Experiments on the Culture of the Rotifer, *Brachionus plicatilis*, with Various Kinds of Food

Tida Pechmanee, Niwes Ruangpanit, Sujin Maneewong and Tanan Tattanon

Introduction

In Thailand, production of the rotifer, *Brachionus plicatilis*, was first studied in 1973, using seed from Japan. In that same year, this rotifer was used to feed the early stage of seabass, *Lates calcarifer* (Bloch), in the first successful attempt at artificial fertilization of this kind of fish (Wongsomnuk, S. and S. Maneewong, 1973-4). This rotifer increased in density from 5 individuals/$m\ell$ to maximum density in 4 to 5 days without adding more food *(Chlorella)*, and that rotifer can grow better in salinity of less than 30‰ than in higher salinity (Chairat et. al. 1973-4).

Suwapeepun (1973) found that this rotifer grows well in 100 - 200 lux light intensity. Pechamanee (1980) found the following for rotifer fed with *Chlorella* in 20‰ salinity water between 25.4°C and 34.0°C: the average life span is 8 days; all are female, each capable of producing 18 small females; each small female can produce eggs within 20 - 26 hours; each egg required 8 - 28 hours for hatching. This rotifer can eat many kinds of food, including phytoplankton, protozoa, yeast, and bacteria (Theilacker and McMaster, 1971), and the amount of food is important for the growth of rotifer population (King, 1966).

The research shows that rotifer has a short life-cycle and many factors effect the growth of rotifer. In mass cultures, some of these factors are difficult to control, but some, such as the kind of food given, can be controlled to bring about optimum growth of rotifer. This experiment was an attempt to discover the effects of various kinds of food on population growth and size of the rotifer, and to examine one process for the cultivation of rotifer in a tropical area.

Materials and Methods

The experiment was divided into 2 parts; work done in the laboratory and work done out-doors. The laboratory portion of the experiment sought to discover the effects of different kinds of food on rotifer, while the out-door portion examined one process of mass culture production of rotifer set up for use in a tropical region and the possibility of using marine yeast as food of rotifer in mass culture.

Laboratory experiments: There were 3 experiments performed in the laboratory. The first was a study of the effect on the population growth of rotifer of using *Skeletonema* sp., *Chasetoceros* sp., and *Tetraselmis* sp. as food. The second was a study of the population growth, in 20 ‰ sea water, of rotifer fed with marine yeast. The third was a study of the size difference in rotifer fed on 4 different kinds of the food: *Tetraselmis* sp., *Chlorella* sp., unidentified blue green alga, spherical in shape and 3 - 5 μ in average diameter and marine yeast.

500 *mℓ* beakers were used as containers for these experiments. From the second day, the rotifer was harvested by draining half the beaker every day and replacing it with the same volume of rearing water. No aereation was given during these experiments, and the density of rotifers and quality of water were recorded every day. The size of rotifer was checked every other day during the third experiment. The experimental rotifers were fed marine yeast for 7 days before the start of the third experiment.

Out-door experiment: In this experiment, 26 ton out-door tanks were used. The rearing water in the culture tanks was adjusted to 20 - 30‰ salinity. Three kinds of food, *Tetraselmis* sp., *Chlorella* sp. (mixed with blue green alga) and marine yeast, were started in a half volume of the tanks (13 tons) with 10 - 20 rotifers/*mℓ* density. In the phytoplankton-rotifer tanks, after two days, rearing water was added to the tanks until they were full. Thereafter, 50% of the rotifers was harvested everyday by draining half the water from the tanks through 63 μ mesh. Rearing water was then added to the rotifer culture tanks to the 26 ton level in order to grow the next batch.

In the marine yeast-rotifer tanks, marine yeast was cultured for 24 hours and then fed to rotifer twice daily. No rearing water was added to these tanks to maintain 13 tons water volume. Rotifers were only harvested at the end of the experiment. During this experiment, the quality of the water was recorded and the population growth of rotifer and the density of food each day were examined.

Fertilizer for food organisms: The formula of chemicals for the phytoplankton used in the laboratory was: $(NH_4)_2\ SO_4$ 100g/ton, agriculture fertilizer formula 16-20-0 15g/ton, and urea 5g/ton. The formula for phytoplankton in the 26 ton tanks was: $(NH_4)_2SO_4$ 1200g, 16-20-0 120g, and urea 60g. The formula for marine yeast used in the laboratory was: sugar 15g, $(NH_4)_2SO_4$ 1g, K_2HPO_4 1g. for 1 litre of water from the fish pond, as the source of marine yeast. When the volume of water was less than 10 ℓ, 1 mℓ of concentrated HCl was added to make the pH level about 4. When the volume was more than 10 ℓ, no HCl was added and the amount of fertilizer per litre was decreased as follows: to each litre of culture water was added sugar 4g, $(NH_4)_2SO_4$ 1 g, and K_2HPO_4 0.25g.

Results

Laboratory experiments: During the study of the effects on the population growth of rotifer of using *Skeletonema* sp., *Chaetoceros* sp., and *Tetraselmis* sp. as food, the salinity of water changed to that of the phytoplankton culture, the pH value in each tank ranged from 8.0 to 8.7, and the water temperature in each tank was the same (Fig. 1). Food density in the experimental containers of the rotifer fed with three alga are shown in Table 1.

Table 1. Food density (10^4 cells/mℓ) in the experimental container of the rotifer fed with *Skeletonema*, *chaetoceros* and *Tetraselmis*

Date	*Skeletonema*		*Chaetoceros*		*Tetraselmis*	
	Supplied	Remained	Supplied	Remained	Supplied	Remained
1	4.7	-	4.8	-	4.1	-
2	5.3	1.3	4.8	-	4.1	-
3	6.3	3.2	7.3	5.0	9.3	0.3
4	8.9	9.5	13.5	17.5	11.5	5.1
5	-	8.3	-	3.0	-	5.4

From the second day, population growth of rotifer fed with *Skeletonema* did not increase, while those fed with *Chaetoceros* increased slightly and those fed with *Tetraselmis* nearly doubled each day (Table 2).

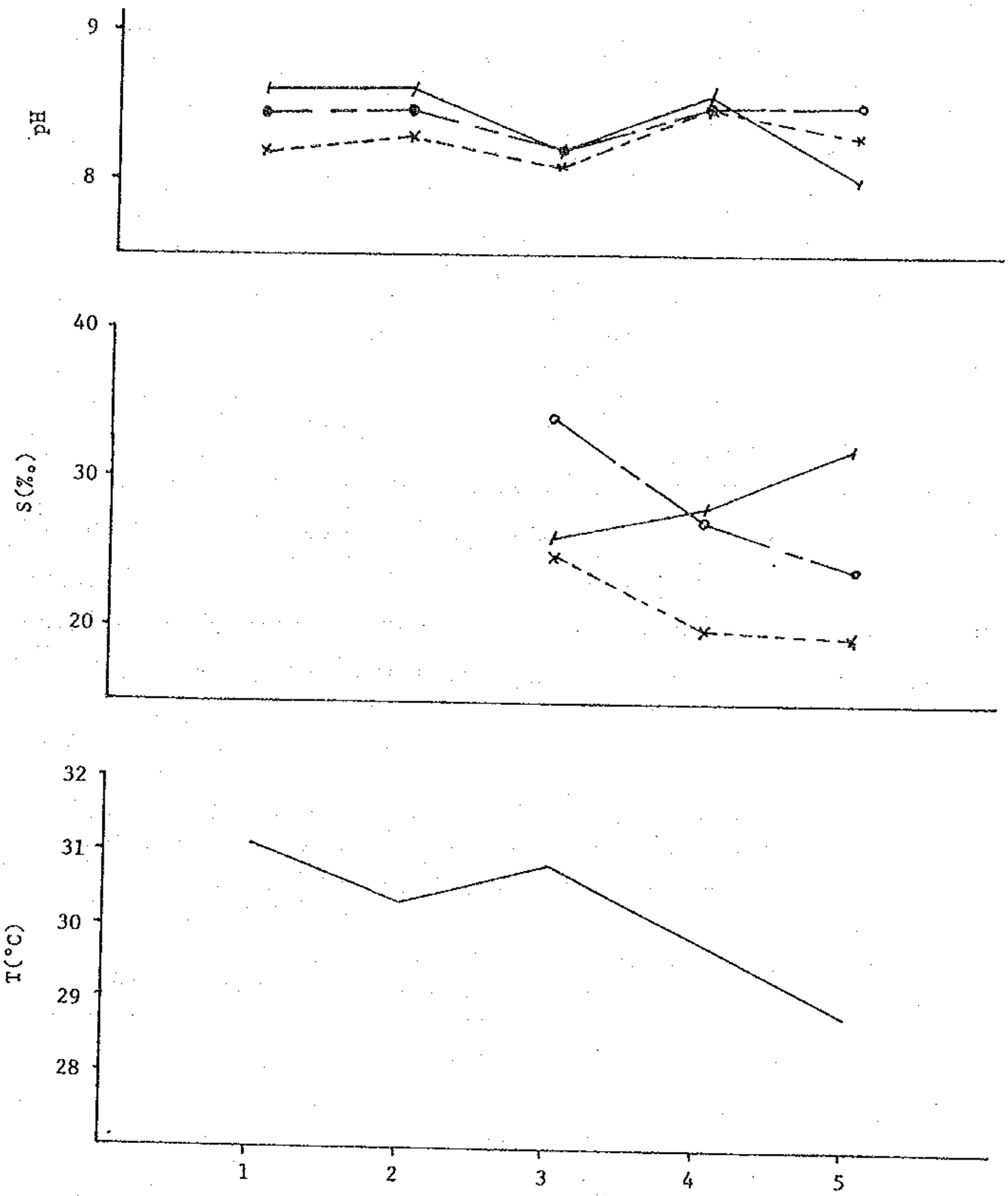

Fig. 1. Water quality in experimental containers of rotifer fed with different food. Water temperature was the same for all containers.

o——o : *Skeletonema*

x------x : *Chaetoceros*

/——/ : *Tetraselmis*

Table 2. Rotifer density (individuals/mℓ), in the experimental container of the rotifer fed with *Skeletonema*, *Chaetoceros* and *Tetraselmis*

Date	*Skeletonema*	*Chaetoceros*	*Tetraselmis*	Water exchanged (%)
1	27	30	38	-
2	23	30	43	50
3	12	17	53	50
4	4	5	54	50
5	2	9	45	-

During the experiment on the population growth, in 20‰ sea water, of rotifer fed with marine yeast, the water temperature (28°C) and pH (7) were nearly constant. The experiment started with 120 rotifers/mℓ which were fed 8×10^6 cells/mℓ of marine yeast twice each day. After being cultured for 24 hours, they doubled in density each day until the end of the experiment (Table 3).

Table 3. Population growth in 20‰ water, of the rotifer, fed with marine yeast, and the water quality in the experimental container.

Date	Temperature (°C)	pH	Yeast (cells/mℓ)	Rotifer (indi./mℓ)	Rotifer harvested (individuals)
1	28.0	7.2	8×10^6	*120 (15)	-
2	28.5	7.1	10×10^6	216 (100)	54,000
3	28.0	7.0	10×10^6	295 (58)	73,750
4	28.0	7.1	7×10^6	204 (84)	51,000
5	28.0	7.0	8×10^6	245 (40)	61,250
6	27.5	7.1	8×10^6	212 (30)	53,000
7	28.0	6.9	-	269 (81)	134,500

* Figure in brackets shows number of rotifer with egg.

During the study of the size differences in rotifer fed with 4 different kinds of food, *Tetraselmis* sp., *Chlorella* sp., unknown blue green alga, and marine yeast, the quality of water for each treatment was not very different (Fig. 2). Food supply and population growth is shown in Table 4. Results showed that the size of rotifers fed marine yeast was 118 μ and 149 μ in width and length respectively, of those fed *Tetraselmis* sp. 145 μ and 185μ, of those fed *Chlorella* sp. 137 μ and 177μ, and of those fed blue green alga 134μ and 166 μ (Table 5).

Table 4. Food supply and rotifer density in the experimental containers using 4 kinds of food.

Date	Food supply (x 10^4 cells/mℓ)				Rotifer density (individuals/mℓ)			
	Tetraselmis	*Chlorella*	Blue green alga	Yeast	*Tetraselmis*	*Chlorella*	Blue green alga	Yeast
1	24	395	1406	100	31 (2)	36 (4)	26 (3)	27 (3)
Δ2	25	167	800	100	32 (14)	44 (19)	47 (19)	29 (2)
3	17	1065	838	100	80 (26)	60 (25)	51 (13)	15 (6)
4	24	963	850	100	70 (33)	75 (18)	68 (19)	14 (1)
5	22	438	713	100	132 (12)	74 (19)	31 (10)	12 (4)
6	40	330	320	100	48 (16)	79 (10)	37 (8)	12 (1)

Figure in brackets shows number of rotifer with egg.

Δ From the second day 50% of the rotifer was harvested every day.

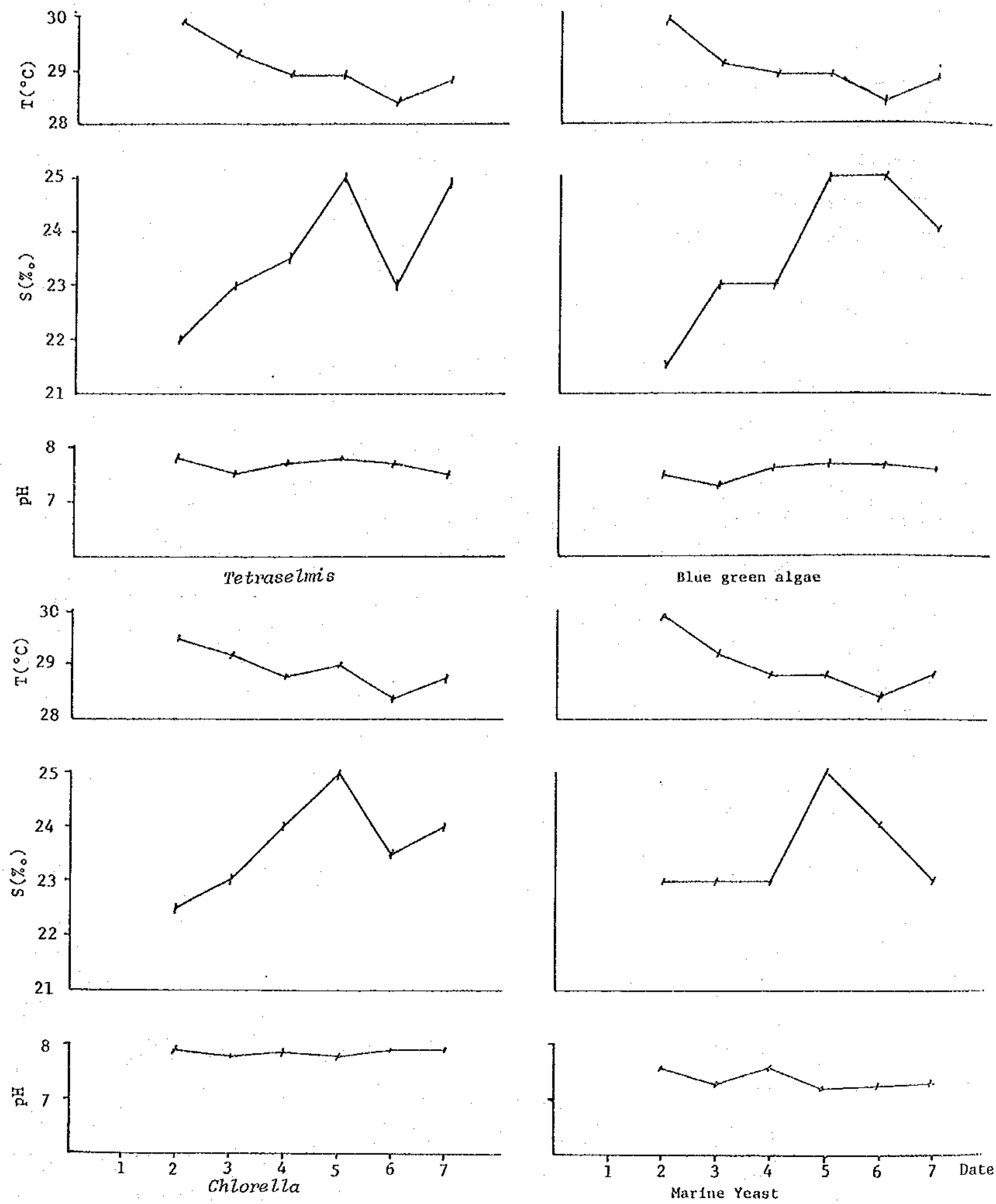

Fig. 2. Water quality in experimental container of rotifer fed with four kinds of food.

Table 5. Lorica size ± standard deviation (micron) of the rotifer fed with different kinds of food.

	Date	*Tetraselmis*	*Chlorella*	Blue green alga	Marine Yeast
Width	1	120 ± 15	120 ± 15	120 ± 15	120 ± 15
	3	139 ± 16	134 ± 14	126 ± 12	199 ± 13
	5	142 ± 11	130 ± 14	133 ± 11	120 ± 9
	7	145 ± 10	137 ± 9	134 ± 9	118 ± 10
Length	1	154 ± 18	154 ± 18	154 ± 18	154 ± 18
	3	169 ± 17	163 ± 13	157 ± 16	153 ± 15
	5	180 ± 13	164 ± 14	166 ± 13	153 ± 9
	7	185 ± 12	177 ± 11	166 ± 11	149 ± 12

Out-door experiment: The water quality for the experiment is shown in Table 6 and Fig. 3, the amount of food used in Fig. 4, and the population growth in Table 7. After 8 days of culturing, the rotifers fed with *Chlorella* yielded 6,994 x 10^6 rotifers per tank, and those fed *Tetraselmis* yielded 7,206 x 10^6 rotifers/tank. The rotifers which were fed marine yeast for 5 days in only 13 tons of water, and which were only harvested at the end of the experiment, yielded 1,807 x 10^6 rotifers.

Table 6. Range of quality of water in rotifer experimental tank (26 tons) fed with *Chlorella*, *Tetraselmis* and marine yeast.

	Tank 1	Tank 2	Tank 3
Chlorella			
Temperature (°C)	27.5 - 29.0	29.0 - 31.0	29.5 - 31.0
Salinity (‰)	23 - 26	23 - 28	26 - 28
pH	7.5 - 9.1	8.3 - 9.5	8.4 - 9.8
Tetraselmis			
Temperature (°C)	27.0 - 29.0	29.0 - 30.0	29.0 - 31.0
Salinity (‰)	24 - 26	23 - 27	26 - 28
pH	8.1 - 9.3	9.8 - 9.8	8.6 - 9.2
Marine yeast			
Temperature (°C)	27.5 - 29.0	29.0 - 33.0	29.0 - 32.0
Salinity (‰)	23 - 25	22 - 25	22 - 24
pH	6.5 - 7.0	7.0 - 7.5	7.1 - 7.7

Table 7. Density of the rotifer and harvest in the 26 ton experimental tank.

Food	Tank	Density of rotifer each day (individuals/$m\ell$)										Harvest ($\times 10^6$ individuals)
		1	2	3	4	5	6	7	8	9	10	
Chlorella	1	13(5)	33(20)	75(31)	80(27)	79(24)	66(16)	80(13)	67(24)	76(9)	55(6)	7,254
	2	12(1)	15(9)	44(8)	90(19)*	86(10)	90(7)	68(7)	38(9)	43(22)	55(17)	6,825
	3	18(3)	26(14)	78(22)	94(11)*	92(12)	62(8)	51(8)	51(15)	51(10)	65(29)	6,903
Tetraselmis	1	14(4)	28(9)	39(17)	114(37)	113(7)*	73(9)	49(11)	55(9)	44(28)	59(9)	5,876
	2	9(2)	18(7)	80(27)	107(10)*	92(16)	73(17)	58(18)	72(9)	70(8)	70(7)	7,956
	3	19(2)	50(26)	68(12)*	70(8)	102(3)	71(6)	67(5)	54(15)	49(17)	59(7)	7,787
Marine** yeast	1	30(14)	61(19)	120(26)	146(19)	162(6)	187(17)	187(16)	230(13)	251(23)	191(10)*	2,483
	2	45(12)	91(8)	106(7)	122(11)	173(12)	127(11)	115(8)*				1,495
	3	40(15)	96(4)	115(6)	126(5)	125(11)	136(8)	115(7)*				1,495

Figure in brackets shows number of rotifer with egg.

* Started harvesting.

** In marine yeast rotifer tank, the water was only 13 tons and harvested rotifer only one time at the end.

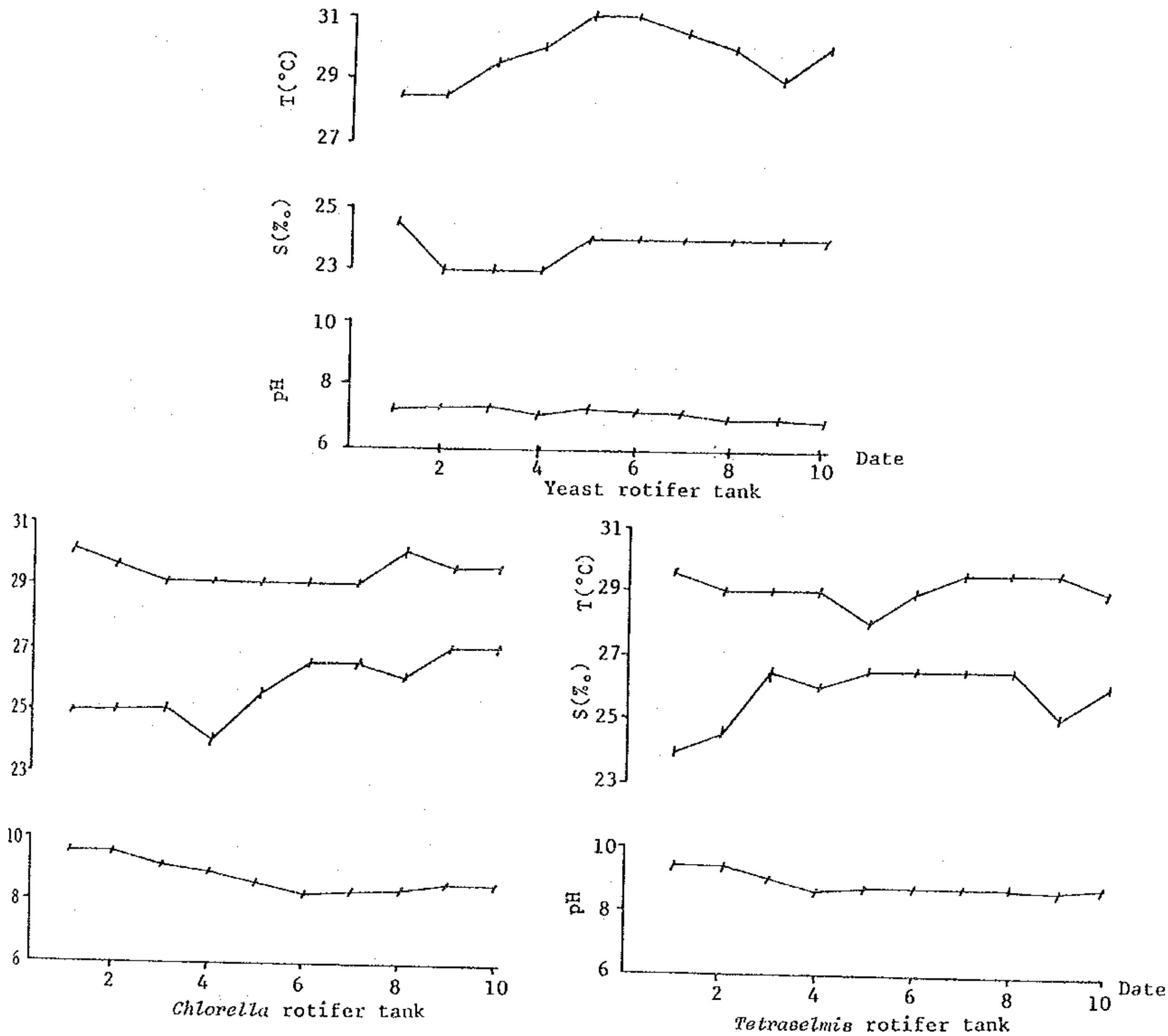

Fig. 3. Water quality in 26 ton out-door tank culturing rotifer fed with different kind of food.

Discussion

The results of the experiment in the laboratory showed that the kinds of food used effected the population growth and size of the rotifer. It seems diatoms are not suitable for feeding rotifer, especially the two kinds of diatoms that were used in this experiment, because the population growth of the rotifer was not good. Marine yeast did show possibilities for use as a food for rotifer if population growth is considered. The results also showed that size of rotifer was smallest when fed with marine yeast and largest when fed with *Tetraselmis:* however, the difference was not very great.

Results of the out-door experiment also pointed to the possibility of using marine yeast as a food for rotifer. It also showed that the process arranged for this experiment could be used for the mass culture of rotifer in tropical regions because the rotifer were harvested continuously for many days at a rather high rate of production.

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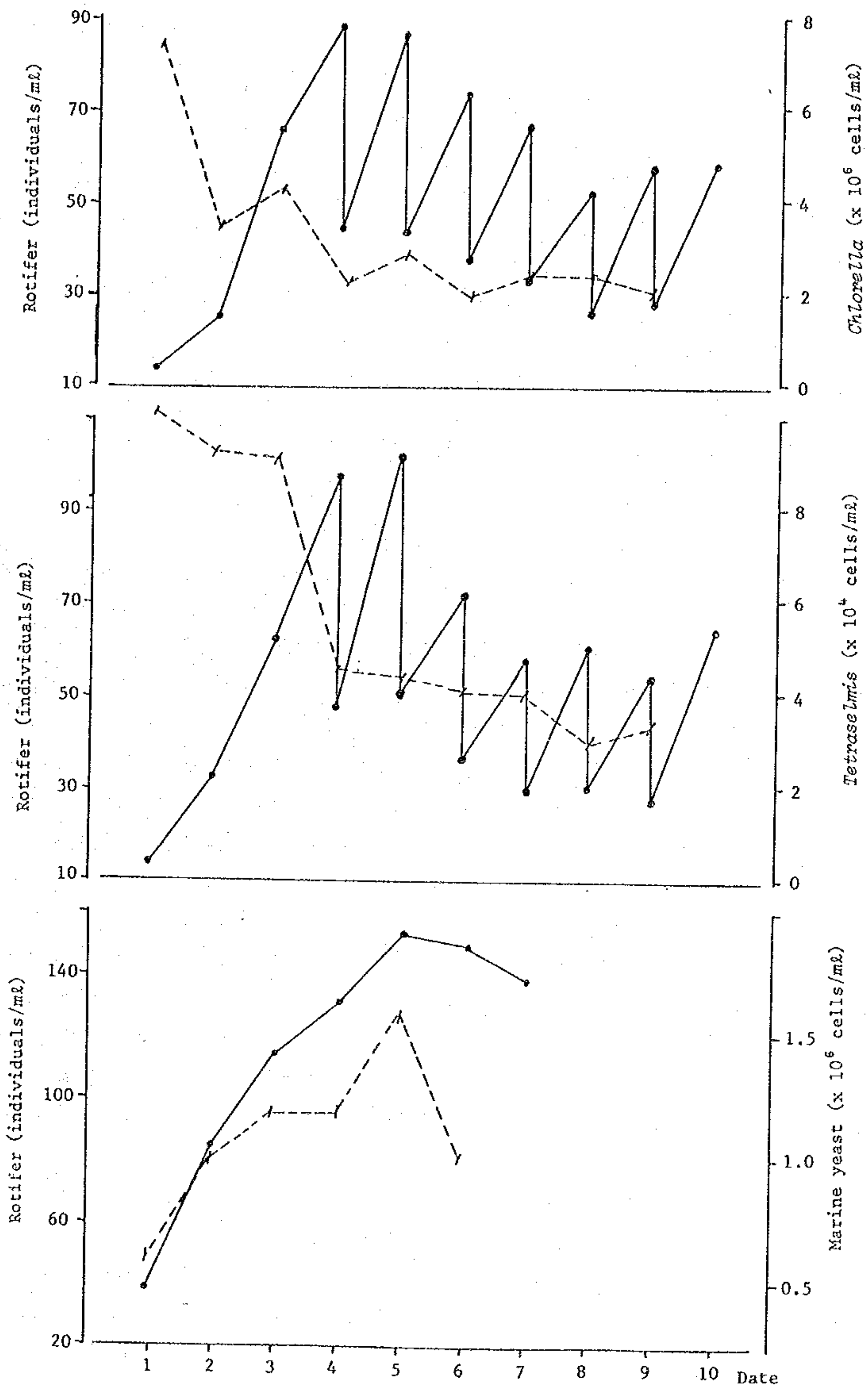

Fig. 4. Density of rotifer and its food in 26 ton experimental tank. ●———●: Rotifer density /-------/ : Food density

Estimation of Feeding Amount for Early Stage of Seabass Larvae, *Lates calcarifer*, Using Rotifer, *Brachionus plicatilis*

Tida Pechmanee, Sujin Maneewong and Paitoon Ugkayanon

Introduction

Calculation of the optimum amount of food to feed each larva per day is important in the culturing of fish especially when the food supply is live and must, itself, be cultured. Feeding larvae at the optimum rate enhances growth and also saves money on seed production. The following experiment was carried out to find an equation for estimating the amount of rotifer, *Brachionus plicatilis*, to feed 2-9 day old seabass larvae, *Lates calcarifer*.

Materials and Methods

First trial: The experiment was performed twice. The first time, six, 30 ℓ, plastic tanks were used, each containing 25 ℓ of lightly aereated water, 33.5 - 34.7 ‰ salinity. The tanks were divided into 2 groups of 3 with 2 different levels of larval density: 20 and 40 individuals/ℓ, respectively. Newly hatched larvae were introduced into each tank in pre-arranged numbers. Throughout the experiment, the water temperature in the tanks ranged from 25.5°C to 29.0°C, and the pH level from 7.7 to 8.4.

Second trial: The second time, four, 30 ℓ, plastic tanks were used, each containing 25 ℓ of lightly aereated water. Newly hatched larvae at a density of 40/ℓ were introduced into each tank. Throughout the experiment, water temperature ranged from 27.5°C to 28.5°C, pH level from 8.0 to 8.6, dissolved oxygen level from 5.2 to 5.9 ppm, and NO_2 level from 8.0 to 22.5 ‰.

Feeding: The rotifer used each day were first filtered and added to *Tetraselmis* water, then checked for density. After that,the amount required for feeding was calculated. The amount of rotifer fed to the larvae was also added to a control tank without larvae, where the number of rotifers remaining and the number added were checked each day.

Feeding took place once each day following the water change; 100% for the first trial, 60% for the second. 1×10^4 cells/mℓ of *Tetraselmis* was added to each tank per day, after which the amount given was checked following the same procedure as for the control tank. Once the experiment had begun, the amount of food remaining from the previous day's feeding was checked each day, just prior to the water change. The amount remaining was subtracted from the total amount given, and the result, divided by the number of surviving larvae, was used to formulate an equation for estimating the amount of feed required for larvae of this age. At the end of each trial, the number of surviving larvae and the total length of 50 larval samples from each tank were checked.

Results

The survival rate and total length for the first trial were 57.6% and 4.38 *mm* for the 20 larvae/ℓ tank, and 64.7%, 4.01 *mm* for the 40 larvae/ℓ tank. For the second trial, the survival rate and total length of the larvae were 35.8% and 4.16 *mm* (Tables 1 and 3).

The number of surviving rotifers in the control tanks fluctuated as shown in Table 5: however, the number of rotifers that disappeared from each larvae tank each day, divided by the number of surviving larvae, represented the amount fed to each larva per day (Tables 2, 4). This data was used to establish an equation for estimating the optimum amounts of rotifer for feeding seabass larvae. These equations were: "$y_1=209.39x - 136.59$" and "$y_2=157.83x - 58.67$", where "y_1" and "y_2" represent the number of rotifers to feed each larva per day when the density of the larvae is 20 and 40 per litre, respectively, and "x" represents the age of the larvae (Fig. 1).

Table 1. Total length and survival rate of 10 day old larvae in the first experiment (T.L. of 2 day old larvae: 2.5±0.1 *mm*)

Larvae density per litre	Rep. No.	Final T.L. ± S.D. (*mm*)	Survival rate (%)
20	1	4.43±0.4	54.2
20	2	4.33±0.4	58.8
20	3	4.37±0.4	59.8
40	1	4.15±0.4	66.8
40	2	3.97±0.4	68.3
40	3	3.91±0.4	58.9

Table 2. Number of rotifers per larvae per day in the first experiment

Larvae per litre	Rep. No.	Age of larvae (days)							
		2	3	4	5	6	7	8	9
20	1	199	598	955	897	1095	1295	1199	1160
20	2	276	642	551	735	1561	1286	935	935
20	3	180	542	722	541	1173	1254	1087	1338
	Average	218	594	743	724	1276	1278	1074	1311
40	1	282	202	687	606	970	728	711	823
40	2	277	277	435	672	732	949	1000	732
40	3	183	504	596	1008	1188	1329	424	722
	Average	247	328	573	762	963	1002	712	759

Table 3. Total length and survival rate of 10 day old larvae in the second experiment (T.L. of larvae newly hatching out: 1.97±0.1 *mm*)

Larvae per litre	Rep. No.	Final T.L. ±S.D. (*mm*)	Survival rate (%)
40	1	4.19±0.5	30.5
40	2	3.88±0.5	27.0
40	3	4.23±0.4	54.2
40	4	4.33±0.6	31.4

Table 4. Number of rotifers per larva per day in the second experiment

Rep. No.	Age of larvae (days)							
	2	3	4	5	6	7	8	9
1	369	164	410	820	820	1066	984	984
2	278	556	648	648	1204	1019	1019	833
3	369	553	560	646	876	1107	1245	1199
4	478	318	398	557	955	955	1115	1035
Average	374	398	504	668	964	1037	1091	1013

Table 5. Density of rotifer (individuals/$m\ell$) in control tank

Date	Experiment 1		Experiment 2	
	Added	Remained	Added	Remainde
1	-	-	8	6
2	-	-	12	6
3	6	4	16	8
4	22	15	17	18
5	27	19	18	15
6	22	21	22	17
7	26	23	25	23
8	21	20	37	29

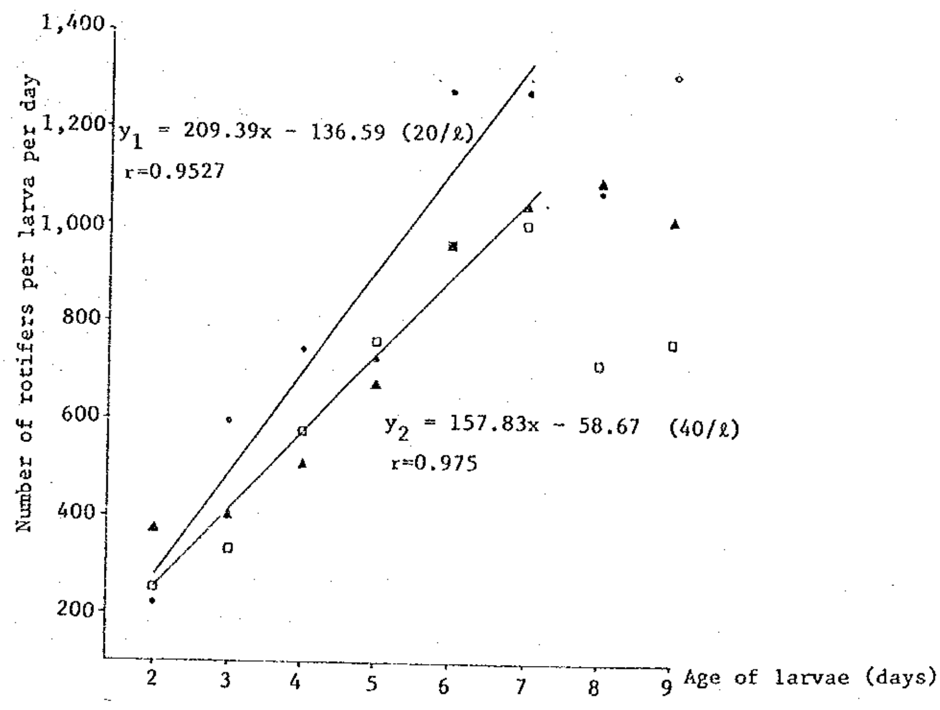

Fig. 1. Amount of rotifers given per larva per day.
●: 20 larvae/ℓ □: 40 larvae/ℓ
in the first experiment. ▲: 40 larvae/ℓ
in the second experiment.

Discussion

The distribution of rotifers in the larvae tanks was unequal and the number of rotifers in the control tank fluctuated, so it was impossible to obtain the real number of rotifers eaten by each larva from this experiment. However, the aim of this experiment was only to estimate the amount of rotifer for feeding each larva each day at this age. It was possible to use the data to formulate the equations because, during this experiment, the larvae grew very fast and survival rates were high.

It was possible to use the equation "y=a+bx" because the correlation coefficient was highly significant, but this equation could be used to determine the amount of rotifer for feeding larvae only at 2 to 7 days old. After that, the data were highly varied and were not used for estimation.

The equations shown above used data from enough replications and seem usable for estimating the amount of rotifer for feeding seabass larvae 2 to 7 days old. However, the amount of rotifer fed to larvae based on these equations was excessive. This is because it was impossible to determine the actual number of surviving larvae each day, so the amount of food given was divided by the number of surviving larvae at the end of the experiment. Because the larvae appear to be sensitive during this period, the amount of rotifer for feeding each day ought to be adjusted, using these equations only as a base.

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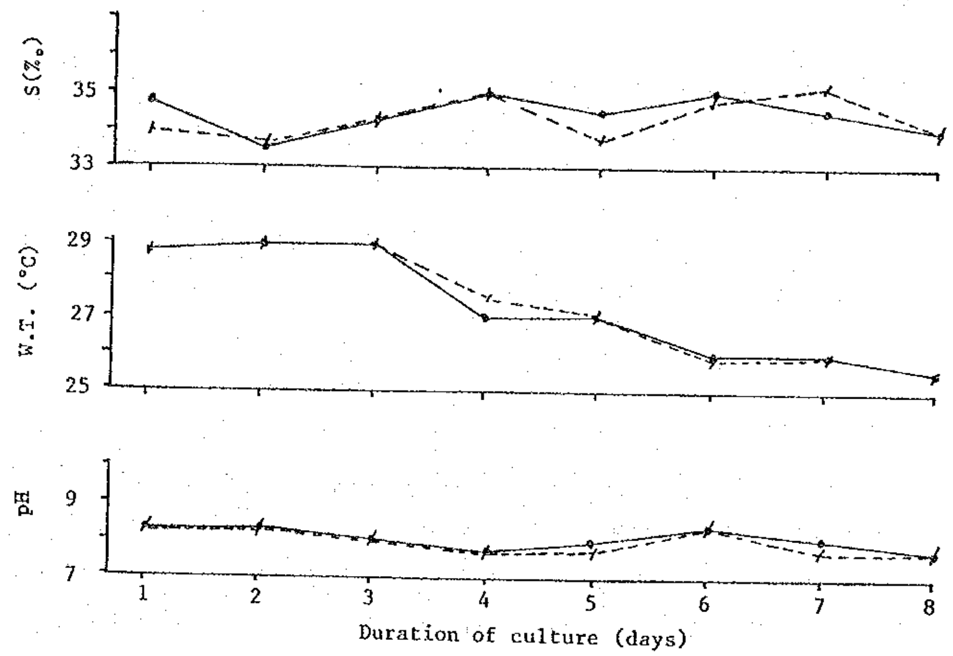

Fig. 2. Average environmental conditions of culture tanks in the first experiment.
●——●: 20 larvae/ℓ. /- - - -/: 40 larvae/ℓ.

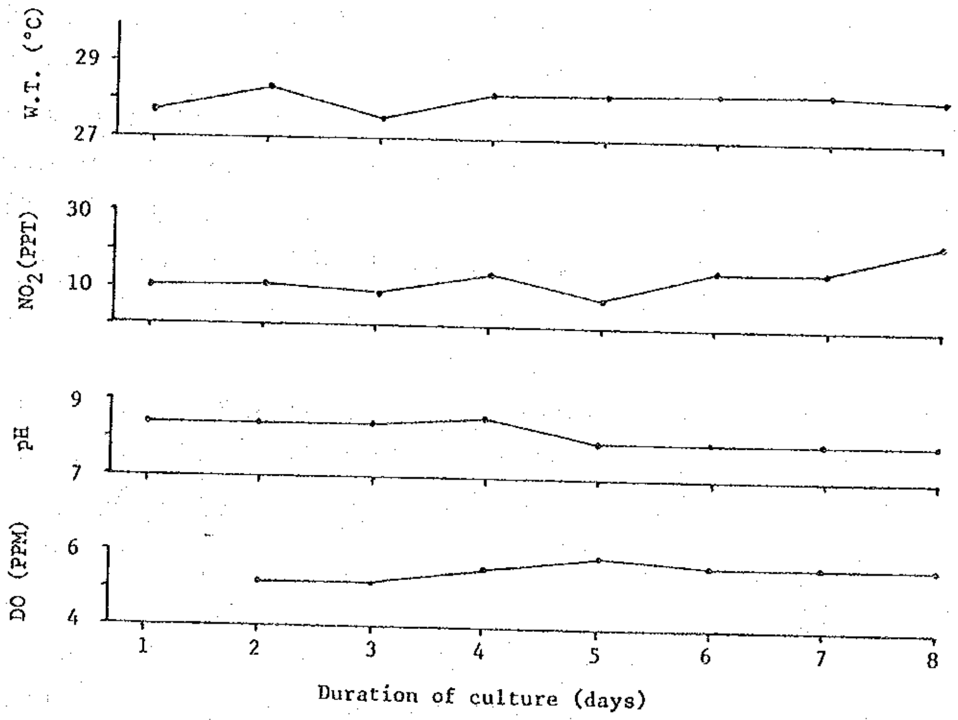

Fig. 3. Average environmental conditions of culture tanks in the second experiment.

Growth Comparison of 11-18 Day Old Seabass Larvae, *Lates calcarifer*, Fed with Nauplius of brine shrimp, *Artemia salina*, and with rotifer, *Brachionus plicatilis*

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Introduction

Two very important food organisms for the larvae of marine fish and shrimp are rotifer and brine shrimp (Girin, 1979). Because the latter is available only from special markets and so is quite expensive, and because the hatching rate of the brine shrimp is dependant on so many factors, it is desirable that rotifer be used as the food source as long as possible. An experiment was therefore carried out to meet the following objectives: first, to compare the growth and survival rates of 11-18 day old seabass larvae, *Lates calcarifer*, fed with rotifer, *Brachionus plicatilis*, to the rates of those fed with nauplius of brine shrimp, *Artemia salina*; and second, to estimate the optimum amounts of rotifer and nauplius of brine shrimp to be used as feed for seabass larvae.

Materials and Methods

Six, 30 ℓ plastic tanks were used, each with 25 ℓ of lightly aerated water of 34 ‰ salinity. One hundred individuals of 11 day old seabass larvae, total length 4.66 *mm*, were introduced into each tank. The tanks were divided into 2 groups of three, and half the larvae were fed nauplius of brine shrimp while half were fed rotifer. Throughout the experiment, the water temperature in each tank was observed to range from 26.5°C to 27.0°C, and the average pH level was 8.5.

Feeding: Naplii of brine shrimp were used immediately after they hatched out. Their density in the hatching tank was checked and the amount required for feeding was calculated daily. The rotifer used daily were first filtered and added to *Tetraselmis* water for 15 min., then their density was checked and the amount required for feeding calculated.

Feeding took place once per day following a 60% water change, and the amount of food given was checked. Each day, prior to the water change, the amount of food remaining from the previous day's feeding was measured. This amount was subtracted from the total amount of food given each day, and the result divided by the initial number of larvae (100), was used in an equation for the estimation of the optimum food amount for larvae of this age. At the end of the 7 day experiment, the number and total length of surviving larvae were checked.

Results

The final, mean total length of larvae fed with nauplius of brine shrimp was 9.63 *mm*, compared to 8.13 *mm* for those fed with rotifer. Their survival rates were 94.7% and 91.0%, respectively (Table 1).

Table 1. Survival rate and total length of seabass larvae, *Lates calcarifer* (Bloch), fed with brine shrimp and rotifer.

Food	Tank No.	Survival rate (%)	Total length of larvae (*mm*)	
			Range	Mean±S.D.
Brine shrimp	1	92	7.0–12.0	9.7±1.2
	2	95	6.7–11.5	9.8±1.0
	3	97	5.3–11.5	9.4±1.1
Rotifer	1	82	6.3–10.0	8.2±0.8
	2	100	5.6–10.0	7.9±0.9
	3	91	5.7– 9.9	8.3±0.8

The amount of food that disappeared from each tank each day, divided by the initial number of larvae, represented the amount fed to each per day (Table 2). This data was used to establish an equation for estimating the optimum amounts of rotifer and nauplius of brine shrimp to be used as feed for the seabass larvae. These equations were: "$y_1 = 63.69x - 630.96$" and "$y_2 = 404.7649x - 3041.67$", where '$y_1$' represents the number of nauplius of brine shrimp to feed each larva per day, 'y_2' represents the number of rotifer/larva/day, and 'x' the age of larvae.

Table 2. Amount of food fed each larva per day

Age of larvae (days)	No. of brine shrimp per larva per day				No. of rotifers per larva per day			
	A_1	A_2	A_3	Average	R_1	R_2	R_3	Average
11	150	100	50	100	1,750	1,750	1,500	1,667
12	150	150	125	142	2,500	2,000	2,000	2,167
13	125	100	225	150	2,500	1,750	1,750	2,000
14	250	200	350	267	2,250	2,000	2,500	2,250
15	250	300	350	300	2,500	2,500	2,250	2,417
16	350	400	400	383	3,250	3,625	3,250	3,375
17	500	500	450	483	4,750	4,375	4,375	4,500

Discussion

After 10 days, total length 4*mm*, seabass larvae can eat nauplius of brine shrimp. To be sure that all samples could eat nauplius, 11 day old seabass larvae, total length 4.66*mm* were selected for this experiment.

The results of the experiment showed that the growth and survival rates of larvae fed with brine shrimp and of those fed with rotifer were not statistically different. This means that rotifer can be used exclusively to feed seabass larvae aged 11 to 18 days.

Similar results have been produced elsewhere. In France (Girin, 1975), *Brachionus plicatilis* was used to feed seabass, *Dicentrarchus labrax* from 4 to 14 days old, total length 7 *mm*. In Japan (Mito, 1967), this rotifer was used to feed serranid fish, *Epinephelus akaara* from 6 to 16 days old, sized 3.5 - 7.0 *mm*. Also in Japan (Fujita, 1973), this rotifer was used to feed red sea bream, *Pagrus major* from 3 to 20 days old, sized 3.1 - 8.1 *mm*. Feeding schedules were as follows:

Dicentrarchus labrax

4-14 days - rotifer/11 - 50 days - brine shrimp

Pagrus major

3 - 20 days - rotifer/ 20 - 35 days - rotifer + copepod or brine shrimp + fish meat.

Epinephelus akaara

6 - 16 days - rotifer

10 - 30 days - brine shrimp

Lates calcarifer

2 - 14 days - rotifer / 8 - 20 days - brine shrimp

As a result of this experiment, the recommended feeding schedule for *Lates calcarifer* should be changed to:

2 - 18 days - rotifer / 19 - 20 days - brine shrimp

While results showed that rotifer can be used until the total length of the larvae reaches 8 *mm* (18 days), the observation was made that, after 4 *mm* (10 days), if the larvae are given a choice, they prefer the nauplius of brine shrimp. Therefore, it is recommended that only rotifer be given until the time arranged for changing to brine shrimp.

It was possible to use the equation 'y = a+bx' to estimate the optimum amounts of rotifer and nauplius of brine shrimp to be used as feed for the seabass larvae because the correlation coefficient was highly significant over the 7 days of the experiment and growth and survival rates were sufficiently high.

The kinds and amounts of food to be given depended more on length and weight of larvae than on their age because larval growth was effected by many factors, such as larval density, temperature, food, etc.

Acknowledgements

We wish to express our deep gratitude to Mr. Pairoj Brohmanonda, Director of NICA. Our thanks are also due to Mr. Tatsuo Watanabe, expert from Japan, and Mr. Chuchat Chairat, senior biologist, who provided many good suggestions and helped to analyse the data from this experiment.

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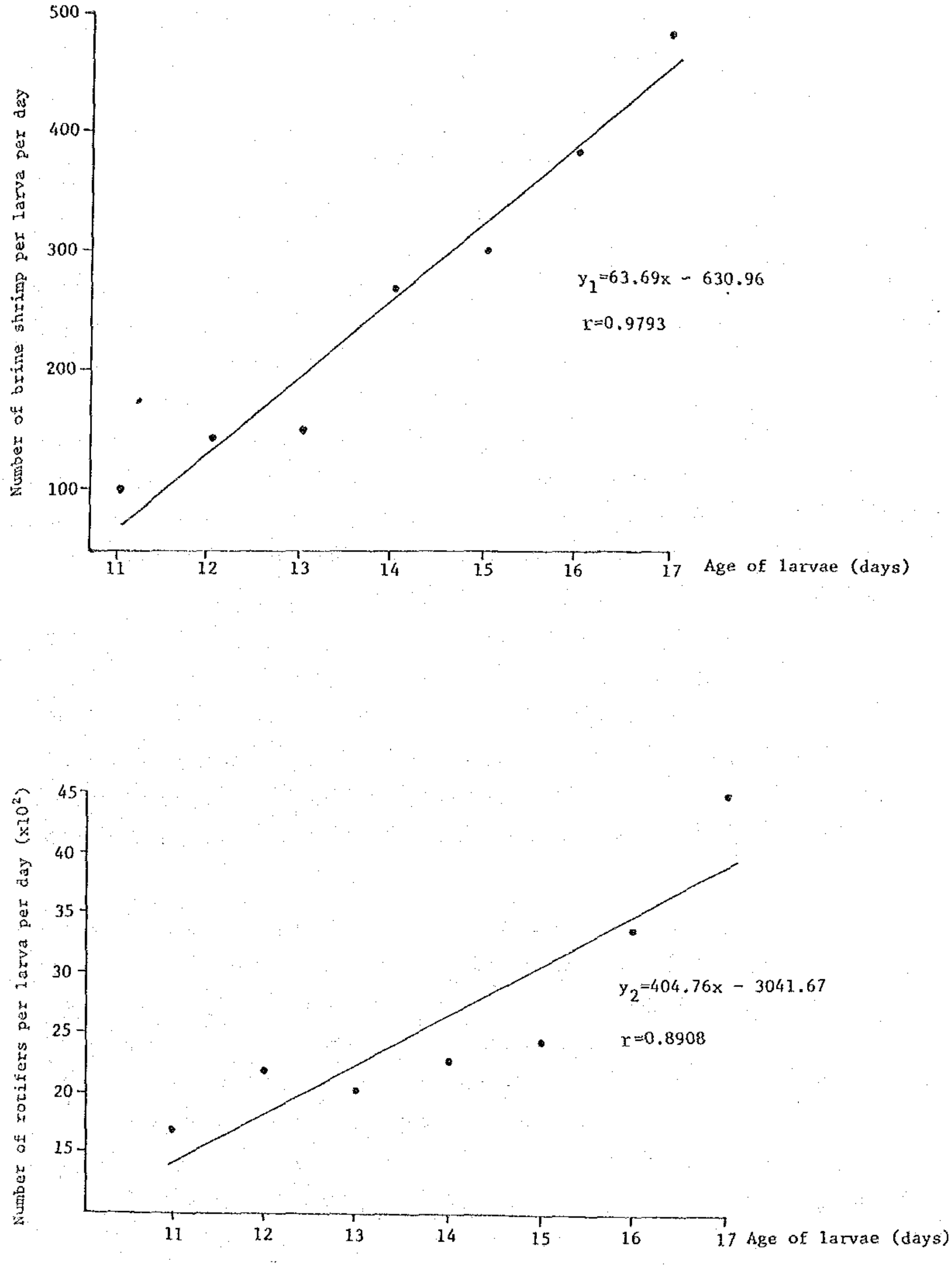

Fig. 1. Amount of food per larva per day.

Study on the Diseases of Seabass, *Lates calcarifer* in Southern Thailand, 1981 - 1983

Yawanit Danayadol

Introduction

In 1981, research was done on fish pathology at the National Institute of Coastal Aquaculture (NICA) in Songkhla, Thailand. Many diseases had been discovered among cultured seabass, either in the hatcheries or in the net cages, and some of these were subjected to pathological study, including gill fluke disease caused by Monogenetic trematoda, white spot disease and Trichodiniasis caused by ciliata, Ergasilus disease caused by parasitic copepoda, Hirudinae disease caused by Annelida, skin disease caused by some bacteria, Columnaris disease caused by Cytophaga, and noninfectuous diseases, such as kidney disease due to nutritional factors.

Materials and Methods

Live samples were brought to the pathology laboratory at NICA from several places, including NICA's Bor-keng station in the outer Songkhla Lake, Koh Yo island also in the outer lake, Hadtraikaew at the mouth of Songkhla Lake, the Chienyai district of Nakornsrithamarat province, and the Tepa district of Pattani province (Figs. 1 and 2)

The samples examined were from 1.5 to 11 cm in total length. They were measured after first being anesthetized with 20 ppm quinaldine. Next, the exterior appearance and the interior organs were examined by microscope. Parts of the skin and gills, and specimens from the organs were observed on slides stained with Gram's stain, and bacteria were observed on some of the samples. Then, bacteria from the skin, liver, and kidney were inoculated into Nutrient Agar and Cytophaga media, and incubated at 20°C, 25°C and 30°C for about 24 - 48 hours. Some disease were examined histopathologically. Specimen were fixed in a 10% formaline solution, dehydrated by alcohol-xylene, embedded in paraffin, cut into 5µ thicknesses, and stained with Harris Haematoxylin and Eosin-y double stain.

Results

Case I - Gill Fluke Disease: This disease was discovered in seabass at NICA's Bor-keng station during the period June to November, 1982. The general symptoms included a change in color to black, open operculum in most fish, and swimming near the surface. Trematoda were observed on smear slides taken from the gill and body surface. Great damage was caused when the Trematoda were attached to the gill filaments and body surfaces. When the disease occurred, the water salinity had decreased from 24 ‰ to a lower level (0 ‰), the water temperature was between 22°C and 30°C, and the pH level ranged from 7.6 to 7.9.

Diagnosis: Gill fluke disease caused by monogenetic Trematoda *Dactylogyrus* sp.

Treatment: The fish were placed in 250 ppm formalin for 20 minutes, then moved to other tanks containing 25 ppm formalin for at least 7 days.

Case II - White spot disease: This disease was discovered in seabass, *Lates calcarifer*, at NICA's Bor-keng station in June, 1981. The general symptoms included a white spot on the body surface, abnormal swimming behavior, open operculum, and, in serious cases, the fish crowded together in one area. Observation of gill and body surface specimens on smear slides revealed ciliata. These parasites had burrowed into the epithelial tissue of the skin and gills. When the disease occurred, the water salinity level ranged from 28 ‰ to 32 ‰, water temperature from 26°C to 26.5°C, and the pH level from 7.6 to 8.0.

Diagnosis: White spot disease caused by *Cryptocaryon* sp.

Treatment: Two different treatments were tried. In one, the fish were placed in a mixture of 250 ppm formalin and 0.4 ppm $CuSO_4.5H_2O$ for 30 minutes. Then they were moved to other tanks containing 0.2 ppm $CuSO_4.5H_2O$ for at least 10 days. In the other, they were placed in a mixture of 0.1 ppm Malachite green and 25ppm formalin for 1 to 2 days.

Case III - Trichodiniasis disease: This disease broke out in a cage culture at Koh Yo island in July and August, 1982. The general symptoms included a change in color to black, some fraying of the fins, and, in serious cases, sluggishness and lack of feeding. Observation of gill and skin specimens on smear slides revealed a large quantity of trichodina. These parasites feed on epithelial tissue and gill filaments (Fig. 2). When the disease occurred, the water salinity ranged from 0 to 24 ‰ , water temperature from 28°C to 32°C, and pH from 7.6 to 7.9.

Diagnosis: Trichodiniasis caused by *Trichodina* sp.

Treatment: The fish were placed in 250 ppm formalin for 20 minutes.

Case IV - Hirudinae disease: This disease broke out in Hadtraikaew in August, 1982. The general symptoms included the presence of Hirudinae parasites, which are visible to the naked eye, the fish's swimming near the surface, and in serious cases, the fish's becomming thin and weak or dying. When the disease occurred, the water salinity level ranged from 28 to 30 ‰, water temperature from 28°C to 29°C, and pH from 7.5 to 7.9.

Diagnosis: Hirudinae disease caused by Hirudinae.

Case V - Ergasilus disease: This disease broke out in the Chienyai district in June, 1983. The general symptoms included the obvious presence of parasites attached to the skin and gills, thinness, sluggish swimming, and open operculum. In addition, about 20,000 fish fingerlings had died. When the disease occurred, the water salinity was 0, the water temperature 28°C, and the pH was 7.8.

Diagnosis: Ergasilus disease caused by *Ergasilus* sp.

Case VI - Skin disease: This disease broke out in the Tepa district in August, 1982. The general symptom was fin rot from which short rod and Gram negative bacteria could be obtained. When the disease occurred, the water salinity level ranged from 0 to 6 ‰, water temperature from 28°C to 30°C, and pH from 7.1 to 7.5.

Diagnosis: Skin disease caused by *Aeromonad hydrophila*

Treatment: Fish were fed 1250 mg Oxytetracycline/1 kg of food/day for 7 days.

Case VII - Columnaris disease: This disease was discovered at NICA's Bor-Keng station in December, 1983. The general symptoms included lesions on the skin which turned a yellowish color, and most fish had fin rot. Long rod, gram negative, and flexible bacteria were observed at first, then some short rod and gram negative mixed on the lesions. Yellowish and Rizoid colony bacteria were grown in a Cytophaga medium. When the disease occurred, the water salinity had decrease to 0 to 8 ‰, water temperature was about 25 °C to 27°C, and pH from 7.0 to 7.8.

Diagnosis: Columnaris disease caused by *Flexibacter columnaris*.

Case VIII - Kidney disease: This disease broke out at NICA's Bor-keng station in November, 1983. The general symptoms included a change in color to black, small abscesses on the body surface, and abdomen and kidney swollen with cysts. When the disease occurred, the water salinity ranged from 0 to 23 ‰, water temperature from 25°C to 30°C, and the pH from 7.0 to 7.8.

Diagnosis: Kidney disease caused by nutritional factors.

Discussion

This paper is a preliminary report on 8 cases of diseases occurring in seabass cultured in southern Thailand from 1981 to 1983 (Table 1). The diseases reported on, including parasitic disease, bacterial disease, and nutritional disease are not examined in detail, which should be the object of a future paper. The kinds of diseases occurring and the damage they result in are increasing year by year.

Table 1. Diagnosis and treatment of the diseases of seabass.

Disease	Diagnosis	Treatment	Result
Gill fluke disease	Caused by *Dactylogyms* sp.	250 ppm formalin for 20 mins. and long bath in 25 ppm formalin for 7 days.	Good
White spot disease	Caused by *Cryptocaryon* sp.	1) 250 ppm formalin mixed with 0.4 ppm $CuSO_4.5H_2O$ for 30 mins. and long bath in 0.2 ppm $CuSO_4.5H_2O$ for 10 days.	Good
		2) 0.1 ppm malachite green mixed with 25 ppm formalin for 1-2 days.	Good
Trichodiniasis disease	Caused by *Trichodina* sp.	250 ppm formalin for 20 mins.	Good
Hirudinae disease	Caused by Hirudinae	-	-
Ergasilus disease	Casued by Ergasilidae	-	-
Skin disease	Caused by some bacteria	Oral administration of 1250 mg oxytetracycline per kg of food per day.	Good
Columnaris disease	Caused by *Flexibactor columnaris*	-	-
Kidney disease	Caused by malnutrition	-	-

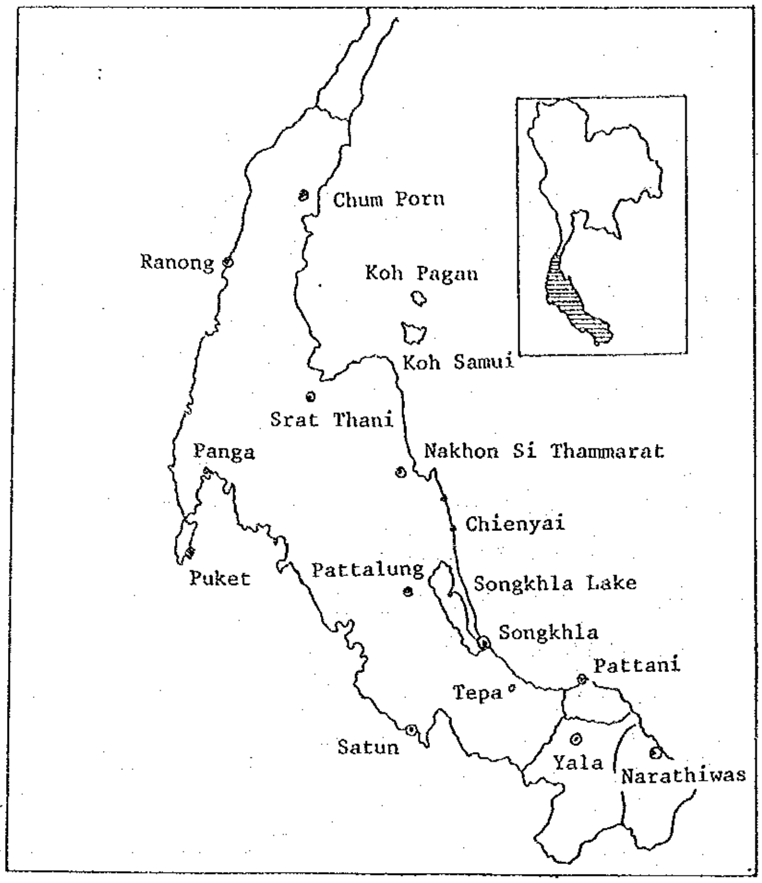

Fig. 1. Map of southern Thailand.

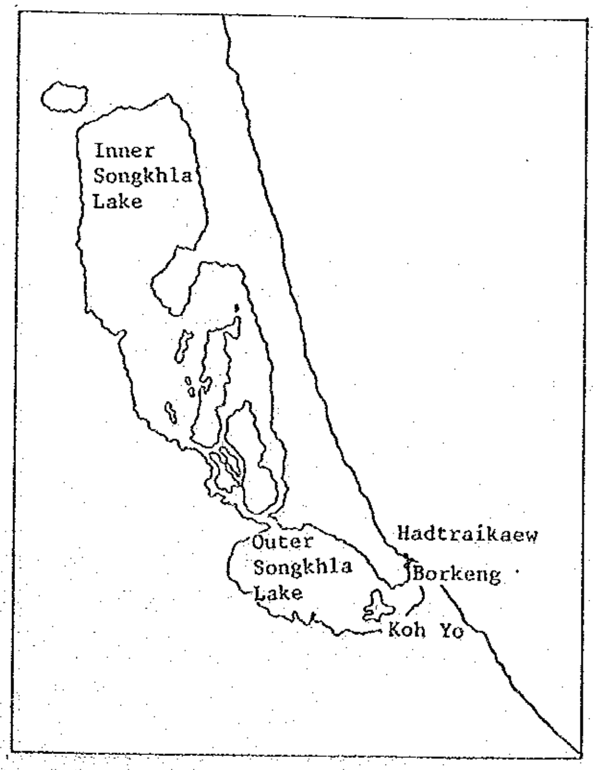

Fig. 2. Map of Songkhla Lake

Study on the Areas of Occurrence and Symptoms of a Kidney Disease in Cultured Seabass, *Lates calcarifer*

Yawanit Danayadol and Jarurat Boonranapanichagit

Introduction

Songkhla was the first coastal area in southern Thailand in which the culturing of brackish water seabass, *Lates calcarifer*, was practised. Later, seabass were also cultured in other coastal areas of the south, such as Nakornsrithamarat, Pattani, Narathiwas, and Satul. As the culturing of seabass spread, fish pathologists began to study the diseases which occurred, discovering gill fluke disease, Trichodiniasis, white spot disease, and columnaris disease among others.

In November, 1983, a disease broke out among seabass cultured at Bor-keng, the culturing area of the National Institute of Coastal Aquaculture (NICA), in the Mongig district of Pattani province, and in the Chienyai district of Nakornsrithamarat. The symptoms of this disease were similar to those of Bacterial Kidney Disease in Salmonids (BKD). (Bullock, et. al., Richards and Roberts, 1978).

This was the first reported outbreak of kidney disease in seabass. It is interesting because, while the symptoms are similar to BKD, bacterial examination and histopathological study found that the disease is not caused by bacteria and is not infectious.

Materials and Methods

Data Collection: In December, 1983, ten diseased seabass were obtained, along with water quality data, from NICA's culture area at Bor-keng, situated at the mouth of Songkhla Lake, and brought to the pathology laboratory at NICA. The fish were anesthetized with 20 ppm quinaldine for 3 minutes, then measured for total length.

Pathological Anatomy: External observation was made of abnormal skin color, eyes, and fins. The abdomen was cut open to observe the liver, heart, stomach, intestines, and spleen. Abnormalities were evident to the naked eye as well as under the stereomicroscope. The kidney was observable only after removing all other internal organs and the swimbladder. Imprint slides were made from the livers and kidneys and stained with Gram's stain with crystal violet, followed by iodine solution, acetone-alcohol, and safranin. The slides were then examined under a microscope. Kidney abnormalities were smeared on a slide and examined directly.

Bacteria from the diseased kidneys were inoculated into the following media: Brain Heart Infusion Agar (BHA), Trypticase Soy Agar (SA), Blood Agar (BA), Tellurite Blood Agar, Blood Agar with Cystein, and modified media of Topping. Each medium was divided into halves for incubation at either 25°C or 30°C for 24 - 48 hours.

The abnormal portions of the stomach, intestine, spleen, liver, kidney, and heart were fixed in 10% formalin, dehydrated in an alcohol and xyline series, then embedded in paraffin. The organs were then sectioned with a microtome into 7μ thicknesses, then either double stained in Harris Haematoxyline and Eosin-y or stained in Alizarin S. Finally, the histopathological changes were observed under the microscope.

Results

Effected areas: Diseased fish were found in the culturing areas of NICA at Bor-keng, of Pattani Province in the Nongig district, and of Nakornsrithamarat in the Cheinyai district (Fig. 1).

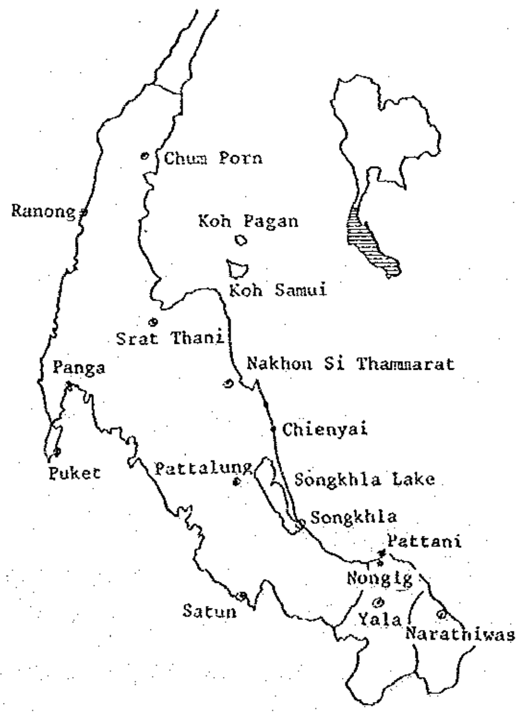

Fig. 1. Map of southern Thailand

General Symptoms: The symptoms of the disease included sluggish swimming, low feeding levels, black body color, exopthalmos (Fig. 2), swelling of the abdomen (Fig. 3), abscesses on the lateral body surfaces, or on the operculum. Parasites were observed on all fish samples (Table 1). Large nodules were observed on the liver (Fig. 4), heart, and especially on the kidney (Fig. 5).

Table 1. Results of observation on samples of seabass suffered from kidney disease.

No. of sample	Body length (cm)	Parasite observed	Nodule coverage in the internal organs			
			Kidney	Liver	Heart	Spleen
1	6.2	Monogenea *Trichodina*	+	–	–	–
2	6.7	Monogenea *Trichodina* *Henneguya*	+	+++	+++	–
3	5.2	Monogenea *Trichodina* *Henneguya*	+	–	–	–
4	6.5	Monogenea *Trichodina* *Henneguya*	++++	–	–	–
5	5.7	Monogenea *Trichodina*	++++	–	–	–
6	6.6	Monogenea *Trichodina* *Henneguya*	++++	–	–	–
7	6.1	*Henneguya* *Trichodina*	++++	–	–	–
8	5.8	Monogenea	++++	–	–	–
9	5.6	Monogenea *Trichodina*	++++	+	–	–
10	5.1	*Trichodina* *Henneguya*	++++	–	–	–
11	5.2	*Trichodina* *Henneguya*	++++	–	–	–
12	4.8	Monogenea *Trichodina* *Henneguya*	++	–	–	–
13	6.0	Monogenea *Henneguya*	++	+++	–	–

– : none ++ : some ++++ : heavy

\+ : slight +++ : moderate

The symptoms present in the diseased kidney varied with the severity of the infection. In a serious case, large nodules were found on all or part of the kidney, causing it to swell to 2 - 4 times normal size. Its color became pale, it grew hard to the touch, and it adhered to the swimbladder. In some cases, large nodules became embedded in the muscle layer, causing abscesses to appear on the lateral surfaces. In the least severe cases, swelling was limited to one or two small nodules on the posterior kidney. A yellowish, needle type crystal (Fig. 6) which appeared on the slides on nodules could be dissolved in 1N. HCl. Bacteria was not found either on the imprint slides or in any of the media cultures.

Histopathological changes: The stomach, intestine and heart were found to be normal, while the liver, spleen, and especially the kidney, were found to be abnormal. There was widespread inflammation. Only a few parts of the renal tube and glomeruli remained. The inflamed area (Fig. 7) was not clearly distinguishable from the normal area. The abnormal area contained widely focused necroses cells. The melanin increased in size and either changed the necrobiotic size or caused the melanin to scatter.

Discussion

The disease occurred in several areas of southern Thailand at the same time, even though the shortest distance between areas was 60 km and the environment was quite different at each. All seeds came from the same hatchery and the same food and similar feeding techniques were used in all areas. Fish farmers in all areas used only deboned flesh of trash fish as the basic food source. Most of the diseased fish were of the same age and size.

The exterior symptoms of the disease were the same in each area; i.e. sluggish swimming, low feeding levels, black body color, exopthalmos, swelling of the abdomen, abscesses on the lateral body surfaces, and nodules in some internal organs, especially the kidney. A fish pathologist would normally relate these symptoms to kidney disesase. Kidney disease in yellowtails, red seabream, and salmonids causes the body color to become black.

Because the yellowish, needle type crystal formed not only in the liver but in the eyes and heart as well, we have supposed the crystals were caused by malnutrition; i.e. an unbalanced mineral intake or an overdose of one mineral. Also, because these crystals dissolve in acid and alkaline, and because they are not stained by Alizarin S, it appears they may be phosphorus.

Histopathological observation showed that these yellowish crystals were being captured by phagocyte, causing most of the melanin particles were scattered. As a result of this cell reaction, nodules were formed which prevented the area within from receiving nutrition, resulting in necrotic cell formation at the center of each nodule. Similar histological changes have been observed in red seabream and other fishes exposed to an overdose of minerals, according to Dr. Toshihiko Matsusato at the National Research Institute of Aquaculture of Japan.

Fish pathologist require more research on the effects of an excessive intake of phosphorus and other minerals, and the effects of Ca-P unbalance in seabass.

Acknowledgement

We wish to thank Dr. Toshihiko Matsusato for advice to studying and writing of this paper.

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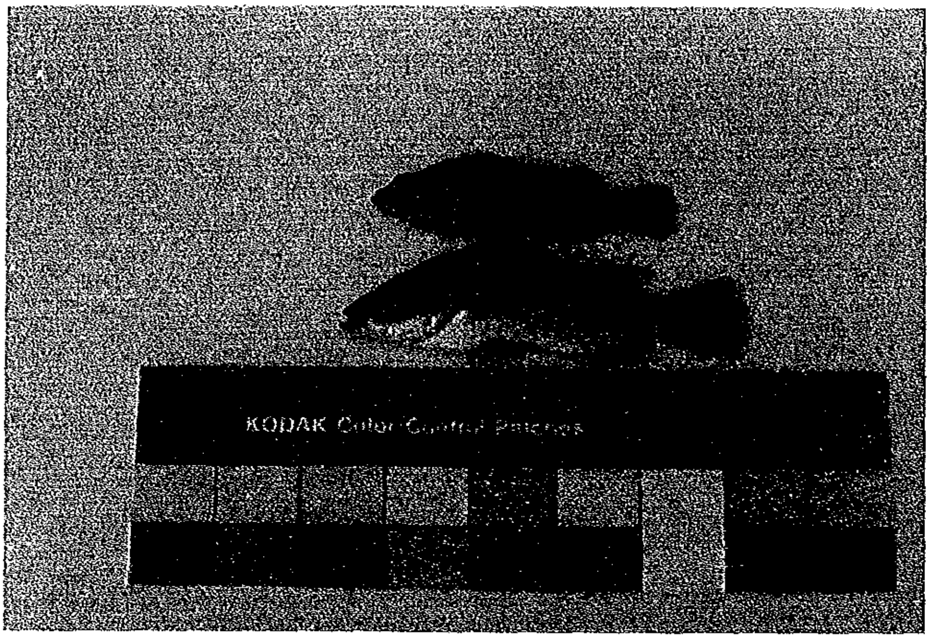

Fig. 2. Dark body color and exophtalmos of kidney disease of seabass. Above: diseased fish. Below: normal fish.

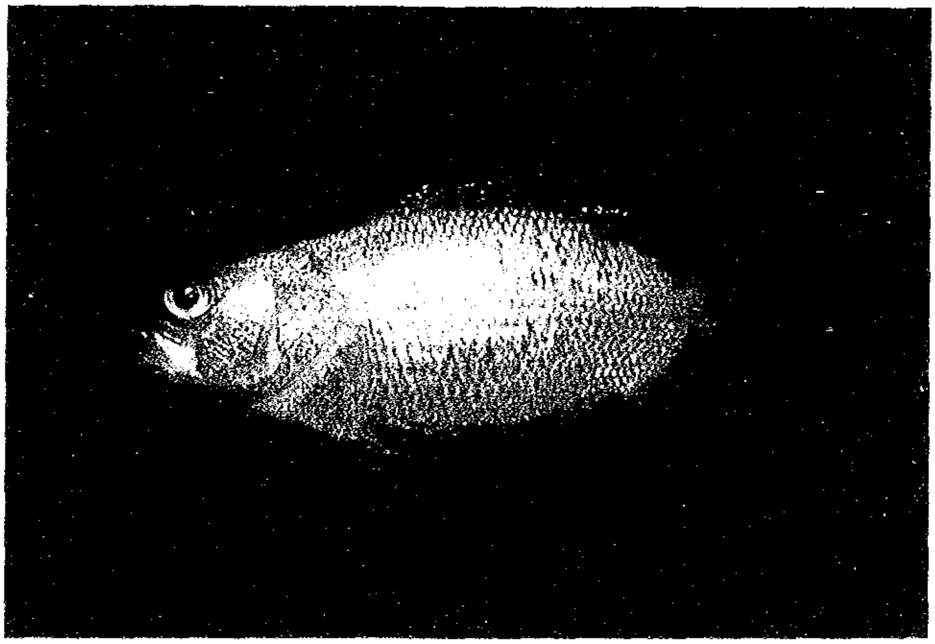

Fig. 3. Swelling of abdomen of seabass caused by kidney disease.

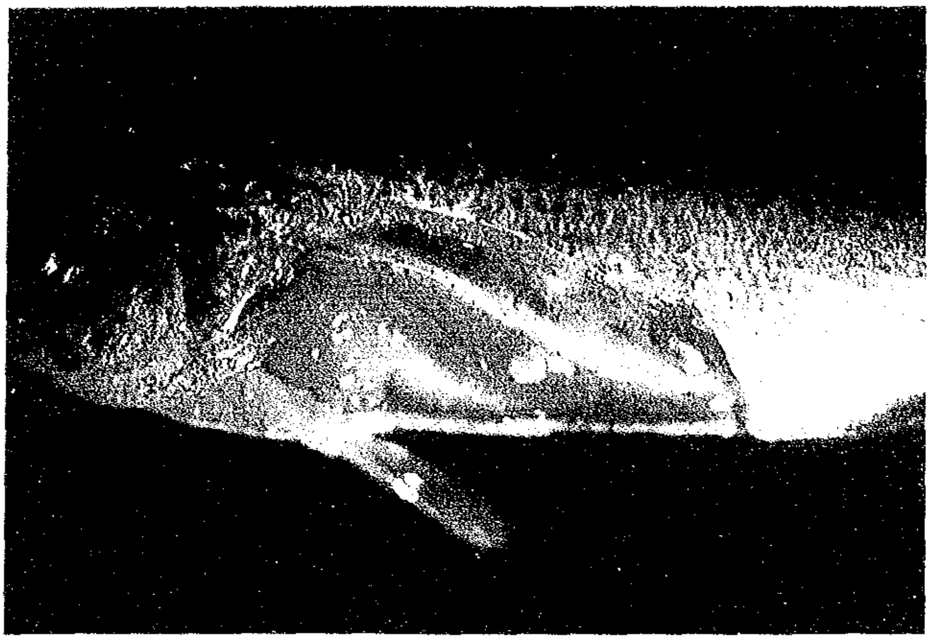

Fig. 4. Nodules on the liver caused by kidney disease of seabass.

Fig. 5. Nodules on the kidney caused by kidney disease of seabass.

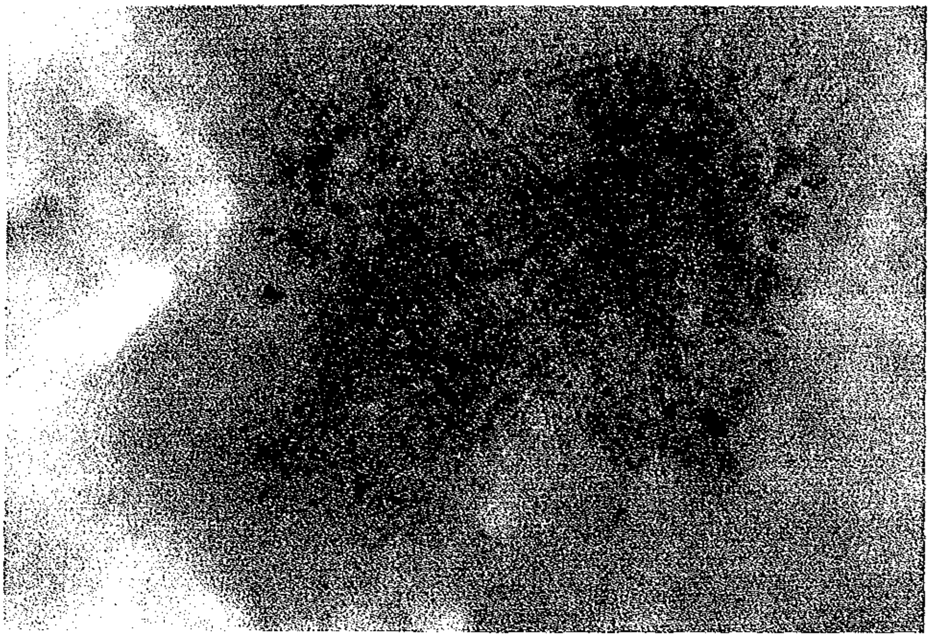

Fig. 6. Needle like crystals on smear slide taken from kidney of seabass suffering from kidney disease.

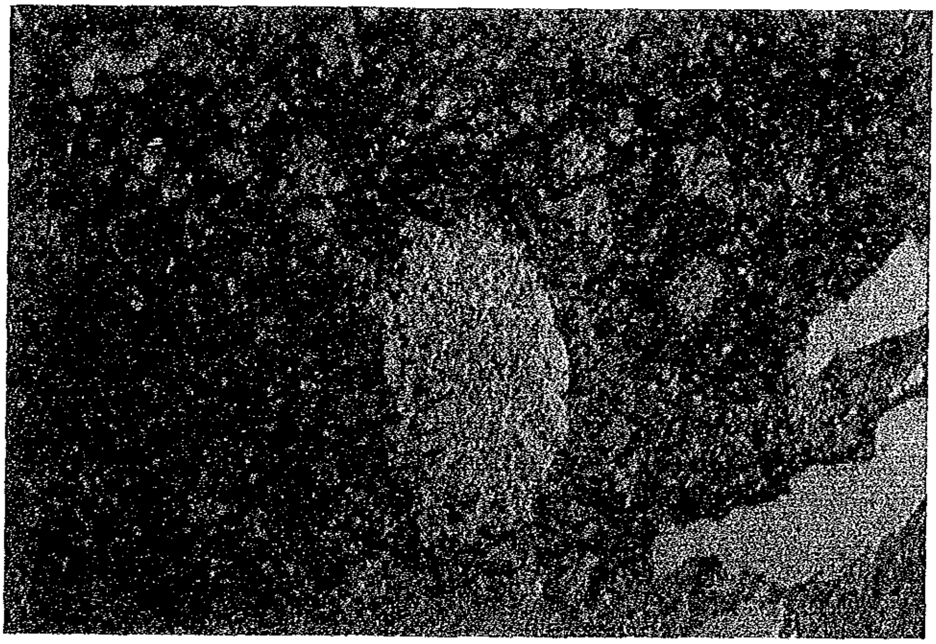

Fig. 7. The inflamed area of a seabass kidney suffering kidney disease.

Report on the Survey of the Spawning Ground of Seabass, *Lates calcarifer*

Pairoj Sirimontaporn, Katsuo Okubo, Toshiyuki Sumida and Hideki Kinno

Introduction

In Songkhla Lake, 300 - 500 tons of fish are caught per year by small scale fishery which consists of gill net, trap etc. The net-cage culture of fishes was introduced about ten years ago, and it has been extended year by year. The main cultured fish is the seabass, *Lates calcarifer,* the seeds of which are distributed to fish farmers by the National Institute of Coastal Aquaculture.

The seabass has much white meat with plain taste, so that it is one of the high value fish. About 80 tons of seabass are produced per year by the net-cage culture in Songkhla Lake at present. However, it is expected to be more extended in the future. Because Songkhla city is one of the bases of trawling fishery, a large quantity of trash fish for use as feed for fish cultures can be obtained at low price. Also an ample supply of seeds will be established there.

Although the seabass is an important fish, the information on its life history is still poor. It is necessary that the life history and living environment of the fish are made clear for selection of suitable culture sites and the improvement of culture technique.

Methods of the survey

The spawning ground is highly likely to be around the mouth of the lake since fishermen use drift nets for catching the matured fish. Therefore the survey was carried out around the limited area containing the mouth of the lake. Also, the survey around a wider area was made to compare the environment between the spawning area and surrounding areas around the coastal area of Songkhla.

The survey periods was from July 25 to August 31, 1983.

The stations of the survey are shown in Fig. 1 and Fig. 2.

The following works were carried out in the survey.

1) Distribution of eggs and larvae around the mouth of the lake.

The eggs and larvae were collected by a plankton net of 330μ in mesh size

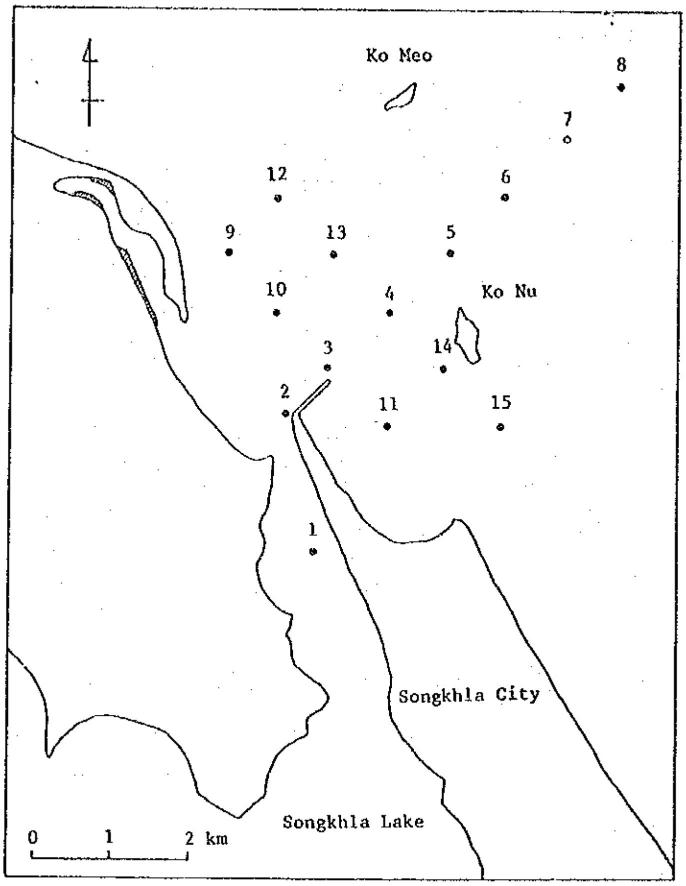

Fig. 1. The stations for the survey around the mouth of the Songkhla Lake. Shaded area shows the survey area of seaweed bed.

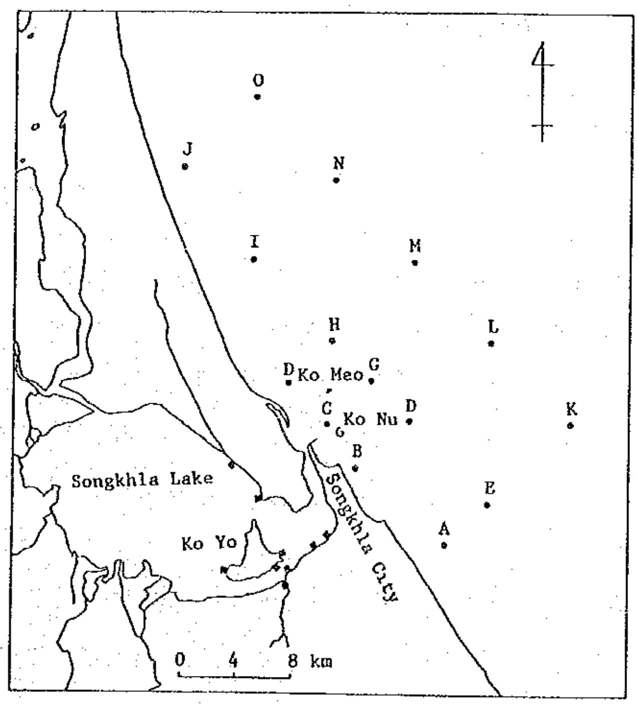

Fig. 2. The stations for the survey in a wider area. The mangrove area surveyed are shown by squares.

hauled through the surface layer of each station for three minutes. The collection was made at stations 0 - 15.

2) Hourly sampling for 12 hours at stations 1 and 2.

The sampling of the eggs and larvae was carried out every hour from 19:00 to 06:00. At the same time, water temperature and salinity were measured by salinity temperature bridge EIL 5005[1], and direction and speed of current were measured by CM-2 current meter[2].

3) Survey in mangrove area

The collection of eggs and larvae was carried out by using a small spoon net of 330μ in mesh size and 20 cm in diameter, a scoop net of about 5 mm mesh, and a small trawling net of 10 mm mesh and 4m long.

4) Survey in seaweed bed area

The collection of eggs and larvae was made by using the same trawling net used in the above survey.

5) Physical and chemical environment around the mouth of the lake.

Water temperature, salinity, and direction and speed of current were measured by the same methods as mentioned above. In addition to those, water depth and transparency were also measured.

6) Distribution of the eggs and larvae in a wider area.

The same method as 1) was employed in the survey at stations A - O.

7) Physical and chemical environment in a wider area.

The same method as 5) was employed in the survey at stations A - O.

8) Laboratory analysis

The eggs and larvae of seabass were sorted out from each sample and counted under a microscope.

Results of the Survey

1) Distribution of eggs and larvae around the mouth of the lake.

The survey was carried out from July 26 to 29.

The results of the survey are shown in Table 1. The largest number of eggs and larvae were collected at St.2 at night on July 27 followed by at the same station at night on July 29. Among 435 eggs and larvae collected during the survey, 343, namely 78.9%, were collected at St. 2. Four hundred twelve, namely 94.7% were collected at Sts. 1-3 locating in the mouth of the lake. Comparing morning and night, 333 eggs and larvae, namely 76.6% of the total were collected at night.

2) Hourly Sampling for 12 hours at Sts.1 and 2.

The survey was carried out at St. 1 on Jul. 28-29, and at St.2 on Aug. 26-27. The results of the survey are shown in Table 2.

In the first survey at St.1, no egg was collected from 19:00 to 03:00, but three eggs were collected at 04:00, then two eggs each at 05:00 and 06:00. The current flowed out from the lake till 21:00, flowed in during 22:00 - 03:00, then again flowed out during 03:00 - 06:00. The maximum speed of current was 0.5 m/sec. at 05:00 during low tide and 0.6 m/sec. at 0:00 during high tide. Water temperature was 30.5°C - 32.0°C and salinity was 33.3 ‰ - 33.8 ‰. It was observed that water temperature tended to be higher in the surface layer than in lower layers, and also that water temperature became about 1.5°C lower and salinity about 0.5 ‰ higher from 00:00. The lowest tidal levels were recorded at 19:30 and 05:00, and the highest at 23:00 at St. 2 on the day.

In the second survey at St. 2, eggs were collected during 21:00 - 01:00, with the largest number of 229 at 23:00 followed by 22 at 22:00. None were collected at 02:00 or 03:00, but 9 - 11 eggs were collected during 04:00 - 06:00. Largest number of eggs were collected when the current was strongest flowing into the lake. The current flowed out till 20:00, but its direction changed around 21:00 when the current of surface layer was flowing out but that of lower layers was flowing in. The maximum speed of the current was 0.75 m/sec. at 05:00 during low tide, and 0.78 m/sec. at 23:00 during high tide. Water temperature was 29.6°C - 31.2°C, and salinity was 27.6 ‰ - 32.8 ‰. At 21:00 and 22:00, water temperature was 0.6°C lower in the lower layer than in the surface layer, and salinity was 6‰ higher in the lower layer than in the surface layer, depending on the change in current direction. The lowest tide level was recorded at 19:00 and the highest at 23:00 on the day.

3) Survey around mangrove area

The survey was conducted on August 4 and 30, but no egg or larva of seabass was collected.

4) Survey around seaweed bed area

The survey was conducted on August 4 and 31. Ten to twenty and eight juvenile fish were collected on August 4 and 31 respectively, their size ranged from 1.5 to 3.0 cm in total length.

5) Physical and chemical environment around the mouth of the lake.

The survey was carried out during the low and high tide periods of neap tide on August 2, and of spring tide on August 23, 24 and 25.

On August 2, water temperature in the morning (low tide) was around 30°C. The vertical and horizontal difference was not observed. In the afternoon (high tide) temperature ranged between 30.2°C and 31.4°C. A weak spring layer was recorded at 2 - 3 m of water depth at the stations 4, 6, 8 and 12 locating offshore. Salinity was around 34‰. The current was not so strong at neap tide. However, a current of northwest direction was distinguishable.

On August 23, water temperature was 29.6°C - 31.0°C, which did not show any tendency. Salinity was around 34‰ except for during the low tide period when it was 31.5 - 33‰. Direction of the current was completely reversed at Sts. 1 and 2 depending on tidal hour, and it was slightly changed at Sts. 4 and 15, as for example, NW or WNW during high tide become N during low tide. At the other stations, it was NNW or NW independent of tidal hour. The current speed was faster at Sts. 1 and 2 than at other stations, being 0.5 m/sec. during high tide and 1.0 m/sec. during low tide at the former stations, compared to 0.1 - 0.2 m/sec. at others.

On August 24, water temperature was 29.6°C - 31.6°C, which did not show any tendency. Salinity which was 33.4‰ - 34.1 ‰, tended to be slightly lower at Sts.1 and 2. The direction of current was the same as on August 23.

On August 25, water temperature was 29.7°C - 31.6°C. It was higher in the surface layer than the lower one at the all stations during low tide in the afternoon, and the weak spring layer was detected in 2 - 3 m of water depth. Salinity was 33.5 ‰ - 34.1 ‰, which did not show any tendency. The direction of current was similar to previous days, but its speed was slower at all stations.

6) Distribution of eggs and larvae in a wider area

The eggs and larvae could not be collected at any of the stations.

7) Physical and chemical environment in a wider area

The transparency was 2.5 - 4.6 m around the coastal area and 6.0 - 8.3 m offshore. It was especially low around the mouth of the lake and its northern coast being 2.5 - 3.0 m. Water temperature was 29.6°C - 30.4°C, and the vertical and horizontal distribution did not show any tendency. Salinity was around 34‰, at all stations except surface layer at Sts. C and D where salinity was 33.0 ‰ - 33.5 ‰. A current direction of NNE and speed of 0.1 - 0.3 m/sec. was distinguishable along the coast at every station except for St. C, situated at the front of the mouth of the lake, where the direction was NE, although it was slightly varied vertically.

Discussion

1. Relationship between spawning and full moon phase

The eggs could not be collected on the morning of July 26. They were first collected from Sts. 3 and 4 on the morning of July 27, then, from St. 2 at night on July 29.

Since the day of full moon was July 25, the results showed that the first spawning was done on the first night after the full moon day. The period of spawning was confirmed till the fourth day after full moon, but it was unknown for how many days the spawning continued because the survey was not conducted after the fifth day.

2. Spawning ground and time

In the hourly sampling from 19:00 on August 26 to 06:00 on August 27 at St.2, eggs started to be collected at just the same time as the beginning of high tide, at 21:00, then many eggs were collected at 23:00. Many eggs were also collected around 22:00 - 23:00 on July 27 and 29 at St. 2. Since these eggs were newly fertilized ones, it was clear that they were spawned just near the collection point. Therefore, it is most probable that the spawning ground of the seabass is situated in the limited area around the mouth of the Songkhla Lake.

It also seems that spawning is started from the time when the tidal current changes from flowing out to in, then it is finished within about two hours.

3. Movement of eggs and larvae

The eggs which are spawned around the mouth of the lake at the beginning of high tide are transferred to the interior of the lake by passing through the channel on the tidal current, the maximum speed of which is estimated at about two knots. However, some part of the egg group seem to be transfeered to the northern coastal area of the mouth of the lake by the current of NW direction. Although actual water movement inside the lake is not clear, the eggs are able to reach around Ko-Yo, a distance of about 5 km, on a flood current the speed of which is assumed to be 0.5 knot on average. Then the eggs, which have been widely distributed, are transferred to around the mouth of the lake again, and flow out to sea on the ebb current, where they appear after 04:00 as shown by the data obtained by the hourly sampling. The tidal current out of the lake flows toward the NNW, so that the eggs, many of which have already been hatched out, are probably transferred to the lagoon situated to the north of the mouth of the lake.

As mentioned before, the movement of eggs and larvae was confirmed by the survey of their distribution. The movement of the juveniles inside the lake, however, could not been made clear by the present survey.

4. Physical and chemical environment.

The feature of the environment outside of the lake is that both water temperature and salinity are distributed uniformly. In the survey on the condition of currents, a stationary current flowing to the NW or NNW has been distinguished, which is also uniform independent of tidal hour except for around the mouth of the lake. Lake water flowing out moves in northerly direction from the mouth of the lake.

Each factor of environment shows uniformity in a wide area outside the lake. However, the strong tidal current flows locally in the mouth of the lake where the spawning takes place, compared with other coastal areas.

Notes: 1) Kent Industrial Measurements Ltd., England

2) Toho Dentān Co., Ltd., Japan

Table 1. The number of the seabass eggs and larvae collected around the mouth of the lake.

Date and time \ Station	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
July 26		0	0	0	0	0	0	0	0								0
July 27 morning		0	0	2	1	0	0	0	0								3
July 27 night		8	277														285
July 28 morning		27	14	25	0	0	0	0	0	0	3	2	0	0	7	1	79
July 29 morning			4	7	1	0	0	5	0	0	0	3	0	0	0	0	20
July 29 night	0	0	48														48
Total	0	35	343	34	2	0	0	5	0	0	3	5	0	0	7	1	435

Table 2. The number of eggs and larvae collected in hourly sampling at Sts. 1 and 2.

Date \ Time	19:00	20:00	21:00	22:00	23:00	00:00	01:00	02:00	03:00	04:00	05:00	06:00	Total
July 28 - 29	0	0	0	0	0	0	0	0	0	3	2	2	7
August 26 - 27	0	0	14	22	229	1	14	0	0	9	11	10	310
Total	0	0	14	22	229	1	14	0	0	12	13	12	317

Report on Aquaculture Ground Survey of Songkhla Lake

Pairoj Sirimontaporn and Tsuguhiro Yokokawa

The seabass, *Lates calcarifer* BLOCH, is an economically important food fish in Thailand. The seabass net-cage culture technique was introduced into southern Thailand about ten years ago and extended into the coastal areas, namely the lakes, creeks and estuaries.

Presently, many seabass farms are concentrated in small areas. Thus, some farms are threatened with pollution and still others are not adequately expanded.

The survey of aquaculture grounds in Songkhla Lake was initiated with the purpose of developing and improving the seabass culture and, generally, the coastal aquaculture in southern Thailand.

General description of Songkhla Lake

1. Songkhla Lake topography

Songkhla Lake is located in two southern provinces, Songkhla and Pattalung, at Lat 7° 08'N. - 7° 50'N. and Long. 100° 07'E - 100° 37'E. Total area is 616,750 rai (98,680 ha). The lake is subclassified into 3 separate areas: Thale Noi, 2,800 ha, the northern area; Thale Luang, 78,280 ha, the central area; and Thale Sap Tonnok, 17,600 ha, the southern area. These three areas are interconnected by channels. The eastern side of Thale Sap Tonnok, the mouth of the lake, opens into the Gulf of Thailand (Fig. 1).

The lake is generally surrounded by farmlands, forests and swamps. Of the approximately 40,000 ha of farmlands, 20% is irrigated.

The population of the extended lake area, including sections of Songkhla, Pattalung and Nakhonsrithammarat provinces, is around one million, of which 35% is in the cities of Songkhla and Hat yai. About 150,000 people live in the coastal areas of the lake, most of whom depend on fishery and agricultural industries. The Songkhla port, located at the mouth of the lake, is the largest fishing port in sourthern Thailand. The chief fishing industry is twaling, with an annual production of 165,000 tons. Over 60% of this produce is trash fish, used as fish meal and feed in duck, pig and fish production.

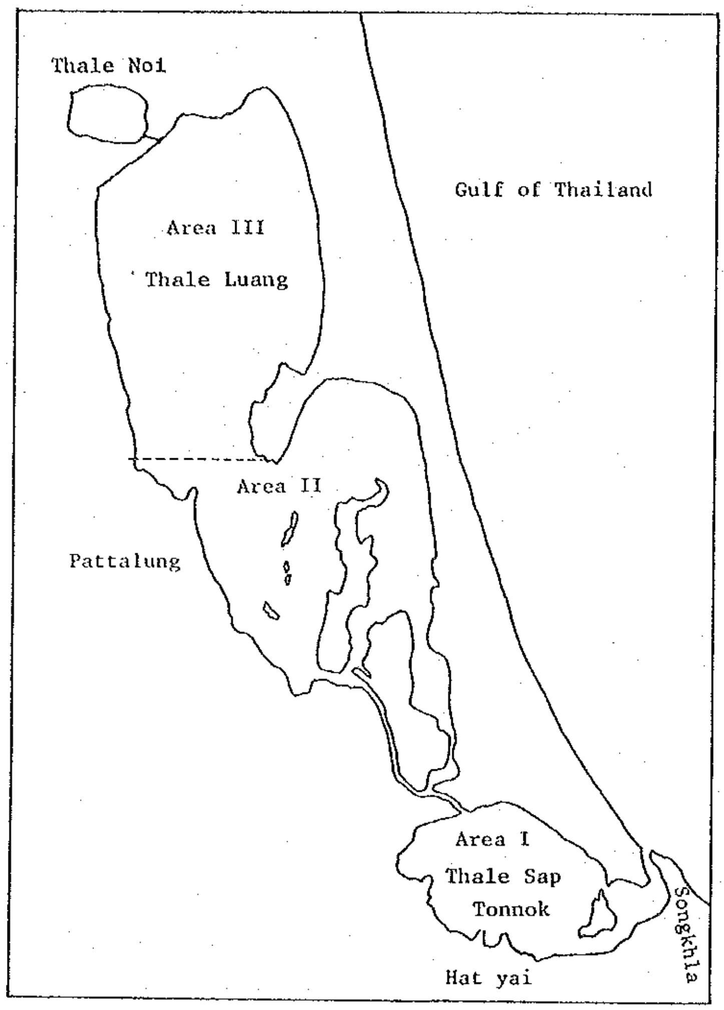

Fig. 1. The map of Songkhla Lake

2. Climate and physical characteristics of Songkhla Lake.

High temperatures and high humidity exist all year round. Average and ranges of temperature and relative humidity are, respectively, 27.5°C, 23.8°C - 31.5°C and 79.0%, 65.6 - 92.0%.

The average total annual rainfall is 2,160 mm and average total rainy days per year is 159 days. About 60% of the total annual rainfall normally occurs from October through December (Fig.2).

Wind direction is southwest from April through September and northeast from October through March. The northeast wind is commonly called the monsoon in this region.

The estimated volume of the freshwater inflow in the lake each year is 5,200 million tons, and annual evaporation from the lake is 70 million tons.

Tide levels in Songkhla Lake are measured at Ko Nu (Nu Island), just outside the lake's mouth. The water level averages 0.74 m above Thai standard sea-level. The highest high tide water level, 1.30 m above sea-level, occurs in the December-January period, and the lowest low tide water level, 0.2 m above sea-level, occurs in the July-August period. Annual range is 1.1 m and daily variation is between 0.3 and 0.6 m (Fig. 3).

The tidal movement range at the innermost part of the outer lake, Thale Sap Tonnok, is less than 5 cm throughout the year. Thale Luang and Thale Noi water levels are unaffected by tidal movement. The tidal water level variation at Ko Yo (Yo Island), located approximately 7 km from Ko Nu, is half of the sea tidal variation and has a time lag of 1.5 hours.

The swiftest current in the lake, 1.2 - 1.5 m/sec., is normally observed during the dry season at the lake's deepest section directly in front of the Songkhla docks.

During rainy season, the water level in all parts of the lake rises 30-50 cm due to waters emptying into the lake from rivers and streams. River water levels sometimes rise more than 1-2 m.

The average water depth in the lake is only 1.0 - 1.5 m in the outer lake, 1.3 - 2.4 m in the inner lake, and 1.0 - 1.3 m in Thale Noi. Some narrow channels and the lake's mouth have depths up to 3 - 12 m. Bottom soil is generally clay and sandy clay from marine and river deposits.

3. Fishing activities in Songkhla Lake.

In Songkhla Lake, the chief fishing activities are trapping and net fisheries. Usual fishing here is listed in Table 1.

Table 1. Fishing gear in Songkhla Lake

Name of gear	Fish
(1) Wan Loi (gill net)	Mullets
(2) Wan Sam Chan (gill net)	Shrimps
(3) Pong Pang (set bag or bag net)	Fish and Shrimp
(4) Mora (fish trap)	Fish and Shrimp
(5) Yor (four-arm scoop net)	Mullets
(6) Wan Roon (shrimp scoop net)	Shrimps
(7) Lob (fish trap)	Shrimps
(8) Wan Sam Kon (small impounding net)	Fish and Shrimp
(9) Wan Lom Yai (large impounding net)	Fish and Shrimp

The main fish species in Songkhla Lake are listed in Table 2.

The annual production of fish from the outer lake is estimated at 300 - 500 tons. However, this figure excludes shrimp and crab production. The inner lake's fish-only production is estimated to be twice that of the outer lake.

Most of the total lake produce is sold in local markets through middlemen, some of it being processed into dry salted fish. Only sillage is frozen-packed and exported. Nearly all small shrimps are dried.

There are five aquacultures in Songkhla Lake. They are:

(1) Seabass (Pla Kapong Kao) *Lates calcarifer*
(2) Grouper (Pla Kao) *Epinephelus* sp.
(3) Tiger prawn (Kung Kula Dam) *Penaeus monodon*
(4) White shrimp (Kung Cha Buay) *P. merguensis*
(5) Freshwater prawn (Kung Kam Kram) *Macrobrachium rosenbergi*

Table 2

Typical and abundant fishes in Songkhla Lake

* 1. *Dasyatis imbricatus*
* 2. *Clupea perforata*
* 3. *Clupeoides lile*
* 4. *Stolephorus tri*
* 5. *Plotosus canius*
6. *Ophichthus rhytidodermatoides*
* 7. *Mugil dussumieri*
* 8. " *longimanus*
9. *Atherion valenciennesi*
10. *Ambassis gymnocephalus*
11. " *kopsii*
12. *Therapon jarbua*
13. " *puta*
14. *Apogon quadrifasciatus*
* 15. *Sillago sihama*
16. *Caranx boops*
17. " *crumenophthalmus*
* 18. *Selaroides leptolepis*
19. *Lutjanus vitta*
20. *Caesio erythrogaster*
21. *Scolopsis dubiosus*
22. " *vosmeri*
* 23. *Leiognathus brevirostris*
* 24. " *equulus*
*25. *Gerres filamentosus*
26. *Pomadasys hasta*
*27. *Pseudosciaena soldado*
28. *Pomacentrus tripunctatus*
29. *Abudefduf bengalensis*
30. *Rastrelliger brachysoma*
31. " *kanagurta*
*32. *Siganus javus*
*33. " *oramin*
*34. *Platycephalus indicus*
35. *Pseudorhombus arsius*
*36. *Synaptura orientalis*
37. *Cynoglossus cynoglossus*
38. " *lingula*
39. Others
Many kinds of Cobiidae

Important migrating fishes

1. *Lates calcarifer*
2. *Epinephelus malabaricus*
3. " *salmonoides*
4. *Lutjanus argentimaculatus*
5. *Eleutheronema tetradactylum*

(* Commercial fishes)

Fresh water fishes

* 1. *Notopterus* spp
2. *Oxygaster* spp.
3. *Rasbora* spp.
4. *Hampala* spp.
5. *Cyclocheilichthys* spp.
6. *Mystus* spp.
* 7. *Clarias* spp.
8. *Xenentodon* spp.
* 9. *Hemiramphus* spp.
10. *Microphis* spp.
11. *Panchax* spp.
12. *Channa* spp.
13. *Monopterus* spp.
14. *Datnioides* spp.
15. *Toxotes* spp.
*16. *Anabas* spp.
17. *Trichopsis* spp.
18. *Trichogaster* spp.
19. *Tetraodon* spp.

Freshwater prawn is cultured only in Thale Noi and in the northern part of the inner lake. The tiger prawn and white shrimp are cultured in the swamps along the outer lake. Seabass and grouper are cultured in net-cages in certain areas in the lake, but grouper is cultured only in the dry season.

Results of field survey

1. Environment survey of aquaculture ground in Songkhla Lake.

   (1) Physico-chemical properties of Songkhla Lake water.

The monthly variation of the physico-chemical properties of the lake water during the survey is shown in Fig. 2.

The range in water temperature was 23°C - 33°C, averaging 29.1°C. Normally, water temperatures closely followed air temperature because of the lake's shallowness. The highest monthly average water temperature was 31.3°C in May and the lowest, 26.7°C, was in November. The water temperature never dropped below 20°C.

Salinity is closely related to rainfall. During the rainy season, nearly all the lake's water is freshwater. After rainy season, seawater gradually seeps into the lake. Normally, 80 percent of the inner lake will become saline (Fig. 4).

Lake water transparency was always low, averaging only 0.67 m. The highest rate, 1.7 m, was in June, and the lowest rate, 0.2 m, was in December. Water transparency is greatly lowered by rain or wind.

The pH ranged from 6.7 to 8.4, averaging 7.6. The pH of the lake water is directly related to the salinity. During dry season, the pH was high in the outer lake, and low in the inner lake and in Thale Noi, corresponding with the salinity. During rainy season, the pH dropped to slight acidity.

The DO value in the lake water indicated saturation or supersaturation during the day in the dry season, but decreased to 80% of saturation during the night. However, during rainy season, the DO value was more than 80% of saturation due to increased movement in the water.

In the aquaculture farms, particularly the seabass net-cage farm, the DO value dropped sharply to 30 - 40% of the saturation from midnight to daybreak in the dry season. During this season, water tempe-

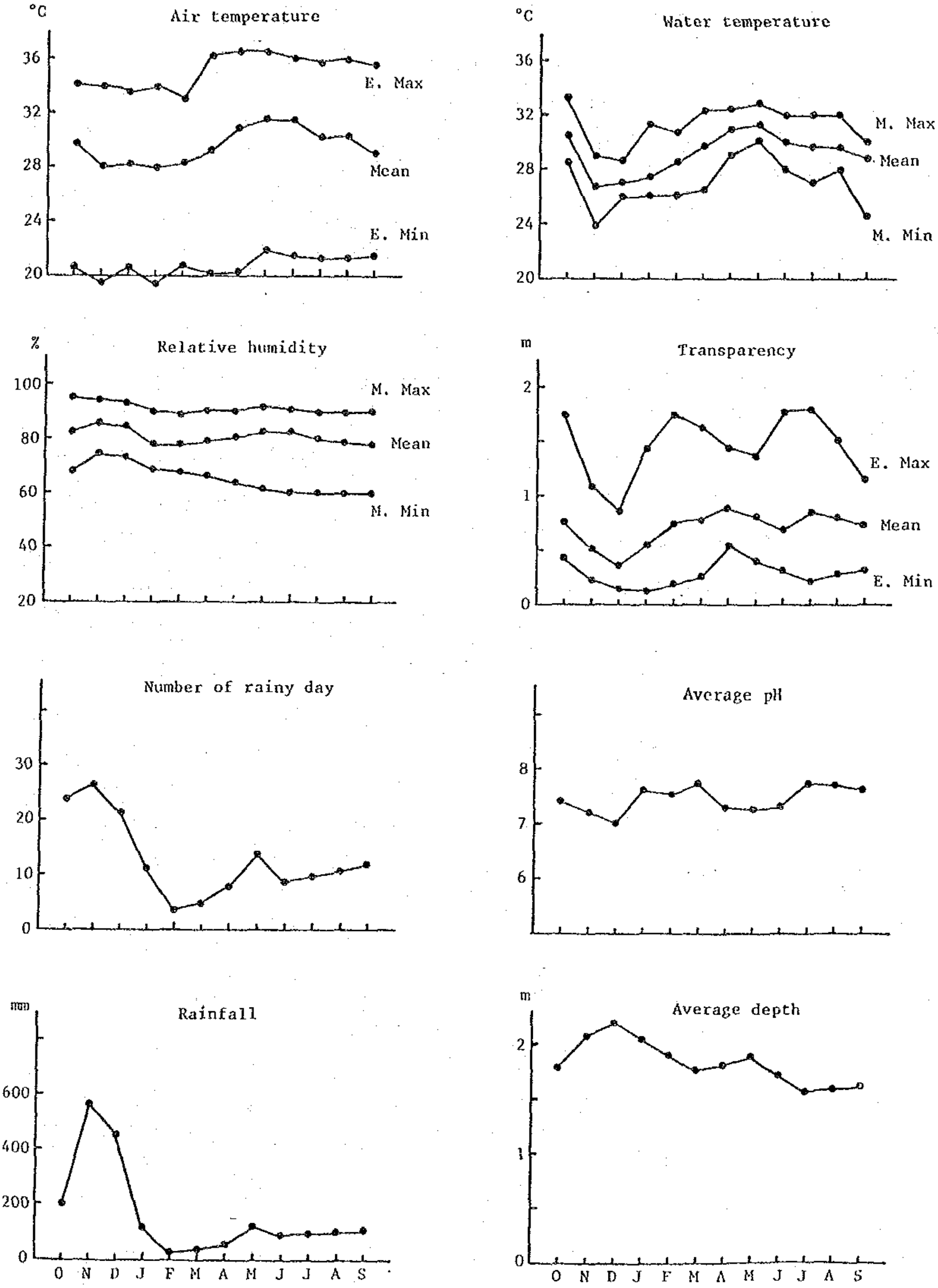

Fig. 2. Monthly variations of climatic and water parameters on Songkhla Lake

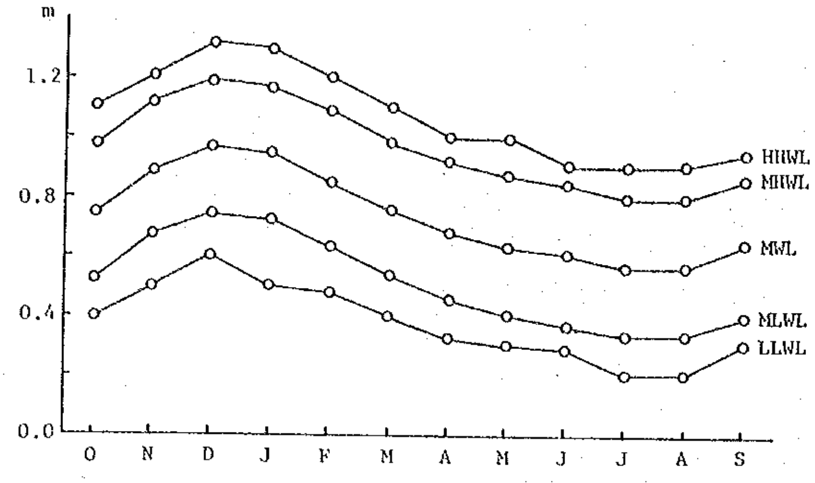

Fig. 3. Monthly average water levels
of Ko Nu, Songkhla

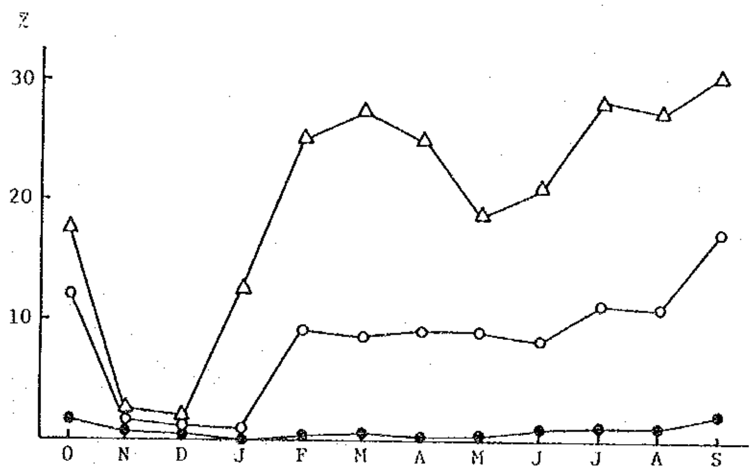

Fig. 4. Salinity variation of Songkhla Lakes.
Closed circle: Area I;
Open circle: Area II; Trianagle: Area III

rature and salinity were high and the water level low (Fig. 6).

The concentrations in the lake water of the nitrogen compound, nitrate-N, and the phosphorus compound, phosphate-P, were normally 0.10 - 0.15 ppm and 0.02 - 0.03 ppm respectively. These concentrations sharply decreased during the rainy season and often were higher near the coast.

In the seabass net-cage farms, the concentrations of nitrogen and phosphorus compounds increased approximately 1.7 and 0.16 ppm, respectively, during the seabass culture season (June through September). Nitrate-N concentration was about 0.02 ppm in the net-cages during this season. Only shortly after the feeding period was an ammonia concentration detected, measured at 0.1 ppm.

The COD value of the lake water was usually below 1 ppm, though sometimes it was shown to be at 2 ppm in the seabass farm.

Neither sulfide nor hydrogen sulfide were observed in the lake water except when the bottom soil was stirred up during changing of the nets.

The lake's water current runs only towards the sea during the rainy season. However, during the dry season, it is very weak in the inner lake and in the outer lake it will flow according to tidal direction (Fig. 7). The water changing rate depended on the tidal movement. The rate for newly set net cages was 100% per 5 min., but that of net-cages set more than 6 months dropped to only 54% per 5 min. due to clotting of the net mesh with dirt and seaweed, mostly of the *Gracilaria* sp. Rates for net-cages set near the shore were only 10 - 20% per 5 min.

During the dry season, the suspended solid (SS) in the lake water averaged 26 ppm, but the rate was higher, 36-66 ppm, in the net-cage farms. It was measured at more than 100 ppm in the lake water during the rainy season.

(2) Bottom soil characteristics in the lake

Using the Tyler mesh No. 150 (0.104 mm), the bottom soil was found to be 95% clay. The bottom soil in the net-cages was very soft and formed a thick, reduced layer (20 - 50 cm).

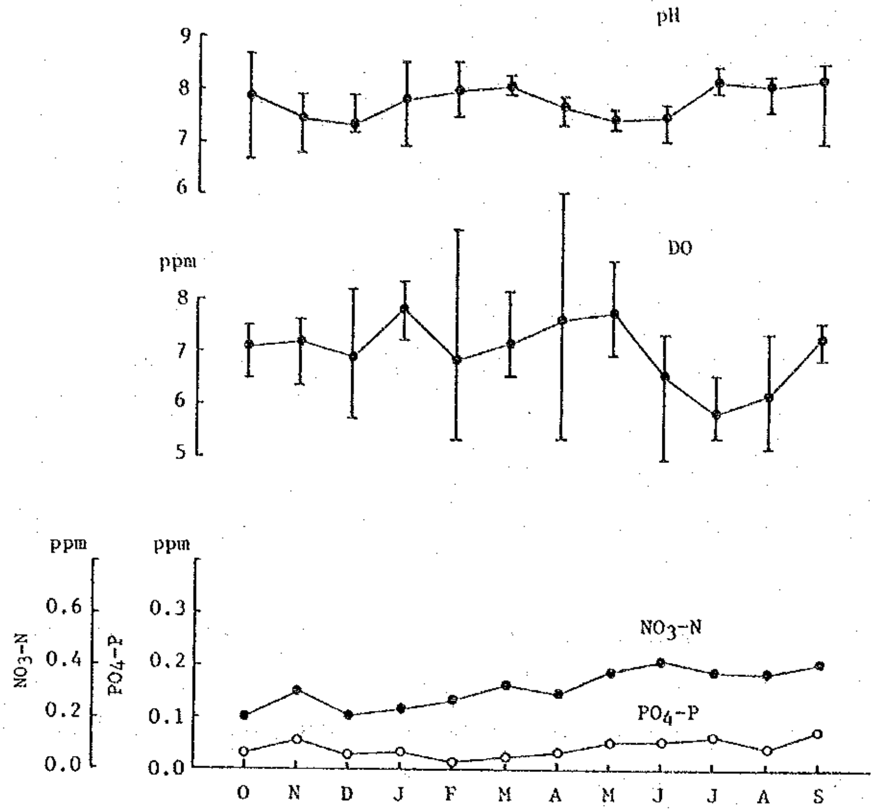

Fig. 5. Chemical properties of water in Songkhla outer lake.

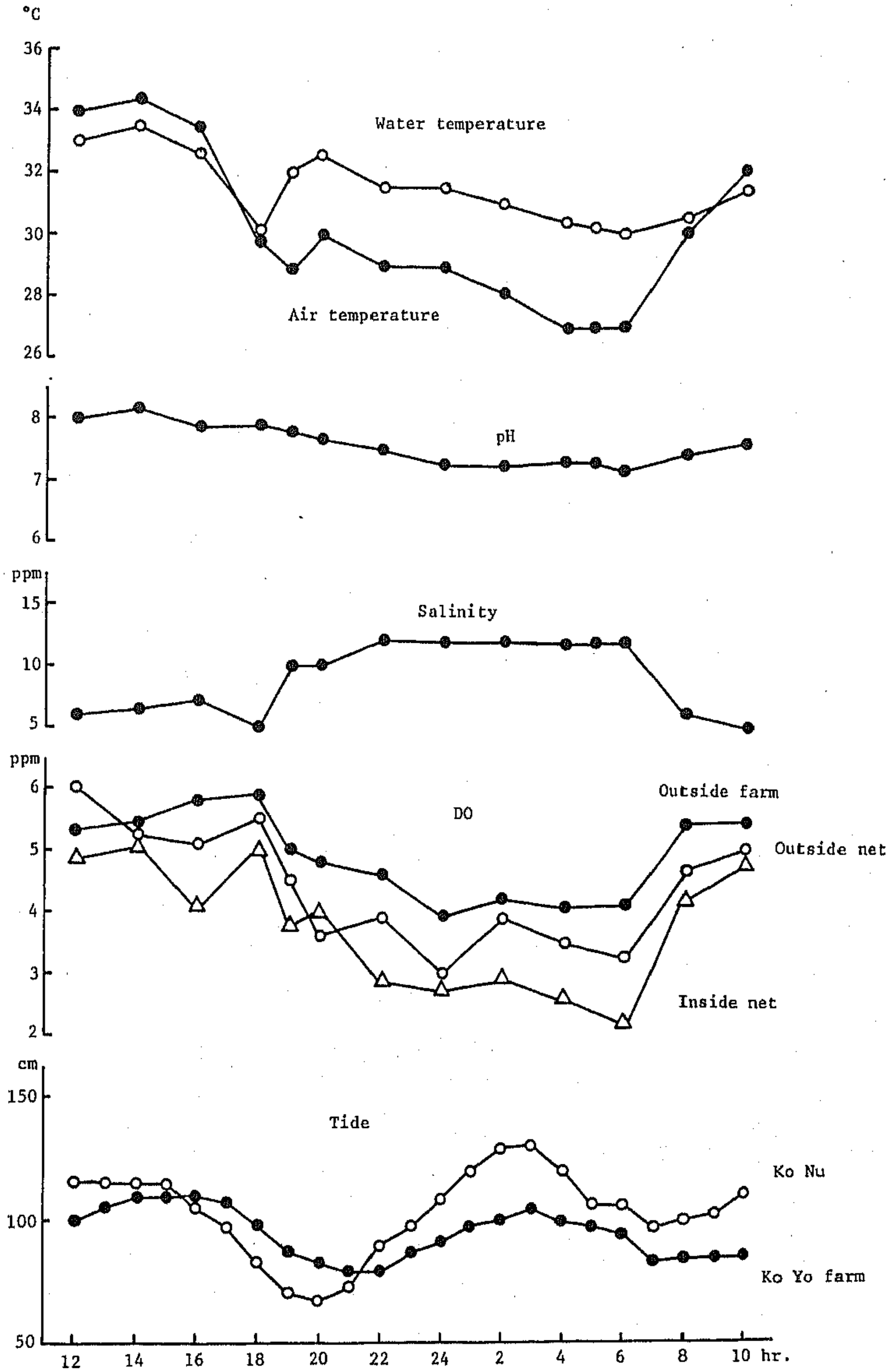

Fig. 6. Daily variation of physico-chemical properties of water in the seabass net-cage of Ban Ko Yo farm (May, 1982).

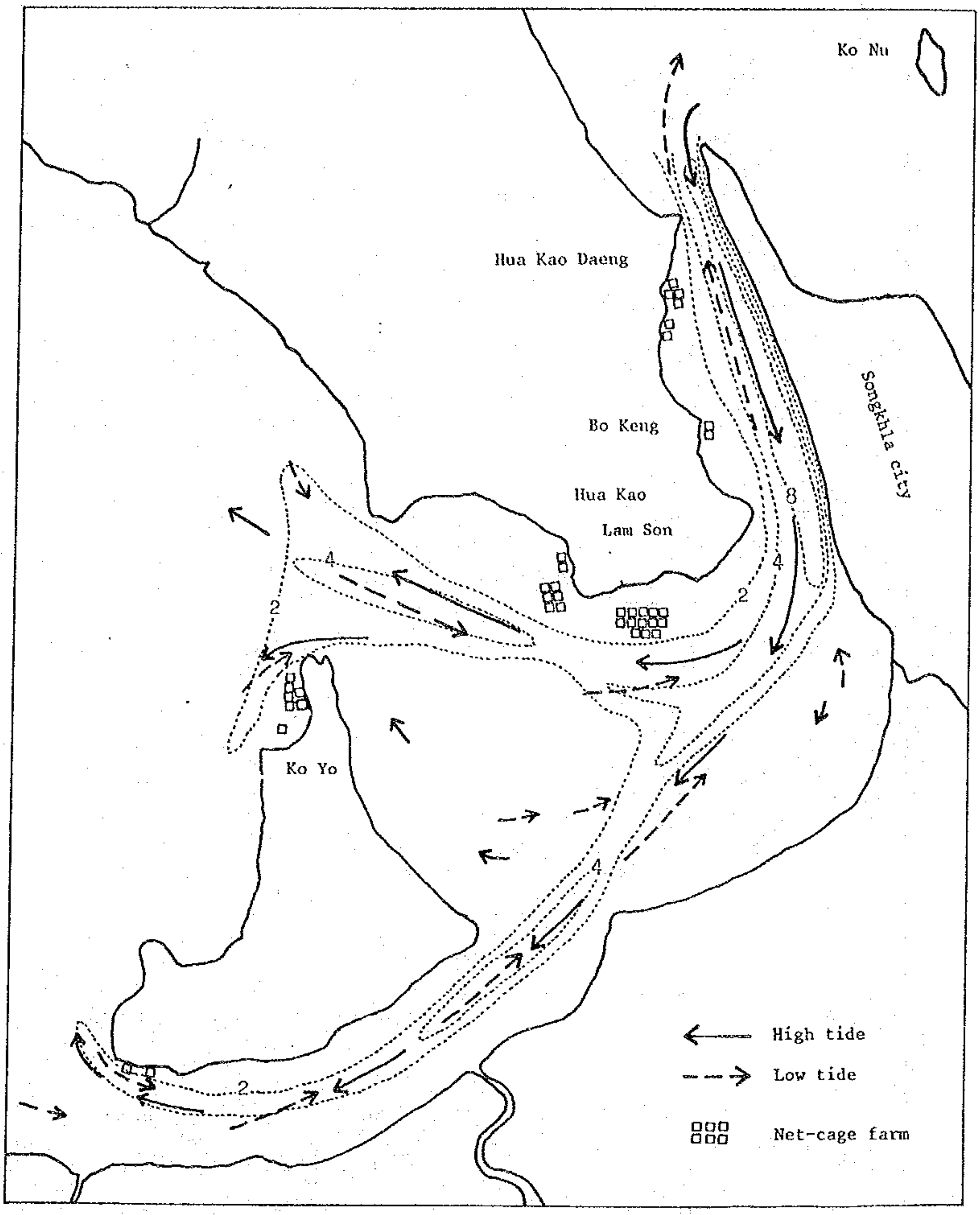

Fig. 7. Flow direction of tide in Songkhla outer lake mouth area

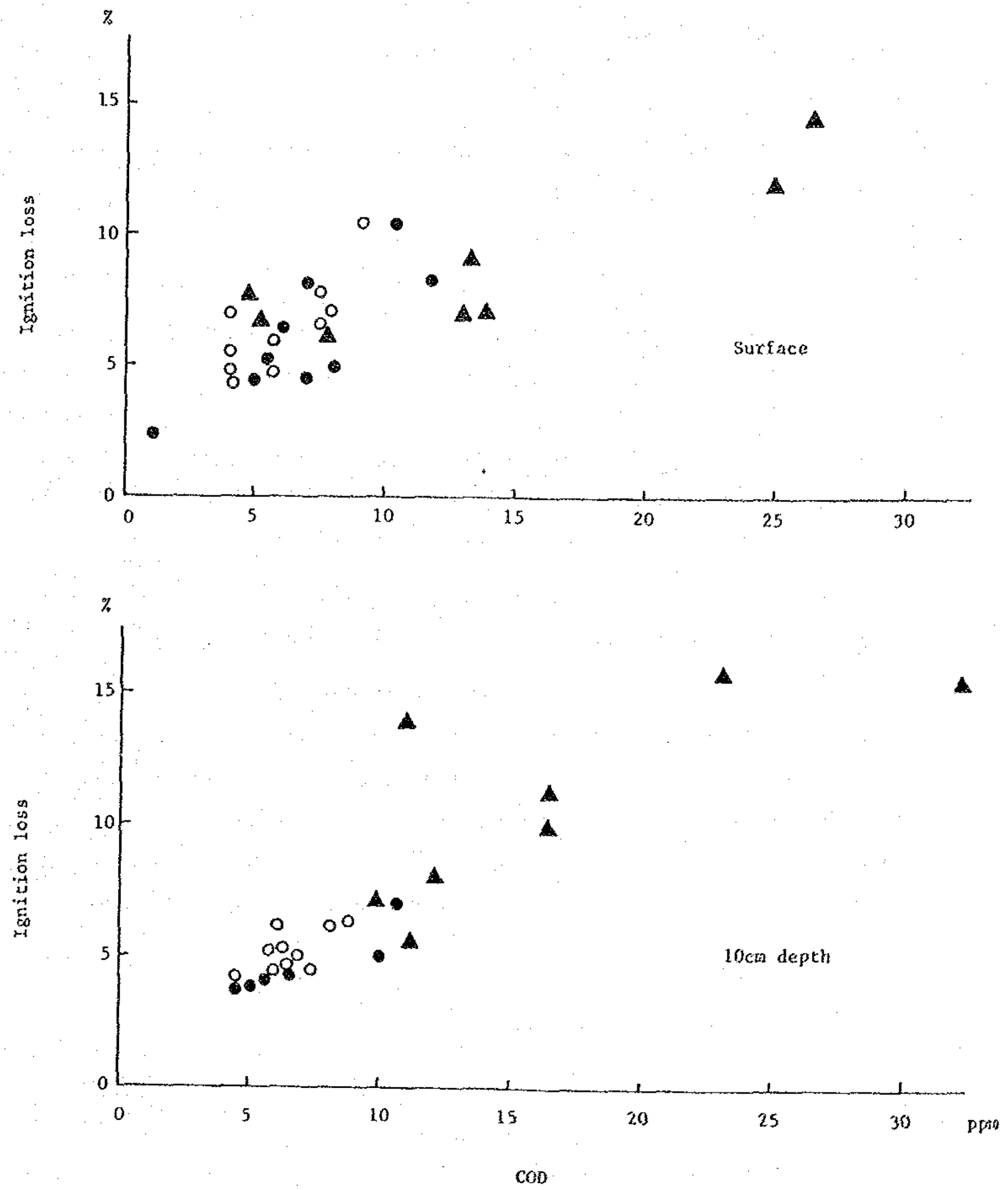

Fig. 8. Relation between COD and ignition loss in bottom soil of the cage-net farms in Songkhla Lake.
Open circle: Hua Kao Daen farm; Closed circle: Lam Son farm; Triangle: Ko Yo farm

The pH of most of the lake's bottom soil was neutral, averaging 7.1 with a range of 6.53 - 7.82. Bottom soil in some areas of the inner lake showed strong solidity. In most of the net-cage farms, the bottom soil was slightly alkaline, 7.1 - 8.5, but in some very polluted areas, the soil alkalinity increased to 8.5 - 8.9.

Ignition loss (IL) values and the organic matter contents measures were not always the same but closely related. The IL and COD values of the lake's bottom soil strongly correlated with each other, averaging 9.9% (4.4 - 16.5%) and 11.26 mg/g (1.2 - 26.5 mg/g), respectively.

In the general lake area, IL was not more than 12% and the COD value not more than 15 mg/g, but in the seabass net-cage farms near housing and factory drainages, these value increased. The bottom soil in net-cages located in areas where the water-changing rate was particularily low showed higher IL and COD values (Fig. 8). The Ko Yo farm had the highest IL (16%) and COD (26.5 mg/g) values.

These values normally decreased in the rainy season, except in some net-cages where the nets covered the surface of the bottom soil.

The sulfide concentration of the bottom soil is also an indicator of pollution in the net-cages, as are IL and COD. The concentration in bottom soils of the general lake area was usually not greater than 0.1 mg/g. Sulfide concentration in the bottom soil of net-cage farms was about 0.22 mg/g (range: 0.14 - 0.34 mg/g), though this value increased near drainages. The average value was proportionate to the COD value.

2. Ecological survey of Songkhla Lake

(1) Fauna and flora in the lake

The distribution of fauna and flora in Songkhla Lake depends on the lake's salinity.

Both the abundance and number of species of phytoplankton increased in January and February, just after the rainy season. A large number of *Nitzschia* spp. exist in the outer and inner lake throughout the year. During the dry season, the density of cells of *Chaetoceros* spp. and *Rhizosolenia* spp. in the outer lake, and *Pediastrum* spp., *Spirulina* spp. and *Surirella* spp. in the inner lake,

Table 3. Phytoplankton in Songkhla Lake

— Area I —

Genus	10	11	12	1	2	3	4	5	6	7	8	9
Amphiprora					R					R		R
Aphanizomenon									+			
Asterionella				R	R						R	
Bacteriastrum	+		R	C	C	R	+	+	+	C	C	C
Biddulphia		R	R	+	+	+	+					
Campylodiscus			R		R							
Ceratium	+			+	+	+	C	+			+	+
Chaetoceros	C	+	+	CC	C	+	CC	C		C	CC	C
Chodatella			R									
Chroococcus		R	R			R						
Corethron			+	+		R						
Coscinodiscus		+	+	C	C	+	+	+	+	R	C	+
Cyclotella			+	R								
Ditylum			R	+								
Guinardia				+	+	+	R	+	+		+	
Gonyaulax				R		R						
Gyrosigma		+	+	+	+		+					
Hemiaulus			+	+	R	+	+					
Hemidiscus												R
Lithodismium			R	R	+							
Lyngbya					+						+	
Melosira				R	R							
Navicula		R	R	R	+	R	+					
Nitzschia	+	C	C	C	C	+	C	C	C	C	C	+
Oscillatoria		R	R	R	C	+	+	+		C		
Peridinium	R	R	R	R	R	+	R			R	R	
Pleurosigma	R	R	R	R	R	+	R			R		
Skeletonema					R							
Spirulina			R	+	+				C			
Thalassionema									+		+	
Thalassiothrix	R		R	R	R	R	R				+	
Triceratium				R								
Rhizosolenia	+		R	C	CC	+	+	C	C	C	C	+

Note: CC ... Abundant, C ... Frequent, + ... Common, R ... Rare
RR ... Very rare

— Area II —

Genus	10	11	12	1	2	3	4	5	6	7	8	9
Amphiprora							R					
Aphanizomenon			+									
Campylodiscus		R	+		+							
Ceratium	+				+					+		+
Chaetoceros	+				+		+	+		C		
Chroococcus		R	R	+	+	R	R	+				
Climacosphenia		R	+				R					R
Closterium											+	R
Coscinodiscus		+	+	+	C	C	+	+	R			
Cyclotella				R								
Dinobryon				R								
Gonatozygon			R		R							
Gyrosigma		+	+	+	+		+				R	
Merismopedia	+	+	C	C	+	R	R					R
Micrasterias			R									
Navicula		R	R	+	+	R	R	R	+	R		R
Nitzschia	R	+	+	+	C	+	+	+	+	+	+	R
Nostoc											+	
Oscillatoria	R	+	C	CC	+	+	+	+				
Pediastrum				+				+				
Peridinium	R	+	+	+	+	+	R	R	R	+	+	R
Pleurosigma	R	R	R	R	+	+	R					
Rhizosolenia					+							
Sphaerocystis									+			
Spirulina			R	+	+	+	+	+	C	C	C	+
Staurastrum			R									
Synedra		+	R			R						
Trichodesmium										R		

-- Area III --

Genus	10	11	12	1	2	3	4	5	6	7	8	9
Aphanocapsa			R		R	R	R					R
Arthrodesmus		+	+									
Ceratium							+					
Chaetoceros	R											
Chroococcus	R	R	R	R	+	C	C	+	+	+		
Closterium			+	+								
Coscinodiscus	R		+		C	+	R	+	C	+		
Cosmarium			+	C	+	+	+	+				
Cyclotella			+	+	R	R	R			+		
Desmidium		R										
Dinobryon		+	+	+								
Genatozygon		R	+	+	+							
Gyrosigma	R		+	+	+	R	R	+	+	+		
Lithodesmium						R						
Merismopedia				+	+							
Microcystis	R		+	C	C	+	+					
Mougeotia		R										
Navicula				+	+							
Nitzschia	R	R	+	C	C	C	C	C	C	+	C	+
Oscillatoria	R	+	R	C	CC	C	+	R				
Pediastrum	R	+	R	C	+	+	C	C	C	C	C	C
Peridinium	R		R		R	R	R					
Pleurosigma	R			R	R	R						
Spirulina		R		+	C	+	C	C	CC	CC	C	C
Staurastrum			+	+	+				+			
Streptonema				R					R			
Surirella			C	+	C	CC	C	C	+	C	+	C
Synedra						R						
Trichodesmium											+	
Xanthidium				+	R							

Table 4. Benthos in Songkhla outer lake
(Average No. /m^2 from 17 samples)

Group	10	11	12	1	2	3	4	5	6	7	8	9
Crustacean												
Upogebia	53	46	41	43	60	89	67	34	26	18	44	136
Apseudes	140	24	126	38	92	210	34	120	89	38	77	59
Gammarus	289	69	134	88	41	171	104	30	30	24	22	41
Shrimp	24	10	6	8	6	14	2	6	2	1	2	2
Larvae												
Copepod	–	2	–	–	–	–	–	–	–	–	–	–
Gnathia	–	–	–	–	–	–	3	–	–	–	–	–
Crangon	1	2	2	9	5	2	3	–	3	1	3	2
Polychaeta												
Nephtys	2	5	5	11	16	9	19	26	21	24	16	18
Kereidae	16	14	20	11	6	9	31	26	36	31	20	11
Orbiniidae	29	2	2	11	7	6	12	9	20	–	19	14
Lumbrinereis	21	5	–	4	1	5	7	6	5	3	13	2
Arabella	8	3	–	2	2	–	2	3	6	3	10	6
Glycera	9	–	–	–	–	1	6	–	–	–	–	–
Ophelia	1	–	–	–	–	–	–	–	–	–	–	–
Sabellidae	–	–	–	–	1	–	4	5	–	–	2	–
(Unknown)	267	2	5	3	5	6	3	17	2	–	2	4

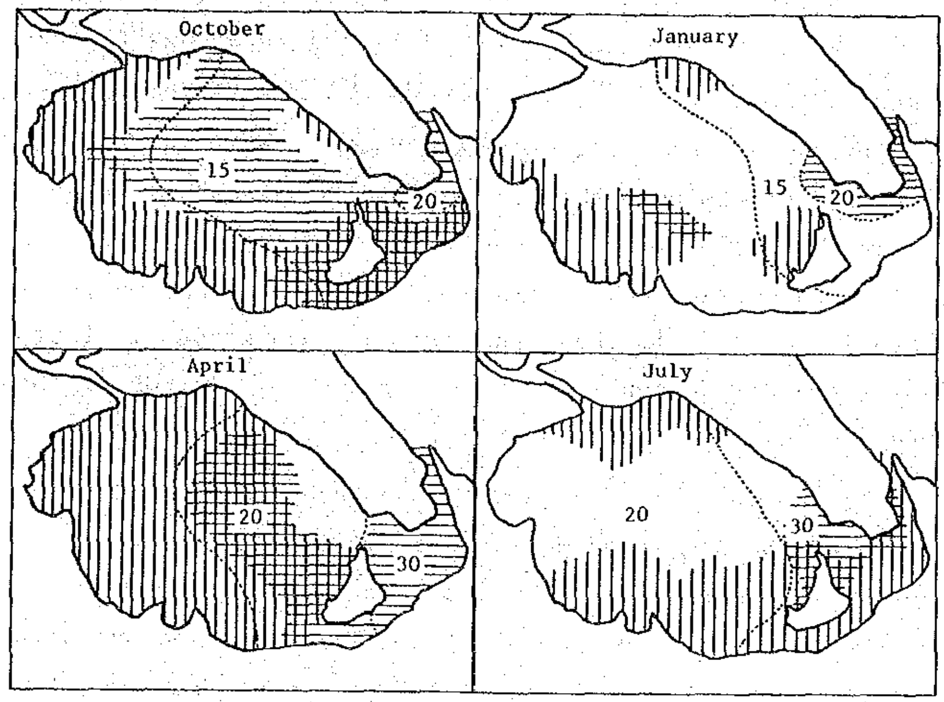

Fig. 9. Distribution of benthos in Songkhla outer lake.

||||||| : crustacean

≡≡≡ : polychaeta

Figures indicate salinity

increased. Both the number of species and the abundance of phytoplankton sharply dropped during the rainy season (Table 3).

Copepoda inhabited the entire area of the lake. The number of Cladocera increased significantly when the area's salinity dropped below 10 ‰, and this was mainly in the southern half of the inner lake. Lucifer and Sagitta existed mostly in the outer lake, their numbers decreasing when the salinity dropped below 10‰.

The survey of benthos was carried out only in the outer lake. Many Crustaceans were observed in the estuaries and mangrove swamps during the entire year. Their abundance increased after the rainy season and decreased again in the dry season. The number of Polychaeta sharply decreased in the rainy season, then gradually increased during the dry season and, by the end of this season, it had spread into the entire outer lake area (Table 4 and Fig. 9).

In the net-cage farms, the abundance and diversity of benthos indicated the degree of pollution. In the unpolluted areas where there were higher water changing rates and thinner reduced layers in the soil, as at the Lam Son farm, the abundance and diversity of benthos was great. However, at the polluted farms, as the Ko Yo farm, the number of benthos, particularly Polychaeta, was very low, and only the *Apssudes* sp. of Crustacean was observed on the surface of the bottom soil. In contrast, a large number of *Nepthys* sp. of Polychaeta were observed at the Hua Kao Daeng farm which was not very polluted.

Aquatic plants in Songkhla Lake exist mainly in the inner lake. Three kinds of plants, *Acetabularis* sp., *Porphyra* sp. and *Glacilaria* sp. grew in the net-cage farms. *Glacilaria* sp., particularly, tended to grow thickly on the net and closed the net-cage mesh (Table 5).

Table 5. Aquatic plants in Songkhla Lake

1. *Acetabularia*	8. *Jussiaea*	15. *Potamogeton*
2. *Blyxa*	9. *Limnanthemum*	16. *Salvinia*
3. *Ceratopteris*	10. *Limnophylla*	17. *Salgassum*
4. *Ceratophyllum*	11. *Najas*	18. *Utricularia*
5. *Glacilaria*	12. *Numphaea*	
6. *Hydrilla*	13. *Ottelia*	
7. *Hygrophilla*	14. *Porphyra*	

(2) The mangrove and swamps along the lake.

The mangroves grow on the sheltered shores, of estuaries and lagoons where salt water penetrates, along sandy or muddy beaches.

There are 36 species of mangroves in Thailand (Table 6), and about 10 species of mangroves were observed on the coast of Songkhla outer lake and the eastern coast of the inner lake. The mangroves of Songkhla Lake are not developed well, and their number has declined considerably during the development of the coastal areas.

Table 6. Mangrove species in Thailand

1.	*Acanthus*	*ebracteatus*
2.	*A.*	*ilicifolius*
3.	*Acrostichum*	*aureum*
4.	*A.*	*speciosum*
5.	*Aegicerus*	*corniculta*
6.	*Avicennia*	*officinalis*
7.	*A.*	*marina*
8.	*Bruguiera*	*caryophylloides*
9.	*B.*	*eriopetala*
10.	*B.*	*gymnorrhiza*
11.	*B.*	*hainensii*
12.	*B.*	*parviflora*
13.	*Ceriops*	*roxburghiana*
14.	*C.*	*tagal*
15.	*Daemonorops*	*leptopus*
16.	*Derris*	*trifolia*
17.	*Excoecaria*	*agallocha*
18.	*Heritiera*	*littoralis*
19.	*Intsia*	*retusa*
20.	*Kandelia*	*rheedii*
21.	*Lumitzera*	*coccinea*
22.	*L.*	*recemosa*
23.	*Melaleuca*	*leucadendron*
24.	*Nipa*	*fruticaria*
25.	*Oncosperma*	*tigillaria*
26.	*Phoenix*	*paludose*
27.	*Rhizophora*	*apiculate*
28.	*R.*	*mucronata*
29.	*Scyphiophora*	*hydrophyllaceae*
30.	*Sonneratia*	*alba*
31.	*S.*	*caseolris*
32.	*S.*	*griffithii*
33.	*Thespesia*	*populnea*
34.	*Xylocarpus*	*granatum*
35.	*X.*	*moluccensis*
36.	*X.*	*oboyatus*

(After Smitinand, T. 1975)

The main species of mangroves along the lake were *Rhisophera* sp., *Avicenia* sp. and *Bruguiera* sp. The *Nipa* sp. was mainly along the inner lake and rivers.

The mangrove swamp is a very important nursery ground for aquatic animals, especially the coastal fishes, shrimps and crabs.

The total swamp area along the lake is around 60,000 ha, 40,000 ha of which is in the northern freshwater area around Thale Noi, with another 20,000 ha along the outer lake and southern parts of the inner lake.

The gill nets for catfish and crab, and shrimp traps and brush traps for grouper and shrimp fry collection are located in the swamps. There are about 96, 1 ha. shrimp farms in the mangrove swamps along the outer lake.

2. Seabass culture in Songkhla Lake

(1) Present situation of seabass culture in Songkhla Lake.

The first trial aquaculture in Songkhla Lake was the shrimp culture (*Penaeus* sp.) in the ponds inside the mangrove swamps along the outer lake about 15 years ago. The freshwater shrimp culture (*Macrebrachium* sp.) in the pen was started 5 years ago in the northern area of the lake. However, shrimp culture techniques are not yet well developed, and production is still limited.

The chief aquaculture in the lake is now the seabass (*Lates calcarifer* BLOCH) culture in the net-cage. It was introduced 12 years ago, in 1972, to local fishermen, by the Department of Fisheries of Thailand.

During the initial years of seabass culture, natural seeds were used solely, but after successful artificial breeding in the tanks at the Songkhla Fishery Station in 1975, artificial seed supplemented the use of natural seeds.

More than 12 million seabass fry were produced by the NICA hatchery in 1983. Six million were sold to local fishermen for culturing and the other half was used for other government projects and restocking. Seabass production from the 256 net-cages, 124 farms, in Songkhla Lake for 1983 was approximately 60 tons.

The present method of seabass net-cage culture in the Songkhla lake general area is described below.

(a) Fry supply

Seabass fry for net-cage culture are supplied mostly by the NICA hatchery and also private hatcheries in the Songkhla and eastern coastal areas in southern Thailand. Normally, 1,000 of the 1.5 - 2.0 cm, 30 day old fry are packed with oxygen and 7 - 8 liters of sea-water into 60×40cm plastic bags. Average salinity is 20 - 25‰, but specific rates, attained by altering the amount of sea-water, can be requested by buyers.

Fry are transported by car and air. They are kept at 20°C - 22°C for long trips. Survival rate is normally greater than 80%.

(b) Nursery

Nursery nets, 1 × 2 × 0.8 m, are made from 1.5 mm mesh plastic mosquito nets. After they are acclimatized to the water, 200 - 300 of the 1.5 - 2.0 cm fry are stocked per net. Nursery term is 1.5 - 2 months until fry size is 4 - 7 cm. Survival rate during this stage is roughly 60%.

(c) Rearing

The rearing net, 5 × 5 × 2.5 m, is made from a nylon net of 3 cm mesh size. The rearing stage is normally 12 - 15 months, depending on the fish's size. Average harvest weight of the fish is 0.8 - 1.5 kg. Because the fish is sold to middlemen who buy according to market demand, both harvest dates and fish size are at a general variance. The rearing stage survival rate is estimated to be 50-60%.

(d) Feeding and management

The average feeding rate during the entire cultivation period for seabass is 3 - 10% of fish body weight per day. This rate varies inversely according to the market price of trash fish, the seabass' main diet. No farmers can store feed as none own freezers or refrigeraters.

The feeding method is to feed the fish little by little until they cease to eat actively. The actual feeding rate at farms in Songkhla Lake is about 10% of fry body weight per day during the nursery stage, 3 - 5% during the first 2 - 3 months of the rearing stage, and less than 3% during the later half of the rearing stage.

Net-cage farmers do not constantly and adequately care for the seabass. Manly net-cages were not changed or washed during the rearing stage. Thus, the net mesh was often clotted with dirt, oil and seaweed (usually the false cylon moss, *Gracilaria* spp.)

During the nursery stage, the farmer will redistribute the fry once or twice a week and place them in nets with fry of similar size. When the fry are 4 - 7 cm in size, they are then transferred to the rearing nets. Some farmers have added a formation (or an intermediate) net, 2 × 3 × 2 m and mesh size 1.5 cm, for raising the fish to a body length of 15 cm, before they are placed in the rearing net. After the nursery or formation stage, the farmers count the number of fry, by using a small bowl, before they are placed in the rearing nets. The farmer does not count the fish again until harvest.

(2) Problem of seabass net-cage culture in Songkhla Lake.

The seabass net-cages are usually set in front of the farmers' houses along the shores of covers or narrow channels, since these locations are most convenient and easily protected from theft. These areas are now very crowded, and some of them are polluted by the culture activity itself. Deaths of fish due to accidents and fish diseases have been more numerous in these areas as reported in recent years.

Some farmers have become aware of this problem and have moved their net-cages off shore. There are many other problems which can be remedied to increase and stabilize production. They are discussed below.

(a) Site: Many net-cages are set very near the shore, some of them only 50 cm away, and in very shallow water. In certain net-cages, the water is only 30 cm deep during the lowest low tide. Dirt and waste from the houses are often thrown directly into the net-cages and will accumulate at the bottom of the net-cage because of weaker water current in these areas.

(b) Net-mesh: The net-mesh of nursery cages are 1.5 - 2 mm and for rearing cages, 3 cm. These small net mesh are easily clotted by dirt, oil, algae and seaweed, thus lowering the water changing rate.

(c) Spaces between net-cages: The net-cages are normally supported by wooden or bamboo poles, and often they are set so there is little or no space between nets, reducing water circulation.

(d) Changing and washing the net: Many net-cages are not washed or changed during cultivation. The sites for seabass cultivation in the Songkhla area very turbid and heavily populated with organic matter. Thus, dirt and algae easily cling to the nets, clotting the meshes. In Songkhla Lake, 30% of the nets were clotted within 2 weeks. The first 20 - 30 cm of net under the surface were also clotted after 3 - 4 months of setting.

(e) Stocking density and feeding rate: Suitable stocking rates for seabass net-cage culture are not yet clearly set. The present stocking rate, based on repeated trial and error attempts, is now recommended to be 100-150 fish per m^2 in the nursery net, and 16-20 fish per m^2 in the rearing net. Recently, some farmers have been trying to stock at rates 2 - 5 times higher than recommended rates, resulting in higher fish fatalities. The feeding rate is partially determined by the feed price and available supply. Normally, the feeding rate is 5 - 10% of fish body weight per day, but this rate usually decreases during the rainy season.