage of the figure shows that few members of age group O_+ have survived and that regions of 1_+ age group were almost completely destroyed.

COMPARISON BETWEEN THE TWO POPULATION.

There exist the following similarities between the two populations. First, young members invade the mussel bed and endevour to grow among the older ones but they undergo a continuous elimination as result of competition and predation. Second, beds suffesed when the younger members succeeded in growing whthin them. Finally, the population in which only the older members survived showed monomodal distributions. Due to the variety and complexity of the histograms a detailed discussion is almost imposible. But if we only take some simple factors from these much better results can be obtained.

As the recruited youngs grow into the bed, the frequency distribution changes from its original monomodality to bimodality. (It is theoretically possible to obtain trimodal histograms when a second recruitment takes place but so far we have been unable to detect such a situation.) The peaks were chosen according to the number of modes in a heigth order. The position of the peaks were graphically plotted as shown in Fig. 3 and 4. In both fiures the highest peaks are represented with black circles and the second peaks with white ones. If a histogram was originally monomodal only black circles were used. In Fig. 3 the circles showing the peaks fall along two lines which represent the growth of two different age groups. These two lines recede from each other causing the gaps between the peaks in the histograms. It may be that the older members check the growth of the younger ones. In the final stage the peaks shift once more when the older members occupy the main peak. This may be due to the fact that those parts into which the youngs have been recruited had fallen off while those parts which eliminated them had survived. In Fig. 4, the circles are also arranged along the line that follows the mussel growth. The main peaks are constituted by modes formed by the original cohort. The peaks formed by the younger mussels which survived to the very end of the population in this place. Because of the disappearance of the peaks formed by the first wave of young recruits the gaps between the peaks of the histograms widens more and more.

DISCUSSION

If a great number of young mussels are recruited into the bed, as did happen in the yacht harbor, the beds survive for only a short period and fall off. If the recruited youngs are eliminated, as did happen around the oil depot, the life of the population is prolonged. When the recruited youngs are scarce, as was the another case, in the fish pond of Akashi, the population composed of members of the same age group survied for a longer time. In whatever case, however, the population dissappeared whithin one generation of major cohort. For the maintenance of the population, there is a severe contradiction; namely that both are not permited to maintain beyond a generation no matter whether younger groups remain or do not among older members. The mussel population has been unable to solve this contradiction in its own living place. May be such contradiction arises from the fact that "a society in the same boat" must be constructed. The mussels bind themselves with byssus to each other for the safety of their own lives on the monotonous concrete wall. And this has its limits. A comparison with mussels growing in a complex rocky shore may prove instructive.

In the beds around the oil depot, the number of young ones is rather moderate when compared to that of other stations. May be they were thinned out severely. If they had been allowed to survive, the population might have declined in a shorter period. Thus the thinning process has a beneficial effect in helping to prolonge the life span of the population. The severer the elimination of the youngs is the stabler the bed will become. Both histograms reveal the fact that only those parts showing a monomodal distribution survive up to the very end of the population. These facts are very similar to those related to plant population.

A comparison of these observations with those of Kyama and Kira (1966) on the soybean is of interest. Their experiment revealed that when the mortality rate, due to self-thining was low, the distribution of the histograms, in terms of weight, assumed a kind of rectangular shape and collapsed all of a sudden. This condition is pretty similar to that observed in the present study where little elimination leads to the falling off of most of the population. When the mussel population's histogram shows the L-shaped distribution, it may incline to collapse. In the case of the soy bean, the weight distribution giving a rectangular mode indicating an homogeneous distribution was unsteady. In the case of mussels an homogeneous distribution has the opposite effect. This may be due to the fact that when in a plant population the thinning out is low, the stems get slender, and hence can't easily endure the rain fall. In the case of mussels, individuals can't vary their own relative growth.

The individuals of the younger class can be thinned out either due to suppression by the dominant age class or simply by predation. The more the mode of the frequency curve is biased towards a maller age class, the higher the rate of elimination will be. Sato (1955) mentioned that in the red pine forest the higher the density is, the stronger the tendecy will be on the frequency mode of the basal area to shift to the L-shape, and the more uneven the increase in individuals will be with the smallest individuals being killed. The normal distribution of the mussel length may be attained by elimination of the smaller clases. A similar phenomenon has been observed in the red pine forest. The smallest trees are killed by too much sheltering from the sun. In very much the same way the larger members of a mussel population may rob the smaller members their food while at the same time selective feeding by predators may contribute to the elimination of the young. Finally only the bed which presents a normal length curve is apt to survive.

The life of a mussel population while it is comparable to that of plants, it can't be directly compared with that of bivalves living on sandy shores. A number of studies have been done on this last topic. Several reports point out the fact that on sand flats younger bivalves can be recruited into and live along with older ones. Orton in 1926 reporting on the shifting in size frequency distribution of *Cardium edule*, found that the mode formed by a younger group merged gradually into the one formed by an older one. This example shows that the younger recruits had not been eliminated to any great extent. Similar results have been obtained by Haskin (1954) on *Venus mercenaria* and by Hughes (1970) on *Scrobicularia plana*. Coe and Fitch (1950) showed that in populations of *Tivela stoltorum* different age groups live and grow together in the same place. Ohba (1959) too, has studied for several years the dynamics of *Tapes japonica* populations containing several age groups. Why bivalves of sand flats can tolerate age differences in their populations may be due to the fact that they are not as gregarious as mussels are. In mussel populations the youngs are killed in competioion for a living space.

Why the action of mussels towards the young is similar to that of plants may be explained by the fact that both are gregarious in nature. But even on sand flats, when the population is very dense and individuals are packed closely together there exists an intense thinning as has been shown by Ohba

(1956).

It may be audacious to compare mussels to plants but in reality plants compete for light in the same way that mussels do for suspended organic matter. Competition in plants follows from the fact that they are supplied with a definite amount of energy during a certain period on a certain area when the population coverage is 100%. In mussels, too, the population arrives to a point where they cover the substratum to capacity. Thus we may liken a mussel community to a forest.

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SUMMARY

The present investigation was aimed at finding out by analysis of length frequency distribution whether recruited spat can grow or not among the older members of a mussel population. Mussel populations growing on tetrapod fields at two different locations were selected for that purpose.

Tetrapod fields being themselves complex habitats caused the formation of uneven beds in which the number of individuals of the younger class varied from place to place. Spat exerted themselves persistently in order to recruit themselves to the bed and be able to grow among the older members. On the other hand the established community persisted in its efforts to eliminate the young individuals. If too many young spats enter the older bed and are able to grow on it, the bed becomes unstable and may even collapse if the young ones are not quickly and efficiently eliminated. The more severe the elimination of the younger individuals is, the stabler the bed will remain.

A normal length frequency distribution indicating a more or less even constitution, represents a stable bed. The so called L-shape distribution indicates an instability in the mussel popuation which, by the way, is just the opposite of what takes place in plant populations. Bimodal distribution is obtained when young individuals are recruited and grow among the older ones. However, the mode formed by the younger individuals disappears in due course. And if it does not, the population may collapse suddenly. At the end, only the normal curve of the population is represented.

摘　要

細見彬文：ムラサキイガイ個体群のサイズ分布の型と群の安定性の関係。

神戸須磨海岸の２カ所のテトラポッドに生育するムラサキイガイ個体群について，移入してきた若い貝が育つかどうかを，群が消滅するまでの間，殻長の頻度分布を分析することによって研究した。テトラポッドの複雑な微地形によって群の繁茂状況はかなりの差があり，移入して育つ貝の数もちょっとした場所の違いによって大きな差がある。若い貝が移入するとそれらはきびしいまびきを受ける。若い貝が多く移入し，多く育つほど群は不安定であり，崩壊に見まわれるようである。また，若い貝をよくまびいた群ほど安定的なようである。安定な群は長さの頻度分布が正規分布に近く，均質であり，また不均質を示すＬ字型分布では不安定である。若い貝が移入して育つと，２山型の分布ができるが，若い貝が作ったグラフの山は途中で消える。消えない場合は群全体がだめになる。最後に残るのは個体群の中で正規分布を持つ部分だけである。

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