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Rearing of Prawn *Penaeus japonicus* with Reference to Ecological Succession*1

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Abstract

The present experiments were conducted to establish a rearing method of prawn with reference to ecological succession.

Special facilities were prepared to obtain the homeostasis in an experimental ecosystem during the rearing experiments. A 30 m³ concrete tank was used for rearing the prawn, *Penaeus japonicus* BATE. A 4 m³ tank was equipped with honeycomb for promoting bacterial activities. A zigzag stream unit, 20 m long was designed for the growth of macro-algae. The water was re-circulated through these tanks by a pump at the rate of once a day.

The results were compared with that of the control tank (30 m³) which was operated by the routine method without water change. Energy flow and ecological succession in the prawn hatchery are discussed in this paper.

Introduction

The rearing methods of prawn *Penaeus japonicus* BATE have been rapidly developed during the last ten years (FURUKAWA, 1972; HIRATA *et al.*, 1975; HIRATA and WADA, 1969; HUDINAGA and KITTAKA, 1966 and 1967; KUREHA and NAKANISHI, 1972). Recently, HIRATA (1975) and SHIGENO (1970) have reviewed the rearing techniques established in Japan.

Most of the techniques, however, have been based on the "drain-off" system. That is, the rearing water enriched by the faeces and uneaten foods are drained off from the hatchery tanks into the natural sea during rearing period and after harvesting the postlarvae. Consequently, the natural seawater then becomes slightly polluted.

On the other hand, many biologists worry about the water pollution by the industrial wastes. However, they do not care about the wastes from their own culture system. If we want to continue the fishery industries in a favourable

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condition forever, the marine biologists must demonstrate how to maintain homeostasis in the artificial ecosystem of their hatchery or culture systems.

The present experiments were conducted to establish a rearing method for prawn without any water pollution based on the principle of a feedback culture system (HIRATA, 1977). The rearing water in the system was re-circulated through a zigzag stream unit designed for growth of macro alga in order to purify the water.

The results obtained in the experiment might be applicable to the mass productions of fish and prawn larvae.

Materials and Methods

The prawn rearing experiments were carried out at the Marine Laboratory for Fishery Sciences of the Kagoshima University mainly in summer 1977, and additional experiment was done in the early summer 1978 to confirm the results of the previous one. Materials used in the experiments were *Penaeus japonicus* BATE obtained from the Usui Fish Market near the Laboratory.

Schematic diagrams of the experimental tanks used in the experiments are

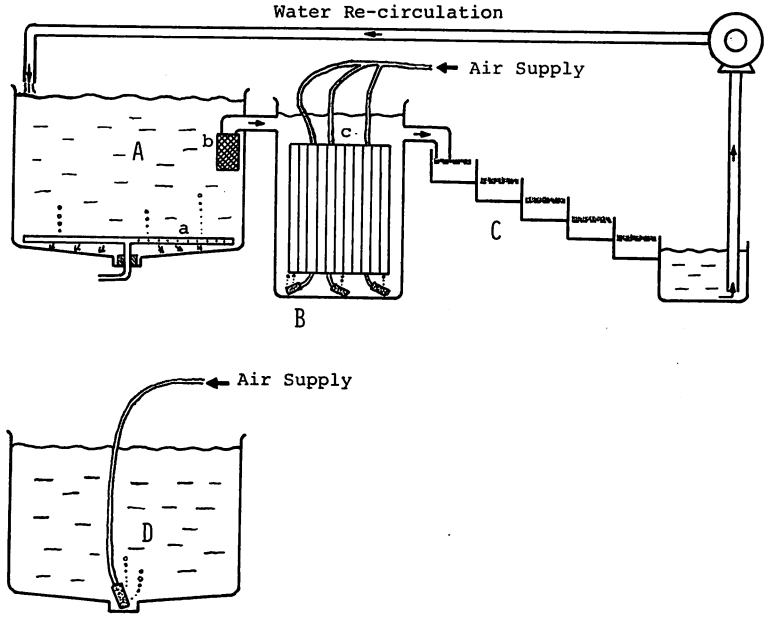

Fig. 1. Schematic diagrams of the rearing system in experimental culture and control tank.

(A); 30-t concrete tank with rotary aeration (a) and net straner (b), (B); 4-t decomposer tank with honeycomb (c), (C); zigzag stream unit covered with 16-meshes net for growth of *Enteromorpha*, and (D); 30-t concrete tank same as (A), but with routine air-stone.

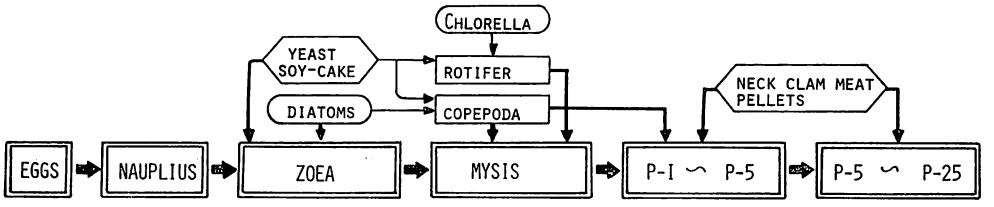

Fig. 2. Trophic organization in the experimental culture for seed production of prawn.

presented in Fig. 1. The experimental culture tank was composed of three subsystems; namely, prawn rearing tank (A), decomposer tank (B) for mineralization by bacterial organisms, and zigzag stream unit (C) for denitrification by macro-alga, *Enteromorpha intestinalis*. All the tanks were made of concrete, and sizes of tank A, B and C were 30-t, 5-t and 3-t, respectively. The water was re-circulated by a 400-W stainless pump at the rate of about once a day from tank C to A. The water flow was made by means of gravity from tank A to B, and also tank B to C. A polyethylene net strainer with 32-meshes was set at the outlet pipe in the tank A to keep larvae from leaving the tank. Later, one more siphon with the strainer was added, because the net of the former one was immediately clogged with wastes such as prawn faeces.

Aeration in the rearing tank A was accomplished by rotating arms moved by compressed air getting out from holes of 1 mm diameter and located every 20 cm on the pipe. The air was directed about 45° towards the bottom of the tank in order to impede the depositions of organic matter on the bottom, and also to maintain the pipe 5 or 10 cm from the bottom to avoid attrition. Velocity of rotation was 7.5 RPH at the beginning, and decreased to about 4.0 RPH at the end of the experiments.

Decomposer tank B was equipped with 16 mm size honeycomb (ITAMI and YOSHINORI. 1977) for bacterial attachment. Strong air was provided through air stones on the floor of the tank in order to maintain aerobic conditions for promoting mineralization.

Zigzag stream unit C was composed of 5 steps having different lengths: 1st step 8.1 m, 2nd step 8.9 m, 3rd step 9.6 m, 4th step 10.2 m and 5th step 10.7 m. Depth and width of the steps were about 0.1 m and 0.2 m, respectively. Size of storage tank connected the 5th step of the zigzag stream was $0.5 \times 0.5 \times 12.8$ m. All the steps were equipped with polyethylene nets (16-meshes) for algal fixation.

Shape and size of control tank D was same as the experimental tank A. The water was kept in stagnant condition during the experiments. The routine aeration system with large air-stone was used in tank D.

The feeding regimes illustrated in Fig. 2 were adapted from HIRATA (1975), but brine shrimp *Artemia* was not supplied during the experiments.

Results

1. Succession of Organisms in the Rearing Tanks

Ecological succession of organisms in the rearing tanks observed in both experimental culture and control tank are presented in Figs. 3 and 4, respectively.

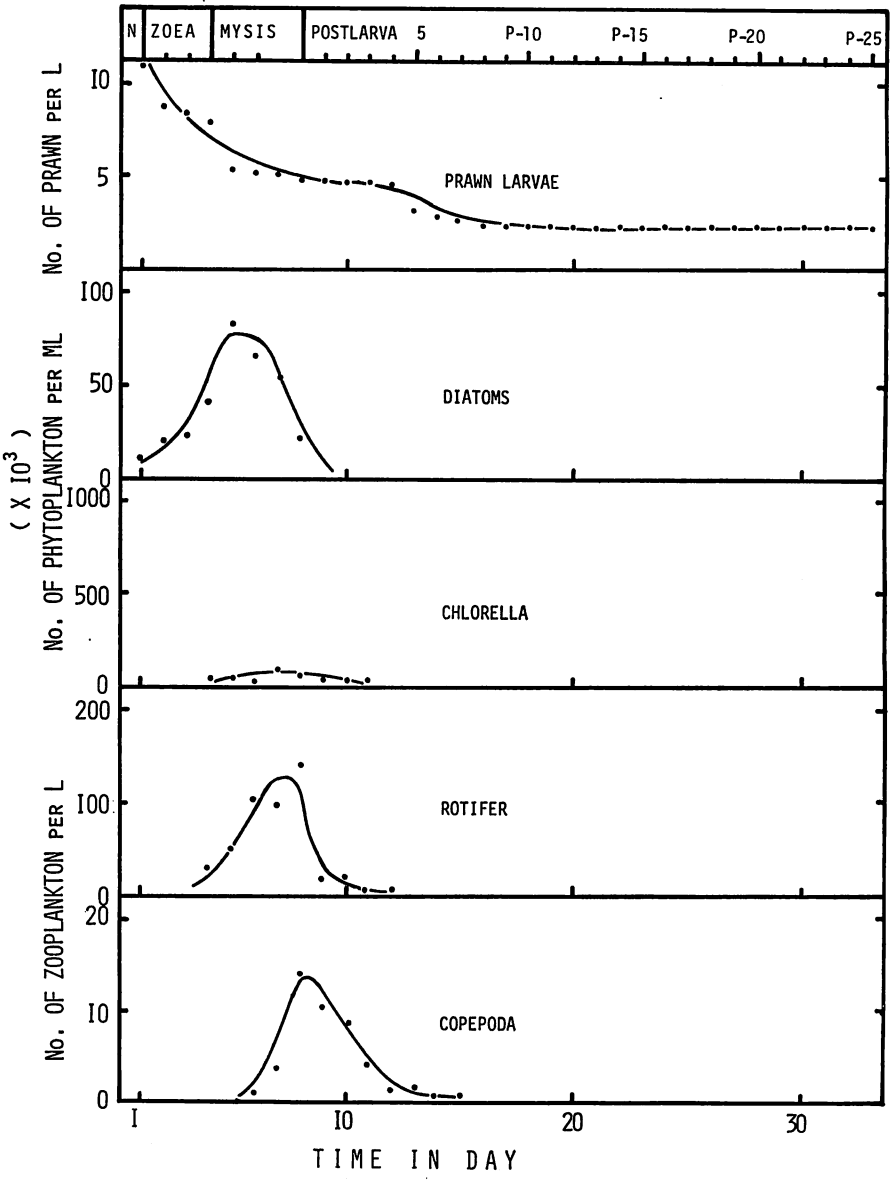

Fig. 3. Ecological succession of living organisms in experimental culture tank.

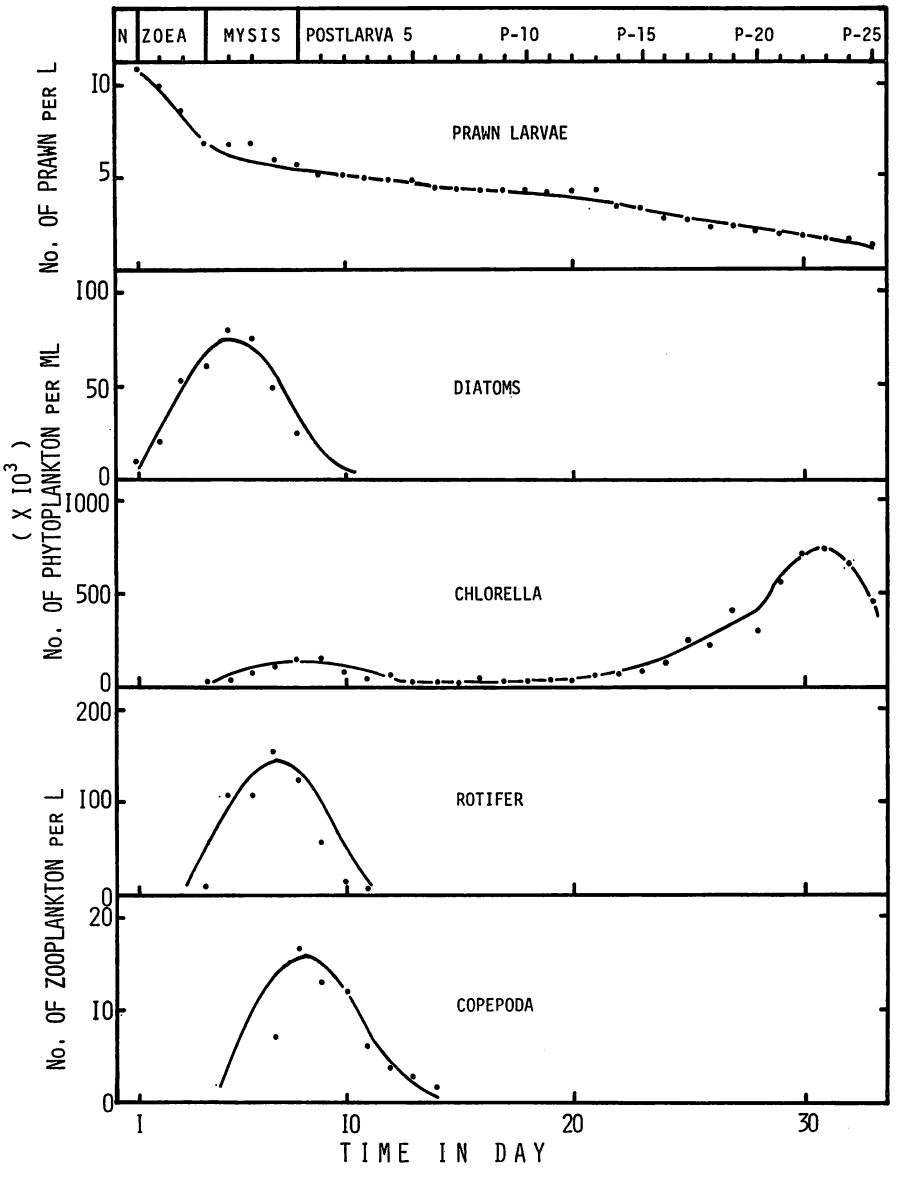

Fig. 4. Ecological succession of living organisms in control tank.

Phytoplankton such as *Chaetoceros* sp., *Nitszchia* sp. and *Chlorella* sp. grew well in the rearing tanks especially in control tank at the beginning of the experiments. Zooplankton, mainly *Brachionus plicatilis* and *Tigriopus japonicus* subordinated to the blooming of phytoplankton from the 5th day after the culture. The population density of zooplankton in control tank was slightly higher than that in the experimental culture tank. That is, the maximum density of *B. plicatilis* was 160 individuals per ml in control and 100 individuals per ml in

the experimental culture tank.

During the second part of the experimental period, all the plankton disappeared in the rearing tanks. *E. intestinalis*, then, started to bloom in the zigzag stream of the experimental culture system. On the contrary, the *Chlorella* grew up again from the 20th day after culture and showed the highest density, 750× 10^3 cells per ml, during the last period of culture.

2. Survival, Growth, and Food Conversion of the Prawn Larvae

The survival, growth and food conversion rates of the prawn larvae cultured in each tank are presented in Table 2 and Figs. 5 and 6.

The results of survival and growth rates were divided into two parts at P-10* old: the first half period until the 18th day of culture (=P-10) and the last half period.

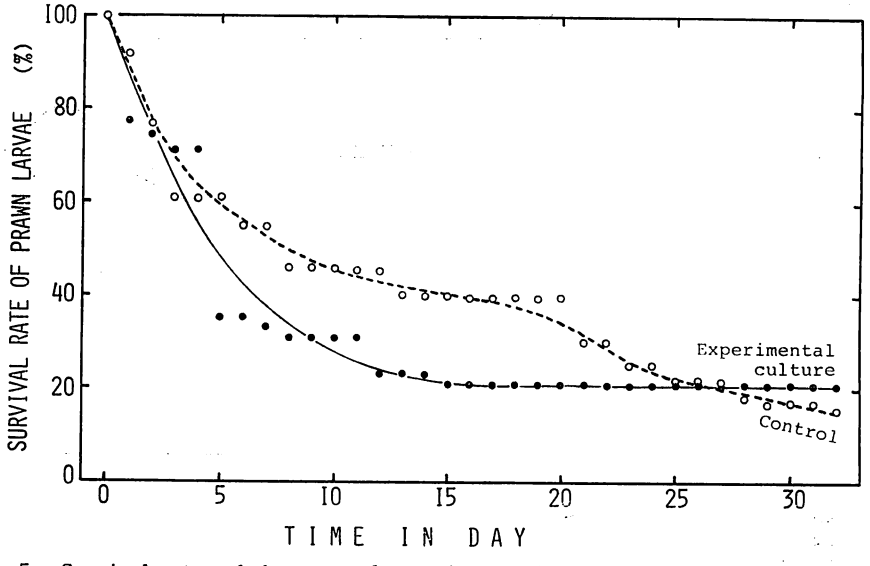

Fig. 5. Survival rates of the prawn larvae in experimental culture and control tank.

During the first half period, the growth rates of the larvae in the experimental culture and control were 0.23 mm/day and 0.37 mm/day, respectively. However, such tendency was entirely reversed during the last half period. That is, the growth rates in former tank was 0.50 mm/day which is extremely faster than that of latter which was calculated to be 0.13 mm/day. Average body lengths of the larvae at the end of experiment were 12.5 mm in the experimental culture and 9.0 mm in control tank.

Survival rate in the former tank decreased suddenly to about 20% during the first half period. Thereafter, a stable survival rate was observed until the end of the experiments. On the contrary, the relative higher survival rate, about

* Nnmber of days after metamorphosis to postlarva (MIYAMURA, 1965).

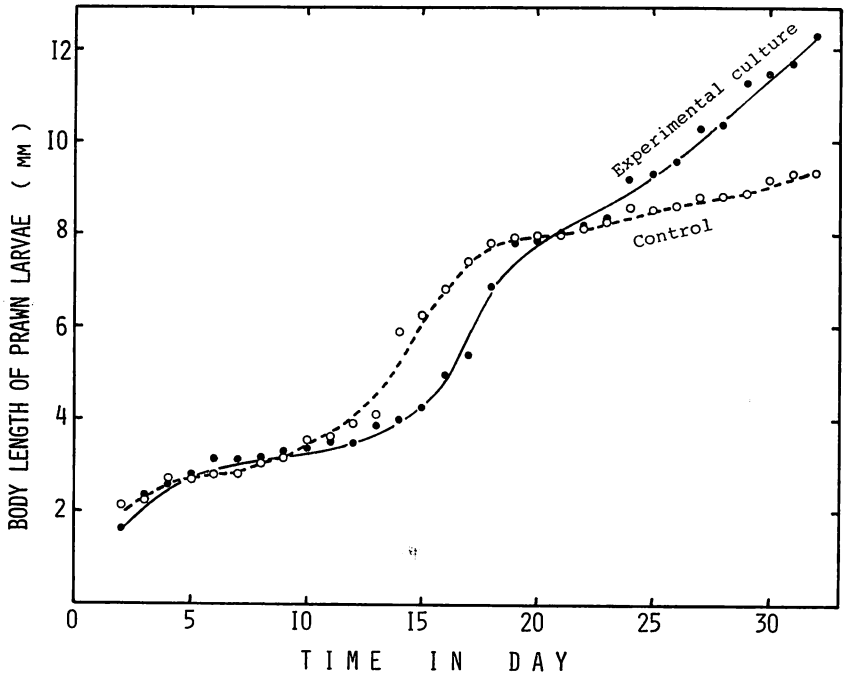

Fig. 6. Growth of the prawn larvae in experimental culture and control tank.

40% was kept in control tank until the P-12 old, but the rate decreased gradually from 40 to 16% through the last half period. The final survival rates in the former and latter tanks were estimated to be 20.4% and 16.1%, respectively.

The food conversion rates are calculated by following formulas:

$$\text{Apparent food conversion rate (A. F. C.)} = \frac{(\text{animals harvested}) \times 100}{\text{total foods supplied}}$$

$$\text{Total food conversion rate (T. F. C.)} = \frac{(\text{animals harvested} + \text{algae produced}) \times 100}{\text{total foods supplied}}$$

The apparent food conversion rates were 8.5% in the experimental culture and 5.1% in control tank. Amount of algae *E. intestinalis* harvested were 8300 g from the zigzag stream in the experimental culture system and 162.3 g of marine *Chlorella* in the latter one. Therefore, a great difference in the total food conversion (T. F. C.) was found. When the amounts of algae were included, the T. F. C. rates were 65.1% in the former and 6.9% in the latter one. The results are summarized in the Table 1.

Average dissolved oxygen content in both tanks were about same, namely 0.39 mg-at/l in the former and 0.41 mg-at/l in the latter one.

Table 1. Survival, growth, apparent food conversion (A. F. C.) and total food conversion (T. F. C.) in the experimental culture and control tank.

	Survival N-P26 (%)	Growth daily (μ/day)	Growth final (mg)	Food supplied (g)	Larvae harvested (g)	Algae produced (g)	AFC (%)	TFC (%)
Exp. culture	20.4	345	18.0	14500	1143	8300*	8.5	65.1
Control	16.1	243	8.8	9050	462	162**	5.1	6.9

* *Enteromorpha* removed from the zigzag stream.
** *Chlorella* discharged finally into the sea. The amount was estimated by population density in the control tank.

The highest value of pH was 9.5 which was found in zigzag stream at around noon time, but lower values were observed at night time. Average pH value in the experimental culture was 8.26, and it was 8.26 in control tank too on average.

The organic phosphates were 0.03 (0.01 to 0.06) μg-at/l in the former culture and 0.05 (0.02 to 0.09) μg-at/l in latter one.

Discussion

It is well known that the prawn *P. japonicus* changes feeding habit according to the larval stages; namely, herbivorous in zoeal stage, omnivorous in mysis stage, and carnivorous in postlarval stage (HUDINAGA and MIYAMURA, 1962).

In the present experiments, the succession of living organisms in the rearing tanks were nearly synchronized to the development of larval feeding habits. That is, when the larvae developed to zoeal stage, phytoplankton such as *Chaetoceros* and *Chlorella* were propagated in the tanks through zoeal stage. When the larvae developed to mysis stage, phytoplankton and zooplankton were simultaneously propagated in the tanks. Thereafter, population of phytoplankton decreased gradually, and then, the larvae developed to postlarval stage and consumed the zooplankton.

All the zooplankton, however, were consumed by the postlarvae at around P-5 old. The larvae were fed frozen clam meat and artificial diet, thereafter.

During the last half period of the experiments in control tank, *Chlorella* bloomed again, but zooplankton such as *B. plicatilis* or *T. japonicus* were not propagated anymore. It might be considered that rotifers and copepods were eaten by the postlarvae.

About 30-t of rearing water enriched with excess nutrients and *Chlorella* cells, faeces, particles like detritus in the control tank were discharged directly into the natural sea near the Laboratory. The amount of *Chlorella* cells drained off were estimated to be about 162 g in wet weight, but the cells were too few to be harvested from the water. The natural sea water was, slightly polluted by the wastes of the prawn seed production.

On the contrary, all the excess nutrients in the experimental culture system were removed by transforming them into macro-alga *E. intestinalis*. About 8300 g of *E. intestinalis* were harvested in the zigzag stream of the experimental culture system. Therefore, the natural seawater was not polluted.

Studies to improve the efficiency of the feeback cultre system for seed production are still being carried on at the Marine Laboratory for Fishery Sciences of Kagoshima University. We hope that more efficient and simpler methods could be devised for practical use in the near future.

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