エゾアワビ稚貝飼育用波板上の付着藻類の消長

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Changes of Algal Community on the Plastic Plates used for Rearing the Abalone *Haliotis discus hannai*

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In the seed production system of the abalone *Haliotis discus hannai*, sessile algal communities on the rearing plates are classified into two categories; the first and the second phase algae. The changes from the first to the second phase algae were observed in detail. On the rearing plates, *Licmophora abbreviata*, *Achnanthes javanica* f. *subconstricta*, *A. kuwaitensis*, *Navicula ramosissima*, *Nitzschia closterium* and *N. acicularis* were observed abundantly as the first phase algae, and they built up stratified overstory assemblages. After the introduction of juveniles of the abalone onto the plates, these algae disappeared, and *Cocconeis costata*, *C. scutellum*, *C. sublitoralis* and *Myrionema* sp. proliferated remarkably and assemblages became a uniform layer of prostrate cells. These second phase algae were seen in small numbers in the early stages before introducing the abalone juveniles. Without grazing pressure of the juveniles, the algal community on the plates did not change to a uniformly layered assemblage. The first and the second phase algae differed in community structure and dominant species. In addition to these differences, the second phase algae were characterized by the remarkable proliferation under grazing pressure.

The effect of such environmental factors as light and water flow on the marine coastal microvegetation has been studied.[1-4] However, the effect of grazing on sessile microvegetation in coastal waters has been less well studied.[5-7] A northern species of abalone, *Haliotis discus hannai*, is of commercial importance in Japan and a new technique of seed production of this species has been developed.[8,9] Developments in the methods of artificial spawning[10] and the discovery of inducer for settlement and metamorphosis of larvae[11,12] have greatly contributed to improvements of the seed production. However, the production of abalone seeds was controlled by initial diet, microalgae, growing on the plastic plates for settlement of the planktonic larvae. A biological engineering system for the abalone seed production has been established in the Oyster Research Institute in Miyagi Prefecture. This system has been applied to the abalone production in the northern Japan to produce about ten million seeds steadily each year. In this seed production system, suitable initial diet was prepared by the following procedure. Transparent plastic plates are kept in an outdoor tank. Within 10–15 days the plates are covered with overstory assemblages of thick filaments of diatom colonies called "first phase algae" and they are used as good food for small juveniles (3–13 mm in shell diameter) of abalone.[13] On feeding by abalone, prostrate algae begin to grow, and after several days the plates are covered entirely with these algae. These algal communities are called "second phase algae" and they are suitable initial food for creeping juveniles of abalone (0.3–3 mm in shell diameter).[13] However, the details of the changes of algal compositions on the plates were not observed so far.

This paper describes the results of observations on the grazing effect of two herbivorous shellfishes on algal communities on the plastic plates used for seed production of abalone, with special attention to the change from the first phase algae to the second phase algae.

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Material and Methods

Experiments were made with outdoor experiment facilities of Mohne Laboratory of the Oyster Research Institute in Miyagi Prefecture for 45 days from 24 September to 8 November 1981. Transparent plastic plates (33×40 cm, 0.1 cm thick) were put in the tank (22.3×2 m, 0.9 m deep) which was continuously supplied with filtered seawater. Continuous aeration and enrichment of ammonium sulfate were made. The plastic plates were kept in the tank for 18 days to be covered with sessile algae. Small juveniles of the abalone *Haliotis discus hannai* were introduced onto the plastic plates covered with sessile algae. Shell sizes of the abalones varied from 9.0 to 13.2 (mean 11.2) mm in diameter and its density on the plates was 227 shells per m^2. A total of 14,400 abalone juveniles were used. For comparison, plastic plates without abalone were also kept in the tank. To check the effect of grazing by other herbivorous shellfish, *Monodonta labio* was also used. The size of *M. labio* was 10.0–15.4 (mean 12.4) mm in shell height and 10.2–15.0 (mean 12.4) mm in diameter. The density of *M. labio* on the plates was 114 shells per m^2.

Samplings were carried out every four to six days after the plastic plates were set in the tank. For counting cell number, all algae in a quadrat (5 cm square) were taken from lower and upper parts of the plastic plate. The cell number for each determination was the average of these two (lower and upper) countings. Species appeared on the plates in small numbers were not counted. From the top to the bottom of the plastic plate, sessile algae in ten cm width were taken and chlorophyll *a* amount was determined using the method of Strickland and Parsons.[14]

Results

During the course of the present study, the water temperature varied from 21.5°C on 24 September to 14.1°C on 8 November, the average over the study period being 18.0°C, and the specific gravity of the water varied from 1.022 to 1.025, the average being 1.024.

The average growth over the study period was 2.1 mm in shell diameter for *H. discus hannai* and 1.4 mm in shell height and 1.0 mm in shell diameter for *M. labio*.

Fig. 1 shows the changes of chlorophyll *a* amount of the sessile algae on the plastic plates. Chlorophyll *a* amount increased rapidly and

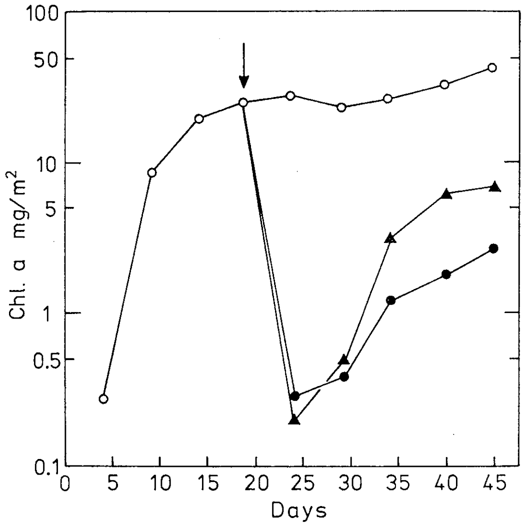

Fig. 1. Changes of chlorophyll *a* amount on the plastic plates after the plates were set in the tanks. Arrow indicates the introduction of herbivorous shellfish onto the plates. (—○—) Without introduction of shellfishes; (—●—) with introduction of *Haliotis discus hannai*; (—▲—) with introduction of *Monodonta labio*.

attained 25.9 mg/m^2 on the 18th day, thereafter it increased slowly with a small decrease on the 29th day to reach 42.0 mg/m^2 on the 45th day in the case of no introduction of shellfish. On the other hand, after the introduction of the two species of shellfish on the 18th day the amount of chlorophyll *a* was drastically decreased by grazing to 0.2–0.3 mg/m^2 in six days, while it began to recover rapidly, but never reached the previous level in 21 days. There was no large difference in the changes of chlorophyll *a* amount between the plates onto which *Haliotis discus hannai* or *Monodonta labio* juveniles were introduced.

The changes of sessile algal composition on the plastic plates are shown in Fig. 2. Before the introduction of the herbivores, the dominant species were *Navicula ramosissima* on the fourth day, *Licmophora abbreviata* on the ninth day, and *Nitzschia closterium* and *N. acicularis* both on the 14th and the 18th day. All these species constituted a community of multilayered upright posture. At this stage the plastic plates were covered with thick filaments of these diatom colonies, and prostrate species, such as *Cocconeis scutellum*, *C. costata*, *C. sublitoralis* and *Myrionema* sp., were not seen in large numbers.

Fig. 2A shows the changes of sessile algal composition on the plastic plates without herbivorous

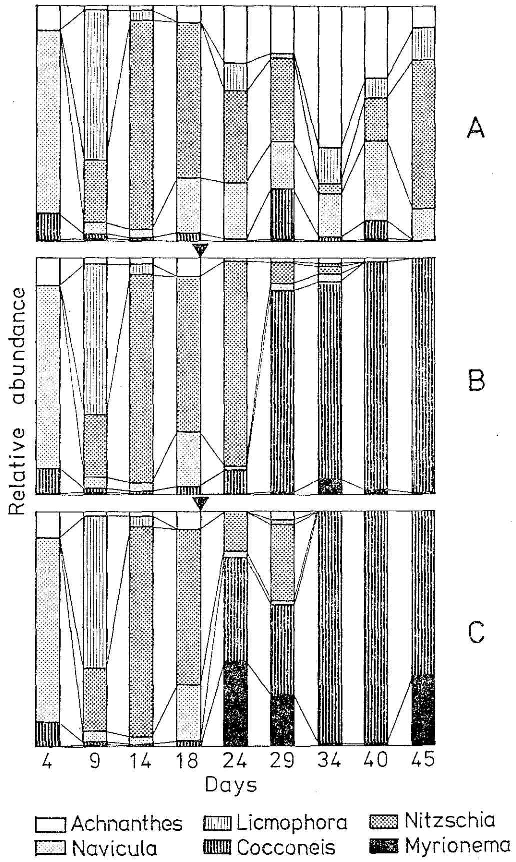

Fig. 2. Changes of the relative abundance of sessile algal cells on the plastic plates after the plates were set in the tanks. The first four figures in A, B and C are the same. A: No herbivorous shellfish was introduced. B: *Haliotis discus hannai* were introduced. C: *Monodonta labio* were introduced. Arrowheads indicate the introduction of herbivorous shellfishes onto the plates.

Achnanthes, *A. javanica* f. *subconstricta* and *A. kuwaitensis*; Licmophora, *L. abbreviata*; Nitzschia, *N. closterium* and *N. acicularis*; Navicula, *N. ramosissima*; Cocconeis, *C. costata*, *C. scutellum* and *C. sublitoralis*; Myrionema, *Myrionema* sp.

shellfish during the course of the present study. In this case, the dominant components of the community changed irregularly from the 18th to the 45th day. The algal community was mainly composed of *Nitzschia* spp., *Navicula ramosissima*, *Achnanthes kuwaitensis* and *Licmophora abbreviata*. They constituted a community of multilayered upright posture. *Cocconeis* spp. and *Myrionema* sp. were seen on the plates but only in small numbers.

Young juveniles of the abalone were introduced onto the plates on the 18th day (Fig. 2B). After the introduction, *Cocconeis* spp. increased remarkably but *Myrionema* sp. were seen only in small numbers. Twenty-seven days after the introduction, the plates were covered mostly with *Cocconeis* spp. accompanied by quite small numbers of *Myrionema* sp. These species constituted a community of single-layered prostrate posture. At this stage, the surface of the plastic plates appeared to be slightly brown due to these prostrate algae.

Herbivorous shellfish *M. labio* were introdcued onto the plastic plates also on the 18th day (Fig. 2C). Only six days after the introduction, such species of prostrate posture as *Myrionema* sp. and *Cocconeis* spp. increased remarkably, whereas such species of upright posture as *Nitzschia* spp. and *Navicula* spp. decreased. Seventeen days after the introduction, the plastic plate was covered only with *Cocconeis* spp. and small numbers of *Myrionema* sp. The species of upright posture disappeared completely at this time of observation.

The changes of cell number of sessile algae on the plastic plates are shown in Fig. 3. In this figure, sessile algae were classified into two categories; 1) species of upright posture (the first phase algae), and 2) those of prostrate posture (the second phase algae). On the plates without introduction of shellfish, the cell number of algae of both categories reached the maximum on the 14th or on the 18th day and subsequently showed irregular changes. Both types of species did not disappear within 45 days. After the introduction of the herbivores, on the other hand, the cell number of species of upright posture decreased remarkably. Those species disappeared completely within 16 days in the case of *M. labio* and within 27 days in the case of *H. discus hannai*. On the contrary, the cell number of species of prostrate posture increased notably after the introduction of the herbivores.

Discussion

The method has already been established to get such suitable food as *Cocconeis* for early juveniles in the system of abalone seed production. In the system, sessile algal communities on rearing plates are classified into two categories, the first phase algae and the second phase algae.[9] Since there was no detailed phycological approach, it was presumed that the second phase algae probably settle on rearing plates after introduction of

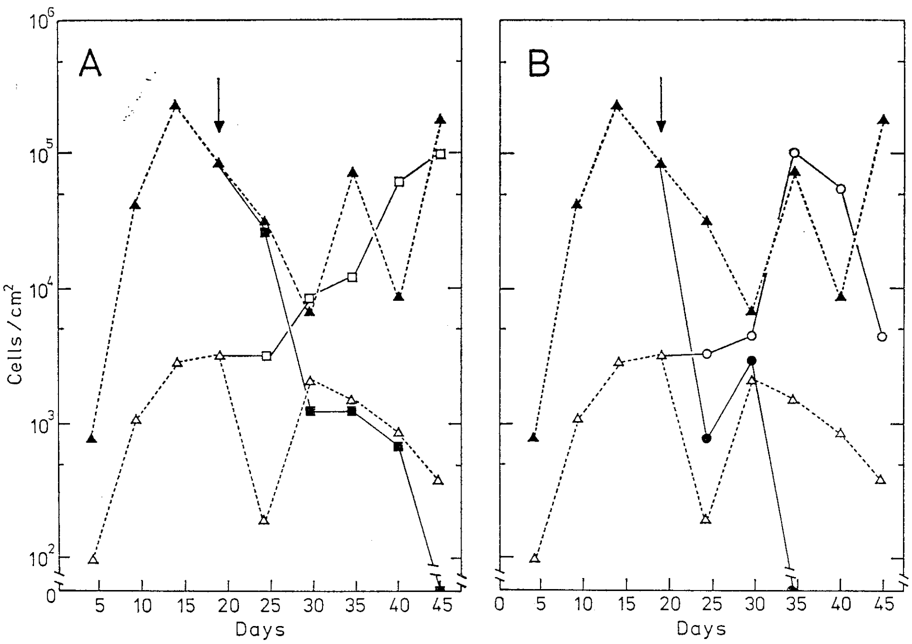

Fig. 3. Changes of the sessile algal cell numbers on the plastic plates after the plates were set in the tanks. Arrow indicates the introduction of herbivorous shellfishes onto the plates. Dotted lines, without introduction of herbivorous shellfishes; (---▲---) the first phase algae and (---△---) the second phase algae. Solid lines, with introduction of herbivorous shellfishes; (—■—) the first phase algae and (—□—) the second phase algae in the case of *Haliotis discus hannai* (A); (—●—) the first phase algae and (—○—) the second phase algae in the case of *Monodonta labio* (B).

abalone juveniles. But the present results indicated that the second phase algae settled on the plastic plates in the early stage before introduction of abalone juveniles (Figs. 2 and 3). As shown in Fig. 3, the second phase algae never developed in large numbers without grazing by herbivorous shellfishes. However, concurrently with the removal of the first phase algae by grazing of shellfishes, the second phase algae began to develop (Figs. 2 and 3). The amount of chlorophyll *a* on the plastic plates indicated that the grazers greatly reduced microalgal standing crop after their introduction. Subsequently, the chlorophyll *a* amount increased even under grazing activities (Fig. 1).

In the studies on development of sessile microvegetation in marine coastal waters, it is said that the community is characterized by stratified overstory structure and predominance of loosely attached species under favorable conditions (*e.g.* intermediate current, high light, low grazing pressure, *etc.*).[4] The removal of a loosely attached overstory is attributed by grazing activity[6,7] and the assemblage becomes a uniform layer of prostrate cells under the extreme of physical harshness.[4] Nicotri[6] reported that there was no obvious response of algal assemblages to the removal by grazing such as an increase in other diatoms. The results of the present experiment agree with those except for an increase of *Cocconeis*. This is the first report that there is a remarkable proliferation of such algae of prostrate posture as *Cocconeis* under continuous grazing pressure (Figs. 1 and 3). Nicotri[6] indicated that such diatoms with potentially tighter adhesion as *Achnanthes* spp. and *Cocconeis* spp. are less affected by grazers. Although *Cocconeis* spp. (including *C. scutellum*) and *Achnanthes* sp. have the strongest adhesive ability among sessile diatoms,[15] it is not clear why only *Cocconeis* spp. remained on the plates. The detail of proliferation process of the second phase algae under grazing pressure remains for a future study.

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