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Qualité des eaux et production dans des bassins équipés de serres en utilisant de l'eau chauffée

Water quality and eel production in Japanese greenhouse ponds using heated water

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1. INTRODUCTION

The annual production of cultivated eels in Japan has increased in recent years, reaching 37,000 t in 1979. The Tokai district located in the central part of Japan has been the main eel producing area over extended periods. Since 1965, however, areas on the main Islands Shikoku and Kyushu (South and Southwest Japan), have gained importance in eel culture, leading to an increased demand for glass eels. Despite the high demand the catch of glass eels has gradually decreased in consecutive years and has become more difficult to satisfy the growing demand. Glass eels are mainly caught between December and March along the Pacific coast of middle and southern Japan. Glass eels caught along the coast are transferred to nursery units were they are trained to feed on a commercial diet. Many fish farmers have experienced high mortalities in glass eel ponds when stocked during the coldest season (January and February). In contrast, stocking the ponds during March and April resulted in comparatively low mortality rates. It was generally believed that the average survival figure of about 50% obtained under the commonly used culture conditions in nursery ponds could be substantially improved by adopting new culture strategies. Increasing the survival rate for glass eels seems to offer the most rational way to meet the high demand for elvers of the appropriate stocking size requested by most farmers for their grow-out units.

Fish farmers generally believed, that the high mortality rates observed in their culture units were related to the drastic decrease in water temperature connected to sudden cool and windy weather situations which occur repeatedly during a short period of time during the winter. Trials to reduce the mortality rate concentrated on introducing temperature control measures through electrical heating. These trials started already around 1968. The temperature was usually maintained above 9°C. However, in contrast to their expectations the farmers obtained no satisfying overall results when employing this strategy during winter months. Therefore, many farmers decided to change their method by growing glass eels under optimum water temperature conditions from the beginning of their active feeding. The optimum temperature for glass eels appears to be between 25 and 28 °C. Growth is substantially accelerated at these temperatures. In order to cope with the heat loss during the cold weather season, such heated ponds were protected by placing them in a greenhouse. This, in fact, was the origin of the new technology employed for eel culture in Japan, and is nowadays well accepted.

2. PRINCIPLES OF GREEN-HOUSE EEL CULTURE IN JAPAN.

The strategy employed in greenhouse eel farming is schematically outlined in Figure 1. Glass eels are stocked into the first nursery pond from December to April. The ponds cover an area of about 10 to 50 m^2. Water depth usually ranges between 0.4 to 0.7 m and water temperature is maintained between 25 and 28°C. Systems for aeration and water circulation are usually installed in the ponds using the well known water wheels. For the primary nursery ponds aeration through airstones using low pressure blowers is also employed. The initial stocking density with glass eels ranges between 150 and 500 g/m^2. Glass eels are initially fed with Tubifex. Thereafter, they are gradually adapted to commercial feeds. This step by step adaptation is reached within a five to ten day period after stocking.
Size selection is first made 20 to 25 days after stocking. The fast growing, bigger fish are selected and transferred to the second nursery pond. Size selection is repeated at intervals of 15 to 25 days in each of the ponds and bigger eels are always transferred every time to the next pond: i.e. transfers are made from first to second and second to third pond each time. Thus, stocking density varies in each of the ponds after sorting. Records are kept so that the overall

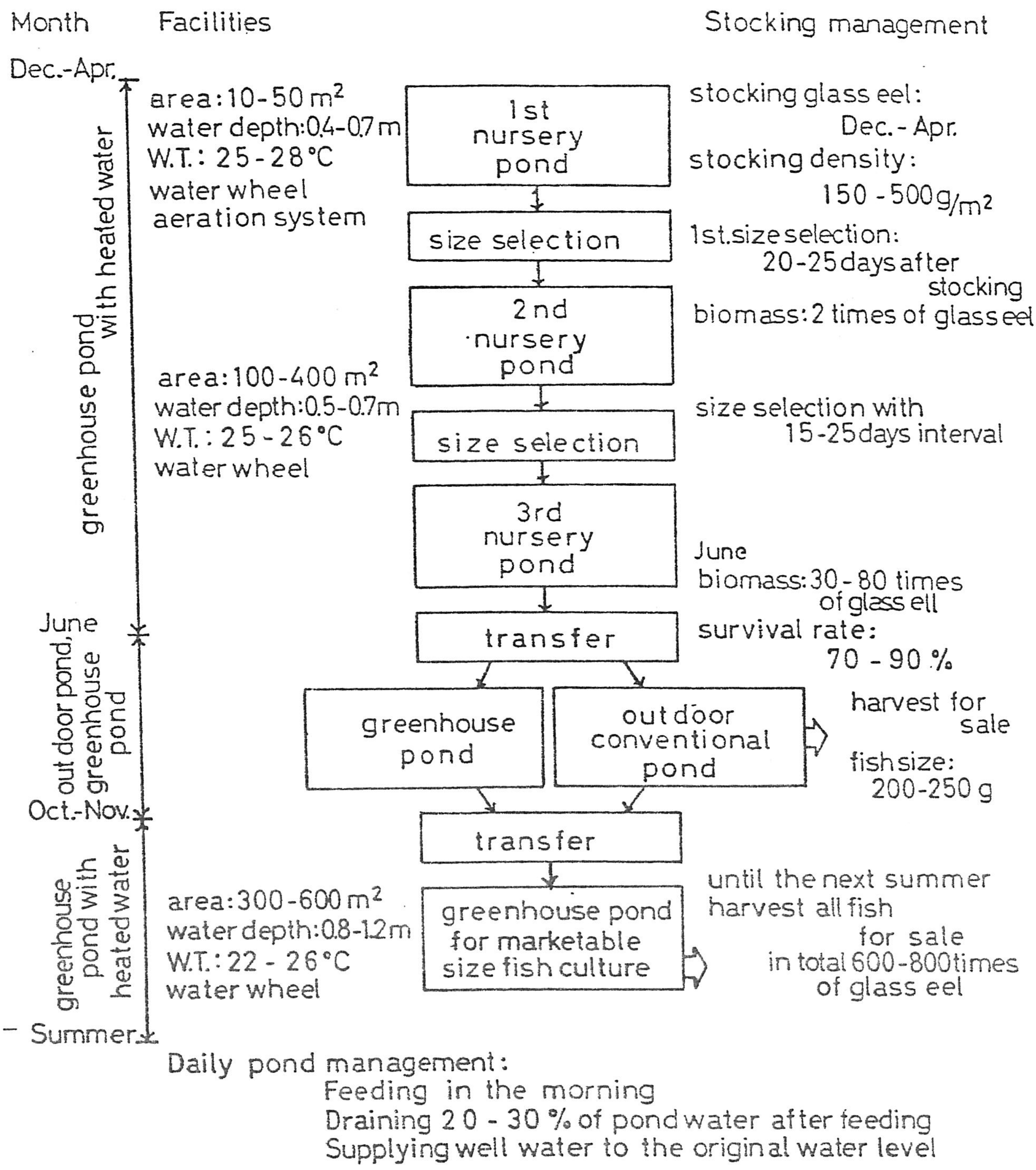

Fig 1 . Schematic explanation of greenhouse eel culture biomass stocked in each pond can be recalculated. The second and third pond usually covers an area of 100 to 400 m^2, with a water depth of about 0.7 m. Water temperature is kept at 25 to 26°C.

Water wheels are placed at the pond surface at several locations and a drainage system is installed at the center of the pond. Daily operational procedures require about 20 to 32% of the pond volume to be drained through the central drainage system. After draining the pond, well water is supplied as make-up water until the original level is reached. Usually, water temperature in outdoor ponds rises above 20 °C in June and stays above this value until the end of the summer season. Therefore, from June onwards eels are transferred from the heated greenhouse ponds to outdoor facilities. Several farmers also use greenhouse ponds during the summer season for grow-out when glass eels are plentiful and space must be utilized without heating to accomodate the available stock. Generally, glass eel rearing in greenhouses results in an increase of biomass until the time of transfer to the outdoor ponds, that is about 30 to 80 times higher than the initial stocking. It is believed by fish farmers that the survival rate for eels raised under the modern warmwater indoor technique has been improved dramatically this reaching 70 to 90%. The outdoor ponds are usually very large. The area covered ranges between 1000 m^2 and 6000 m^2, at a water depth of about 1 m. Usually only one or two water wheels are installed in such large ponds. Using the repeated sorting procedure the fastest growing fish are ready for sale in summer at a weight of approximately 200 - 250 g, provided the initial stocking of the system with glass eels started in December of the previous year, or at latest in January. Smaller eels maintained in outdoor ponds are transferred to the larger ponds in a greenhouse between October to November. These ponds have been used for production of market sized eel (pond area: 300 to 600 m^2). From December onward the pond water is heated to continue the grow-out farming. Harvesting is undertaken several times a year, depending on the market demand (multiple cropping). All fish will have reached market size by the following summer.

3. GENERAL SURVEY ON THE PERFORMANCE OF EEL PONDS

Although the eel culture in greenhouse ponds has recently become very popular in Japan, only a very few scientific reports on system performance are available.
This study summarizes several investigations undertaken by the author between June 1977 and November 1978 (Chiba, 1980a). They are concerned with farms operating in two regions within the Aichi Prefecture. This Prefecture is located on the Pacific coast in the central part of Japan. It is one of the main eel producing areas, which is known for its long tradition in eel farming.

3.1 Location of fish farms surveyed and methods used

Four ponds from three fish farms in Jinnoshinden-cho, and 7 ponds from three fish farms in Atsumi-cho were chosen as study sites for the purpose of this investigation. The location is depicted in Figure 2. The Jinnoshinden-cho area is a reclaimed land adjacent to the seashore. The wells used as water supplies are usually between 63 to 130 m deep. The conductivity of well water is high and the water is slightly salty. Accordingly, the concentrations of Cl^-, Ca^{++}, Mg^{++} and SO_4^{--} are relatively high. In contrast, the wells at the sites in Atsumi-cho are only 2 to 6 m deep. Well water is low in salt content and low in conductivity as well. At intervals of about 20 days water samples were taken from selected ponds and from wells and various water quality parameters were analysed. Data on culture facilities and conditions at farm sites and on farming results were obtained through direct repeated interviews of the fish farmers.
Water quality criteria determined were:
(1) water temperature (mercury thermometer),
(2) pH-values (colorimetric method),
(3) dissolved oxygen content (Winkler method, NaN_3-modified method),
(4) total ammonia-nitrogen (Indophenol method)

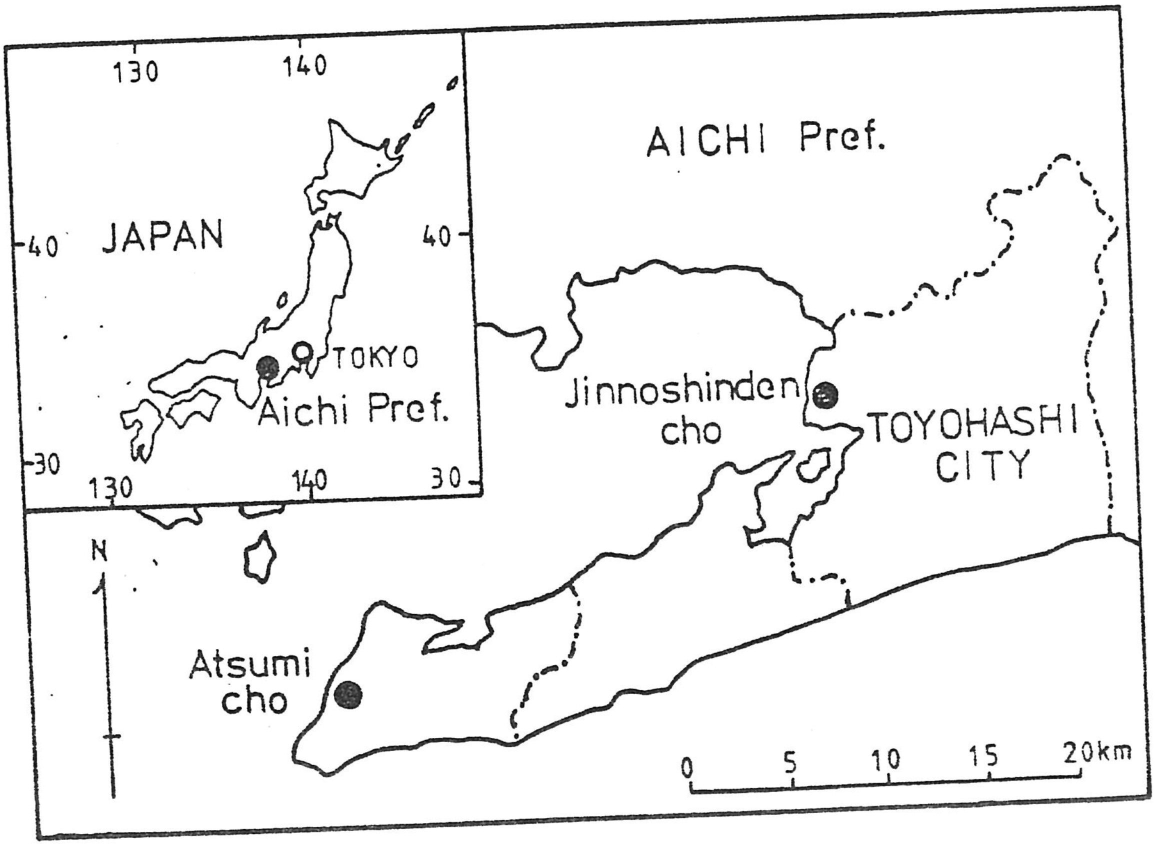

Fig. 2. Location of fish farms within the area of investigation (insert).

(5) nitrite-nitrogen (G.R. reagent method),
(6) nitrate-nitrogen (ion sensitive electrode),
(7) alkalinity (BCP alkalinity),
(8) phosphorous (Deniges-Atkins method),
(9) COD (alkali digestion method),
(10) Ca^{++} and Mg^{++} (EDTA titration method),
(11) Sulfate (nephelometry),
(12) Cl^{-} (Mohr method),
(13) Sodium- and Potassium concentration (atomic absorption spectrometry).

3.2 Results

3.2.1 Water Quality

The results on water quality obtained through regular sampling of well and pond water are summarized in Table 1. Maximum and minimum values as well as calculated means are indicated for most of the quality criteria investigated. Total ammonia-nitrite, nitrite-nitrogen and chemical oxygen demand (COD) was always substantially higher in pond waters than in well waters. Nitrate-nitrogen concentrations and the alkalinity values were also slightly higher in the ponds. At the investigated farming sites in the Jinnoshinden-cho area the alkalinity level of the well water (make-up water) was relatively high. Usually fish farmers tend to use well water with moderate alkalinity levels, and frequently mix well waters of high alkalinity with those of lower alkalinity. In contrast to the observations on nitrogen compounds, no significant changes have been observed between pond waters and well waters with regard to the content of Ca^{++}, Mg^{++}, SO_4^{--}, Cl^{-} and Fe . Taking long-term observations into account (regular water quality measurements over several years) one can say that maximum concentrations for ammonia-nitrogen, nitrite-nitrogen and phosphate-phosphorus in conventional stagnant water eel ponds are leveling at 0.5 ppm, 0.26 ppm and 0.53 ppm, respectively (Chiba, 1980a). Compared to these values, the concentrations were markably higher in the greenhouse ponds investigated. This holds especially for the total ammonia concentrations, which amounts to 17.0 ppm and 26.4 ppm in the Jinnoshinden and Atsumi area, respectively. These values can be considered as extremely high. When calculating the un-ionized ammonia fraction at given temperatures and pH-values, the maximum NH_3

Table 1 . Quality of well and pond water of greenhouse eel farms in Aichi Prefecture.

Water quality		well water			pond water		
		maximum	minimum	mean	maximum	minimum	mean
Temperature	°C	21.8	17.1	19.40	27.5	20.0	25.49
pH		7.4	6.3	7.01	7.7	7.1	7:37
DO	%	61.4	18.8	39.43	156.7	26.1	72.04
NH_4-N	ppm	2.75	ND	1.445	26.40	0.08	6.304
NO_2-N	ppm	0.08	ND	0.014	6.00	0.02	1.240
NO_3-N	ppm	8.40	0.94	4.701	24.00	5.60	11.260
PO_4-P	ppm	0.13	ND	0.081	2.58	0.15	0.877
COD	ppm	0.54	ND	0.066	7.48	1.34	6.300
COD_f	ppm	-	-	-	3.92	0.65	2.101
Alkalinity	me/l	3.75	0.68	1.672	3.64	0.68	1.369
Ca	ppm	630	61	268.1	452	45	183.9
Mg	ppm	210	43	139.9	222	18	106.5
Fe	ppm	6.56	0.04	1.556	0.40	0.10	0.20
SO_4	ppm	314	19	163.9	274	18	106.9
Cl	ppm	3082	228	1678.0	2340	190	1093.0
Na	ppm	970	65	444.4	-	-	-
K	ppm	22.0	6.5	14.90	-	-	-
Zn	ppm	0.04	ND	0.03	-	-	-
Conductivity	µ/cm	5000	160	861	-	-	-

CODf : Water sample was filtered by 0.1 µ membren filter.

-N levels were 0.249 ppm and 0.653 ppm, respectively. They are 12.1 and 31.7 times the recommended EIFAC safety level.
Dissolved oxygen (DO) content ranged between 26.1 to 156.7 % saturation level at farm sites of the Jinnoshinden area. In fish farms of the Atsumi area comparable oxygen levels were 58.3 and 91.4% of the saturation level. Supersaturation of oxygen was observed only in a few cases, where heavy phytoplankton blooms occurred.

3.2.2 Operational relationship between stocking density and water wheel size.

As already outlined fish farmers employ several water wheels in their eel ponds. Usually, the size and number of water wheels are decided on the basis of fish farmers' experience with regard to biomass and pond area. Fish farmers have also learned how to arrange most effectively the position of the water wheels in the ponds. Positions are chosen not only to create a good mixing of the water mass but also to achive a certain current speed and current pattern, in order to concentrate the faeces and the surplus feed near the centre, where the water outlet is installed.

Fish farmer's experience has shown that the installation of an extra water wheel was very effective in improving the feeding activity of fish which have exhibit a reduced appetite. This practice seems to promote the appetite of the cultured fish under normal feeding conditions.

Water wheels used in greenhouse pond culture are available in capacities of 0.5, 1.0 and 2.0 horse powers. The relationship between fish stock size in the pond, total pond area, total horse power and number of water wheels is demonstrated in Figure 3. Data were obtained through interviews of several pond farm owners and represent, therefore, the present state of the art at commercial farm sites.

A linear relationship can be demonstrated between the pond area and the horse power of water wheels. Further, another relationship exists between biomass of fish stocked and the horse power of the water wheels. These relationships can be expressed by the following equations:

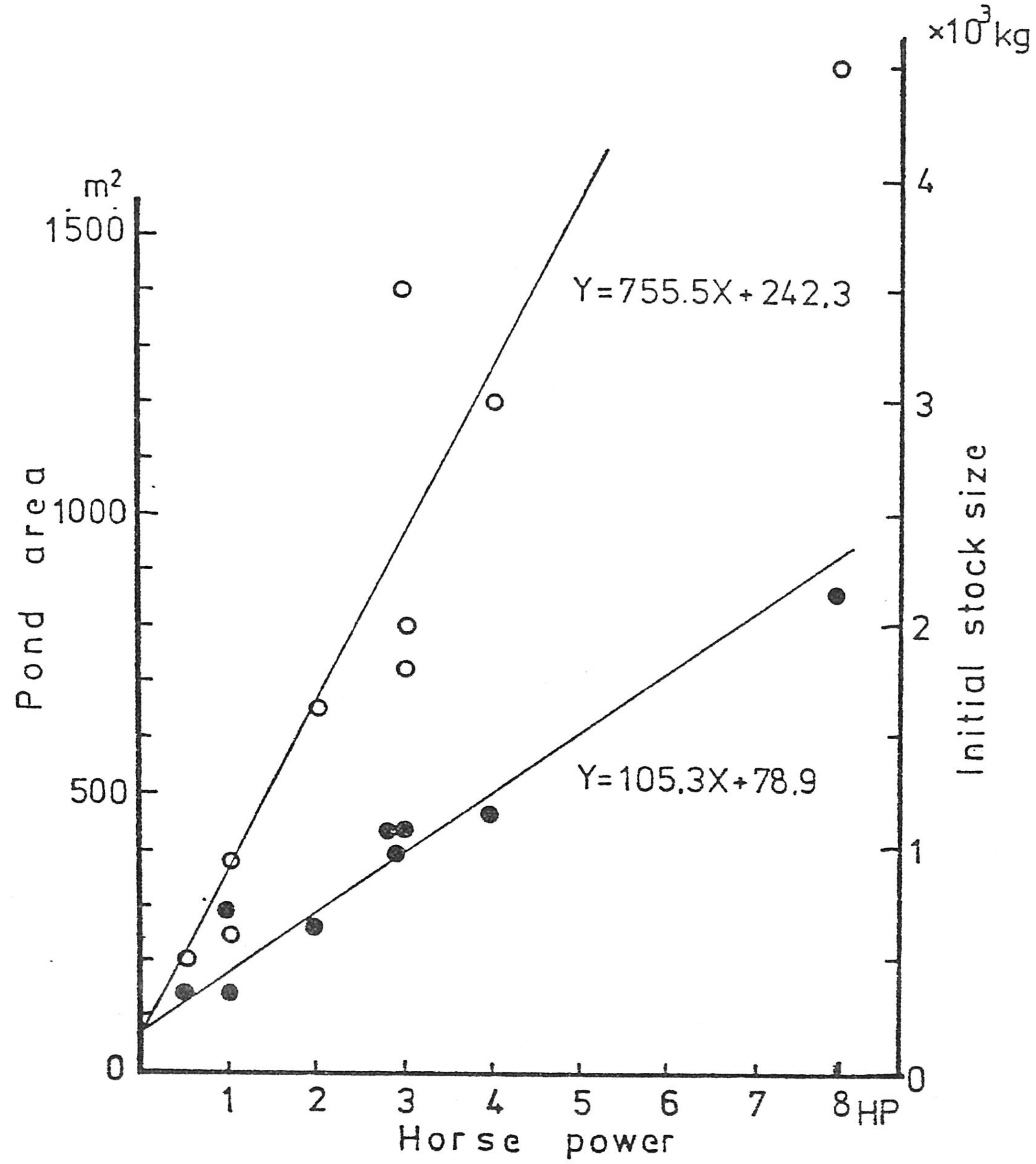

Fig. 3 . Relationship between horsepower of water wheels, pond size (closed circles) and initial stocke size (open circles) in greenhouse eel ponds.

(1) $Y = 755.5x + 242.3$ where Y is the amount of fish stocked into the pond (kg) and x represents the total horse of all water wheels employed

(2) $Y = 105.3x + 78.9$ where Y is the pond surface area (m^2) and x presents again the total horse power of the water wheels.

Even though the individual fish culturist decides on the number of water wheels to be installed into his system independently from other farmers, the linear correlation between pond size, initial biomass stocked, and horse power of water wheels can be established.

From these observation it seems reasonable to assume that the horse power of the water wheels has a proportional impact on the oxygen transfer rate through the pond water surface, and therefore the oxygen supply clearly restricts the amount of fish to be stocked in each pond. Overstocking will soon result into depleted oxygen levels which in turn reduce the feeding activity (appetite).

In conclusion, one could say that the water quality characterics in greenhouse eel ponds are:

(a) high concentrations of nitrogen compounds and phosphorous, which are believed to be metabolised and excreted by the fish at a high rate;

(b) low concentration of those substances which are involved in the overall budget at a low metabolic rate, such as Ca^{++} and Mg^{++}.

4. LONG-TERM OBSERVATION ON THE PERFORMANCE OF A GREENHOUSE EEL POND FARM (A CASE STUDY)

4.1. Site description and farm operation.

In one fish farm at Atsumi-cho (Aichi Prefecture) extended observation was performed by the author between December 1980 and August in 1981. At intervals of about 20 days, water samples were taken from greenhouse eel ponds and analysed immediately. Daily pond management strategies were recorded by the fish farm, and the results of culture operations were obtained through personal interviews with the fish farm owner. This study, therefore, provides a realistic insight into

system performance under current operational practices.
The fish farm operates a total of eel ponds in. There are four conventional outdoor ponds and seven ponds covered by two greenhouses. The area covered by each of the four outdoor ponds is approximately 594 m^2. Those ponds located inside the greenhouses range between 66 m^2 to 396 m^2 in size. The ponds in one are used produce stocking sized fish from glass eels while the others are for grow-out to obtain marketable sized fish of about 2oo - 250 g average weight.
Water heating is achieved by oil-fired boilers with capacities of 500.000 Kcal/h and 750.000 Kcal/h which are provided beside each greenhouse. In each pond IIto IV water wheels are installed. Their location within the ponds is illustrated in Fig.4. Compared to many other eel farms in Japan the size of this fish farm is relatively small. The typical farming procedure for this fish farm is outlined in the flow-chart in Fig.5. This chart resembles very closely the general scheme depicted in Fig.1.
Each year 20 to 30 kg of glass eels were introduced which grow usually very fast. Repeated size selection and restocking of the second and third nursery ponds was performed while heating the pond water is continuously until June. During June and July, most fish are transferred from the greenhouse ponds to the outdoor facilities. At this time the largest size group of fish has reached an average weight of about 20 g, while the majority of the smaller fish have attained an overall weight between 3 and 10g. Between October to November fish are transferred to the greenhouse ponds again. Pond water heating in the greenhouses in not started until December. Harvesting begins usually in February when a substantial portion of the fish stock has reached commercial size. Harvesting is continued until summer when all fish have finally attained market size. Thus, from an initial stocking of 20 to 30 kg of glass eels,. the total production period lasts generally 1.0 to 1.5 years and the total annual production of commercially sized eels in this unit is estimated to reach 14 to 18 tons.

4.2 Variation of pond water quality during a normal culture period.

Well water utilized in this fish farm originates from two different depth. The water quality data for the two wells are shown in Table 2. There was only a minor difference in water quality between them. Low pH values, alkalinity, and low levels of Ca^{++} , Mg^{++} , Na^{+} and K^{+} are

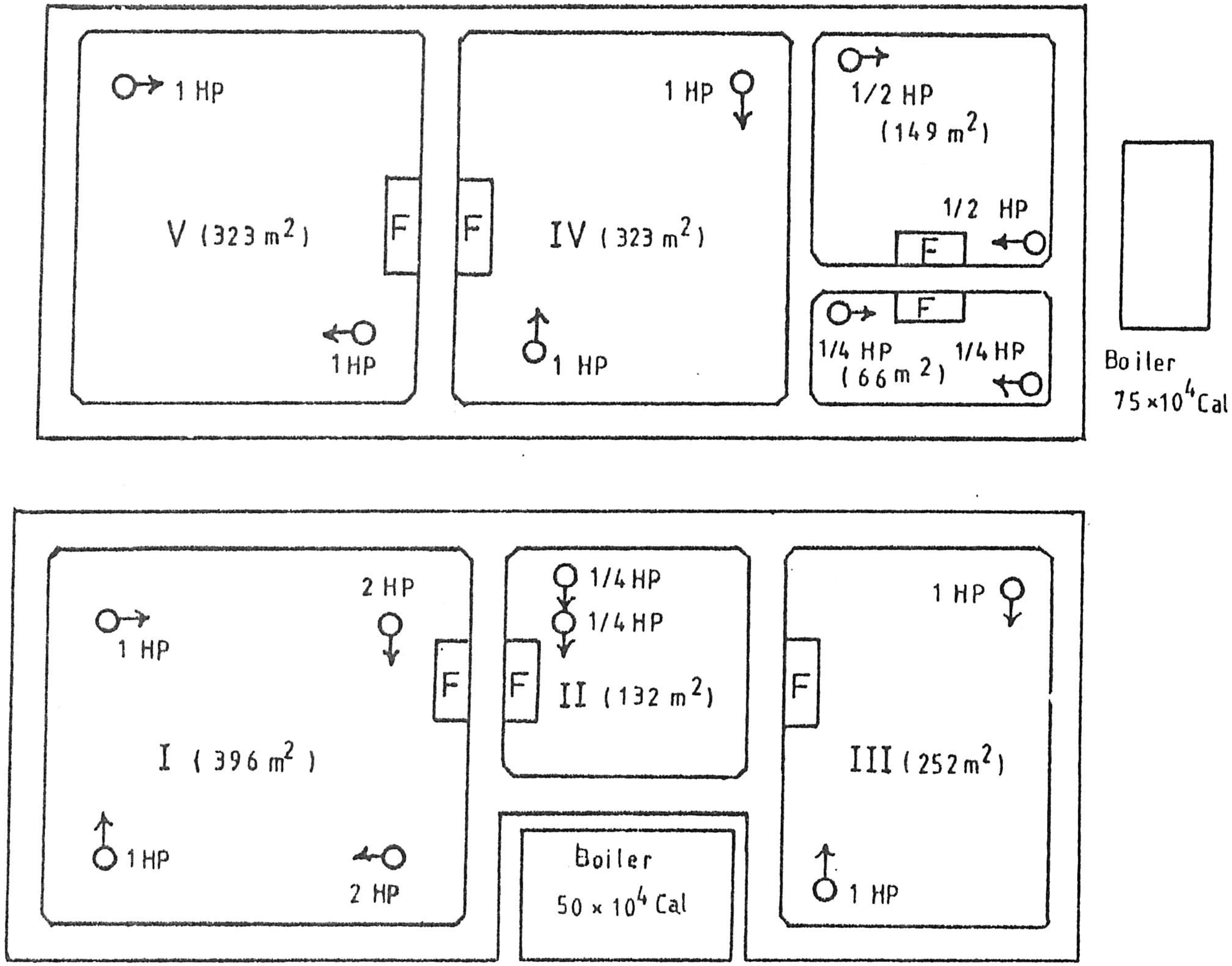

Fig. 4. The layout of the greenhouse eel ponds in the fish farm investigated. Size of ponds in m^2 is indicated in brackets. F : feeding place ; ♂ : location of water wheels and the direction of water movement created by these wheels. The horsepower (HP) of each is indicated next to each arrow.

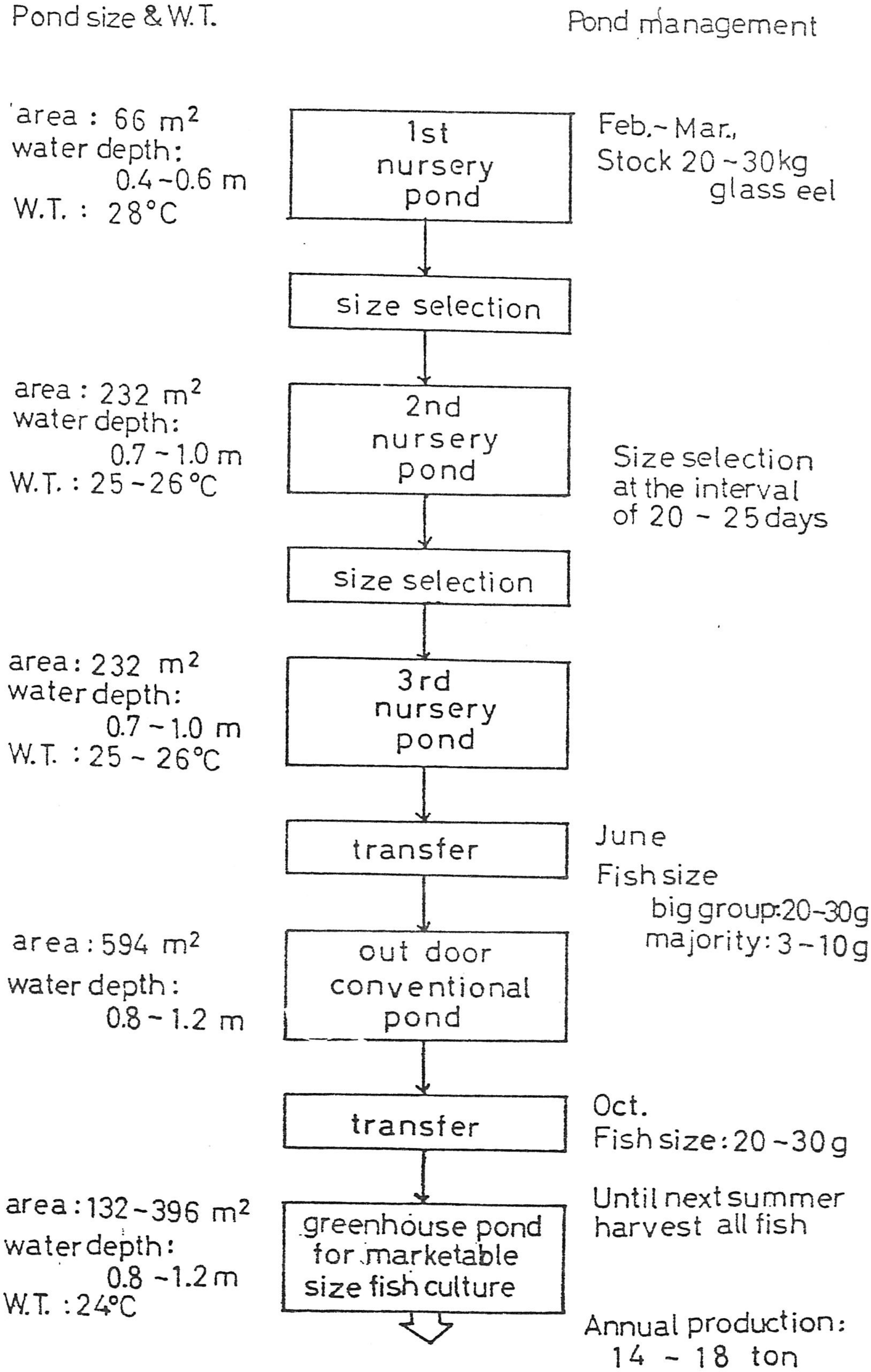

Fig. 5. Procedure of eel culture in the fish farm investigated

the special characteristics of both wells.
Water quality fluctuations observed in Pond I and III are shown in Fig. 6 and 7. In these two ponds the fish culture for table-sized eels continued over extended time periods without any interruption. In pond I the cultivation period started with the beginning of December and lasted until the middle of August of the following year. In pond III eel culture extended from the end of November until the middle of June next year.

Throughout the culture period the dissolved oxygen content fluctuated generally between 60 and 80‰ of the saturation level. However, few exceptions occurred and no clear trends in oxygen levels were observed. In contrast, other water quality factors exhibited a long-term upward trend in their concentration, also showing irregular fluctuations on a short-term basis. Especially the nitrogen compounds, such as total ammonia, nitrite and nitrate and phosphorus increased remarkably between March and June. After June a decrease in concentration of all these water quality factors was observed, except for pH-values and dissolved oxygen concentrations in pond I.

These levels of water quality factors were influenced by the excretion from fish, the decomposition of uneaten food and faeces, and by the dilution with fresh well water supplied as make-up water.
Low concentrations of nitrogen compounds, phosphorus and COD in the starting phase of cultural period were due to a temporarely reduced food supplie. During this period a so-called gill-kidney-inflamation disease occured and fish did not feed very well. From May onwards an irregular fluctuation in several water quality factors was observed. One major reason for the occurence of these irregularities was the amount of well water added daily to the ponds. Besides regular water exchange through the cleaning procedure, the intermittant harvesting fish for sale or for size selection also requires the exchange of pond water. This requires sometimes an extensive water exchange, reaching more than 50‰ of pond volume. This operational procedure must have contributed to the large variation in water quality.

The range of water quality fluctuation is summarized in Table 2, including maxima and minima values obtained over the entire investigation period.

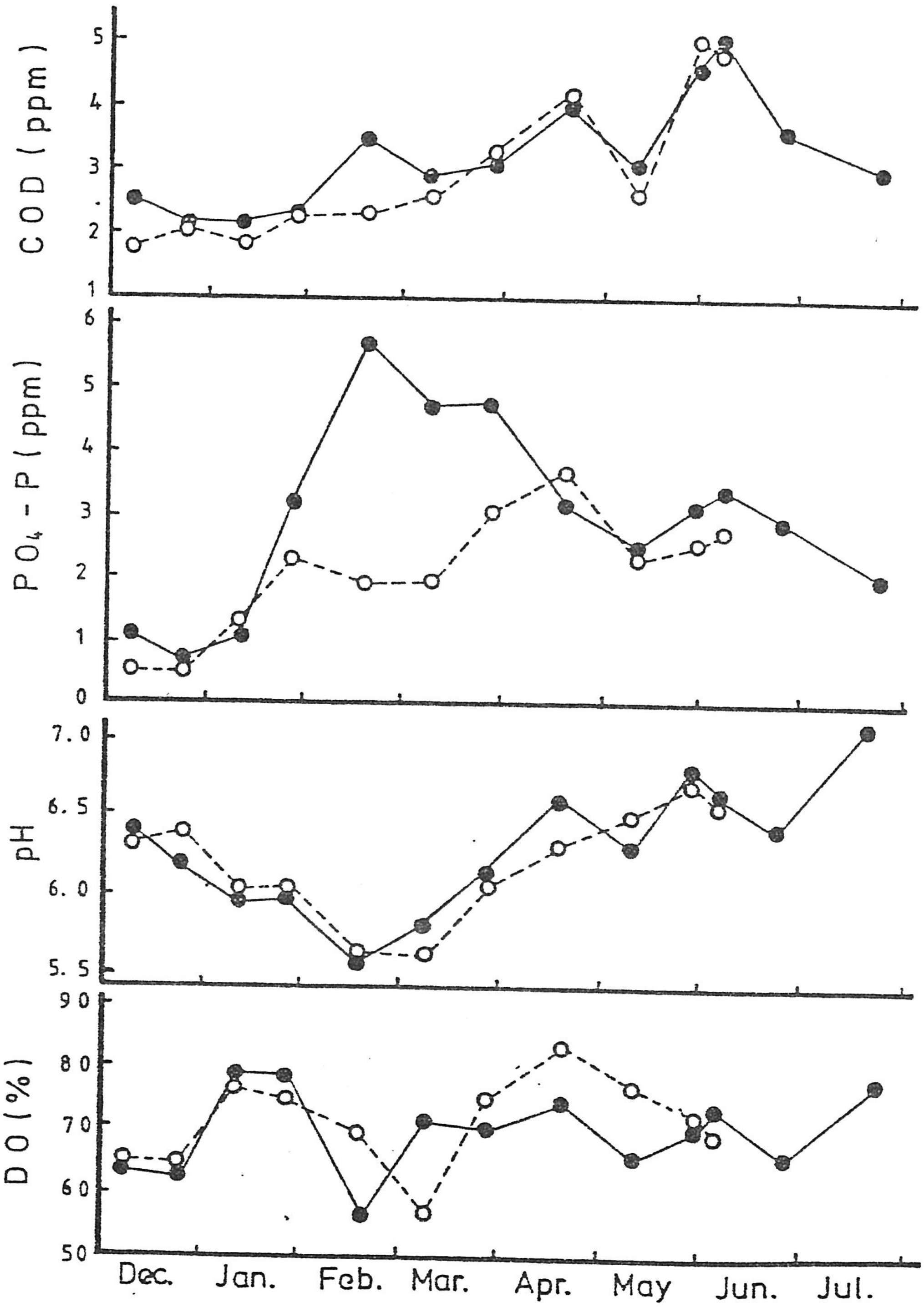

Fig. 6. Long term fluctuations in DO, pH, PO_4-P and COD in pond I (--o--) and III (—●—). Data represent observations over the entire culturing period.

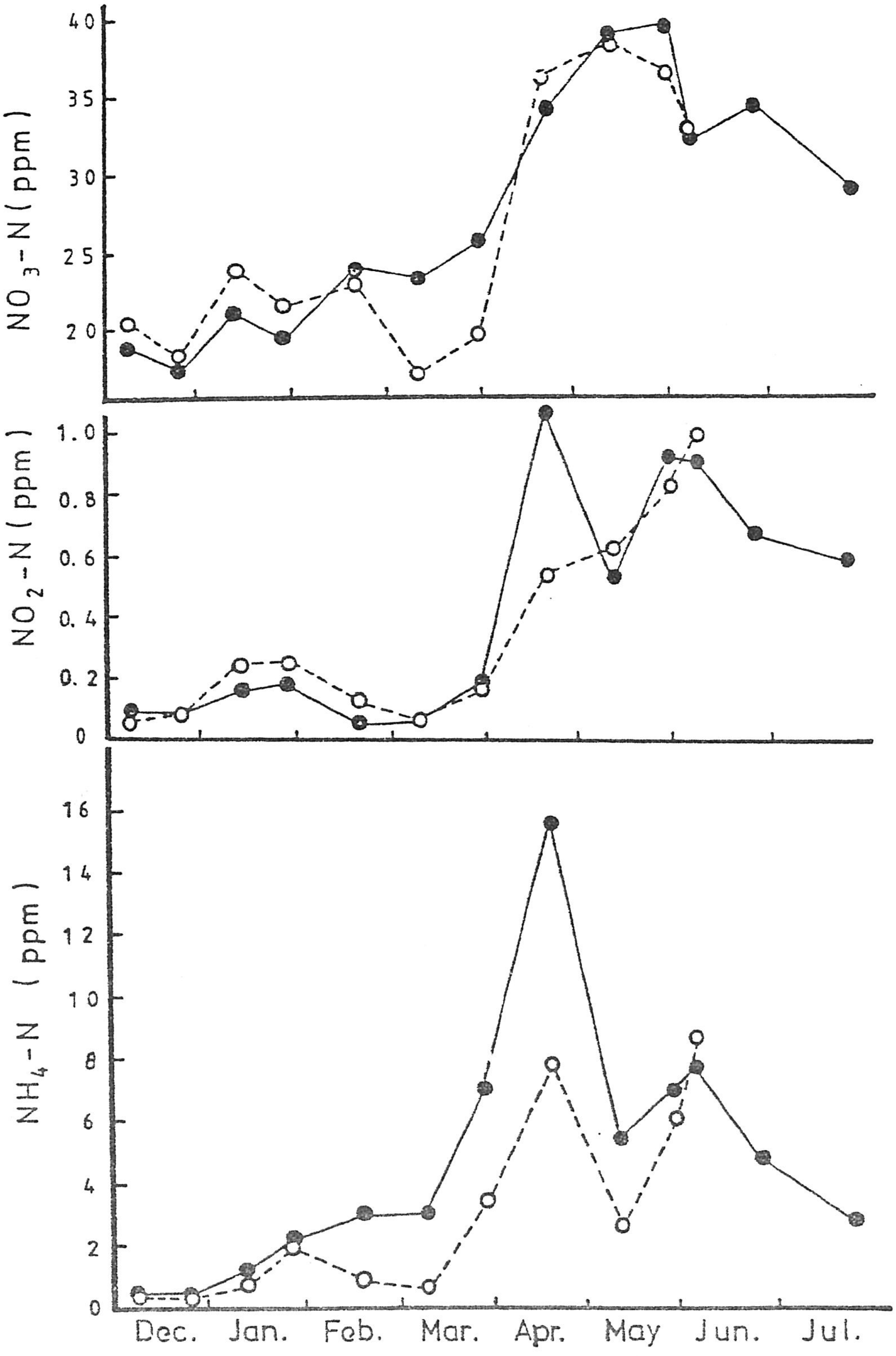

Fig. 7. Long term fluctuations in NH_4-N, NO_2-N and NO_3-N concentrations in pond I (--o--) and pond III (—●—). Data represent observations over entire culturing period.

Table 2. Quality of well water spplies utilized as sources for culture ponds.

Water quality criteria		Well - No.1 (4 m)	Well - No.2 (8 m)
Water temperature	°C	21.1	17.6
pH		5.8	5.4
DO	%	-	-
NH_4-N	ppm	0.20	0.02
NO_2-N	ppm	0.01	0.01
NO_3-N	ppm	11.0	25.6
PO_4-P	ppm	0.077	0.016
COD	ppm	1.09	0.49
Alkalinity	me/l	0.424	0.210
Na	ppm	39	31
K	ppm	5.0	3.5
Ca	ppm	63	50
Mg	ppm	14	23
Fe	ppm	ND	ND
SO_4	ppm	98	112
Cl	ppm	93	54

4.3. Diurnal fluctuation of water quality in a greenhouse pond.

Diurnal fluctuation of water quality was also observed in two ponds (pond I and pond III) for the following water quality criteria: NH_4-N, NO_2-N, NO_3-N and dissolved oxygen. The observations startet at 11:00 hours on the 4th of June in 1981 and ended at 14:00 hours on the 5th of June.

The results are shown in Fig. 8. No clear tendency was observed with regard to the fluctuation of water quality factors.

Dissolved oxygen, for example, fluctuated irregularly between 66 and 78% of the saturation level in pond I and between 62 and 75% in pond III. The lower saturation values occurred during the night. The

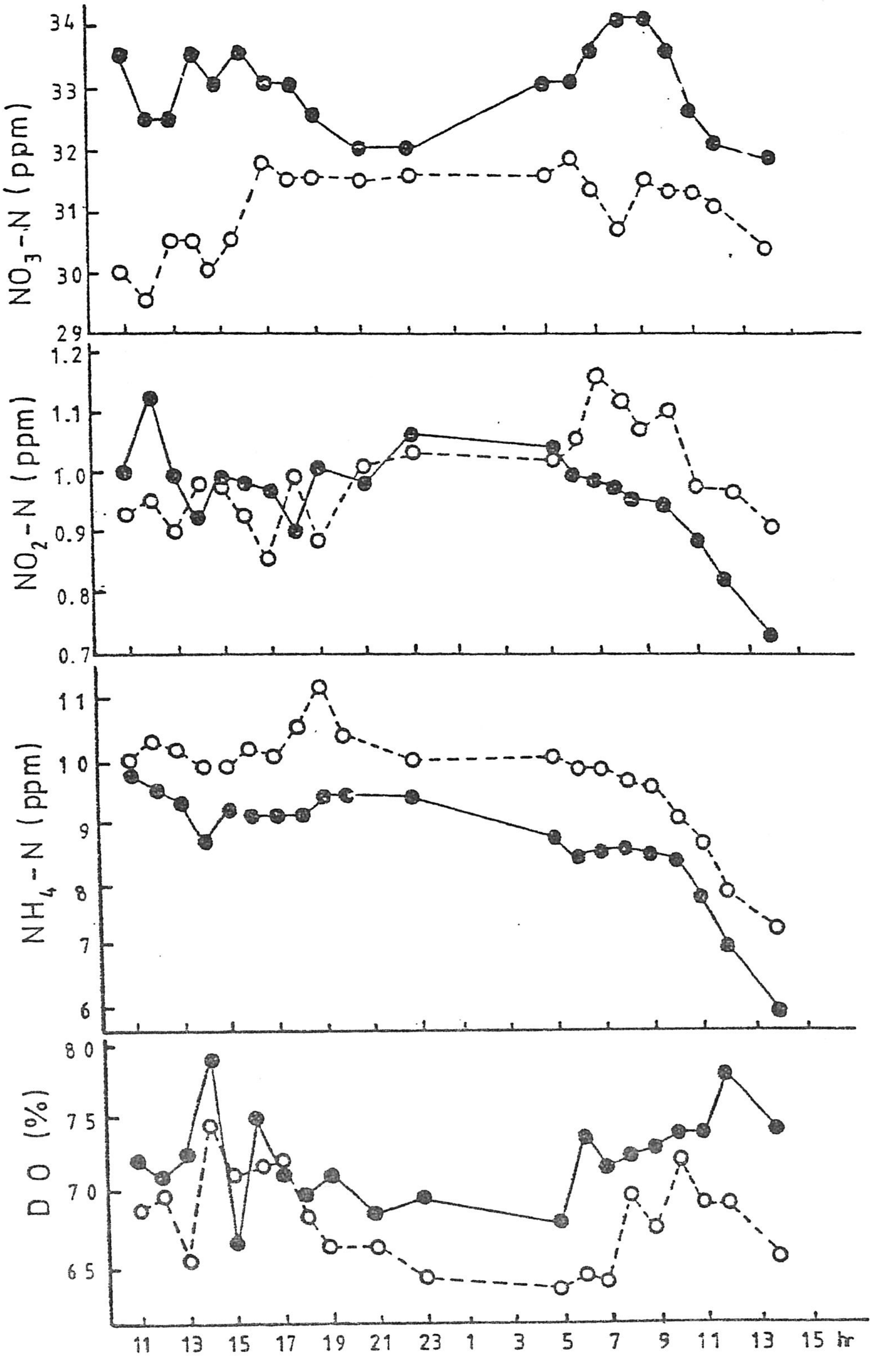

Fig. 8 . Diurnal fluctuations of DO, NH_4-N, NO_2-N and NO_3-N values in ponds No. I (--o--) and III (—●—). Samples taken June 4th and 5th , 1981.

photosynthesis of green alga, Chaetophora sp., might have contributed to the elevation of dissolved oxygen in the ponds during the daytime. Inorganic nitrogen compounds did not vary substantially in both ponds. However, the available data do not indicate a clear tendency for these factors.

Presently no clear explanation can be offered regarding the relationship between these fluctuating inorganic nitrogen compound. Further observations including other factors such as organic nitrogen and bacteriological activity are required to derive at reasonable explanations. As described above the tendencies in water quality fluctuations were not clear. However, the decrease of morning values of inorganic nitrogen compounds were remarkable. They startet between 9:00 and 10:00 hours. To some extent these changes can be explained as a dilution effect through the addition of fresh well water. Since the oxygen concentration near the inlet was determined at about 20%of the saturation level, the supply of oxygen defficient make-up water was probably one reason for the sudden decrease of the oxygen content of pond water in the morning.

As a general conclusion, it can be statet that the water quality factors investigated did not fluctuate drastically within one day in those greenhouse ponds which contained a moderate green algal bloom.

4.4. Production output of a heated greenhouse pond.

The production results in the greenhouse ponds of the investigated fish farm are shown in Table 4. Usually, the fish grown to table size are harvested intermittently and young fish are restocked and transferred between ponds at several times during the culture period. Therefore, the total biomass of fish harvested and the relationship between stock size and harvest and the daily growth rate per fish (weight gain) cannot be evaluated in a conventional manner.

In general, the food conversion efficiency can serve as a reasonable indicator of system performance under practical culture conditions. The average food conversion efficiency in greenhouse pond culture is estimated to approach 60 %. This figure is based on the overall data provided by fish farmers.

Table 3. Water quality characteristics in greenhouse eel culture ponds in the farm investigated. Data represent minimum and maximum values observed during the entire investigational period. Roman numbers identical with pond number.

Water quality criteria		I	II	III	IV	V
Water temperature	°C	22.6-26.4	23.2-26.4	22.8-25.9	22.6-26.2	25.2-27.2
pH		5.6-7.1	5.9-6.6	5.6-7.1	5.9-6.5	6.3-7.4
DO	%	56.4-78.9	51.5-87.6	57.0-77.0	63.6-90.1	67.1-90.8
NH_4-N	ppm	0.23-15.6	0.15-5.50	0.10-10.0	0.10-2.00	0.50-7.00
NO_2-N	ppm	0.06-1.06	0.13-0.70	0.06-0.97	0.06-0.36	0.18-3.40
NO_3-N	ppm	17.7-39.5	16.4-36.7	17.0-33.5	15.2-34.5	19.5-30.0
PO_4-P	ppm	1.11-5.73	0.65-2.50	0.50-5.05	0.48-1.96	0.44-1.48
COD*	ppm	2.27-8.27	1.45-5.45	1.52-8.15	1.23-4.11	1.28-5.62

* : Sample was filtered by 0.45 µ glass filter.

Table 4 . Results of eel culture in heated water pond in greenhouse

Items \ Fish Pond	I	II	III	IV	V
Pond area (m^2)	396	132	252	323	323
Culturing period (calender month)	'80.12.1 -'81.8.18	'80.11.30 -'81.5.23	'80.11.29 -'81.6.12	'80.12.1 -'81.5.19	'81.4.12 -'81.7.31
Amount of fish stocked (initial) (kg)	2476	555	982	500	152
Amount of fish restocked (kg)	4100	355	1550	335	265
Total amount of fish stocked (kg)	6576	910	2532	835	417
Initial stocking density (kg/m^2)	6.25	4.20	3.90	1.55	2.13
Intermediate harvest* (kg)	7782	1320	1700	240	1010
Harvest (kg)	300	580	2030	825	635
Dead fishes (kg)	363	45	53	77	2
Amount of feeding (kg)	7139	1276	2536	1155	2134
Feed conversion efficiency (%)	26.18	81.11	49.33	26.58	57.64
For 1 kg body weight increase					
Heavy oil (l)	7.74	4.61	7.39	37.22	1.95
Electric energy (KWH)	19.53	1.55	5.62	19.42	4.63

*Harvest for sale or transfer to other ponds

Examining the production figures in this fish farm in relation to the food conversion efficiency, it seems that the figures obtained from ponds I and IV are better than those determined from ponds III and V. Pond II, however provided the best results. It is suggested that the low food conversion efficiency in pond I and IV were caused by the reduced amount of feed supplied during a short period when the so-called gill-kidney-inflammation disease occurred.

The overall amount of fuel and of electricity used for each kg of fish weight increase estimated for each pond. The estimates are also included in Table 4. The calculation is based on the assumption that oil was mainly consumed during the culture period when water had to be heated, and electricity was consumed proportionally to the total house power of water wheels installed in each pond.

The amount of fuel burned for 1 kg weight gain for various ponds ranged between 1.95 to 37.11/l. The smallest figure (1.95 l/kg) was obtained in pond V, while the culturing period included the months where heating was not necesssary. Therefore, low consumption figures should be considered as an exceptional situation. The fuel consumption for pond II and III were estimated to reach 4.61 and 7.39 l per kg fish weight gain, respectively. In these two ponds water was heated throughout the entire culturing period. Food conversion efficiency values were normal or even excellent when compared to average pond culture sucess. These values are also similar to those obtained in glass eel culture (5.2 to 19.7 l kg).

The values calculated for the consumption of electric energy varied between ponds from 1.55 to 19.53 KWh per kg biomass gain. Low energy consumption values were estimated for ponds with high food conversion efficiency. This holds for both oil and electricity costs. Pond II and III with good or excellent food conversion efficiency could be considered as typical examples for the energy consumption in greenhouse pond eel culture, amounting to 4.6 l and 7.39 l oil and 1.55 and 5.62 KWh electricity per kg weight increase.

5. OXYGEN AND AMMONIA-NITROGEN BUDGET IN GREENHOUSE EEL PONDS

5.1. Estimation of oxygen budget in a greenhouse pond

Greenhouse eel ponds are usually operated without allowing a heavy phytoplankton bloom to occur. Dissolved oxygen input is believed to be provided mainly by water wheels. A first trial to estimate the oxygen budget in a greenhouse pond was undertaken by Chiba (1980b). The most important variables that influence the oxygen consumption in such ponds were the size of fish stock, pond water volume, bottom mud, sediment and the water volume drained each day.
Photosynthesis through phytoplankton populations, supply of fresh well water and the oxygen transfer through diffusion from the air were regarded as the major factors which supply oxygen to the system.

Oxygen comsumption rates and input rates were determined in the laboratory for each of the above mentioned key factors. The amount of oxygen supplied by fresh well water, and the amount of oxygen carried out from ponds with discharging pond water were calculated on the basis of average values observed in a number of samples.

Finally, the oxygen dissolution rate from air was calculated as the difference between the sum of input rates from all oxygen consuming factors and from all oxygen supplying factors mentioned above, except dissolution rate from the air through the pond surface. Oxygen balance was estimated at water temperature of 24°C, a fish density of 6.35 kg/m^2 and 12.70 kg /m^2 and one third of daily pond water replacement using fresh well water. The results are summerized in Table 5.

The amount of oxygen consumed by eels was higher than for any other system component, reaching 76 to 86 % of the total consumption rate. This was followed by the components pond water, bottom mud and sediment, and by the water volume discharged. In greenhouse ponds the fish stocking density was very high. These values are much higher than

Table 5. Estimated oxygen budget in a greenhouse pond of 396 m^2 surface area, based on oxygen consumption rates of eel, pond water and bottom, the rate of photosynthesis by phytoplankton, pond water discharge, and well water supply.

Oxygen budget was culculated based on the following figures:–
oxygenconsumption rate of eel: 2,336 ml/kg day ; oxygen consumption rate of water : 0.18 ml/l·h ; oxygen consumption rate of bottom mud : 1,103 ml/m^2h; photosyntgesis of phytoplankton : 0.41 ml/l·h (10 hour per day); water depth: 0.6 m; DO in pond water: 4.85 ml/l (mean value of all values observed); DO in well water: 2.32 ml/l (mean value of all values observed).

Stocking density (kg/m^2)	Supply			Consumption		
	Category	ml/day	%	Category	ml/day	%
6.35	Photosynthesis	2,460	12.6	Eel	14,834	76.1
	Carrying into by well water supply	460	2.4	Pond water	2,592	13.3
	Dissolution from the air	16,579	84.7	Bottom mud and sediment	1,103	5.7
				Carrying out by pond water discharge	970	4.8
	Total	19,499	100.0	Total	19,499	100.0
12.70	Photosynthesis	2,460	7.2	Eel	29,667	86.4
	Carrying into by well water supply	460	1.3	Pond water	2,592	7.6
	Dissolution from the air	31,412	91.5	Bottom mud and sediment	1,103	3.2
				Carrying out by pond water discharge	970	2.8
	Total	34,332	100.0	Total	34,332	100,0

those obtained in a stagnant pond (14%, Nakamura, 1963).

The oxygen supply through photosynthesis by phytoplankton and through make-up water inputs were estimated to reach fairly small values of 7.2% and 12,6%, respectively. Consequently, the dissolution rate from the air had been estimated to give the highest values of 85 to 92%. According to fish farmers' experience in greenhouse ponds, eels start surfacing soon after water wheels had been stopped. This fact supports the assumption that oxygen is mainly transferred through water wheels.

5.2. Estimation of the ammonium-nitrogen budget in a greenhouse pond.

When considering the extremely high NH_4-N concentrations in greenhouse ponds, one may expect that the NH_4-N budget in such pond is different from that in stagnant water ponds. It seems important to identify the reasons why such high total ammonia concentrations do occur in greenhouse ponds. This would allow the development of adequate water quality control measures. On overall estimate of the NH_4-N budget in a greenhouse pond was attempted by the author in 1978 (Chiba, 1980b). Bottom mud and organic sediments were assumed to be the determining factors involved in increasing total ammonia concentrations.

The utilization of NH_4-N by primary production and through assimilation by bacteria were considered as factors involved in NH_4-N deacrease. Additionally, water discharge contribute to the removal of the total ammonia load. In estimating the NH_4-N balance, the average values from several reports on NH_4-N excretion rates in eels as well as values for the other engeneering factors measured in the laboratory were utilized.

The NH_4-N balance was calculated for two stocking densities(6.35 kg/m^2 and 12.7 kg/m^2) in 396 m^2 ponds (water temperature 24°C). The results are summerized in Table 6.
The NH_4-N excreted by fish contributed most to the total ammonia budget (97.7 to 98.8%) while the amount originating from bottom mud showed only 1.2 to 3.3%. The utilization of NH_4-N by phytoplankton and by bacteria was very low (1.5 to 2.9%). Almost all NH -N (97.1 to 98.5 %)was removed from ponds by the water discharge.

Table 6. Estimated NH_4-N budget in a greenhouse eel pond of 396 m^2 surface area, based on fish excretion rates, dissolution rates from bottom mud and sediment and dilution by well water addition.

NH_4-N budget was culculated based on the following figures:-
NH_4-N excretion by fish : 637 mg/kg·day(average value of published data); dissolution from bottom mud and sediment (average value of observed values) : 2214.7 mg/m^2·day(at the center of pond: ø 2.8 m), 66.9 mg/m^2·day (other part of the pond bottom); well water NH_4-N concentration:0.748 ppm(average value of several well water observed); utilization of phytoplankton and bacteria:0.206 mg/l·day (average value of several pond water observed).

Stocking density	Input			Removal		
(kg/m^2)	Category	g/day	%	Category	g/day	%
6.35	Excretion	1,602	94.2	Utilization of phytoplankton and bacteria	49	2.9
	Dissolution from bottom mud and sediment	40	2.3	Carrying out by pond water discharge	1,652	97.1
	Carrying into by well water supply	59	3.5			
	Total	1,701	100.0	Total	1,701	100.0
12.70	Excretion	3,204	97.0	Utilization of phytoplankton and bacteria	49	1.5
	Dissolution from bottom mud and sediment	40	1.2	Carrying out by pond water discharge	3,254	98.5
	Carrying into by well water supply	59	1.8			
	Total	3,303	100.0	Total	3,303	100.0

The installation of several water wheels in the pond and the daily exchange of pond water is one characteristic in greenhouse eel pond management that has been invented by fish farmers following trial and error. The main purpose was to dissolve oxygen and drain suspended solids which are mainly composed of faeces and uneaten feeds. This type of pond management seems to be very succesfull. Usually, the settled sediments are concentrated in a small circular area at the pond center with a diameter of about 2 meters. Most of sediments are drained through the outlet system.

According to the determinations in the laboratory the oxygen consumption rate and the NH_4-N releasing rate from bottom mud and sediments were observed to be very high in the center of the pond and low near the pond walls.

If the sediment is not removed from the pond, the water quality in terms of oxygen levels and NH_4-N budget reach toxic values making it difficult to culture fish at such high densities.

6. THE EFFECT OF WATER QUALITY ON EELS IN GREENHOUSE PONDS

It is well known that unionized ammonia is toxic to fish at very low concentrations. It was reported by the Mie Prefectural Inland Fisheries Station (1978) that growth rate of eels decreased at total ammonia-nitrogen concentrations of more than 20 ppm. Considering the given values for pH and temperature, the un-ionized ammonia concentration was calculated to reach 0.067 ppm. The general observations in ponds of this study showed maximum total ammonia (NH_3-N and NH_4-N) values of 26.40 and 17.00 ppm in the Jinnoshinden-cho area and Atumi-cho area, respectively. In those cases, maximum free ammonia-nitrogen concentrations (NH_3-N) were estimated to reach 0.653 and 0.249 ppm. Although these values were much higher than the reported harmful concentration of 0.067 ppm, no obvious abnormal conditions were observed in exposed eels. Moreover, a high food convension efficiency was obtained in the pond in which 17.00 ppm NH_4-N occurred. However, nothing is known on the overall exposure time to these maximum concentrations, since observations are usually made at the interval of twenty days. Usually, pH values are low in greenhouse ponds and therefore the toxic free NH_3-N fraction will be fairly low. However, future studies on the tolerance of eels to un-ionized ammonia are required, that consider not only pH and temperature but also the daily maximum exposure time to elevated levels.

With regard to NO_2-N, Yamagata (1979) reported, that under experimental condition, growth rate of eels decreased in the presence of NO_2-N levels above 30 ppm. From about 1980 onwards a number of reports became available from various farm sites that mention a reduced appetite or an increased mortality under greenhouse culture conditions with high NO_2-N concentrations.

These effects are caused by methemoglobinemia occuring in eels at NO_2-N concentrations between 7.8 and 10.5 ppm (AMAND et al. 1981, KUBOTA et al. 1981).

Under experimental conditions it was reported that a reduced feeding activity and decreased growth rates occured at DO concentrations below 29 to 35 % saturation (ITAZAWA, 1971) or 45 to 55 % DO in air saturation (Mie Pref. Inl. Fish. St., 1979). In the general observations on water quality in fish ponds on the one occasion that loss of appetite was observed the following water quality condition occurred: water temperature = 20°C; pH-value = 7.2; DO = 26.1 %; NH_4-N = 2.35 ppm; NO_2-N = 0.02 ppm; PO_4-P = 15 ppm. Depleted dissolved oxygen levels might be considered as the major cause in reduced appetite. Reduced appetite was not observed in the pond when DO levels were higher than 41.3 % of the saturation level.

7. DISKUSSION AND CONCLUSION

Greenhouse ponds for eel culture can be stocked at high densities yet resulting fast growth rates. The success can be considered as a result of the improved culture method. However, high production costs are only justified if good production figures can be garanted. Otherwise, the price for this advantage is not worth the effect. However, the high amount of electricity, oil and ground water consumed for supplying oxygen from the air, for keeping high water temperature and good water quality conditions pays under good management.

Several attempts have been made to avoid heat loss and economize on oil consumption by doubling or tripling the vinyl sheet of the greenhouse cover. Insulation with other materials was tried. Further, heating well water with the warm discharge pond water (heat exchangers) have been undertaken by fish farmers in order to recover part of the energy used for heating. For electricity no special attempts to reduce costs have been tried. The water wheels are necessary for oxygen supply and sediment removal. Therefore it is not possible to reduce the number of water wheels installed in each pond. However, one fish farm obtained good results in economizing oil and ground water consumption by providing a sedimentation tank beside the fish ponds and removed sediments with only a small amount of pond water from these, thereby reducing the exchange rate. Furthermore, there are several cases of fish farms in which ship propellers are used together with water wheels to create a sufficient current. They seem to be useful on removing sediments and at the same time saving directly energy costs.

As described above, several trials have been made to find the best pond management for reducing production costs. Since fish is stocked at high density, heavy organic loads occur in the ponds due to intensive feeding. Despite the already developed pond management procedures, water quality factors, such as NH_4-N, NO_2-N, NO_3-N, PO_4-P, and COD still increase in concentration.

Therefore, adequate methods to properly counteract the accumulation of these substances is essential and can be considered as a major problem area for continued research and development. From the practical stand point the following trials should be encouraged: (1) Improving the structure of the feeding place in order to avoid the wasteful scattering of uneaten food items into the pond. (2) Preparation of feeds which do not easily desintegrate in the water. (3) Integration of water treatment facilities with parts of recirculation system in order to reduce the concentration of NH_4-N, NO_2-N, and other organic substances. (4) To develop an effectiv oxygen transfer method, which dissolves oxygen at low costs.

From the physiological point of view, the limiting factors in water quality and those concentrations which allow fish to grow in healthy condition should be identified by multidisciplinary investigations. It is necessary to establish standard management procedures to control water quality.

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Etat actuel de l'élevage des pectenidés au Japon
Present status of scallop sea farming in Japan

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1. Introduction

Scallop and chum salmon are the most successful examples representing sea farming fisheries of Japan in recent years. Abalone, sea bream, kuruma shrimp and blue crab are counted as next successful species. A large number of seeds of these species have been released every year for stocking purposes (Table 1). Particularly, it is noted that as many as 1.5 to 2.2 billion seeds of scallop have been released a year in recent years.

Production of scallop in Japan had depended upon catching of natural stocks until about 1965. In 1965, an epoch-making spat collecting technology was developed, which made it possible to produce young scallops of more than 3 cm in shell length in large quantity helped by intermediate rearing technology. By using such young scallops, propagation releasing them to the sea and hanging culture are now done in such areas as Hokkaido, Aomori, Iwate and Miyagi prefectures in northern Japan (Fig. 1). Fig. 2 shows changes in annual production of scallop by propagation as on-bottom culture and off-bottom culture as mainly hanging culture. It shows that the production by both of these methods has markedly increased after 1970. In 1977, the production by propagation method amounted to 43,500 metric tons and that of hanging culture method to 83,200 metric tons, making the total landing as much as 126,700 metric tons. After 1977, production of scallop by hanging culture sharply decreased owing

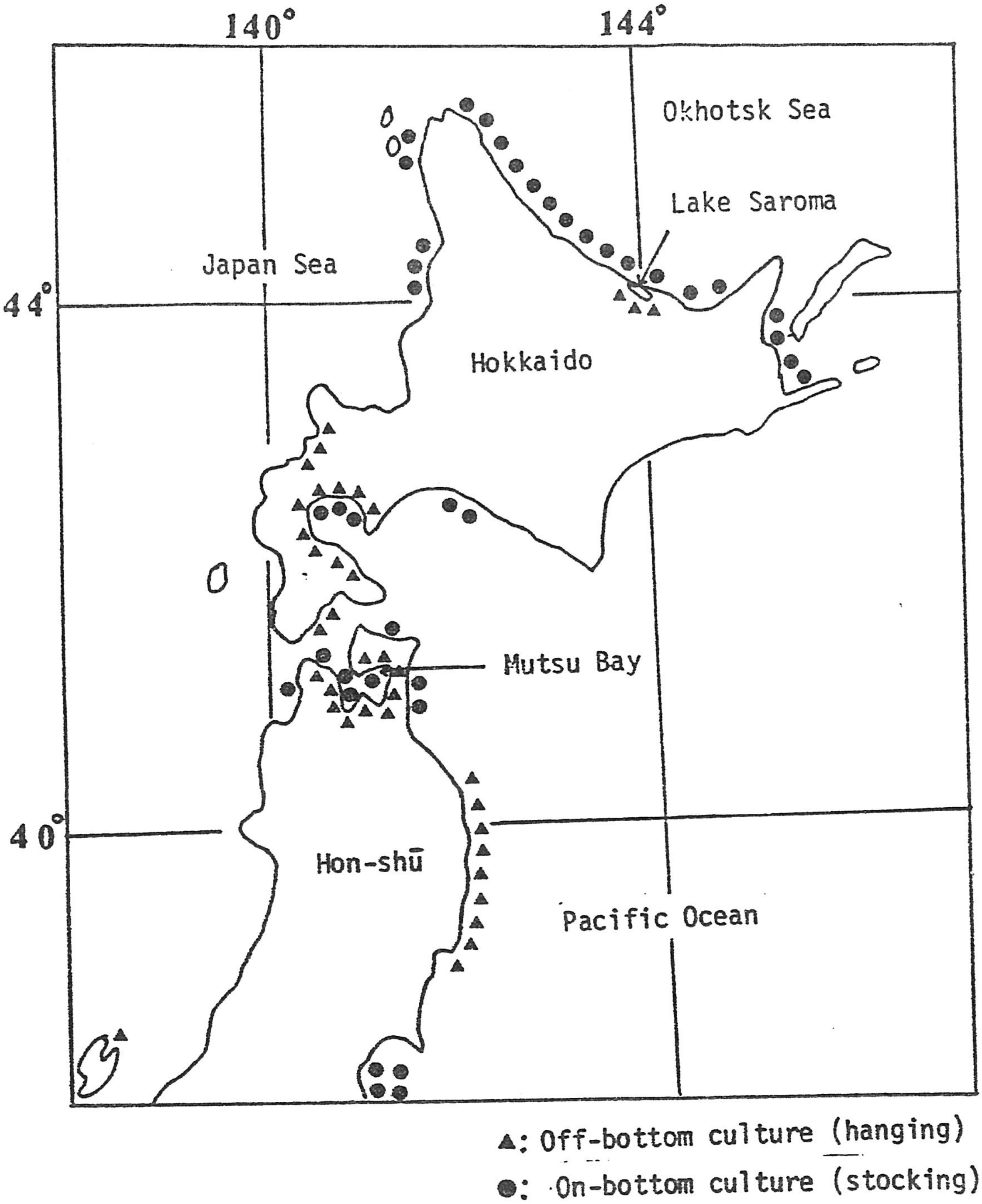


Fig. 1 Location of scallop sea farming in Japan

Table 1 Releasing of seeds for sea farming in Japan

(Unit: 1.000 fish)

Species \ Year	1977	1978	1979	1980
*Scallop	2,139,363	1,566,655	1,699,127	1,525,333
Abalone	7,145	7,143	8,462	10,645
Sea bream	4,667	5,109	8,600	10,358
Chum salmon	1,106,000	1,212,000	1,463,000	1,896,000
Kuruma shrimp	255,515	280,075	337,229	283,323
Blue crab	6,917	7,870	12,171	11,499

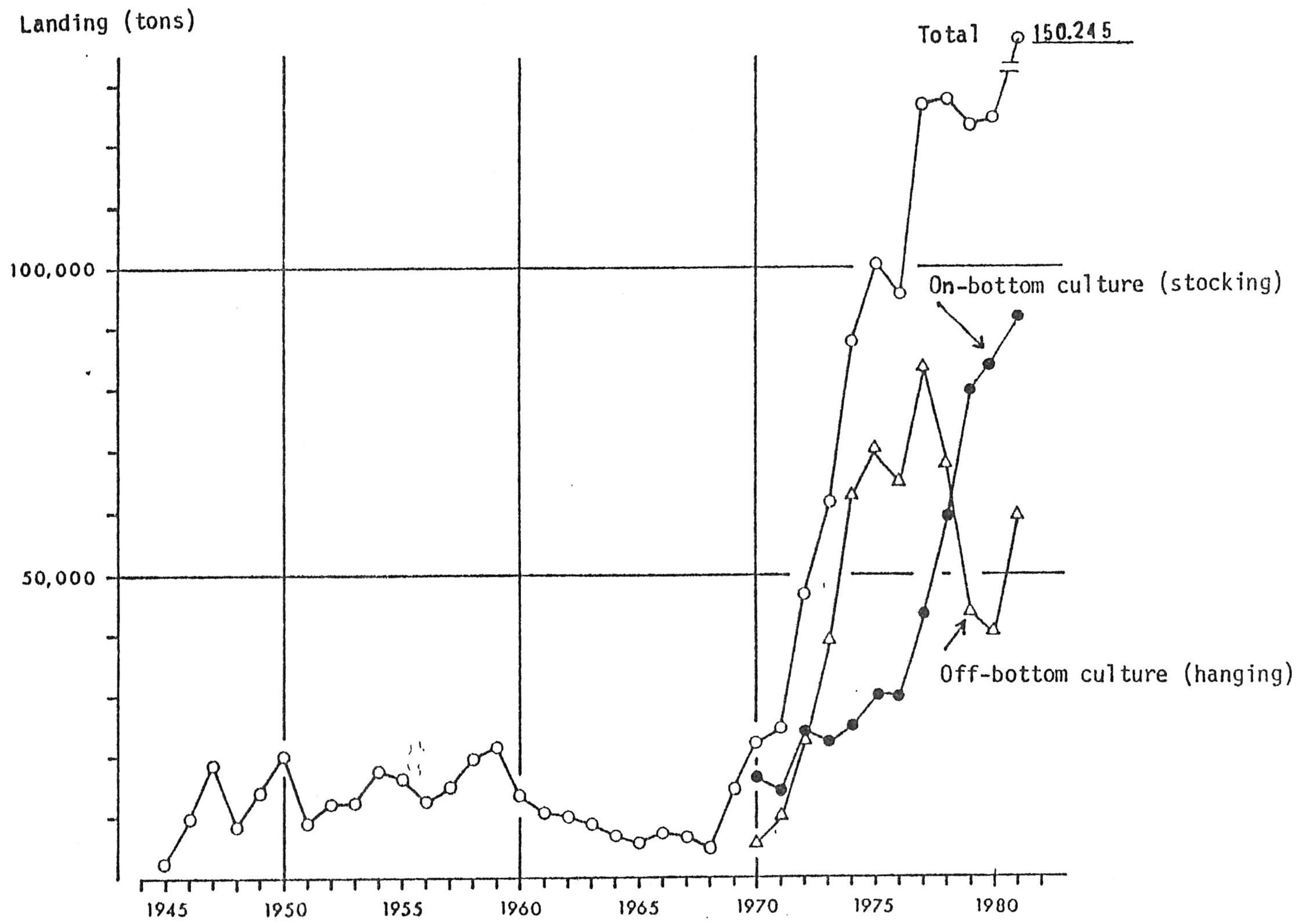


Fig. 2 Scallop productions in Japan from 1945 through 1981

to mass mortalities of cultured scallops. While, production by propagation increased. Thus in 1981, out of the total production of 150,200 metric tons, 91,100 metric tons were the catch from propagated stocks and 59,100 metric tons the production from culture. The value of the total production in 1981 amounted to as much as 39 billion yen.

2. Characteristics of Scallop Production in Japan

The rapid development of scallop production in Japan owes much to biological characteristics of the seeds.

The major habitat area of scallops is sandy sea bottom in cold water areas. They produce quite a large number of larvae in their spawning period of spring. These larvae become attached to sea bottom substrata by their byssus after about one and a half months and then metamorphose. In summer to autumn, they detach themselves from substrata by cutting byssus and begin their sea bottom life anew. Natural spat collection is a method with which to catch such attached and metamorphosed spat in large quantity by using artificial spat collectors, making use of the knowledge that scallops have substratum attached life at certain early stage of their life cycle.

Experimental natural scallop's spat collection and releasing practices were first begun in Lake Saroma of Hokkaido in 1936. These practices had met, however, with many problems and released spats hardly showed up in production. In the 1960s, long line type spat collection technique that uses polyethylene bag-nets, and hanging type intermediate culture technique were introduced, which made it possible to massproduce spat seed of more than 3 cm in shell length. These massproduced seeds have been used for propagation as well as for hanging culture purposes.

Recently, it has become possible to rear the seeds for about a year until they reach the size of 4 to 5 cm in shell length before released in May to June. It was found further that the disturbance ring of growth of the shell formed in winter during intermediate culture process becomes a natural marker which helps distinguish between these artificially released scallops and natural ones. This helped make it easier for us to determine the effect of scallop seeding upon the production.

3. Enhancement of Mother Stock Population of Scallop in Sarufutsu, Hokkaido

The face that massproduction of scallop seeds became possible led to prosperous scallop seeds releasing in various places in Hokkaido and in Mutsu Bay of Aomori prefecture. In this paper, stocking of scallop in Sarufutsu area of Hokkaido, facing the Sea of Okhotsk, is described; in Sarufutsu, released seeds of scallop became established as mother stock populations.

As shown in Fig. 3, Sarufutsu is located in northern Hokkaido facing the Sea of Okhotsk. Its coastline is 33 km in length and most of the coastal areas along this coastline are excellent scallop fishing grounds. Fig. 4 shows catches of scallop in Sarufutsu area after 1940. It continued to decline after the peak catch of 13,800 metric tons in 1942 and in 1963, it dropped to only 369 metric tons after which scallop fisheries was prohibited.

Under such circumstances, fishing ground surveys and releasing practices have been conducted since 1971 centering on the once good fishing grounds in order to establish mother stocks of population scallop and thus renewed reproductions by means of mass releasing of scallop seeds and thereby increasing of the resources.

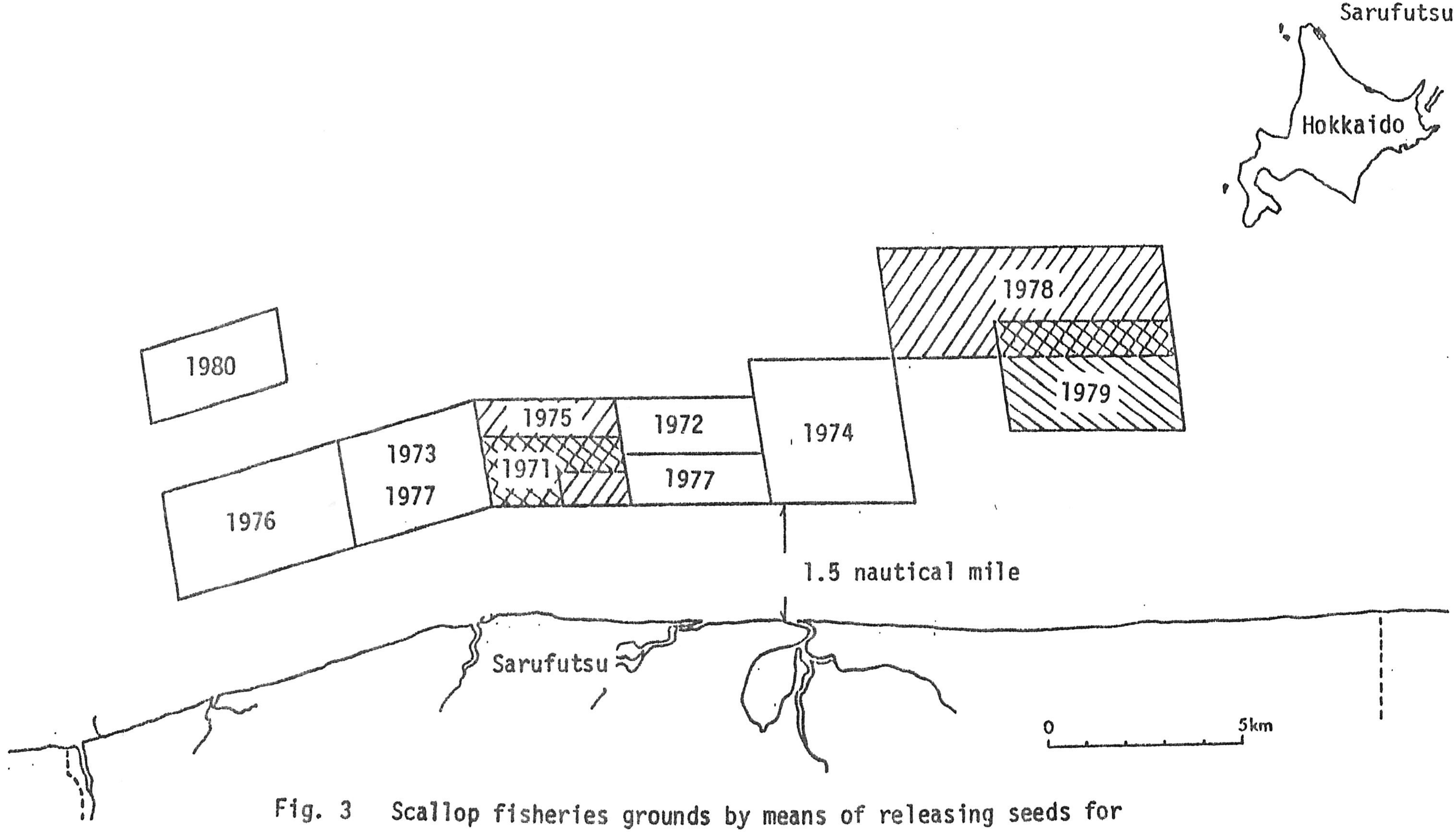


Fig. 3 Scallop fisheries grounds by means of releasing seeds for the stocking in Sarufutsu area since 1971.

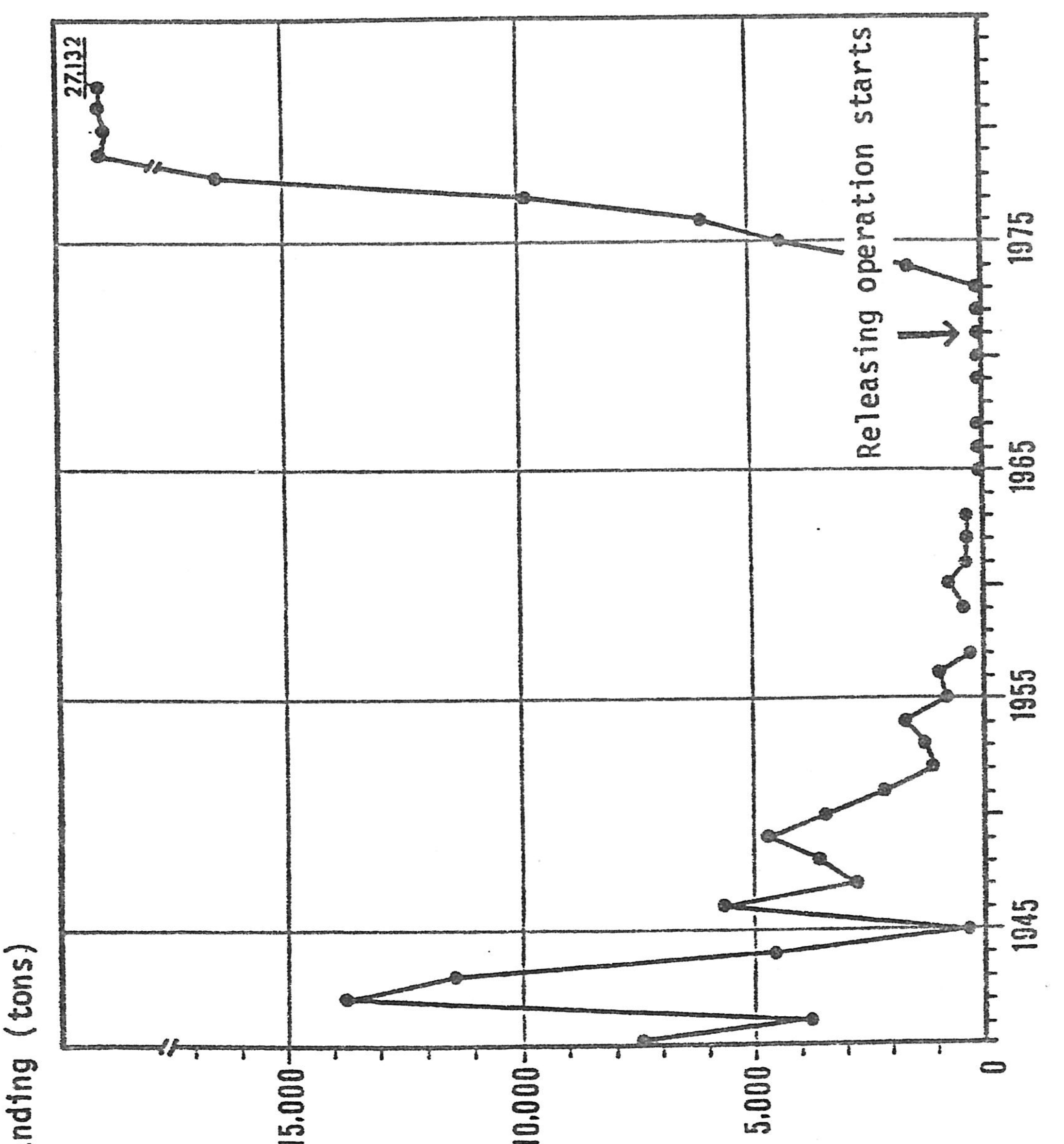


Fig. 4 Scallop productions in Sarufutsu area since 1940

In 1965, a survey was carried out to examine the state of deserted fisheries grounds after prohibition of scallop fisheries. Fig. 5 gives the results of the survey showing number of indivisuals of scallop, starfishes and sea urchins found per 100 square meters. The fauna of megalobenthos species in Sarufutsu area was composed of 10.1% of scallop, 52.8% of starfishes, 34.7% of sea urchins and 2.4% of other species. Sea urchins were dominant in the fisheries ground of more than 4 nautical miles off from the coast while starfishes were dominant in most of the places within 4 miles from the coast. In only a few places within 4 miles from the coast, scallop was the dominant species. Age composition of scallops surveyed during the years from 1963 to 1971 when the seeds were first artificially released showed that old aged scallop of more than 7 years old occupied 50% and young aged ones were very scarece. In 1971, a survey of habitat environment was conducted. The areas selected for this survey were those within demarkated areas of A, B, C and D shown in Fig. 5 wherein scallop was dominent. As a result, it was confirmed that those areas were fit for scallop growth and good as their habitat. After removing starfishes and sea urchins, 14 million seeds of scallop were released to areas a, b, c and d in 1971. Likewise, 57 million seeds of scallop were released to areas e, f, g and h in 1972. From existing knowledge, releasing of seeds at an optimum stocking density of 5 individuals per square meters was set as the target.

As a result, of the 57 million seeds released in 1972, it was found that their survival rate one year after the release was 31.5% and it was 28.9% two years after the release. The maximum density of distribution of scallop was 5 individuals per square meters. And, as shown in Fig. 6, the distribution of such megalobenthos species as starfishes and sea urchins showed a marked difference from that of the state of before the seeds were released in 1971. The fishing ground where starfishes and sea urchins were dominant in 1971 changed to a fishing ground where scallops occupied 87% of megalobenthos species in 1974.[1]

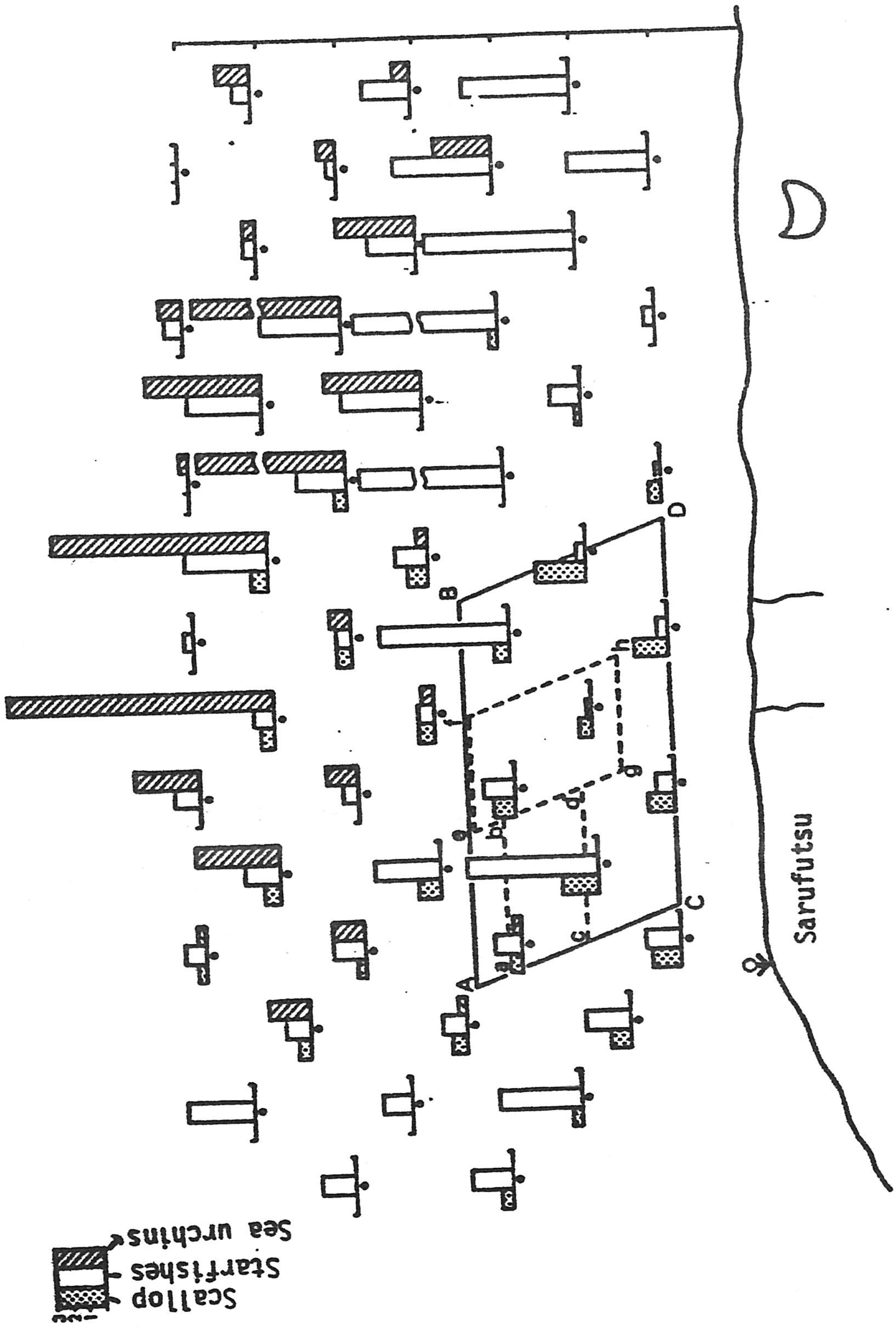
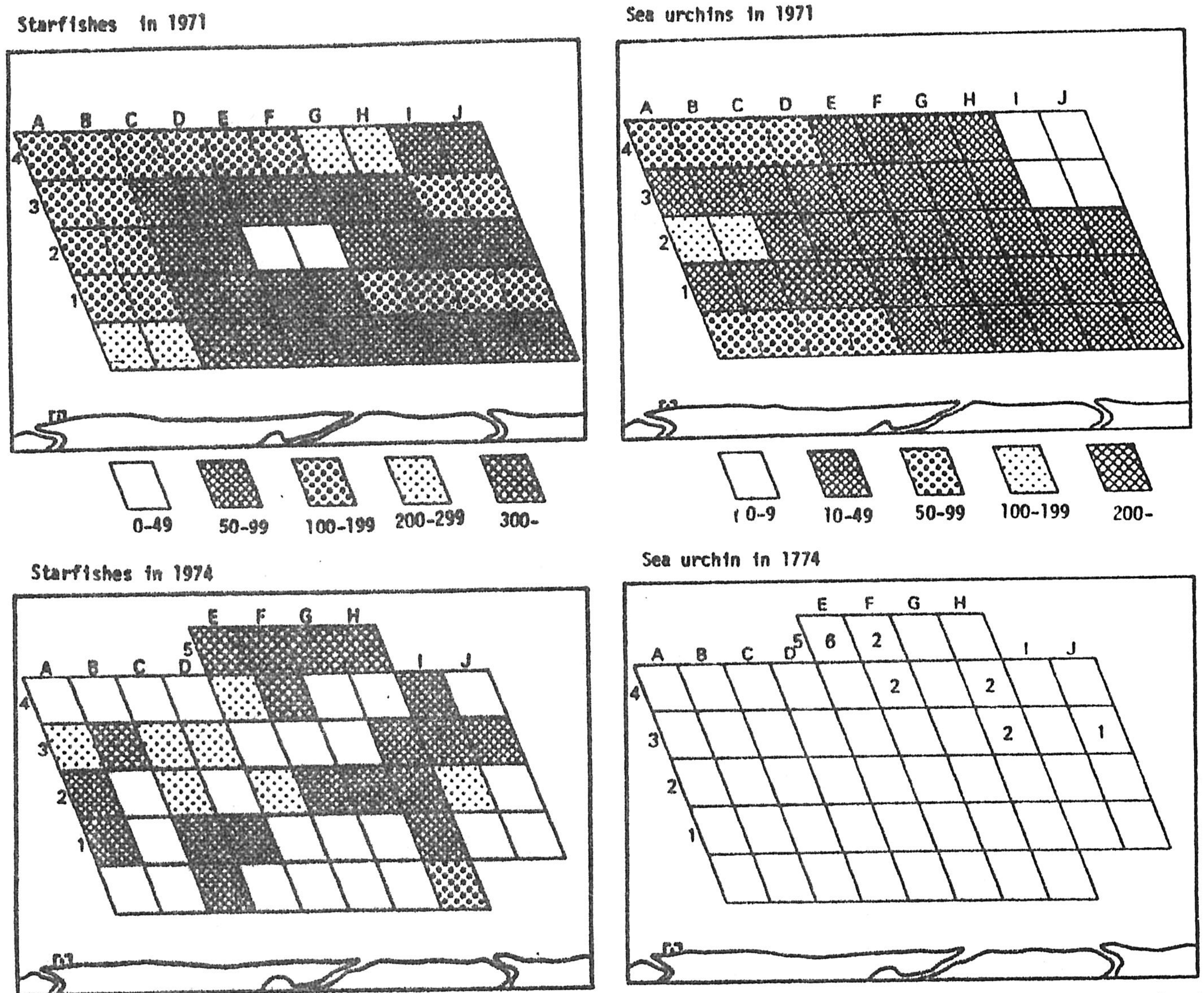


Fig. 5 Megalobenthos per 100 m^2 of bottom in Sarufutsu area in 1965



Unit : per 2,800 m^2 of sampling by bearm trawl net

Fig. 6 Populations of starfishes and sea urchins before/after releasing of scallop seeds

Thus decrease of starfishes and particularly sharp decrease of sea urchins was noteworthy. It is also noted that naturally reproduced scallops have begun to occur every year after 1971 and thus the scallop fishing grounds have rehabilitated. Table 2 shows changes of annual number of released scallop seeds after 1965 and the landings. In 1974, three years after 14 million seeds were released in 1971, 1,663 metric tons of scallop were caught from these stocks. Likewise, 4,334 metric tons of scallop were caught in 1975 from the stocks of 57 million seeds released in 1972. Approximately 60 million seeds had been released a year from 1973 to 1977. Because of the fact that naturally reproduced scallops increased in number, the number of released seeds was decreased. Further, releasing of seeds was ceased from 1980. While the landings have continued to increase year after year and it has been maintained at about 27,000 metric tons in recent years.

Supposing that if survival rate is 30%, catch rate is 80% and weight with shell at the time of fishing is 250 g per indivisual, estimated catch from released seeds of 60 million in number becomes 3,600 metric tons. This clearly suggests that the landings of scallop in Sarufutsu after 1974 include not only released seed scallops but also naturally reproduced ones. Especially in recent years most of the landings are occupied by naturally reproduced ones and it is thought that released scallops account for about 10% of the total catch.

Naturally reproduced scallops in Sarufutsu occur in a very characteristic way. Fig. 7 shows the areas of occurrence of scallop population by year class. Scallop populations in each year from 1973 to 1976 showed that they do not occur mixed in same place. Their distribution expands outwardly from released area, gradually forming belts of scallop beds towards both offshore and land.[2]

Table 2 Records of releasing scallop seeds and landing in Sarufutsu Fisheries Cooperative

Year	Releasing seeds (Unit:ten thousand)	Landing (tons)
1965	10	65
1966	3	41
1967	33	60
1968	36	0
1969	100	69
1970	200	52
1971	1,400	41
1972	5,700	78
1973	6,000	70
1974	6,000	1,663
1975	6,000	4,334
1976	7,000	6,113
1977	6,000	9,891
1978	5,000	16,439
1979	3,500	28,031
1980	0	27,650
1981	0	27,169

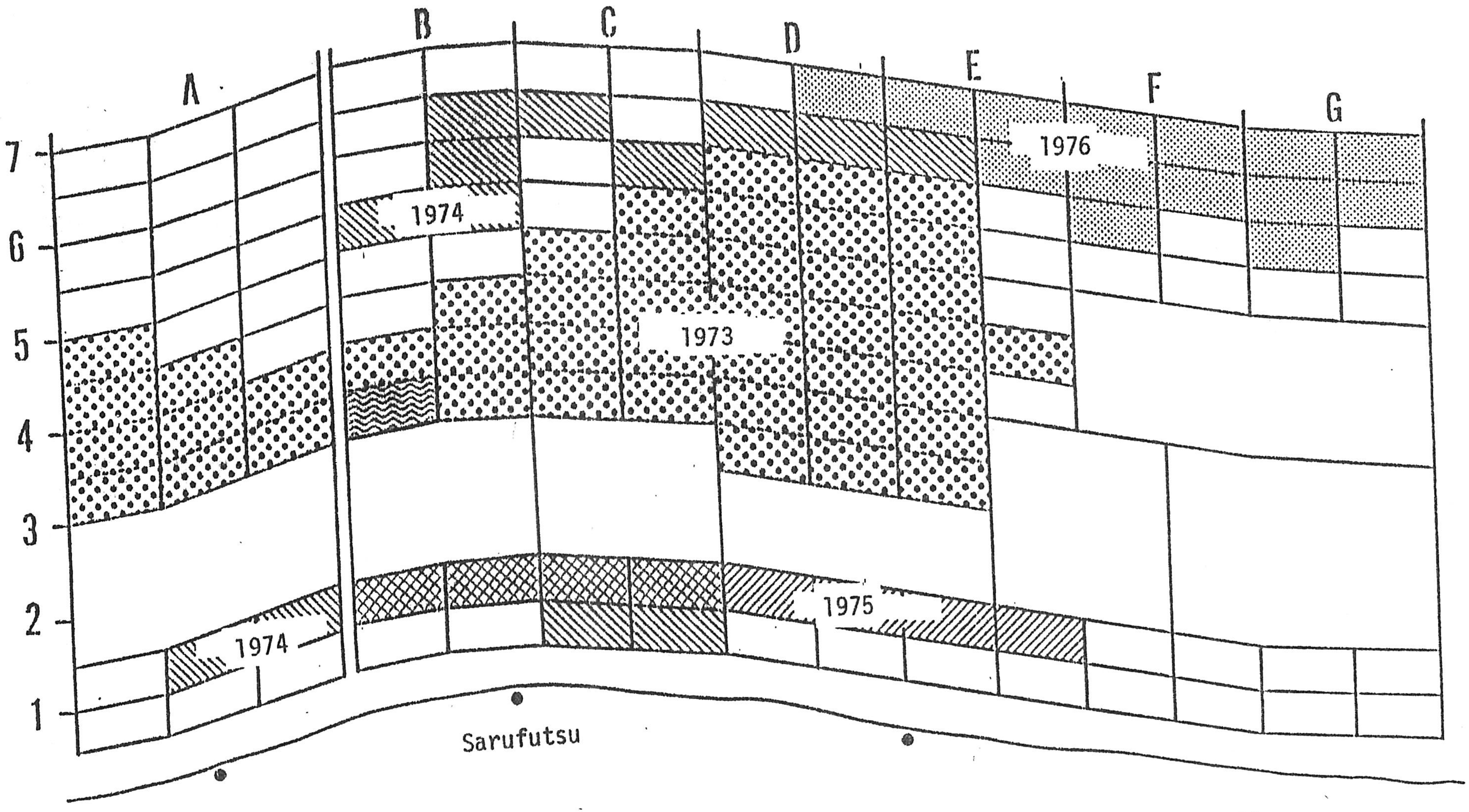


Fig. 7. Occurrence of wild scallop populations in Sarufutsu area during the periods from 1973 through 1976

In 1979, 8 years after mass releasing of seeds began, scallop populations in Sarufutsu were formed in wide and extensive area parallel to the coast line of approximately 15 miles in length and 7 miles in width. The average density distribution within 121 surveyed demarkated areas was 1.4 individuals/m^2 and the highest density found was 10.8 individuals/m^2. The result of another survey conducted in 1980 revealed that estimated total stocks of scallop within all areas of Sarufutsu of up to 8 miles from the coast was 117,000 metric tons.

As described earlier, in Sarufutsu, naturally reproduced scallops which had ceased to be seen for the past ten odd years began to appear in 1971 after mass releasing of scallop seeds was started. Scallop populations have thereafter gradually increased centering around seed released areas. These phenomena attest to the fact that released seeds of scallop have established self-reproducible populations and, because of this, it is thought that the once deserted fishing grounds have been rehabilitated as good scallop fisheries grounds. The fact that starfishes, that is predators of scallop, were removed prior to releasing of seeds, increased populations of released scallop prevented naturally spawned spats from being predated upon by starfishes etc. and that small number of parent scallops regained their reproductive power since scallop populations became dominant and so forth can be attributable to the reoccurrence of naturally reproduced youngs of scallop following the release of seeds in 1971 after the lapse of ten odd years notwithstanding the fact that released youngs of less than one year old scallop could not take part in spawning activity immediately after the release. This example of scallop releasing in Sarufutsu is an example in which a population of species regained its reproduction power. Thus, increase of stocks seems to indicate the result of relationship between reproductive function of populations and the pressure of density of populations.[3]

4. Problems in Scallop Sea Farming

Encouraged by successful results of scallop propagation projects in Sarufutsu, similar propagation projects have been undertaken by fisheries cooperatives in various places. Not in all the places have the propagation projects succeeded like in Sarufutsu area, however, but there have been increasing number of cases where they have succeeded in increasing the production by mass releasing of seeds. In such cases, they do not expect that reproduction takes place in released scallops like in Sarufutsu's case and therefore, their propagation efforts have been continued to stock one generation scallop into the sea.

As the scallop propagation expanded, several problems have emerged. One of them is the problem of overstocking. For example, in Mutsu Bay of Aomori prefecture, it is estimated that optimum stocking density under which proper biological production of scallop could be maintained is about 6 individuals per square meters. But in Mutsu Bay, scallop seeds production has been done in commercial scale and therefore, a large number of seeds of scallop have been overstocked in the fishing ground.

Fig. 8 shows the relationship between released number of scallop seeds for stocking purpose plus number of seeds used for hanging culture and resultant production in Mutsu Bay. In those years when about 800 million seeds had been released annually, production had continued to slightly increase. However, the production did not increase even if number of released seeds increased to 1,200 million and further to 1,600 million: the production levelled off at about 20,000 metric tons as a ceiling figure.[4)]

The example above indicates that releasing of seeds in appropriate number compatible with carrying capacity of target sea area is necessary. In other words, even if any large number of seeds are released to this, in the fishery cooperative No. 1, very high survival rate has been achieved as a result of well managed, proper releasing of sound and healthy seeds.[5)]

There are many problems left which need to be solved, like the question of quality of seeds, carrying capacity as related to stocking density etc. Efforts are being made by those who are concerned to overcome these problems. Accordingly, further development of scallop propagation and hanging culture can be expected in the event that all such problems that come in the way of releasing and culturing efforts are solved and overcome.

without respect to productivity of fishing ground, scallops do not grow but also their survival rate decreases. And thus, a natural balance of biological production becomes impeded, which in turn might ruin the fishing ground in the end. It is necessary to take this into account.

Next, there is a question of quality of seeds. Cultured scallops in Tohoku region and Hokkaido died in mass in recent years. In order to solve this problem, various investigations and experiments were conducted. As a result, it was made clear that this problem of mass death could be overcome by doing away with overstocking of culture, rearing of healthy seeds and by improving management of culture techniques. Declined quality of seeds like in cultured scallops has led to unexpectedly poor survival rate in certain cases of propagation.

In Mutsu Bay, surveys have been carried out, in order to study changes in the state of released scallops, at every fishery cooperative in which releasing of 1979's seeds was done. Table 3 shows the result of investigations at 8 fishery cooperatives. It is noted that there is a big difference in mortality between 1.3% of fishery cooperative No. 1 and 98.1% of No. 8. Rate of occurrence of abnormal scallops is low at 1.3% in fishery cooperative No. 1 but high in fishery cooperatives No. 4 and No. 5, though mortality is low in the latter two fishery cooperatives. Because of predations etc., survival rate declines further before they are caught.

From these findings, it is understood that stocking efforts in nearly half of these fishery cooperatives have not resulted in economically viable business. In the fishery cooperative No. 8 in which almost all released scallops died, the cause of this failure is attributed to the way of rearing of spats before they were released: abnormal seeds were produced which, it is believed, resulted in total failure. In contrast

Table 3 Mortality of man-made scallops on eight Fisheris Cooperative(F.C.) 5)

F.C.	Statue of scallops shown by death, abnormal and normal in % (Death / Abnormal / Normal)	Operation of releasing of scallop seeds: Period		Numbers	Per m^2	S. L. (cm)	Remarks in summer, 1980: S. L. (cm)	T. W. (g)
1	1.3 / 1.3 / 97.4	Winter 1979		50[1]	5.4	3.62±0.44	7.97±0.52	57.7 ± 9.6
2	9.4 / 1.0 / 89.6	〃		3,440	6.6	3.19±0.46	7.19±0.55	38.1 ± 8.0
3	11.4 / 6.8 / 81.8		Spring 1980	370	4.6	4.71±0.56	6.52±0.55	25.8 ± 6.4
4	12.6 / 27.8 / 59.6		〃	1,280	8.5	5.12±0.63	7.55±0.62	46.2 ± 9.9
5	21.2 / 29.9 / 48.9 16.5 / 33.8 / 49.7	〃	〃	917	21.8	3.90±0.49 4.05±0.65	6.98±0.66 6.80±0.63	40.8 ± 10.8 37.6 ± 8.8
6	59.6 / 17.1 / 23.3	〃		1,200	—	3.66±0.55	7.05±0.64	39.3 ± 10.7
7	68.8 / 9.0 / 22.2	〃		1,099[3]	11.1	3.80±0.47	7.04±0.52	32.9 ± 7.2
8	98.1 / 1.3 / 0.6	〃		2,089[1]	12.3	3.61±0.45	7.87±0.54	51.9 ± 10.1

Death Abnormal Normal

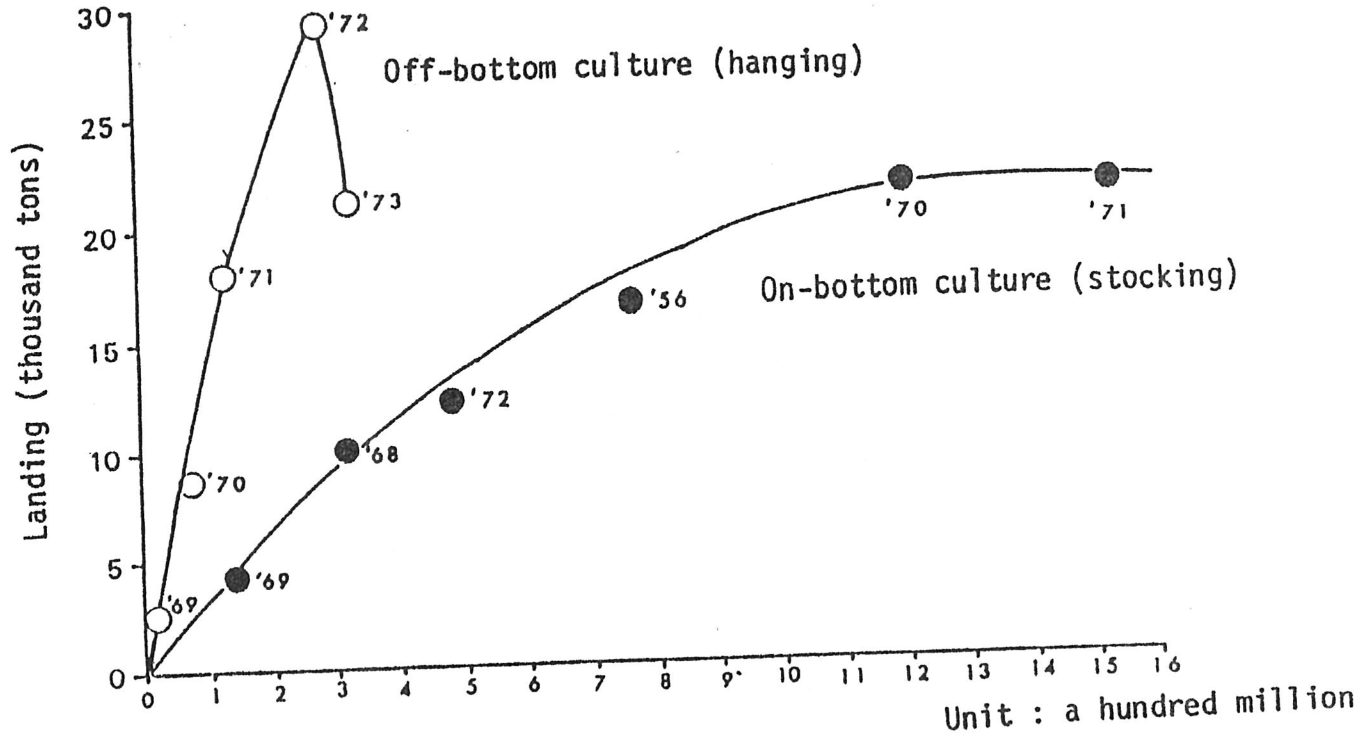


Fig. 8 Amount of scallop seeds used for sea farming related to the landing in Mutsu Bay [4)]

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