水工研技報
水産土木3 1982
pp. 15~25

Structure of Kuruma Shrimp Culture Pond

Toshifumi NOMA*

Contents

1. Briefing of shrimp culture in Japan

In Japan, people appreciate sea foods, especially live and fresh fishes. They prefer sea bream, lobster, shrimp etc, so the rearing of these species had been expected. The culture of Kuruma shrimp (*Penaeus japonicus*) was initiated at Amakusa, Kumamoto Pref. in 1902[1]. Today the shrimps are cultured in the warm district of South-West Japan and its yearly production has been increasing, in 1979 the production is about 1,500 ton[2].

The flourish of the shrimp culture might owe to the late Dr. Hudinaga and his successors, and also to shrimp culturists, it should be added that the technique of mass production of shrimp seed is established.

The original shrimp culture was performed in net enclosure pond[3] (enclosed by bamboo net) with 100 m² surface area, and shrimp culture of this type had expanded in Amakusa district.

This type used to be damaged by storm surge, as a countermeaure, the base of the pole that sustained the net, was strengthened by stones or concrete. Neverthless, with a little amelioration it was still damaged by storm surges, it happened that the culture pond was dug in a salt pan. And even an embankment was tried for the shrimp culture.

The embankment could not keep dominant type of the culture, for it had problems of high mortality of shrimps by shortage of water exchange and to be expensive of its construction. So the semi-embankment type was designed in about 1920. This type, combination of net enclosure and submerged dyke has such characters as :

a less expensive compared with full embankment,
b larger water exchange rate,
c. smaller wave force acting on the poles.

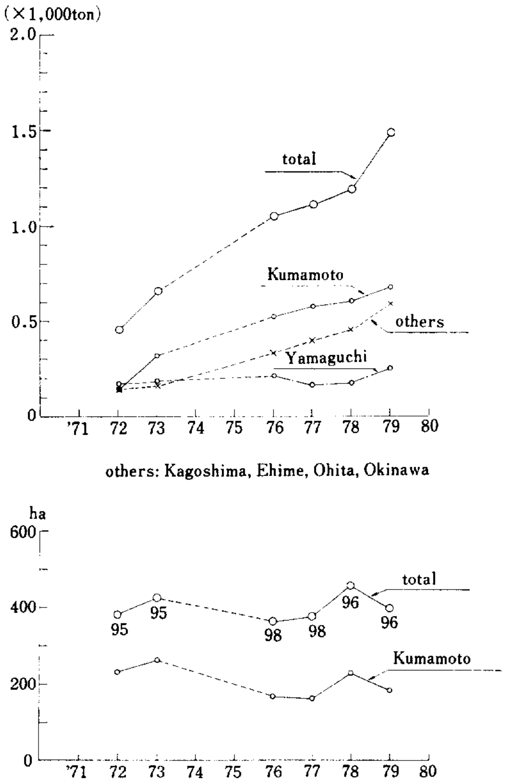
Today the semi-embankment type is dominant in Amakusa.

Thus, shrimp culture ponds can be classified as

a semi-embankment type,
b embankment type, which are converted from obsolete salt pan or kantakued paddy field,
c inland pond (shrimp culture tank),

---

* Hydraulics on Aquaculture lab.



The figures attached to total line are the percentages of embankment type pond

Fig. 1 Yearly change of Kuruma shrimp culture

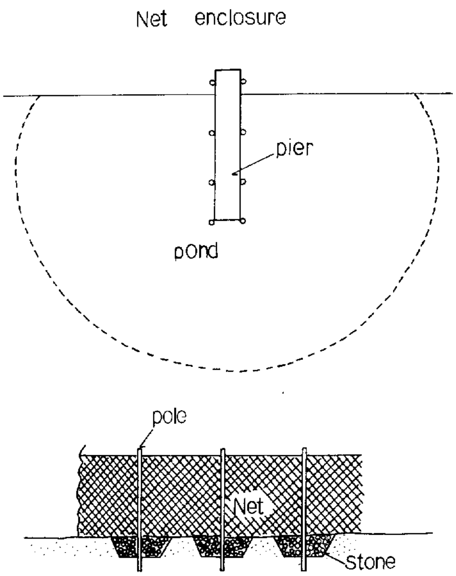


Fig. 2 Net enclosure

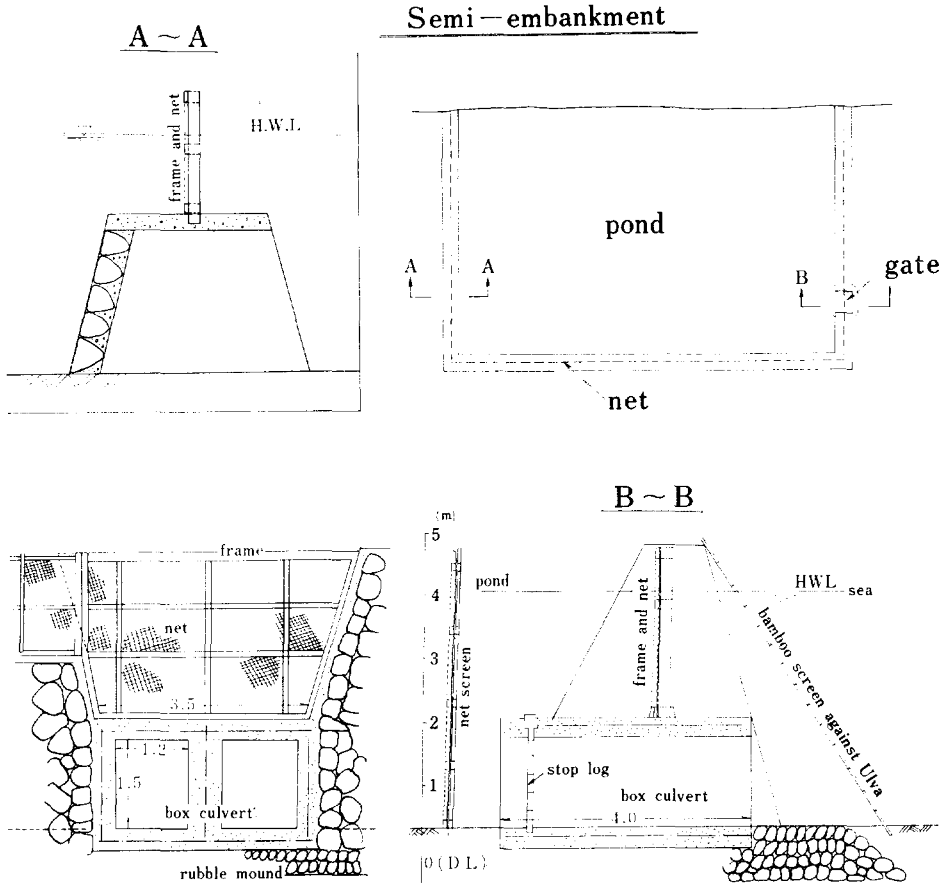


Fig. 3 Semi-embankment

d others.

The former two utilize the tidal energy for water inter- and ex-change. The third uses mechanical pump.

Fig. 4. shows the relation between the yield and surface area of the pond, in Amakusa in 1970[3]. It tells us the yield varies from pond to pond, and its yields were from 100 to 300 gr/m^2 in that time. After that time, the yield in the district has gradually increased, as shown in Table 1, and per unit area production has reached 400 gr/m^2.

Per unit area production of each types are shown in Table 2. Tank culture is highest. This difference is attributed to the pond management.

2. Items to be considered

Now concerning to the planning the shrimp culture pond, there are so many items to be considered[4][5].

a natural conditions such as ; climate, topography, tide, risk of storm surge etc,

b socio-economical conditions.

Pond is also designed so as to fit for the demands of the shrimp, and to facilitate the pond

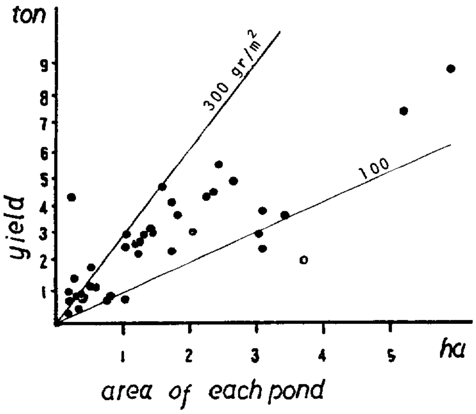


Fig. 4 Yields and areas of pond
Amakusa (1970)

Table 1 Types of the Pond and yield (gr/m²)

Semi-embankment	Embankment	Tank Culture
400	400	2,500

Table 2 Yearly Change of Production of Amakusa dist.

1974	510 (ton)	
1975	513	
1976	517	
1977	573	
1978	596	159.5 ha (374 gr/m²)

Table 3 Management Works

Preparatory works
- oxidation of sand bed
- (chemical sterilization in Tank culture)
- substitution of bed materials
- repairment of facilities
- predator control
- water curing

Works in rearing period (include the pre-stocking rearing)
- feeding
- water quality control
- ulva (*Ulva lactuca*) control
- predator control

Harvest
- (with pound net or dragnet with electric shocker)

management. The animal's demands are ;

food, living space, DO, adequate water temperature, clean and soft sand bed permissible to easy burrowing.

The pond management works can be listed up like as shown in Table 3.

Before the shrimp fry is introduced into the pond, the substrate is ploughed repeatedly for the purpose of oxidation of the bed materials, the deteriorated sand may be substituted, and the predator fishes are eliminated. The facilities are repaired, and on occasions, sand will be supplemented. For the works, the pond is desired to be dried up.

In embankment type, about ten days before the fry introduction water is let into the pond, and water is controled so as to let propagate the diatoms in adequate density.

In April and May, the shrimp fry is introduced into the pond, this period is also the spawning season of the predator fishes, sea bream (*Pagrus major* and *Acanthopagrus schlegelii*) and gobby (*Tridnetiger obscurus*). The eggs of the predator fish, 0.8 mm in diameter, intrude into the pond through the net screen.

After hatching out, the juvenile of predator grows more quickly than shrimp fry. When the juveniles become bigger than the fry, they start to devour the latter. On occasion, to prevent the egg intrusion, the net screen with fine mesh even smaller than the egg's diameter is adopted.

The penetration of the noxious ulva (*Ulva*), its subsequent decomposition seriously deteriorated both water and bottom soil, is in some part, inevitable.

Because of predation plus ulva, the shrimp culture in the same pond is expected to be as short as possible. This is the reason why the pre-stocking rearing, i.e. nursery pond is adopted. The nursery pond occupies 10~20% of whole pond area, is made so as to be easily managed.

Now a day, swarming of ulva is checked by inducing and keeping a bloom of unicellular planktonic algae such as diatoms. Sometime ulva may happen to be scooped out or eliminated by chemicals (RADA).

The shrimp pond is managed with the above mentioned works, so the fundamental requirements and engineering items for a shrimp culture pond are as shown in Table 4.

Table 4 Fundamental Requirements for a Shrimp Culture Pond

requirement	Engineering item
to hold the animals	enclosure, sand bed
to have high rate of sea water exchange, also ability of flushing out of organic matters	flow velocity
to be able to keep adequate water depth	gate and submerged dyke
to be prevented from the predator fish	screen net
another	access for bulldozer into the pond etc.

The type of enclosure is generally determined by the importance of disaster prevention, in Japan. If there can be a storm surge, the embankment type shall be adopted. The embankment may, however, cause deformation of shoreline, erosion or sand accumulation, so the attention is needed for its adoption.

The water depth can be kept about 1 m in summar season. The bottom elevation is M. L. W. L. (mean low water level) and M. S. L., for tank culture. The minimum thickness of sand bed is 10cm.

The dimension of water gates is determined from the exchange flow rate needed and ability of flushing out the drift sand around the water gate[6]. Concerning the latter, the maximum flow velocity greater than 0.4 m/s is adopted in Himeshima.

Net screen consists of net fence for drifting matters and fine net against predator fish. Fine net of 2 mm mesh is adopted for nursery pond, and 3 mm for culture pond.

3. Water quality control

So as to culture soundly the shrimp, the water quality should be properly kept. The dissolved substances concerning to the water quality are, DO, organic matters(metabolite and food residue), NH_4, H_2S etc. Concerning DO, it was well known that DO should be kept more than 6 ppm.

$$\begin{aligned} &\text{DO} > 6\,\text{ppm} \\ &NH_4 < 0.1\,\text{ppm} \\ &\text{W. T.} < 30^\circ\text{C} \end{aligned}$$

The water quality control method is essentially a promotion of the water exchange rate. For DO control, however aeration with mechanical power is apt to be adopted. For hydrogen sulfide control, ion-oxide can be dispersed into the pond.

If the density of phytoplanktons is properly kept, DO is supplied by them, so DO is controlled by the density of the planktons, in this case, the water exchange rate is determined by coloration of pond water.

In tank culture, it was revealed that, in addition to the water exchange rate, flow velocity is important. The adequate velocity is 7～15 cm/s. Less than 7, the organic matter can not be flushed out, beyond 15, bed sand is moved.

So as to increase the water exchange rate, shallow water is expected, neverthless, shallow water is apt to be changed quickly its water qualities by a heavy rain, or high atmospheric temperature in summer season. So water depth should be properly kept.

The water exchange flow rate should be determined so as to keep the concentrations of the dissolved substances in adequate or allowable levels.

For the semi-embankment or embankment type, supposing thorough mixing in the pond, the concentration of dissolved substance, M, changes

$$V\frac{dM}{dt}=q(M_e-M)+\lambda \quad \cdots\cdots(1)$$

where, V : water volume of the pond, q : effective exchange flow rate/tidal period*), M_e : concentration in outer sea, λ : supply rate of the substance and t : time.

Eq. (1) becomes

$$M=\left\{M_0-\left(M_e+\frac{\lambda}{q}\right)\right\}e^{-\frac{q}{V}t}+\left(M_e+\frac{\lambda}{q}\right) \quad \cdots\cdots(2)$$

$$M_{t=\infty}=M_e+\frac{\lambda}{q}$$

Fig. 5 shows the Eq. (2). At infinite time M becomes $M_e+\frac{q}{\lambda}$, if there is no pollution or supply,

---

*) q is not interchange flow rate, that is expressed by

$$q=\zeta\cdot S$$

where, ζ : tidal range, S : surface area of the pond.

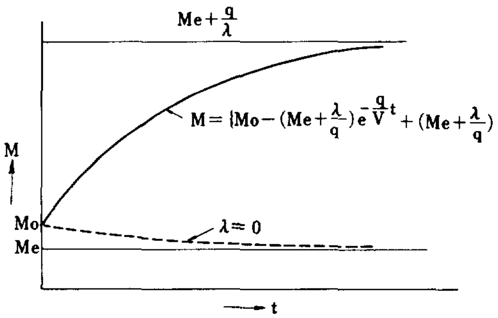


Fig. 5 Change of Dissolved Substance

M becomes M_e like dotted line.

DO change

Supposing there is no O_2 supply by phytoplankton, DO change can be expressed by Eq. (3),

$$V\frac{dc}{dt}=K(c_s-c)+q(c_e+c)-\beta \quad \cdots\cdots(3)$$

where, c : DO, c_s : saturation concentration of DO, β : O_2 consumption rate, K : coefficient of O_2 supply.

$$K=K_2+K_s$$

K_2 : reaeration coefficient by flow velocity, in case of Air Bubble Curtain (A. B. C.)

$$K_2=\frac{2}{\sigma L}\sqrt{\frac{D_m u_m}{h_f^3}}(1-e^{-\frac{\sigma L}{2}}) \quad \cdots\cdots(4)$$

where, D_m : molecular diffusion coefficient of O_2 into water, u_m : maximum velocity by A. B. C., h_f : frictional depth, σ : coefficient of flow velocity attenuation$\left(\sigma=\frac{f}{H_f(1-2H_f)^2}\cdot\frac{1}{h}\right)$, L : length of pond perpendicular to flow and K_s : coefficient of O_2 dissolution from bubbles.

Integrating Eq. (3), with $c=c_0$ at $t=0$,

$$c=\left\{c_0-\frac{Kc_s+qc_e-\beta}{K+q}\right\}e^{-\frac{K+q}{V}t}+\frac{Kc_s+qc_e-\beta}{K+q} \quad \cdots\cdots(5)$$

We can estimate the DO, at $t=t$ by Eq. (5),

$$c_{t=\infty}=\frac{Kc_s+qc_e-\beta}{K+q} \quad \cdots\cdots(5)'$$

In this case also, at $t=\infty$ DO can be given by Eq. (5)'

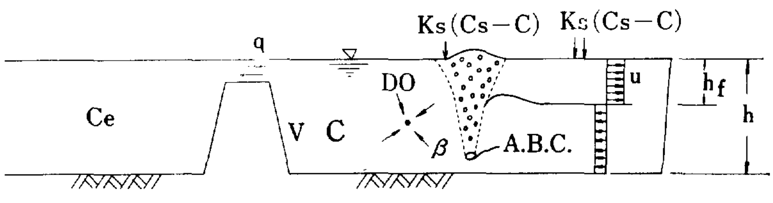


Fig. 6 Definition sketch of aeration by A. B. C.

Determination of flow rate

Concerning to the dissolved substance, M, the concentration at infinite time, $M_{t=\infty}$, should be the allowable one. When we know λ, the exchange flow rate can be given by

$$q=\frac{M_a-M_e}{\lambda} \quad \cdots\cdots(6)$$

$(M_a=M_{t=\infty})$

In the same manner, for DO,

$$q=\frac{\beta-K(c_s-c_a)}{c_e-c_a} \quad \cdots\cdots(7)$$

$(c_a=c_{t=\infty})$

Inversely, when q is given by the tidal condition, for example, we can calculate the required rate of O_2 supply, K, by

$$K=\frac{\beta-q(c_e-c_a)}{c_s-c_a}$$

Methods[7)]

When we start to consider the exchange flow rate with mathematical model, there is the supposition of thorough mixing in the pond, so there should not be a stagnation of flow in the pond. One of the countermeasures for such stagnation is gate operation, tidal current control with training dyke will be another.

The training dyke, as shown in Fig. 8, being located in reciprocal tidal currents, can control flows with "be easy to" downward, and "be difficult to" upward flow in the figure.

The coefficients of discharge of the inlet which is constructed with training dyke are changed by flow condition, it induces the tidal residual flow in a reciprocal flow.

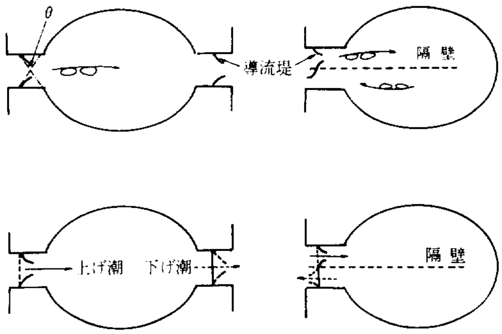


Fig. 7 Tidal current control by training dyke

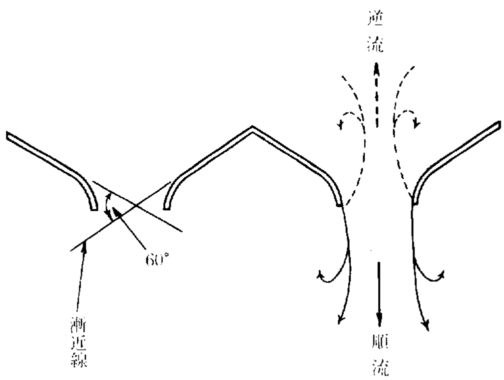


Fig. 8 Configuration of training dyke

4. Examples

Embankment type : Himeshima Shrimp Culture Ponds

Fig. 9 shows a empankment type culture pond, Plan view of Himeshima Shrimp Culture Pond,

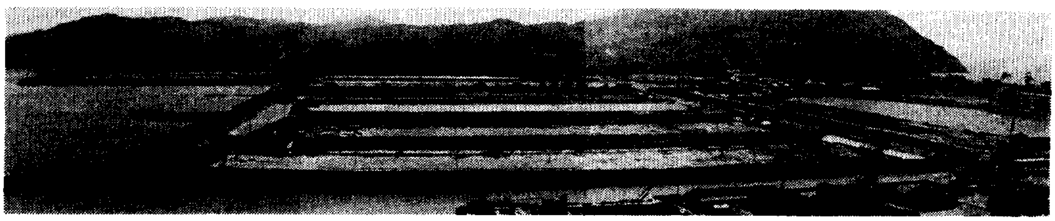


Photo. A View of Himeshima Shrimp Culture Pond

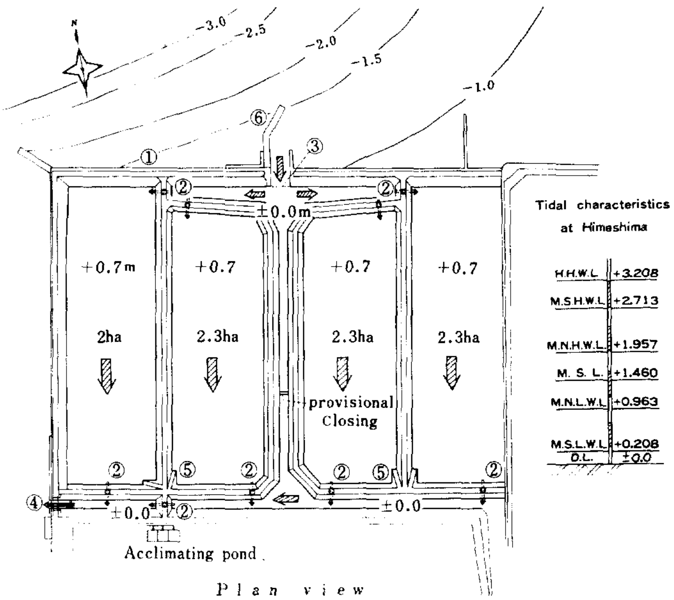


Fig. 9 Plan View of Himeshima Shrimp Culture Pond (converted from Kantakued land)

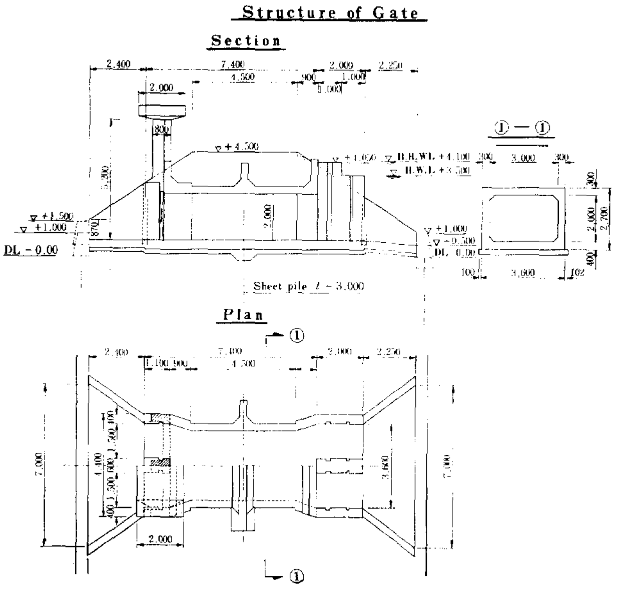
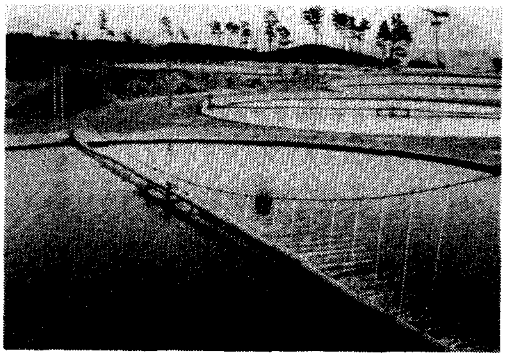


Fig. 10 Structure of gate

converted from kantakued paddy field. There are 4 ponds, each has from 2 to 2.3 ha surface area, has 2 gates. With gate operation, when the tide is arising, upper side gates in the figure are opened so as to let the water into the pond, and when the tide is falling, the lower gates are opened. Thus the pond water flows almost one way. The figures, +0.0, +0.7 etc indicate the bottom elevation, each pond can be drained up at mean spring low water level. The accesses are for working machines, such as plough and cultivator.

Fig. 10 shows the structure of gate. In the figure left side is pond, and the fine mesh net screen, 0.6 mm mesh, smaller than egg size of predator fishes, is set in this portion. It has to be well brushed in ebb of spring tide.

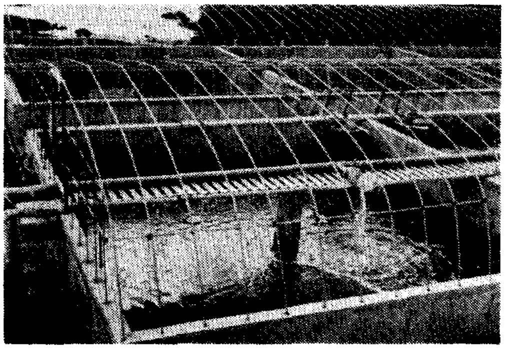
Shrimp culture tank : Mitsui-Nohrin Inc.



View of the tanks
1,000m^2×13　2,000m^2×1

Rearing tank in preparation
In about a week seed will be released

Doubble bottomed tank structure
with synthtic hurdles



Hatchery tank
8×100m^3(7.2×7.0×2.0)

Acknowledgement

Many people have helped in various ways during the preparation of this paper. I am grateful to Mr. NAKAMURA, Kumamoto Pref. Fish. Exp. St. and to Mr. FUJITA, Tarumizu Aquaculture Center of Kagoshima Pref. Fish. Exp. St. who sent me reprints and references.

I am indebted to Mitsui-Nohrin Co. and Himeshima Kuruma Shrimp Culture Co. who have permitted the reproduction of their photographs and figures.

References

1) HOMMA A. : Aquiculture in Japan, Japan FAO Association, 1971.
2) Fisheries Agency : Annual of Statistics on Fisheries and Aquacultural Production.
3) YAMAMOTO K. et al. : Kuruma Shrimp Culture in Kumamoto, Documentation of Kumamoto Pref. Fish. Exp. Sta., 1972.
4) KURATA H. and K. SHIGUENO : Recent Progress in the Farming of Penaeid Shrimp, FAO Technical Conference on Aquaculture, 1976.
5) SHIGUENO K. : On Kuruma Shrimp Culture Technique, 1969.
6) Gyoko-Senkai Kaihatsu Consultant Co. : Consultant Report on the Planning of Himeshima Shrimp Culture Pond, 1976.
7) NAKAMURA M., S. HAGINO and T. NOMA : A Proposal of Pollution Control by Training Dike, UMI to SORA, Vol. 50, 1975.

クルマエビ養殖池の構造

乃 万 俊 文*

摘　　要

この報文は1980年6月京都国際会館で開催されたUJNR（日米天然資源協力プログラム）水産増殖部門会議に発表したものである。

クルマエビ養殖における管理作業等を水産土木の立場から整理して養殖池として考慮すべき項目にふれ，また水質保全のため必要な事項についてもふれた。

* 漁場水理研究室