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REPORTS OF FISH CULTURE RESEARCH SUPPORTED BY ROCKEFELLER FOUNDATION

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REPORTS OF FISH CULTURE RESEARCH SUPPORTED BY ROCKEFELLER FOUNDATION

THE FIRST FIVE TECHNICAL REPORTS

CARRIED OUT IN TAIWAN,

1966—1968

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CHEMICAL AND BIOLOGICAL STUDIES OF FISH PONDS AND RESERVOIRS IN TAIWAN*

By Wen Kuang Liaw**

Introduction

Lin and Chen (1966) demonstrated decisively the effectiveness of superphosphate in improving fish crop in the freshwater fish ponds and reservoirs in Taiwan in 1965. Since then the use of this inorganic fertilizer has become a common practice in local fish farming (Lin, 1968).

Fertilization of fish ponds is not new and many studies concerning its practical and theoretical aspects have been published (Neess, 1946). However, a great deal is still unknown as to the kind and the dosage of fertilizer that should be applied to a particular fish pond so that the most profitable result can be obtained. This is true at least in Taiwan (Lin, 1968). Furthermore, the extreme diversity of the physical, chemical and biological conditions of each individual pond often makes the application of the results obtained from one place to another difficult. The purpose of this investigation is then to accumulate basic information concerning the physical, chemical and biological aspects of selected fertilized and unfertilized fish ponds and reservoirs in this particular area. Although the results presented here in this report are not new academically, they are important, however, for two reasons: (1) these results represent the first set of basic limnological data ever collected from freshwater fish ponds in this area on which planning for further studies may be based; (2) these data may serve as first hand information which the fish culturists can use as a guide for the improvement of fertilization practice and pond management.

The Ponds and Reservoirs Selected for Study

The ponds and reservoirs studied can be arbitrarily grouped according to their nature of water supply, geographical location and size into four categories.

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* This project was supported by Rockefeller Foundation Grant and carried out in the Chupei Station of Taiwan Fisheries Research Institute with the assistance especially of C.N. Lin, Y.F. Wu and C.C. Chiu during the period from August, 1966 to June, 1968.

** Associate Professor of Zoology, National Taiwan University, Taiwan.

(1) The semi-flowing reservoirs at Taoyuan

The 241 reservoirs of the Taoyuan Canal Irrigation System can be grouped under this category. Among these, some 120 reservoirs have been used for fish culture by the Taoyuan Retired Servicemen Fish Propagation Administration (RETSER). In the present investigation six of these reservoirs were selected for periodic and occasional observations. They are ponds number 2021, 5017, 8103, 8109, 8004 and 1019. Of these 2012 and 5017 are highly productive ponds, while the rest, except the last one, represent less productive ones (table 1). Pond 1019 did not belong to the RETSER and was unfertilized until last June. Completely unfertilized ponds were not found among the RETSER ponds.

Table 1. Area, fish production and P_2O_5 dosage of the Taoyuan fish ponds selected for the study (data from Lin, 1968)

Pond No.	P_2O_5 dosage (kg/ha)			Mean yield of pretreatment period, 1959-1964 (kg/ha/year)	Yield after treatment (kg/ha)			Area (ha)
	1965	1966	1967		1965	1966	1967	
2012	0	20	20	630	902	747	1,159	8.9
5017	0	40	40	780	1,293	1,242	1,219	6.3
8103	80	80	80	364	662	498	673	4.8
8004	0	80	80	113	279	388	520	7.8
8019	0	100	100	115	244	323	434	9.4

All these ponds received their main water supply from Shihmen Reservoir through canal system, and were all subject to great fluctuation in water level during the year. The maximum depth of these ponds during high water level season ranged approximately from three to four meters.

(2) Small fish ponds receiving water from the rice fields and wells

Ponds of Chupei and Lukang Fish Culture Stations of Taiwan Fisheries Research Institute belong to this category. These ponds are characterized by their small size and shallowness (usually less than 1 meter in depth).

(3) Small natural lake and reservoir located in the valley

The small natural lake, Liyutan (19.3 ha) located at Puli in central Taiwan, and the reservoir of approximately the same size formed by damming of a valley at Miaoli belong to this category. These two bodies of water, are common in having no regular water supply from canals. Their water supply depends mainly on springs, rain and runoff from surrounding area. Liyutan is divided into two parts, the inner (B) and the outer (A), by an embankment. The water of the two parts was interconnected through an outlet during high water season. The maximum depth of the outer part of the lake was approximately five meters, while that of the inner part was about seven meters at the time of observation. The maximum depth of Tanwen Reservoir was about six meters.

(4) Large reservoirs

Shihmen Reservoir and Sun-Moon Lake fall into this category. These waters are characterized by larger area and greater depth as compared to other inland waters on this Island. The maximum depth of Shihmen Reservoir was approximately 90 meters and that of Sun-Moon Lake about 18 meters during high water level season. These waters were also relatively unpolluted, therefore they can be taken as substitutes for unfertilized waters in making comparative studies.

Material and Methods

Regular and occasional samplings of water and plankton have been made from the above mentioned bodies of waters since February 1967, and it is still underway. This paper gives the results obtained in 1967.

1. Temperature

Temperature of the water was recorded in most cases by a thermistor attached to a Galvanic Cell Oxygen Analyzer (Precision Scientific Co.) from the surface to the bottom at 25 cm intervals.

2. Depth of visibility

The depth of visibility or Secchi disc transparency of the water was determined by using a standard Secchi disc of 25 cm diameter as described by Welch (1948).

3. Conductivity

Conductivity of the water was measured *in situ* by using a portable conductivity meter (Toa Model CM-3M).

4. Water analysis

Water samples were usually taken from near the outlet and from the inflow water in the canal directly by 500 ml polyethylene bottles for the surface water, or by a water sampler (Kitahara Model B) for the deeper layer or bottom water. The water samples collected were brought back to the laboratory as soon as possible and stored in a freezer if immediate analysis could not be made.

Analytical procedures of total alkalinity, total hardness, $CaCO_3$, $MgCO_3$, soluble phosphorus, nitrate, nitrite, silicon and true water color followed those given in the eleventh edition of Standard Methods for the Examination of Water and Waste-water (American Public Health Association, 1961). Chloride was determined by Conway microdiffusion technique (Long, 1961). Dissolved oxygen of those samples collected in February was determined by standard Winkler method, others by direct measurement in the field by the Galvanic Cell Oxygen Analyzer which had been calibrated against the chemical method before each series of measurements.

$KMnO_4$ consumption by the method described by Saijo (1962). pH of the water was measured mostly in the field by a portable Photovolt pH meter with a combined electrode.

5. Plankton

Plankton samples were collected from the central region of the pond and the reservoir by towing the weighted surface plankton net (25 cm mouth diameter, 50 cm long, No. 25 bolting silk) obliquely from the bottom to the surface. Samples collected in this manner were intended for detailed taxonomic studies. For quantitative study, samples were collected at the same time by using the one liter capacity water sampler to collect 5 to 20 liters of water, depending on the apparent amount of plankton present in the water. The water was then filtered through the plankton net to get concentrated plankton samples.

In the laboratory the whole content of the plankton sample collected by the water sampler was examined for zooplankton, and the quantity of each species determined. But, for phytoplankton a suitable amount of aliquot was taken for examination only and the quantity of each form determined by calculation.

6. Primary production

The primary production of the water was determined by two ways:

(1) Light and dark bottle method. This method involved the measurement of changes in dissolved oxygen due to photosynthesis over a period of time. Two sets of light and darkened bottles (each of 500 ml capacity) were filled with pond water of different layers and then suspended at the depths where the water was taken, for five to six hours (usually from 1000 to 1600 hours) on a clear day. Then the bottles were removed from the pond water, and the oxygen content in each bottle was determined by the Galvanic Cell Oxygen Analyzer. Difference of the oxygen content between light and dark bottles was taken as a measure of the phytoplankton photosynthesis that had taken place at each depth. To get equivalent carbon assimilation rate, the results of the oxygen measurements were multiplied by a factor of 1.33 (Saijo, 1962).

(2) By determination of chlorophyll concentrations. In this method usually 200 ml of pond water was taken by the water sampler and filtered through fine filter paper (Toyo No. 5C) by suctioning. Then the filter paper was placed into 40 ml 80% acetone solution in a dark place for 24 hours for the extraction of the pigment. After filtration, the acetone extract was then measured for absorbances at wave lengths of 645, 652 and 663 mμ respectively. The concentration of chlorophyll a and b was calculated according to Mackinney (1941).

Results and Discussion

I. Chemistry

1. Dissolved oxygen

Oxygen is the last hydrogen or electron acceptor in the oxidative phosphorylation chain of aerobic respiration in a living system. It is also a by-product of the photosynthetic assimilation in living green plants. Therefore, the measurements of dissolved oxygen in an aquatic habitat can not only be used to define the quality of the water but it can also be taken as a mean for the estimation of the gross photosynthesis and the total community respiratory process (Odum, 1959). It is also well known that oyygen affects fish life in many ways and that sufficient oxygen supply to the pond water is mandatory for maintaining active and healthy fish life. For this reason a thorough knowledge of the extent of the fluctuation of oxygen concentration in a fish pond is of vital importance to pond management.

Some of the dissolved oxygen measurements of selected ponds and reservoirs taken during the investigation period are plotted in figures 1-5. These figures are intended mainly to show the extent of oxygen fluctuation with depths and time in different types of waters used for fish culture.

Taoyuan fish ponds (figure 1): Taoyuan fish ponds are all located near the coast, and are all well exposed. For this reason these ponds are usually under the effect of strong prevailing winds which produce sufficient surface turbulence, resulting in effective mixing of the entire water column even in hot summer months. Besides, frequent inflowing and discharging of the water for irrigation also help a great deal in the mixing of the water. Therefore, these ponds are usually isothermal almost to the near bottom and the oxygen concentrations vary very little from surface to the bottom. Cases of well defined stratification, however, could also be found occasionally in August (probably in July, too) on extremely calm and hot days when there were no discharge and inflow to agitate the pond water.

The difference between fertilized and unfertilized ponds was quite obvious from the distribution curves. In unfertilized pond 1019, oxygen concentrations of the upper water were only slightly oversaturated, showing very little photosynthetic assimilation apparently due to less abundant phytoplankton. And oxygen concentrations in the bottom water were slightly undersaturated, showing probably thorough mixing of the water and less oxygen consumption by the oxidation of organic matter and respiration of living organisms. On the contrary, the oxygen contents of the fertilized pond 5017 on a well agitated day were greatly supersaturated all the way to the bottom. This indicates great excess of photosynthesis

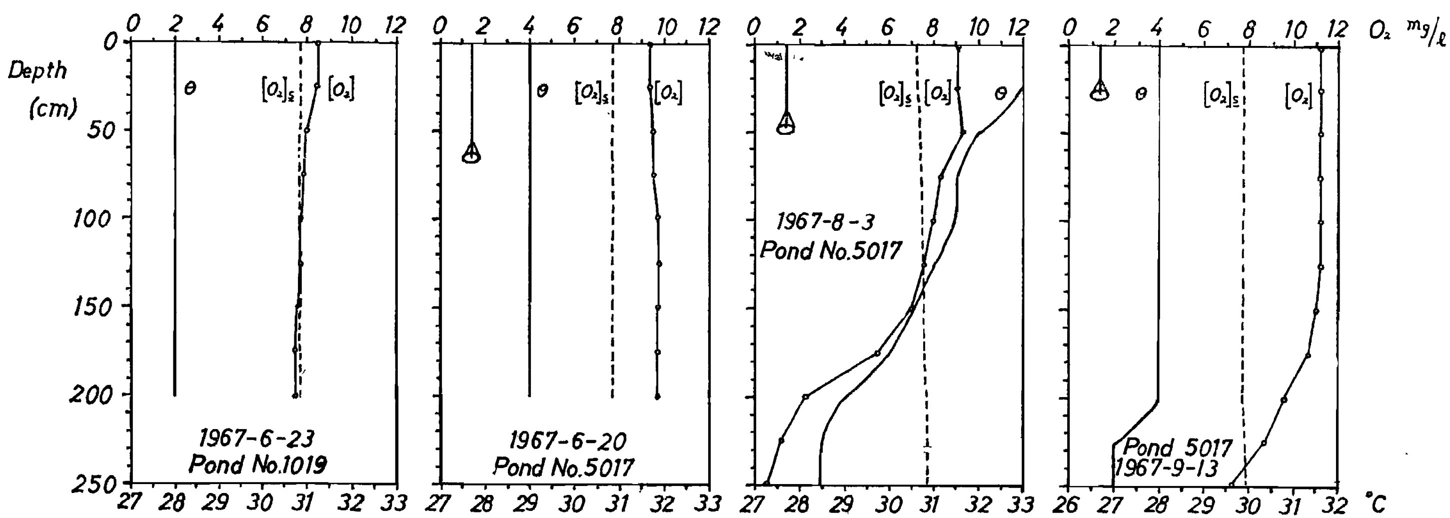

Figure 1. Vertical distribution of temperature (θ) and dissolved oxygen $[O_2]$ in Taoyuan fish ponds No. 1019 and No. 5017 in the summer. $[O_2]_S$, saturation based on table of Truesdale, Downing and Lowden (1955) without atmospheric pressure correction. The depth of Secchi disc transparency is also indicated in pond No. 5017. Depth of pond No. 1019 was about 2.5 m; of pond No. 5017, about 3 m.

over respiration due to the heavy algal bloom that has been observed.

The amount of phytoplankton present in the water can be roughly indicated by Secchi disc readings should there be little turbidity. High oxygen concentrations were usually associated with low Secchi disc readings (see also figure 5).

Considering the shallowness of the pond (maximum depth about 3 m at the time of measurement), the stratification on a hot calm day (e.g. August 3) was remarkable. This was probaby caused partly by the heavy bloom of the phytoplankton. The autoshading effect of the upper dense phytoplankton population no doubt cut short the light penetration and thus caused rapid loss of photosynthesis with increasing depth. The depletion of oxygen was then probably caused by the combined effect of the loss of photosynthesis in deeper layer, the lack of circulation, and the decomposition of the large amount of organic matter that had been added in the form of night soil in addition to the inorganic superphosphate. The high $KMnO_4$ consumption (24.8 ppm) and high true water color (15 Pt unit) indicate the presence of a large amount of organic matter in the water. To avoid the depletion of oxygen in deeper water, it is advisable that no or very little organic fertilizer be added to the pond during hot summer months.

Tanwen Reservoir and Liyutan (figure 2): Located in the valleys far away from the coast as compared to Taoyuan ponds, local topography of these two bodies of waters provides protection from strong wind action. Therefore, in these waters stratification was usually well defined during hot summer months. The upper layers of the waters were also well oxygenated, apparently due to intense photosynthesis. The relatively low oxygen concentrations of Tanwen Reservoir on September 14, indicatod the start of a circulation of the water due to the drop of temperatures. The phenomenon is probably the same as reported in some experimental artifical circulation in which the mean oxygen concentration is usually found decreasing during the initial phase of the circulation (Halsey, 1968). According to Hutchinson (1957), it can be postulated that reduced photosynthetic rate combined with the chemical oxidation of hydrogen sulfate and organic matter were the likely causes of the oxygen reduction in this reservoir at this time. The organic matter content in this water was high as indicated by high $KMnO_4$ consumption (34.72 ppm) and high water color (25 Pt unit).

Shihmen Reservoir and Sun-Moon Lake (figure 3): Since the maximum depth of Shihmen Reservoir reached to about 90 meters, the present data are obviously too incomplete to warrant any meaningful discussion on the vertical distribution of oxygen. However, from the data plotted in the figures, it can be postulated that the vertical distribution of oxygen in this reservoir was probably of orthograde type as described

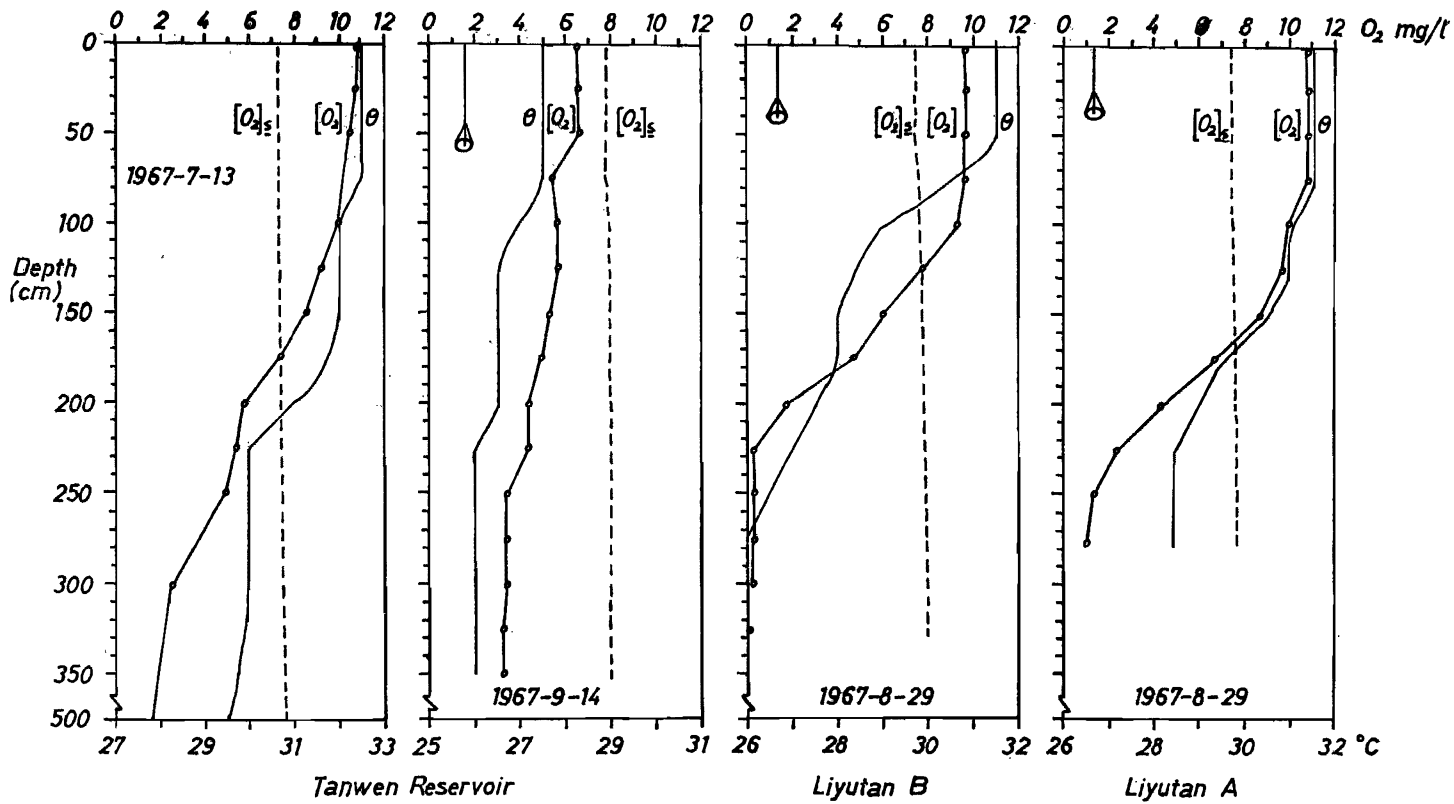

Figure 2. Vertical distribution of temperature (θ) and dissolved oxygen [O_2] in Tanwen Reservoir and Liyutan in the summer. $[O_2]^s$ indicates saturation. The depth of Secchi disc transparency is also indicated.

by °Aberg and Rodha (Hutchinson, 1957). The nearly uniform distribution of oxygen, probably without much decrease in the deeper layer, was perhaps caused by mixing of water by the large current usually observed in the reservoir. The oversaturation observed in the epilimnion on September 12 indicates apparently greater rate of photosynthesis. As the reservoir is relatively new and unpolluted, and very little organic matter seemed to be present in the water as indicated by low $KMnO_4$ consumption (7.98 ppm) and true water color (2.5 Pt unit), the undersaturation occurred even in the epilimnion on July 24 and August 2 was probably due to higher respiratory metabolism of zooplankton over photosynthesis. The low Secchi disc reading recorded on August 2 was not due to dense plankton population, but rather to high turbidity caused by heavy rain.

The vertical oxygen curve in Sun-Moon Lake obtained in August was also of orthograde type. Higher concentration in the metalimnion probably indicates that there was greater photosynthetic activity there.

From the foregoing discussion it is clear that in unfertilized or relatively unpolluted waters the magnitude of vertical variation of oxygen was small, and there was usually a balance between photosynthesis and respiration. On the other hand, in heavily fertilized or polluted waters the fluctuation was usually great and photosynthesis was greater than respiratory process in the epilimnion. In the hypolimnion, respiration and oxidation of organic matter associated with loss of photosynthesis usually depleted the oxygen from the water to a critical level.

Diurnal variation of dissolved oxygen The general pattern of diurnal variation and the magnitude of daily fluctuation of dissolved oxygen in different ponds are shown in figures 4 and 5, Maximum concentration of oxygen was generally found in between 1500 and 1600 hours, while minimum concentration was usually observed just before dawn (between 0500 and 0600 hours). It has been noticed that the smaller the body of water, the greater the fluctuation (as in small Chupei ponds); and the greater the Secchi disc transparency, the smaller the difference between maximum and minimum concentrations. These phenomena were obviously caused by the difference in the rate of gross photosynthsis in different ponds.

2. Hydrogen ion concentration

Ranges and means of surface and some bottom pH in different ponds and their inflow waters are shown in table 2 and figure 6. It is apparent from this table that pH also varied considerably, although with less magnitude as compared with oxygen, from pond to pond and also from time to time in the same pond. The fluctuation was greater in fertilized ponds, and especially in those ponds having heavy algal blooms such as ponds 8004, 8103, 5017, Chupei ponds, Tanwen Reservoir and

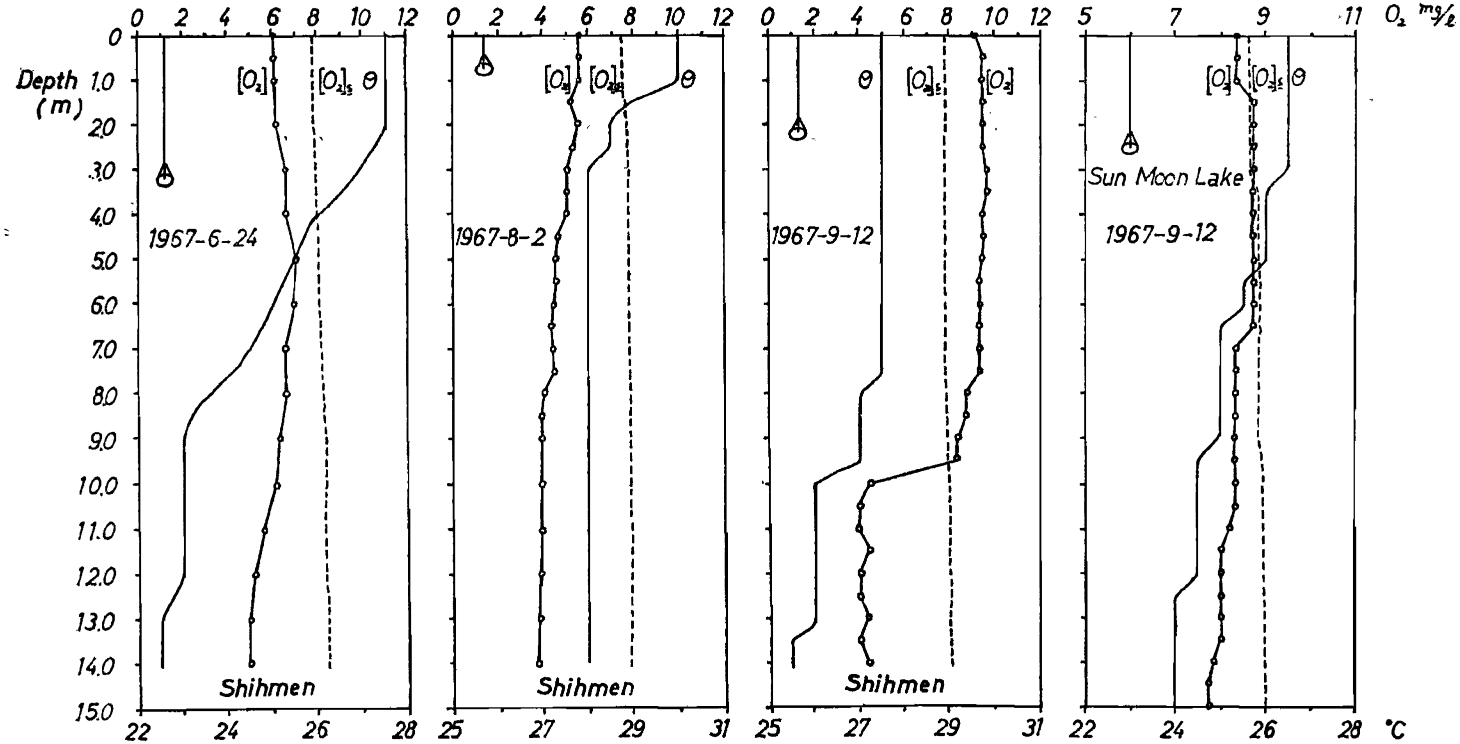

Figure 3. Vertical distribution of temperature (θ) and dissolved oxygen $[O_2]$ in Shihmen Reservoir and Sun Moon Lake during the summer. $[O_2]_s$ indicates saturation. The depth of Secchi disc transparency is also indicated. Depth at the site of observation about 90 m in Shihmen Reservoir and 18 m in Sun Moon Lake. Saturation curve of Sun Moon Lake data were corrected for altitude at 750 m.

Liyutan. Therefore, the magnitude of the pH fluctuation can also be taken as a rough index of the primary production of the pond. The fact that all inflow and bottom waters had lower pH than that of the pond water indicates clearly the photosynthetic effect on the pH of the pond water. The mean surface pH of Liyutan, being only slightly alkaline, was the lowest among all waters investigated although its maximum may be over 9 in some cases.

Table 2. Ranges and means (in parentheses) of surface and bottom pH in various ponds measured on different days and at various hours during daytime except that of pond no. 5017 and Tanwen Reservoir in which night measurements are also included. p indicates pond water; i, inflow water.

Pond	Surface pH	Bottom pH	Pond	Surface pH	Bottom pH
8004p	8.2-9.6 (8.7)	—	8019p	8.0*	—
8004i	8.1*	—	Chupei C-3	8.6-10.1 (9.5)	—
8103p	8.1-9.6 (8.9)	—	Tanwen	7.1-8.6 (8.1)	6.3-7.1 (6.8)
8103i	7.2-7.6 (7.4)	—	Liyutan A	6.8-9.4 (7.6)	—
5017p	7.8-9.5 (8.4)	7.0-7.8 (7.3)	Liyutan B	7.1-9.0 (7.9)	7.0-7.2 (7.1)
5017i	6.9-7.0 (6.9)	—	Shihmen	8.0-8.5 (8.3)	7.7-8.0 (7.8)**
1019p	8.4-8.7 (8.5)	—	Sun-Moon L.	8.3-8.4 (8.4)	7.9-8.3 (8.1)**
2012p	7.8*	—		—	—

* mean of one set of measurements only

** at 18 meters depth

3. Total alkalinity

The total alkalinity of surface waters investigated ranged from 23.94 (Liyutan) to 188.73 (Lukang ponds) ppm $CaCO_3$, with majority of the waters above 40.0 ppm (tables 3 and 4). These values are high as compared with that of Japanese lakes in which 60% are in the range of 10.0-30.03 ppm (Satomi, 1962). Taoyuan fish ponds varied greatly from pond to pond although they have a common ultimate water supply from Shihmen Reservoir (having 63.84 ppm total alkalinity at surface water). It is believed that the chemical condition of the water supply had been greatly modified as it ran through canals passing through different land conditions.

Table 3. Chemical conditions of ponds and reservoirs in Taiwan.

1. Taoyuan

Chemical conditions	5017 pondwater		5017 inflowwater		8103 pondwater	
	Range	Mean	Range	Mean	Range	Mean
Total alkalinity as $CaCO_3$	38.37–44.95	42.44	32.00–71.23	51.64	21.35–42.71	32.03
Total hardness (Ca, Mg)	63.34–90.00	72.40	57.74–82.24	70.07	45.23–59.43	52.33
$CaCO_3$	30.00–45.10	37.94	35.95–52.09	44.01	25.94–49.64	37.79
$MgCO_3$	18.76–60.00	34.46	21.79–30.17	25.98	14.79–19.29	17.04
Phosphorus	0.044–0.176	0.074	0.034–0.223	0.125	0.064–0.318	0.191
Nitrate nitrogen	0.115–0.575	0.345	—	0.268	—	0.002
Nitrite nitrogen	0.038–0.079	0.059	0.019–0.310	0.165	0.015–0.046	0.031
Silicon (SiO_2)	1.312–3.669	2.509	1.763–4.399	3.051	3.506–3.749	3.628
Chlorides	14.49–25.62	20.06	—	15.58	9.78–17.30	13.54
Conductivity ($\mu\mho$/cm, 20°C)	189.6-282.0	233.7	189.6-298.8	244.2	136.0-182.6	159.3
$KMnO_4$ consumption	24.45-25.07	24.77	25.81-46.56	36.19	20.10-20.22	20.16
Color (Pt unit)	14-15	14.5	17-45	31.0	6-13	9.5

Concentrations are in mg per liter unless otherwise indicated.

Fish Ponds

8103 inflowwater		8004 pondwater		8004 inflowwater		2012 pondwater	8019 pondwater	1019 pondwater
Range	Mean	Range	Mean	Range	Mean	Mean	Mean	Mean
29.64-43.46	36.55	41.66-132.0	72.60	71.53-74.74	73.14	120.0	118.0	44.5
54.60-73.77	64.19	74.55-120.0	91.57	103.48-112.22	107.85	115.0	130.0	84.13
40.76-47.05	43.91	32.26-48.09	40.12	70.18-70.90	70.54	67.5	60.0	51.61
13.84-26.72	20.28	31.07-80.00	51.12	33.30-41.32	37.31	47.5	70.0	32.51
0.028-0.062	0.045	0.026-0.354	0.136	0.015-0.019	0.017	0.052	0.047	0.009
—	0.109	0.002-0.018	0.010	—	0.057	0.040	0.019	0.002
0.014-0.033	0.025	0.019-0.230	0.125	0.027-0.028	0.028	—	—	0.015
5.128-9.551	7.340	1.884-6.588	4.467	4.155-6.086	5.121	3.272	5.386	2.128
—	14.90	5.55-12.05	9.25	4.40-16.96	10.68	14.10	5.60	16.72
190.9-204.0	197.5	204.0-228.0	215.1	—	200.2	319.0	273.0	204.0
16.89-21.32	19.11	13.58-73.58	35.22	6.57-12.31	9.44	—	—	19.52
10-13	11.5	17-18	12.5	3-6	4.5	—	—	6.0

Table. 3. Chemical conditions of ponds and reservoirs in Taiwan.

2. Liyutan and

	Liyutan A		Liyutan
	Range	Mean	Range
Total alkalinity as $CaCO_3$	16.06 -33.00	24.19	16.21 -33.00
Total hardness (Ca, Mg)	15.91 -23.46	19.12	13.82 -24.37
$CaCO_3$	10.20 -14.40	11.54	8.60 -13.68
$MgCO_3$	5.88 - 9.66	7.58	5.22 -10.69
Phosphorus	0.028- 0.046	0.035	0.015- 0.046
Nitrate nitrogen	0.044- 0.062	0.053	0.002- 0.058
Nitrite nitrogen	—	0.033	—
Silicon (SiO_2)	0.798- 5.933	3.966	1.965- 6.467
Chlorides	2.398- 4.694	3.297	2.800- 5.294
Conductivity (μ℧/cm, 20°C)	32.9 -77.9	61.3	32.9 -74.7
$KMnO_4$ consumption	15.15 -22.75	18.95	12.99 -25.28
Color (Pt unit)	9-13	11	6-13

Concentrations are in mg per liter unless otherwise indicated.

Tanwen Reservoir

B	Upper Tanwen		Lower Tanwen	
Mean	Range	Mean	Range	Mean
23.94	98.41 -120.16	109.29	97.22 -118.93	108.08
18.90	99.53 -104.20	101.87	105.83 -119.51	112.67
11.03	56.04 - 60.40	58.22	56.43 - 73.38	64.91
7.84	39.13 - 47.16	43.15	46.13 - 49.40	47.77
0.028	0.096- 0.143	0.120	0.064- 0.148	0.106
0.030	—	0.022	—	0.030
0.013	—	0.186	—	0.081
4.831	1.868- 3.425	2.647	1.608- 6.264	3.936
4.037	—	—	—	24.50
60.2	268.6 -307.1	287.9	268.6 -307.1	287.9
19.14	22.50 - 39.74	31.12	26.58 - 42.85	34.72
10	14-30	22	18-32	25

Table 3. Chemical conditions of ponds and reservoirs in Taiwan.

3. Shihmen Reservoir

Chemical conditions	Shihmen Reservoir				
	Surface		10 m		18m
	Range	Mean	Range	Mean	Range
Total alkalinity as $CaCO_3$	60.63-69.05	63.84	43.35-61.53	52.44	63.62-66.21
Total hardness (Ca, Mg)	73.8-98.79	86.09	75.6-102.2	88.91	79.07-92.38
$CaCO_3$	50.96-51.00	50.98	51.67-62.30	56.99	54.60-69.08
$MgCO_3$	47.83-70.00	58.92	23.93-39.92	31.93	24.47-23.30
Phosphorus	0.018-0.030	0.024	0.014-0.019	0.016	0.018-0.041
Nitrate-nitrogen	—	0.037	—	0.068	—
Nitrite-nitrogen	0.016-0.054	0.016	0.026-0.037	0.032	0.015-0.018
Silicon (SiO_2)	4.625-4.074	4.349	5.534-4.780	5.158	4.723-5.858
Chlorides	6.75-16.54	11.65	—	7.68	11.40-12.07
Conductivity ($\mu\mho$/cm, 20°C)	195.5-206.4	201.0	205.4-226.7	215.9	199.5-230.4
$KMnO_4$ consumption	5.69-10.28	7.98	7.80-11.10	9.45	8.22-12.99
Color (Pt unit)	2-3	2.5	2-3	2.5	3-5

Concentrations are in mg per liter unless otherwise indicated.

and Sun-Moon Lake

	Sun-Moon Lake					
	Surface		10 m		18 m	
Mean	Range	Mean	Range	Mean	Range	Mean
64.92	103.73-109.40	106.67	95.27-115.81	105.54	116.75-132.42	124.59
85.73	146.27-160.31	153.29	155.52-168.65	162.09	173.08-188.39	180.74
61.84	89.93-105.83	97.88	—	107.46	111.70-112.20	111.95
23.89	54.48-56.34	55.41	—	61.19	61.38-76.19	68.79
0.030	0.007-0.032	0.022	0.016-0.017	0.017	0.009-0.009	0.009
0.083	—	0.059	—	—	—	—
0.016	—	0.030	—	0.038	—	0.026
5.291	4.601-6.827	5.576	—	4.642	4.612-5.047	4.830
11.74	5.01-5.42	5.21	—	—	6.60-7.58	7.09
214.0	299.2-331.2	315.2	306.0-349.6	327.8	309.4-386.4	347.9
10.61	5.52-5.56	5.57	—	8.01	—	5.79
4	—	1	—	2	—	3

Table 3. Chemical conditions of ponds and reservoirs in Taiwan.

4. Chupei Fish Ponds (averages of measurements

Chemical conditions	A-1	A-2	A-3	A-4
Total alkalinity as $CaCO_3$	108.33	94.14	119.90	117.33
Total hardness (Ca, Mg)	146.60	149.87	155.27	143.73
$CaCO_3$	117.00	116.07	107.33	106.67
$MgCO_3$	29.40	33.80	47.94	36.06
Phosphorus	0.070	0.097	0.048	0.058
Nitrate-nitrogen	0.045	0.039	0.153	0.095
Nitrite-nitrogen	0.018	0.288	0.042	0.033
Silicon (SiO_2)	3.101	3.542	6.751	2.960
Chlorides	14.50	13.75	11.90	14.00
Conductivity ($\mu℧$/cm, 20°C)	—	—	—	—
$KMnO_4$ consumption	17.57	46.46	14.96	23.85
Color (Pt unit)	12	21	14	15

Concentrations are in mg per liter unless otherwise indicated.

made on a single day or several days in December 1967)

A-6	C-1	C-2	C-3	C-4	C-5	Ground water
117.35	132.36	139.63	116.20	112.20	110.26	255.0
142.60	152.80	—	130.00	140.00	144.67	208.0
102.21	114.20	—	88.47	104.67	106.73	104.0
40.39	38.60	—	41.53	35.33	37.94	104.0
0.051	0.402	0.190	0.143	0.045	0.038	0.019
0.020	0.029	—	0.008	—	—	0.019
0.005	0.078	0.013	0.008	0.058	0.004	—
2.801	6.583	5.362	7.994	2.376	0.771	9.000
11.10	16.50	—	16.50	17.40	18.40	16.50
—	—	—	339.0	—	—	401.0
17.36	14.56	41.52	46.37	20.77	18.49	—
14	12	18	19	15	14	—

Table 3. Chemical conditions of ponds and reservoirs in Taiwan. Concentrations are in mg per liter unless otherwise indicated.

5. Lukang fish ponds and others

Chemical conditions	Lukang ponds (May 5, 1967)			Ground water to eel ponds at Panchiao
	Eel pond	Others	Groundwater	
Total alkalinity as $CaCO_3$	157.55	188.73	194.73	158.14
Total hardness (Ca, Mg)	97.23	183.95	77.48	55.52
$CaCO_3$	34.83	64.12	59.83	23.14
$MgCO_3$	62.40	119.83	16.65	32.38
Phosphorus	0.472	0.234	0.932	0.276
Nitrate-nitrogen	—	—	—	0.329
Nitrite-nitrogen	—	—	—	0.039
Silicon (SiO_2)	6.588	2.014	—	13.158
Conductivity ($\mu\mho$/cm, 20°C)	293.7	1157.0	373.8	390.6
Color (Pt unit)	20	24	8	8
$KMnO_4$ consumption	—	—	—	7.65

Table 4. Total alkalinity of the waters investigated

Range ppm	Number of ponds
0.0-20.0	0
21.0-40.0	2
41.0-90.0	3
91.0 or more	16

Total alkalinity has been found to be of value as an index of the pond productivity. In studying the alkalinity of Japanese lakes, Satomi (1962b) found out that there was a positive correlation between the logarithm of fish production and the alkalinity in the lake water. Similar relationship was also found in Minnesota ponds by Moyle (1946) as shown in the following table.

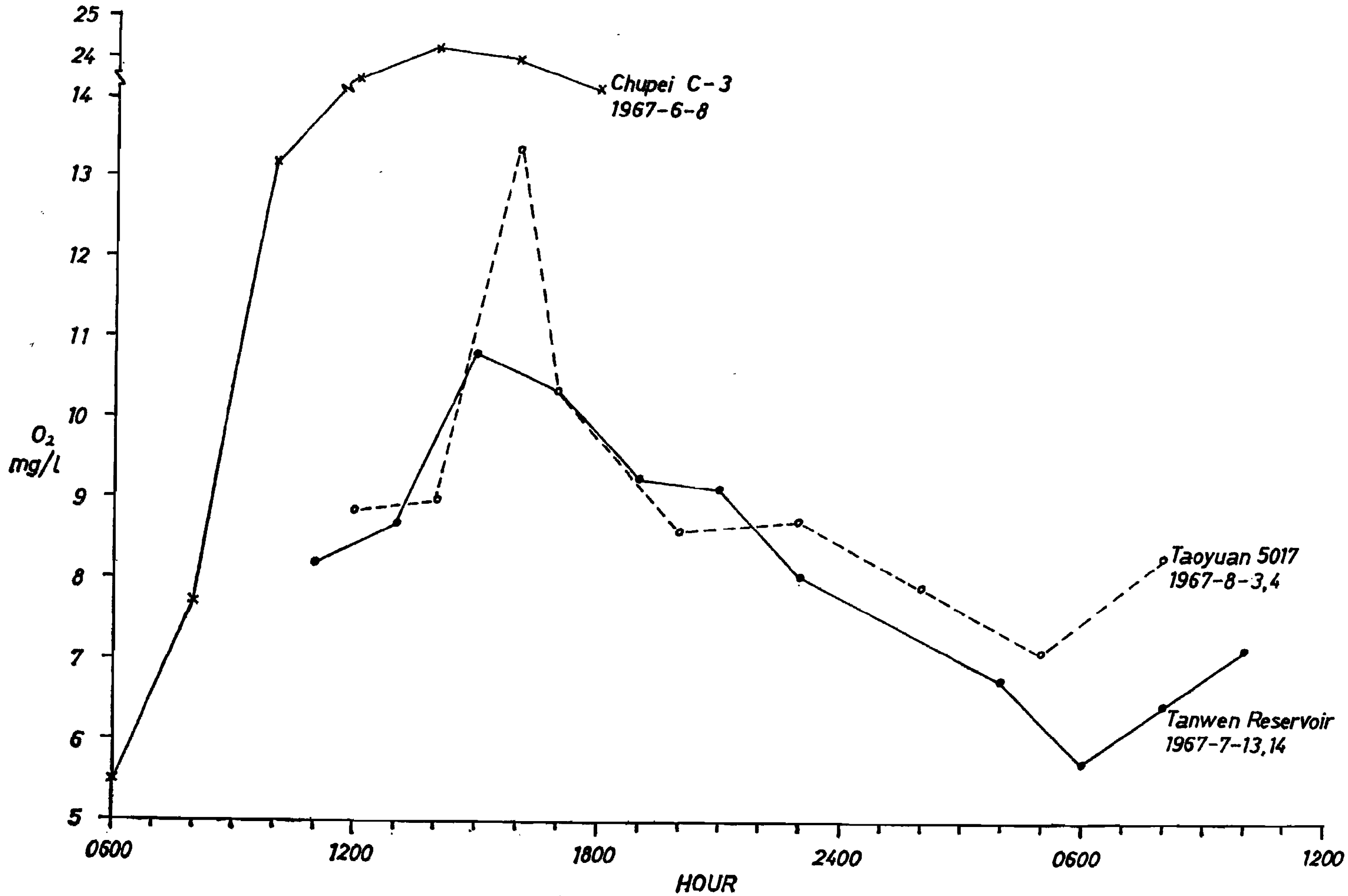

Figure 4. Diurnal fluctuation o dissolved oxygen in different ponds.

Table 5. Annual yield of yellow pikeperch fingerlings in pounds per acre and total alkalinity of 69 Minnesota rearing ponds (from Moyle, 1946, table 1)

No. of ponds	Total alkalinity (ppm)	Average yield (pounds per acre)	Maximum yield (pounds per acre)
7	8.0- 20.0	17.1	50.0
7	21.0- 40.0	28.3	83.0
20	41.0- 80.0	63.3	234.0
15	81.0-120.0	62.7	232.0
20	121.0 or more	48.2	194.0

A comparison of the average fish yield of Taoyuan fish ponds with total alkalinity in the pond water (table 6) shows that high fish yields also seem to associate with high alkalinity, but the relationship is less definite. This is probably due to the effect of factors of non-chemical nature. Take pond 5017 for instance, the shape of the pond basin probably has more to do with the exceptionally high production. The basin of this pond is in such a form that much water is still retained in the pond even during dry season when the water must be drained out for irrigation. And much water in the pond means much space for the fish to live in.

The use of total alkalinity as an index of fish yield is of interest. However, the data accumulated here are still far from complete. Further investigations are certainly needed for the drawing of more definite conclusions.

Table 6. Average annual fish yield in Taoyuan fish ponds and Liyutan and their total alkalinity

Ponds	Total alkalinity (ppm)	Average fish yield (kg/ha/year)*	
		Prefertilization (1959-1964)	Post fertilization (1965-1967)
2012	120.0	630	936
8019	118.0	115	340
8004	72.6	113	396
5017	44.4	780	1,251
8103	32.0	364	611
Liyutan	24.1	149(1964-66)	493(1967)

4. Chlorides

Chlorides occurred in the waters investigated in concentrations between 3.30 and 24.5 ppm. The fact that the concentration of chlorides in inland waters varies with the distance between the water and the sea, and that waters nearer to the sea usually contain much chloride (Bayly, 1964; Hutchinson, 1957) is also generally true in the present data as shown in the following figures.

Ponds arranged in the order of closeness to the sea	Average chloride concentration, ppm
5017	20.06
1019	16.72
8019	5.60
8103	13.54
8004	9.25
2012	14.10
Chupei ponds	11.10-18.40
Tanwen Reservoir	24.50
Shihmen Reservoir	11.65
Sun-Moon Lake	5.21
Liyutan (A and B)	3.67

However, other factors besides the effect of the sea are likely involved in causing the variations of chloride concentration in the inland waters. It has been found in Minnesota waters that high chlorides are mostly observed in polluted waters or in areas of Cretaceous rock (Moyle, 1946). Therefore, in the present data the exceptions found between the water nearest to the sea (pond 5017) and the water most remote from the sea (Liyutan) could be attributed to the fact that the difference in distance to the sea is not large enough to cause clear cut difference, and that the degree of pollution of the ponds was different.

Aside from seasonal variation chlorides in pond water, especially in those ponds situated in the coastal area, also fluctuated to some extent within a few days as can be seen from the following measurements obtained from pond 5017:

Date	Chlorides, ppm
1967-9-25	16.4±0.1
9-26	17.0±0.6
9-28	17.0±0.8
9-30	18.4±0.4
10-2	17.5±0.3
10-4	13.2±0.4

Such short term fluctuation is probably caused by daily meteorological changes, such as rain and changes of the strength and direction of winds.

As to the effect of chlorides on fish production, Lin (1968) has attempted to associate the fish yield of Taoyuan ponds with chloride concentrations. He is of the opinion that high fish yield is correlated to high concentration of chlorides. A re-examination of this matter with additional data presented here (cf. table 6 and the chloride data) also reveals that a positive correlation between these two is generally present. But, again the effect of non-chemical factor such as the amount of water retained in each pond during dry season cannot be neglected in making such a comparison.

5. Total hardness

Total hardness in the surface water of ponds and reservoirs investigated was in the concentration between 18.90 and 155.27 ppm. Again Liyutan was the lowest and Chupei pond A-3 the highest. Comparison of the total alkalinity and the total hardness shows that these two chemical factors were closely associated; high alkalinity was usuallv associated with high hardness. Also shown in table 3 is that the fraction of $CaCO_3$ in the total hardness was higher than that of $MgCO_3$ in most waters.

6. Phosphorus

Phosphorus is probably the most important element in the ecology of an aquatic environment, since it affects biological productivity in many ways. Also because it is never present in nature in large quantity that it is likely to become a limiting factor to the production of the water (Hutchinson, 1957). For this reason, frequent measurement of the phosphorus content in the water of a fish pond is important from the practical point of view.

It can be seen from table 3 that phosphorus in surface waters studied varied from 0.009 ppm in the unfertilized Taoyuan 1019 to 0.472 ppm in the eel pond at Lukang. Ground waters, polluted waters and small ponds such as those at Lukang and Chupei usually have much higher phosphorus contents. The phosphorus concentration in the ground water at Lukang reached as high as 0.932 ppm, the highest of all measurements.

The waters under investigation can also be roughly grouped on the basis of phosphorus content (table 7) according to Yoshimura's scheme (1932) (in Moyle, 1946). The table shows that fertilized Taoyuan ponds are ranked from fair to very good in phosphorus fertility. However, it is odd that two highly productive ponds 5017 and 2012 are classified good only, while less productive ponds 8004 and 8103 are in the category of very good. If this classificatory scheme is correct, then factors other than phosphorus could have been involved in determining the production of these ponds. This matter clearly demands further investigation.

The data presented here have indicated that phosphorus content not only varied a great deal from pond to pond but also fluctuated greatly in the same pond due to the addition of superphosphate and the change of phosphorus content in the inflow water (table 8). If the time of observation coincided with that of the addition of superphosphate, the resultant measurements would be much higher than the other observations

Table 7. Classification of the waters studied on the basis of phosphorus content

Ponds and reservoirs	Phosphorus (ppm)	Phosphorus fertility
Taoyuan 1019, Sun-Moon Lake	0.000-0.02	low
Taoyuan 8019, Liyutan, Shihmen, Chupei A-3, C-4 and C-5	0.021-0.05	fair
Taoyuan 5017, 2012, Chupei A-1, A-2, A-5 and A-6	0.051-0.10	good
Taoyuan 8103, 8004, Chupei C-2, C-3, Tanwen Reservoir	0.11 -0.20	very good
Chupei C-1, two Lukang ponds, Panchiao eel ponds	0.21 or more	excessive

Table. 8. Changes of phosphorus, pH, chlorophyll contents and water level in Taoyuan fish pond 5017

Date	Water level (m)	Super-phosphate added (kg)	pH (at 1200 hr)		Phosphorus, ppm			Chlorophyll a+b (mg/l)
			Surface	Bottom	Surface	Bottom	Inflow water	
9-23	1.50	—	8.0	7.9	0.053	0.055	—	0.111
9-24	1.50	—	8.5	8.3	0.058	0.056	—	0.168
9-25	2.26	—	7.9	7.9	0.060	0.064	0.063	0.056
9-26	2.00	50	7.7	7.8	0.176	0.184	0.085	0.057
9-27	2.67	—	8.2	—	0.121	0.132	0.155	0.049
9-28	2.70	—	8.9	8.3	0.071	0.077	0.223	0.137
9-29	2.68	—	8.9	8.3	0.060	0.064	0.178*	0.146
9-30	2.54	—	8.9	8.1	0.051	0.057	0.113*	0.153
10-1	2.51	25	8.7	8.5	0.087	0.136	0.148*	0.135
10-2	2.56	25	8.5	8.0	0.079	0.063	0.121	0.115
10-3	2.64	—	8.5	8.0	0.051	0.058	0.159	0.149
10-4	2.78	—	8.3	7.8	0.062	0.081	0.147	0.125

* water in the canal, but did not enter the pond.

which were made when there was no addition of superphosphate. The phosphorus content in the water would reach a maximum immediately after the application of superphosphate and then decrease gradually to the prefertilization level within 5 or 6 days. Phosphorus content in the inflow water depends largely on the amount of agricultural runoff it receives from the surrounding rice fields, and the degree of sewage contamination. Because phosphorus in the pond water has such a varied nature, it is felt that the above classification of pond fertility would be more meaningful if based on the average phosphorus content obtained from a long period of observations in the prefertilization period in each year before the pond is restocked with fish. Since data obtained in such manner would probably represent fairly well the original phosphorus level in the pond water, it can also be used to determine the amount of superphosphate that should be added to a particular year. Besides, the determination of the range of phosphorus content in the inflow water is also important, because it will give us some idea about the amount of allochthonous phosphorus supply of the pond water in nature.

Comparison of the phosphorus contents in the pond water and in the inflow water, together with the observation of the trend of the phosphorus decrease after the addition of superphospate indicates that the loss of the phosphorus added to the pond either by man or by nature is immediate. The loss of phosphorus from the water could be due to the absorption of the increasing population of the algae (as indicated by the increase in the amount of chlorophyll), and the adsorption of bottom mud and soil (Hepher, 1958). As the total alkalinity of this pond is relatively low (44.0 ppm on the average during the time of observation), the fraction of phosphorus lost as precipitate of calcium phosphate was probably small. The fact that almost all of the bottom phosphorus contents are greater than that of the surface water suggests that some of the phosphorus adsorbed by the bottom mud and soil was probably released as the pH of the bottom water increased (Hickling, 1968; Neess, 1946).

7. Nitrogen

Nitrite nitrogen occurred in the waters investigated in the range between 0.005 and 0.288 ppm. The lowest and the highest values were both found in ponds at Chupei. The concentration of nitrate nitrogen varied from 0.002 to 0.345 ppm. The lowest and the highest values were found in Taoyuan ponds 8103 and 5017 respectively. It seems that high concentrations of nitrogen were usually observed in ponds having high $KMnO_4$ consumption and water color.

8. Silicon

The lowest silicon concentration in the waters investigated was found in Chupei pond C-5, having only 0.771 ppm; the highest value, 13.158 ppm was found in the ground water at Panchiao which supplied the eel ponds. Taoyuan ponds ranged from 2.128 to 5.386 ppm in silicon contents. Comparison of inflow water and the pond water in Taoyuan indicates that there was a decrease of silicon content in the inflow water as it entered the pond. The loss of silicon could be due to absorption by the diatoms.

9. Conductivity

Average conductivity of surface water varied from 60.2 $\mu℧$/cm found in Liyutan B to 1157.0 $\mu℧$/cm found in Lukang fish ponds. The exceptionally high conductivity found in the water of Lukang fish ponds was apparently due to the effect of the sea, as these ponds are only a couple of hundred meters away from the ocean. Majority of the waters were in the range of 200 to 300 $\mu℧$/cm. Ground waters had higher value, ranging from 373.8 to 401.0 $\mu℧$/cm, with an average of 388.8 $\mu℧$/cm. Measurement of conductivity can be taken as an approximate estimate of the total nutrient salts present in the water, since there is a positive correlation between these two measurements as shown in figure 7.

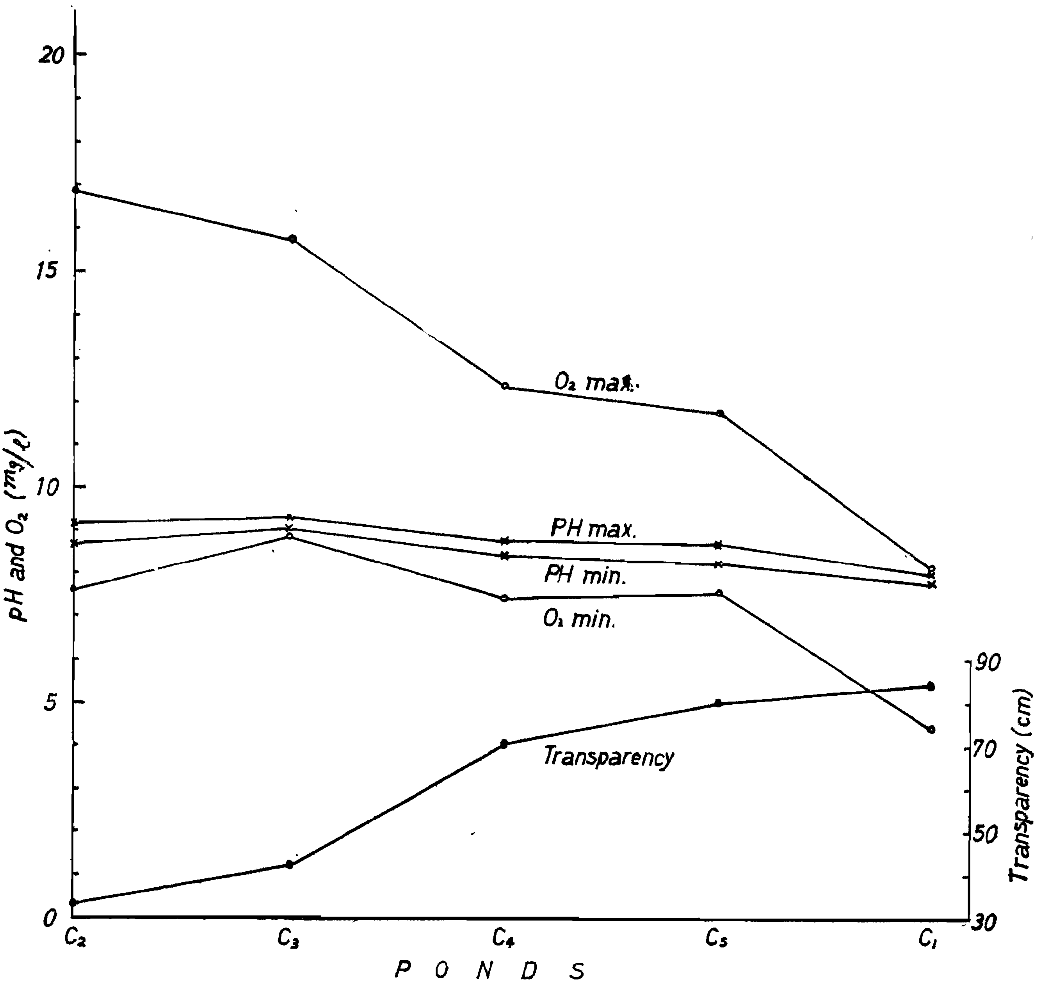

Figure 5. Secchi disc transparency, average daily maximum and minimum O_2 and pH in Chupei fish ponds recorded in November and December (Mean of 4 days measurements). Mean daily temperature range 21.0-25.5°C in November, 15.0-18.5°C in December in all ponds.

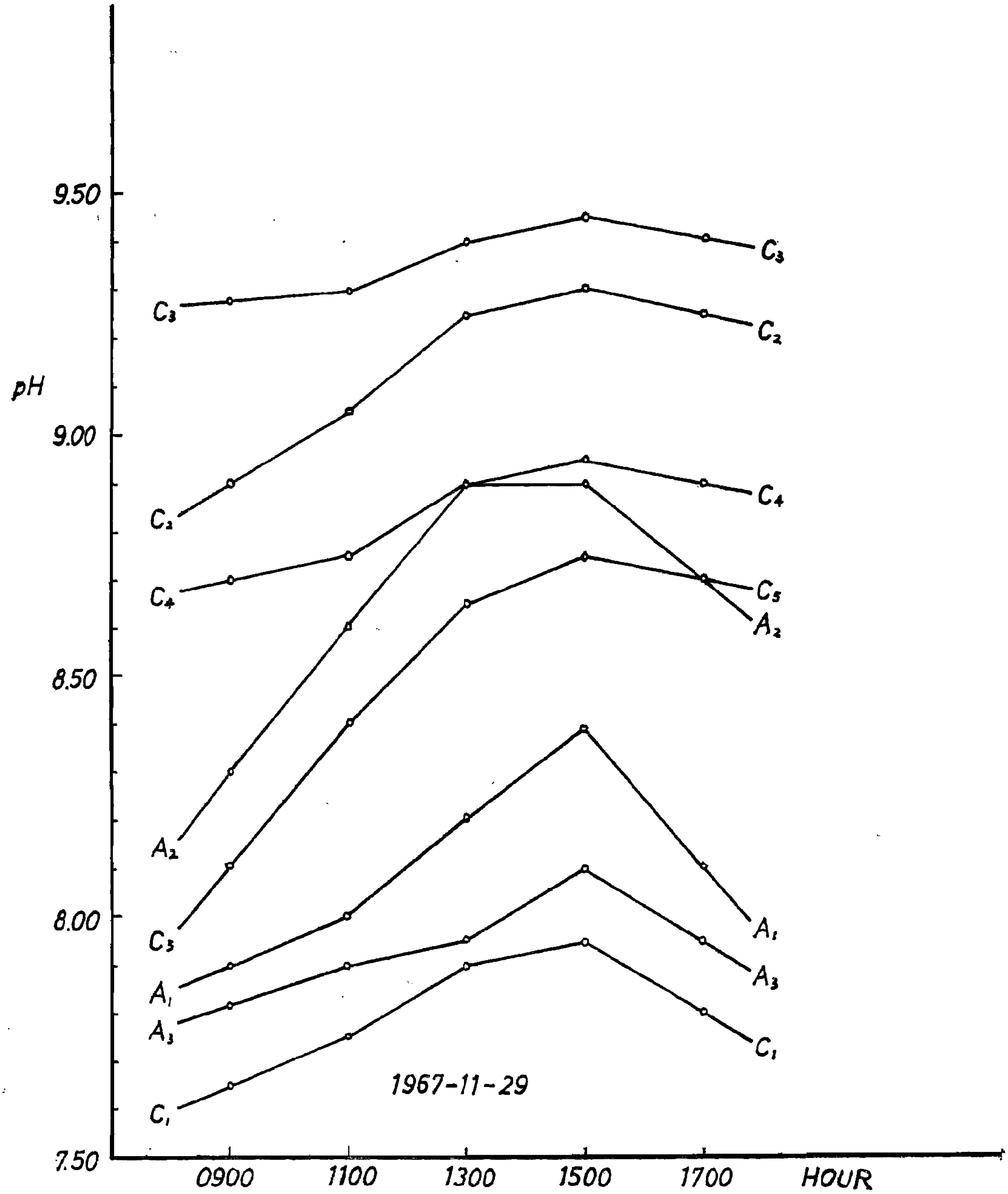

Figure 6. pH variation during daytime hours in Chupei fish ponds.

10. $KMnO_4$ consumption and true water color

$KMnO_4$ consumption of the waters investigated varied from 5.52 ppm to 46.46 ppm. The true water color followed approximately the same course, ranging from 1 to 31 Pt unit (figure 8). Low $KMnO_4$ consumption and water color were usually found in relatively uncontaminated waters such as Sun-Moon Lake and Shihmen Reservoir. On the other hand, high consumption of $KMnO_4$ and high water color were usually found in polluted waters and ponds heavily fertilized with organic matter. Examples of these ponds are Taoyuan pond 5017, ponds at Chupei and Tanwen Reservoir.

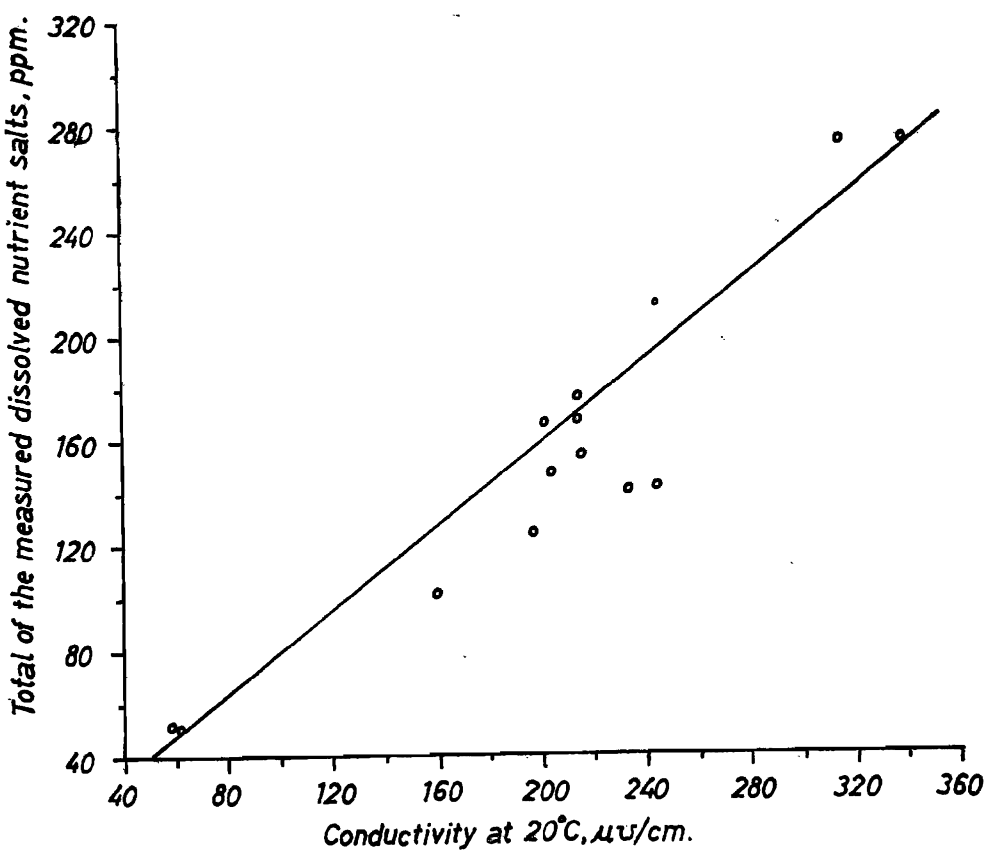

Figure 7. Correlation between total of the measured salts and conductivity.

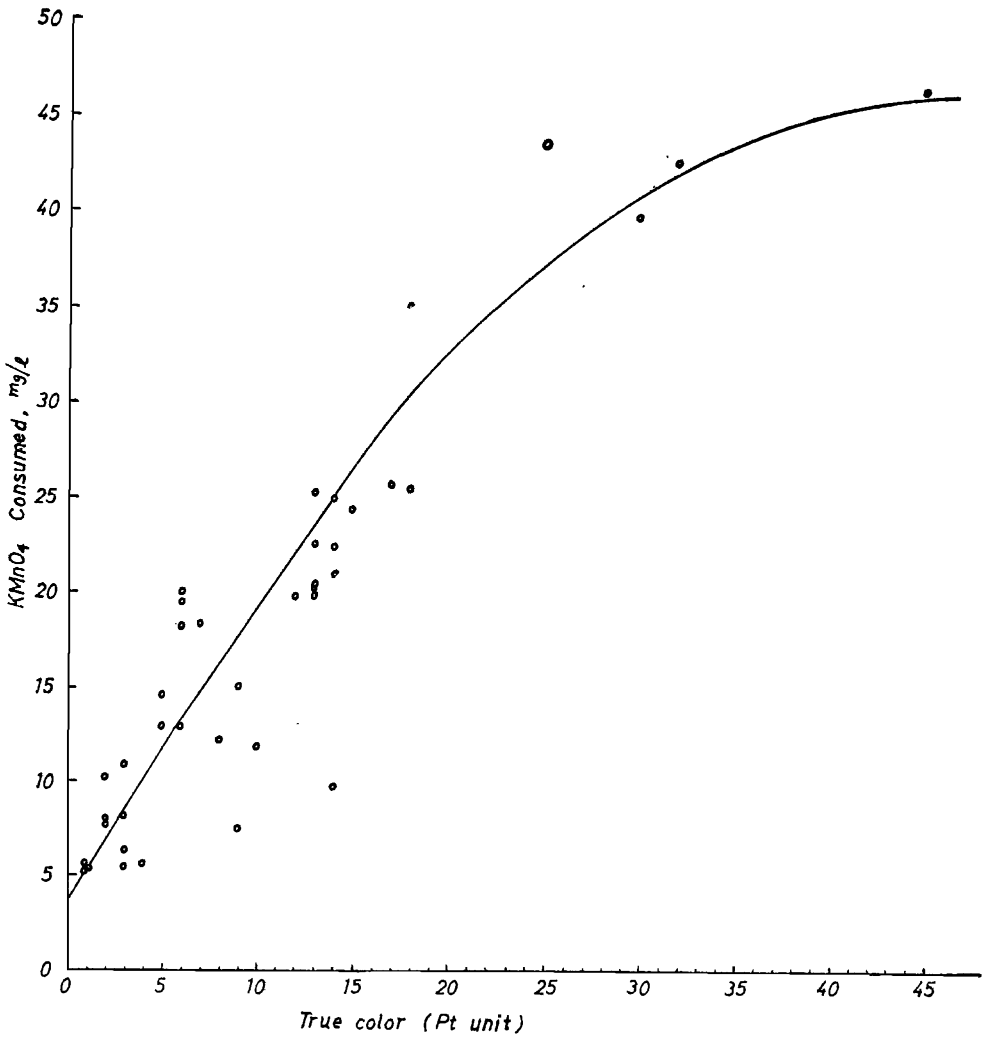

Figure 8. Correlation between true water color in Pt units and organic matter content in mg $KMnO_4$ consumed per liter of water.

II. Biology

Only preliminary notes on the quantitative and some qualitative aspects of the plankton and the primary production of the waters investigated will be presented in the present report. Detailed account of the species composition of the plankton, especially of zooplankton will be given elsewhere.

1. Primary production

Several primary production measurements by the conventional light and dark bottle method were made in selected ponds and reservoirs in the summer of 1967. Results of these measurements are shown in table

9. The depth of 1.5 meters was chosen because this was about the mean depth or approximately the level of compensation of most Taoyuan ponds.

Table 9. Primary production (gross photosynthesis) expressed in the rate of oxygen production of selected reservoirs and ponds measured by light and dark bottle method.

Ponds or reservoirs	Date of measurement	mg $O_2/m^2/hr$ to a depth of 1.5 m	Equivalent mg $C/m^2/hr$	Secchi disc transparency in cm
Taoyuan 1019	1967-6-23	97.5	129.6	30*
8103	6-20	298.1	396.7	50
8004	6-21	500.0	665.0	50
5017	6-20	604.2	805.5	64
5017	9-28	1455.0	1935.1	46
5017	10-2	713.5	949.0	38
Chupei C-3	11-4	1935.0	2573.6	45
Tanwen	6-13	335.0	445.6	—
Tanwen	9-14	492.5	641.5	58
Shihmen	8-2	161.0	214.4	75

* Water turbid due to strong wind and wave actions.

The effect of the application of superphosphate on the primary production of the water is obvious when the data of Taoyuan pond 1019 and Shihmen, the two completely unfertilized waters, are compared with those of others. Tanwen Reservoir had been heavily fertilized with various forms of organic fertilizers until June. In spite of the large amount of organic matter that had been added to the reservoir, the primary production was still quite low as compared with Taoyuan ponds fertilized mainly with superphosphate. Since July superphosphate only instead of organic matter has been added to the water. The improvement of the water condition can be seen from the increase of the rate of oxygen production per unit area. The increase in the primary production could be attributed to the combined effect of the superphosphate and the discontinuation of using organic matter as fertilizers. Too much organic matter in the water probably has a harmful effect on the production of phytoplankton in this reservoir.

In Taoyuan pond 5017, the algal bloom seemed to begin in June, when the water level of this pond reached the highest and there was the least drainage. The algal bloom reached its maximum probably in August and September, then declined gradually as the pond water was heavily drained out for irrigation. Other Taoyuan ponds probably followed this same course, although considerable individual variation in this regard may exist. Ponds 5017 and 8004 could be taken as representative of highly productive ponds in Taoyuan area.

The values of pond 1019 and Chupei C-3 were based on surface determinations only, therefore it could be much higher than the true primary production value of the whole trophogenic column. On the other hand, the value of Shihmen must be lower than the true value if the entire trophogenic zone is to be considered. The water of this reservoir was very clear and the level of compensation must have extended to a considerable depth as can be seen from the vertical distribution of its dissolved oxygen (Fig. 2).

2. Plankton

(1) Shihmen Reservoir

As shown in table 10, the plankton of Shihmen Reservoir was relatively poor both in number of individual and variety. Protozoans seemed to be the most abundant zooplankton group, comprising 50 to 70% of the total. *Ceratium hirundinella* predominated throughout the entire period of investigation. Other protozoan species found were several species of *Difflugia*, two species of *Dinobryon* and one species of *Actinosphaerium*.

Table 10. Abundance (number per 10 liters of water) of major plankton groups found in the surface water of Shihmen Reservoir. Figures in parentheses indicate percentages.

Plankton group	Date of collection			
	67-6-23*	67-8-2	67-9-11	67-11-9
Zooplankton, total	288	236	496	180
Protozoa	206 (71.5)	152 (64.4)	263 (53.0)	110 (61.1)
Rotifera	10 (3.5)	19 (8.1)	72 (14.5)	45 (25.0)
Cladocera	2 (0.7)	— —	12 (2.4)	— —
Copepoda & Nauplius	70 (24.3)	65 (27.5)	149 (30.1)	25 (13.9)
Phytoplankton, total	1450		1240	340
Chlorophyceae	630 (43.4)		570 (46.0)	170 (50.0)
Cyanophyceae	210 (14.5)		190 (15.3)	60 (17.6)
Bacillariophyceae	610 (42.1)		480 (38.7)	110 (32.4)

* sample from 10 meter layer.

Copepods and nauplius were the second abundant zooplankton group in most cases. Nauplius was usually present in greater abundance than its adult form.

Rotifers occurred in greater variety than others. A total of 14 species and varieties were identified. Of these, *Keratella cochlearis irregularis*, *K. valga tropica* and *Collotheca sp* were the most frequently found species. *Pompholyx complanata* and *Polyarthra trigla* occurred less frequently but in large number occasionally. The rest, *K. cochlearis macrocantha*, *K. valga asymmetrica*, *Brachionus diversicornis*, *B. forficula laevis*, *B. urceolaris*, *Asplanchna siboldi*, *Hexarthra mira*, *Testudinella patina* and *Lepadella oblonga* were rare.

Cladoceran was the least abundant and the least frequently found zooplankton group. Only one species, *Bosmina longirostris* was found in samples collected on June 23 and September 11.

Among the algae, Chlorophyceae was dominant, comprising at least 43% of the total phytoplankton population. Bacillariophyceae or diatom next, and Cyanophyceae the least abundant group. There were very few species present in each group. A couple of species of *Pediastrum* in the green algae group; several species of *Anacystis* in the blue-green algae group, and several species belonging to *Synedra* and *Navicula* were found in the diatoms.

(2) Taoyuan ponds

The percentage of protozoans in Taoyuan ponds was usually quite small except on June 21 in pond 8004 and in the unfertilized pond 1019, comprising almost 90% of the entire zooplankton in the former, and more than 50% in the latter ponds (table 11). *Ceratium hirundinella* was dominant in ponds 8103, 8004, and 1019, while in pond 5017 *Difflugia spp.* and *Euglena spp.* were more commonly found. These species also occurred in ponds 8013 and 1019, but were quite rare in pond 8004. Since the occurrence of *Dinobryon* species as dominant plankter in water has been considered characteristic of nutrient-poor water or in otherwise productive waters at seasons of nutrient depletion (Hutchinson, 1957), the presence of this form in 8004 during pre-fertilization period (Liaw and Lin, 1957) but not in post-fertilization period could be taken as a sign of nutrient depletion. Being constructed originally as reservoirs of the irrigation system, most of the Taoyuan ponds such as 8004, 8019 and 1019 among the investigated, which are away from villages and receive little organic matter from surrounding waters are usually poor in nutrient if not fertilized. However, some ponds such as 5017, which receive much runoff water from the surrounding rice fields and village sewage drainage, the addition of superphosphate seems to have less striking effect on production. *Dinobryon* was never found in this pond and *Ceratium hirundinella* was also rare.

Table 11. Abundance (number per 10 liters for zooplankton, per 1 milliliter of water for phytoplankton) of major plankton groups found in surface water of selected Taoyuan ponds. Figures in parentheses indicate percentages.

Plankton group	Pond 8103		Pond 8004			Pond 5017			Pond 1019
	67-6-21	67-9-13	67-6-21*	67-8-4	67-9-13**	67-6-20	67-8-3+	67-9-13	67-6-22
Zooplankton, total	747	287	—	490		330	34	221	581
Protozoa	296	8	—	9		124	10	84	306
	(39.7)	(2.8)	(87.7)	(1.8)		(37.6)	(29.4)	(38.0)	(52.7)
Rotifera	421	80	—	103		195	24	136	252
	(56.4)	(27.9)	(7.5)	(21.0)		(59.2)	(70.6)	(61.5)	(43.3)
Cladocera	—	7	—	28		2	—	1	8
	—	(2.4)	—	(5.7)		(0.6)	—	(0.5)	(1.4)
Copepoda & nauplius	30	192	—	350		9	—	—	15
	(3.9)	(66.9)	—	(71.5)		(2.6)	—	—	(2.6)
Phytoplankton, total	43.7	19.9	34.4	20.9	106.2	107.0	7.1	274.0	9.66
Chlorophyceae	41.5	3.2	19.0	1.5	1.3	13.5	4.6	36.9	4.72
	(95.0)	(16.2)	(55.2)	(7.2)	(1.2)	(12.6)	(64.7)	(13.5)	(48.7)
Cyanophyceae	1.1	13.7	9.8	19.4	98.9	89.6	1.5	227.4	0.06
	(2.5)	(68.9)	(28.5)	(92.8)	(93.2)	(83.7)	(20.6)	(82.9)	(0.6)
Bacillariophyceae	1.1	3.0	5.6	—	6.0	3.9	1.0	9.7	4.88
	(2.5)	(14.9)	(16.3)	—	(5.6)	(3.7)	(14.7)	(3.6)	(50.7)

* Too much sand grains present in the quantitative sample to make accurate enumeration of zooplankton. Percentages of each group, therefore, estimated from qualitative sample.

** Sample lost after the examination of phytoplankton.

\+ Sample collected from 2.5 meter layer.

Rotifers were, in most cases, the most important zooplankton in Taoyuan ponds. A total of 20 species and varieties were found (table 12). In view of the fact that all these ponds were located in the same general area and received the same water supply from Shihmen Reservoir, variations in species composition and abundance between ponds and also within pond at different times were striking. Of these species and varieties found, only three species were common to the four ponds, and, six species common to the three fertilized ponds. Among the four ponds studied, the greatest number of species was found in pond 5017. Although the unfertilized pond 1019 had the least number of species, the total rotifer population was larger than that of most of the other ponds.

Table 12 also indicates that among the rotifers, *Brachionus diversicornis* was probably the most important species in fertilized ponds. It dominated in ponds 8004 and 5017, and also commonly occurred in pond 8103 throughout the entire season. *Trichocerca sp.* subdominated in three ponds. *Brachionus forficula laevis* occurred dominantly in pond 8103. *Keratella cochlearis tecta* and *Pompholyx complanata* also occurred in large number in this pond, but only on June 21. They were entirely absent from other collections. *Brachionus angularis* was dominant in pond 1019 and subdominant in pond 5017.

Table 12. Rotifers found in selected Taoyuan ponds in the summer of 1967. ++++, dominant; +++, subdominant; ++, common; +, present; —, absent.

Species and varieties	Pond 8103	Pond 8004	Pond 5017	Pond 1019
Brachionus angularis	+	—	+++	++++
B. budapestensis	+	—	+	—
B. calyciflorus anuraeiformis	—	—	++	—
B. calyciflorus dorcas	—	+	+	—
B. diversicornis	++	++++	++++	—
B. forficula laevis	++++	+	+	+
B. urceolaris	+	—	—	+
Keratella cochlearis tecta	++++*	+	++	+
K. cochlearis macrocantha	+++	+	+	—
K. valga asymmetrica	—	—	+	++
K. valga monostrosa	—		+	++
K. valga tropica	++	—	—	—
Trichocerca sp.	+++	+++	+++	+
Filinia longiseta	+	+	++	—
Pompholyx complanata	++++*	—	—	—
Hexarthra mira	+	—	—	—
Monostyla sp.	+	+	+	—
Asplanchna siboldi	++	+	++	—
Anuraeopsis fissa	++	+	+	—
Colotheca sp.	—	—	++	—

* Dominant only in one case.

Cladoceran was again the poorest group. One species, *Diaphanosoma paucispinosum* was found in 8103; two species, *Diaphanosoma brachyurum* and *Alona affinis* in 8004 and two species, *Bosmina longirostris* and *Daphnia pulex* in 5017. In 1019 only *Bosmina longirostris* was found.

Adult copepod was relatively uncommon, but could occur in large quantity under certain circumstances. Nauplius was much more common and abundant than its adult form.

Phytoplankton occurred in Taoyuan ponds in great number (table 11) as well as in great diversity except in the unfertilized pond 1019. Altogether 19 genera of Chlorophyceae, 8 genera of Cyanophyceae and 7 genera of Bacillariophyceae were found in the four ponds investigated. It is interesting to note that in unfertilized pond and in pre-fertilization period (in February) and in early part of post-fertilization period (in June) of fertilized ponds, green algae comprised the bulk of phytoplankton population except in pond 5017, Then the dominant forms seemed to shift gradually to the blue-green algae toward the end of the summer. Diatoms never seemed to occur in great abundance and become dominant except in pond 5017 in February and in pond 1019 (table 13).

The difference in species composition of phytoplankton among the four ponds was striking as revealed by the difference in dominant and subdominant genera as shown also in the table. Of these ponds, 5017 was rather unique probably because of its special environment as discussed previously. *Pediastrum* seemed to be the most important in ponds 1019, 8103 and 8004; *Phormidium*, *Oscillatoria*, next, followed by *Anabaena*, *Spirulina*, *Melosira* and *Synedra*. In pond 5017, *Melosira* dominated in pre-fertilization, *Phormidium*, *Scenedesmus* and *Spirulina* in post-fertilization period. *Scenedesmus* seemed to occur most abundantly,

(3) Liyutan

Rotifers, comprising at least 93% of the total zooplankton population except in one case, was the most important zooplankton group in this lake (table 14). A total of 17 species and varieties were identified from the samples collected from both parts of the lake. Of these, *Keratella cochlearis tecta* occurred in great number all the time and was the most important species. Other species found were *Brachionus calyciflorus dorcas*, *B. forficula laevis*, *B. diversicornis*, *Trichocerca sp.*, *Brachionus calyciflorus anuraeiformis*, *B. angularis*, *Asplanchna sp.*, *Keratella valga tropica*, *Colotheca cornata*, *Filinia longiseta*, *K. valga asymmetrica*, *Pompholyx complanata*, *Polyarthra trigla*, *K. valga monostrosa*, *Monostyla bulla* and *Hexarthra mira* in the order of abundance and frequency of occurrence. Although lake A and lake B are two parts of the same water divided merely by an embankment, great difference in the rotifer fauna was observed. Samples collected at different times also showed great variation in species composition.

Table 13. Dominant and subdominant genera in each of the major phytoplankton group in Taoyuan ponds. ** and * indicate dominant and subdominant of all groups respectively.

Pond	Date	Chlorophyceae		Cyanophyceae		Bacillariophyceae	
		Dominant	Subdominant	Dominant	Subdominant	Dominant	Subdominant
8103	6-21	*Pediastrum***	*Gloeocystis**	*Anacystis*	*Spirulina*, *Merismopedia*	*Synedra*	*Melosira*
	9-13	*Pediastrum**	*Scenedesmus*	*Phormidium***	—	*Synedra**	*Navicula*
8004	2-22	*Pediastrum***	—	*Oscillatoria**	—	*Melosira**	*Synedra*
	6-21	*Pediastrum***	*Cosmarium*	*Anabena**	*Phormidium*	*Melosira**	*Synedra*, *Cymbella*
	8-4	*Pediastrum**	—	*Oscillatoria***	*Anacystis**	—	—
	9-13	*Scenedesmus*	—	*Phormidium***	*Spirulina**	*Synedra**	*Navicula*
5017	2-21	*Scenedesmus**	—	*Oscillatoria**	—	*Melosira***	*Synedra*
	6-20	*Scenedesmus*, *Coelastrum**	*Golenkinia*, *Selenastrum*	*Phormidium***	*Anacystis*	*Navicula*	*Synedra*
	8-3	*Scenedesmus***	*Schroederia**	*Spirulina*	*Merismopedia*	*Navicula*	—
	9-13	*Pediastrum*, *Ankistrodesmus**	*Schroederia*, *Tetraedron*, *Cosmarium*, *Staurastrum*	*Spirulina***	*Phormidium*	*Synedra*	*Navicula*
1019	6-22	*Pediastrum***	*Ankistrodesmus*	*Oscillatoria*	*Anabaena*	*Melosira**	*Synedra*, *Navicula*

Table 14. Abundance (number per 10 liters for zooplankton, per 1 milliliter of water for phytoplankton) of major plankton groups found in the surface water of Liyutan. Figures in parentheses indicate percentages.

Plankton group	Lake A		Lake B	
	67-8-29	68-4-2	67-8-29	68-4-2
Zooplankton, total	352	19478	408	210
Protozoa	184 (52.3)	1040 (5.3)	4 (1.0)	6 (2.9)
Rotifera	63 (17.9)	18352 (94.2)	392 (96.1)	202 (96.2)
Cladocera	5 (1.4)	—	—	—
Copepoda & nauplius	100 (28.4)	86 (0.5)	12 (2.9)	2 (0.9)
Phytoplankton, total	6.7	37.3	9.2	25.0
Chlorophyceae	0.2 (2.3)	4.3 (11.6)	0.4 (4.3)	1.0 (4.0)
Cyanophyceae	4.0 (59.8)	20.9 (56.0)	4.2 (45.7)	12.0 (48.0)
Bacillariophyceae	2.5 (37.9)	12.1 (32.4)	4.6 (50.0)	12.0 (48.0)

Of the protozoans, *Ceratium hirundinella* and *Dinobryon sertularia* were found. The first species occurred in both lakes and was found in every collection usually in greater number, while the second species occurred only in lake A on August 29.

Copepods and nauplius were common. They occurred in both lakes in all collections but not as numerous as the protozoans in most of the cases.

Only two species of Cladoceran, *Bosmina longirostris* and *Diaphanosoma brachyurum* were found in the sample collected on August 29 from lake A.

Of the phytoplankton groups, Cyanophyceae and Bacillariophyceae comprised the bulk of the total population in every case in both lakes. *Anacystis*, *Anabaena*, *Lyngbya*, *Oscillatoria* and *Spirulina* were found in the Cyanophyceae, *Navicula*, *Synedra*, *Melosira* and *Suriella* in the Bacillariophyceae, and *Staurastrum*, *Scenedesmus*, *Closterium* and *Pediastrum* in the Chlorophyceae. Of these, *Synedra* and *Lyngbya* were the dominant; *Anabaena*, *Anacystis* and *Staurastrum* were the subdominant genera. The difference in phytoplankton composition and abundance between these two lakes was not as striking as in zooplankton.

(4) Tanwen Reservoir

Differences in the abundance and number of species of plankton in Tanwen Reservoir before and after the addition of superphosphate were quite striking as shown in table 15. Before the addition of superphosphate, only two species of rotifers, *Brachionus diversicornis* and *Asplanchna siboldi*, were found. On the contrary, 7 more species, *Brachionus angularis caudatus*, *B. calyciflorus anuraeiformis*, *Anuraeopsis fissa*, *Trichocerca sp.*, *Filiinia longiseta*, *Keratella cochlearis tecta* and *Lecane sp.* were found after the addition of superphosphate. Of these species, *B. diversicornis* was the dominant, *B. angularis caudatus* and *B. calyciflorus anuraeiformis* the subdominant.

Table 15. Abundance (number per 10 liters for zooplankton, per 1 milliliter of water for phytoplankton) and number of species (or genera in phytoplankton) of major plankton groups found in the surface water of the lower section of Tanwen Reservoir. Figures in parentheses indicate percentages.

Plankton group	Abundance		Number of species	
	67-7-13	67-9-14	67-7-13	67-9-14
Zooplankton, total	21	877	3	12
Protozoa	—	15 (1.7)	—	2
Rotifera	6 (28.6)	846 (96.5)	2	9
Cladocera	1 (4.8)	1 (0.1)	1	1
Copepoda & nauplius	14 (66.6)	15 (1.7)		
Phytoplankton, total	43.8	151.3	4	9
Chlorophyceae	—	2.1 (1.4)	—	2
Cyanophyceae	42.9 (97.9)	69.4 (45.9)	2	4
Bacillariophyceae	0.9 (2.1)	79.8 (52.7)	2	3

Acanthocystis sp. and *Euglena spp.* were found among the protozoans collected on September 14.

Only one cladoceran species was found in each sample. *Bosmina longirostris* in sample collected on September 14, and a damaged specimen of *Diaphanosoma* (probably *D. brachyurum*) in sample collected on July 13.

Copepods and nauplius were the dominant zooplankton group in the sample collected before the addition of superphosphate, although its abundance did not change much in both collections.

Of the phytoplankton, Cyanophyceae was dominant pre-addition of superphosphate, while Bacillariophyceae was dominant after the addition of the fertilizer. Although the abundance of Cyanophyceae increased from 42.9 to 69.4 per ml after the addition of superphosphate, it comprised only 45.9% of the total phytoplankton population. Chlorophyceae was entirely absent from the sample collected pre-addition of superphosphate. Of all phytoplankton groups, *Navicula* was the dominant and *Phormidium* and *Spirulina* the subdominant genera in this lake.

The difference in plankton abundance and species composition was probably associated with the changes of chemical factors after the addition of superphosphate as shown in table 16. Of these chemical factors, the increase of phosphorus and the decrease of organic matter contents seemed to favor particularly the increase of the production of plankton in this water. The decrease of the silicon content after the addition of superphosphate was probably due to the occurrence of large number of diatoms.

Table 16. Chemical conditions of Tanwen Reservoir before (July 13) and after (September 14) the addition of superphosphate.

Chemical condition	1967-7-13	1967-9-14
Conductivity (μ℧/cm, 20°C)	268.6	307.1
Total alkalinity, ppm	97.22	118.93
Total hardness, ppm	105.83	119.51
Phosphorus, ppm	0.064	0.148
Nitrite nitrogen, ppm	0.145	0.016
Silicon, ppm	6.264	1.608
$KMnO_4$ consumption, ppm	42.85	26.58
Color, Pt unit	32	18

Conclusion

Among the chemical conditions investigated, phosphorus and total alkalinity are of special interest. These two factors could be used as indices of pond production or to define pond types. However, much more data are required in order to get more definite conclusions.

In view of the extremely varied nature of the pond conditions, it is felt that frequent and continuous observations and measurements are needed for the description of the whole picture of pond conditions. It is also felt that average phosphorus content in the pond water obtained from frequent measurements in the prefertilization period may be of value in serving as a guide for the determination of the dosage of superphosphate that should be added to a particular pond in a particular year. In addition to this, information about the phosphorus content in the inflow water is also important.

Thermal and oxygen stratification could occur even in the well exposed and agitated Taoyuan ponds in hot summer months, if the ponds are heavily fertilized with organic matter in addition to superphosphate. To prevent the depletion of oxygen from occurring in deeper layer, it is advisable that no or very little night soil or other forms of organic matter be added to ponds during hot summer months.

In Taoyuan fish ponds, the amount of water seems to play an important role in determining the fish yield. Therefore, in the evaluation of the effect of superphosphate on fish production, this space factor must be taken into consideration. Otherwise, the result could be misleading.

The data so far accumulated are still far from complete for us to say anything with certainty about the correlation between chemical factors and the biological aspects. However, the increase of the phosphorus content in the water by the addition of superphosphate undoubtedly has a favorable effect on the production of the water. Algal blooms always occurred in fertilized ponds, but rarely in unfertilized or relatively unpolluted waters, such as Shihmen Reservoir, Sun-Moon Lake and Taoyuan pond 1019. Furthermore, greater number of species of plankton was found in fertilized than in unfertilized waters. In unfertilized waters, the population of zooplankton was usually larger and the dinoflagellate, *Ceratium hirundinella* was rather common.

More green algae and diatoms were found in unfertilized than in fertilized waters. Blue-green algae usually occurred in large amount in fertilized or in polluted waters. In all the waters investigated, *Pediastrum* was the dominant and *Scenedesmus* the subdominant genera in green algae. *Anabaena*, *Anacystis*, *Spirulina*, *Oscillatoria* were common blue-green algae. In diatoms, *Synedra*, *Melosira* and *Navicula* were common.

Rotifers were always the most diverse and usually the most abundant zooplankton group in the waters investigated. Species of *Keratella* and *Brachionus* appeared to be the most important among the rotifers found. The former, including *K. cochlearis* and *K. valga*, occurred most commonly in deeper waters such as Shihmen and Tanwen Reservoirs; the latter, including *B. diversicornis*, *B. regularis*, *B. forficula laevis*, etc. were more common than *Keratella* in shallow ponds and reservoirs.

Aside from small Chupei ponds, Taoyuan pond 5017 appeared to be the most productive one among the waters investigated. The high primary production of this pond could be attributed to the constant supply of phosphorus from the inflow water, rich supply of carbon source from the decomposition of large amount of allochthonous organic matter, the high chloride content and the maintenance of relatively large amount of water even during the period of heavy drainage. Because of these unique pond conditions, this pond obviously deserves further investigation.

Certain amount of errors may be present in the results of the abundance of the plankton primarily due to the method of sampling. Considerable amount of small protozoans and unicellular algae such as *Chlorella* would have certainly passed through the seemingly fine plankton net. And larger and more active zooplankters, such as copepods and cladocerans would have less chance to be caught by the one liter capacity water sampler. The scarcity of cladocerans in the samples could also be due to the fact that they are more littoral in nature. For these reasons, it is felt that in addition to net plankton, total plankton obtained by centrifuge or settling certain amount of water should be used in future studies of these ponds and reservoirs.

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PHOSPHORUS DYNAMICS AND PRIMARY PRODUCTION IN FERTILIZED PONDS*

By Cheng Nan Lin

Taiwan Fisheries Research Institute

Chupei Laboratory

Introduction

Liaw and Lin (1967) found that the phosphorus content of some ponds of the Taoyuan Fish Farm varied from 0.044 to 0.354 mg/l. The high content is evidently due to fertilization with superphosphate and those ponds without fertilization always remain below the 0.044 mg/l level unless they are enriched by the inflows from the watershed areas after a heavy rain. To improve primary production and consequently the fish yield, Lin and Chen (1966) were able to increase fish production, by the application of superphosphate, from 50 to 300 per cent dependent on the condition of the ponds. Encouraged by the striking results of Lin and Chen's experiments, the Taoyuan Fish Farm extended the use of superphosphate from eight experimental ponds of some 30 ha in 1965 to over 700 ha in 1967. The results were that in 1965, without superphosphate application, the fish production in the 600 ha ponds was 535 kg/ha/year, and in 1966 and 1967, with application of superphosphate, 608 and 757 kg/ha/year respectively. The use of phosphate to enhance pond production is well known and the experiments and practice carried out in the Taoyuan Farm have proved beyond doubt the value of superphosphate as fish pond fertilizer. But from the economic point of view there remains a great deal of information which is required to determine the optimum quantity and frequency, for example, of the fertilizer to be applied for the best benefit. The present study is a part of a research project which aims to solve these problems.

Methods

Pond No. 5017 of Taoyuan Fish Farm, with an area of 6.32 ha was selected for the study. Some 15,000 of fresh-water fishes, principally

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silver carp and big-head, were stocked in this pond.

The observations were made from September 23 to October 5, 1967. Being in the dry season, the maximal water depth only reached 1.5 m at the beginning of the observation. Considering the small amount of the water, superphosphate, $Ca(H_2PO_4)_2$ was not applied until September 25, when it rained heavily enough to raise the water level to 2.26 m. On September 26, 50 kg of superphosphate was applied. The fertilizer contains 18% P_2O_5. The time of application was between 7:00 and 8:00 a.m. The fertilizer was applied by dissolving it first completely in water and then dispersed to the surface of pond water. Again on October 1 and 2, superphosphate was applied 25 kg each day.

Both surface and bottom water samples were taken with Kitahara No. B water sampler at 12:00 each day. The pH, phosphate and chlorophyll concentrations were measured as soon as possible. phosphate concentrations of inflow water (if there was any) was also determined. The water level was measured daily so as to determine the effects of water quantity on pH, phosphate and chlorophyll concentrations.

The methods used to determine phosphate, chlorophyll, and pH were as follows.

(1) Phosphate

Determination of phosphate was according to the standard methods of the American Public Health Association (1960), using stanous chloride as reducing agent. Light absorbance after reduction was determined with a Spectronic 20 spectrophotometer (Bauch & Lomb, model 33-29-95-01), using 590 mμ wave length.

(2) Chlorophyll

By using a vaccum pump, 200 cc of water sample was filtered through the Toyo No. 5C quantitative filter paper. Then the filter paper was immersed in 20 cc 80% acetone solution and put in a dark place for 24 hours. The light absorbance of chlorophyll extract was determined with the Spectronic 20, using 3 different wave lengths, namely 645, 652, and 663 mμ for each sample. The chlorophyll concentration was calculated by the following formula (Mackinney, 1941).

$$C_{a+b}=D_{645}\times 20.2+D_{663}\times 8.02$$

while, C_{a+b}=concentration of chlorophyll a+b, mg/l

D_{645}=light absorbance when using 645 mμ wave length

D_{663}=light absorbance when using 663 mμ wave length

(3) pH

pH value was measured with a portable glass electrode pH meter (Photovolt, model 126).

In order to observe the changes of phosphate concentrations after application of superphosphate in a smaller body of water and to compare with the results obtained from Pond No. 5017, a fertilization experiment was carried out at the Chupei Fish Culture Station, using Pond No. C3.

Pond No. C3, with an area of 0.1 ha and 80 cm in mean water depth, has been used to stock some 260 silver carp, big-head and their hybrids. 1.5 kg of N-P fertilizer (ammonium sulfate 35.5%, superphosphate 64.5%) has been applied in 5-6 days interval since October 11, 1967. Fertilizer was applied at about 8:00 a.m. and water sampling was made at 3:00 p.m.

The methods used to determine pH, phosphate and chlorophyll concentrations were the same as previously described. However, daily chlorophyll concentrations had not been measured.

Results

A. Taoyuan fish pond No. 5017

The changes of pH, phosphorus, and chlorophyll concentrations of pond No. 5017 are listed in Table 1, and shown in figure 1.

(1) Changes of phosphorus concentrations

From Table 1, it is found that phosphorus concentrations increased abruptly just after application of superphosphate. For example, after 50 kg of superphosphate was applied on September 27, the phosphorus concentrations increased from 0.060 to 0.176 mg/l. Similarly, after 25 kg of superphosphate was applied on October 1, the phosphorus concentration increased from 0.051 to 0.087 mg/l.

But the high phosphorus concentrations due to fertilization could not remain unchanged; it decreased steadily until a minimum level of concentration before fertilization was reached. For example, after fertilization on September 26, the phosphorus concentration increased to 0.176 mg/l, and then declined gradually to 0.051 mg/l on September 30, 5 days after fertilization. 25 kg of superphosphate was applied on October 1 and phosphorus concentration increased to 0.087 mg/l. Three days later, the phosphorus dropped to a concentration of 0.051 mg/l.

Phosphorus concentrations of the bottom layer were often higher than that of surface layer during the entire observation period except on September 24 and October 2.

(2) Changes of chlorophyll concentrations

Chlorophyll concentrations increased after application of superphosphate. After fertilization on September 26, the chlorophyll increased rapidly and reached the highest value, 0.153 mg/l on September 30. On October 3, the chlorophyll concentration increased from 0.115 to 0.149 mg/l obviously due to the effect of fertilization on October 1 and 2.

The rapid drop of chlorophyll concentration on September 25 was probably due to the diluting effect caused by the heavy rain occurring on the night of September 24. After the rain the water level increased from 1.5 to 2.26 m.

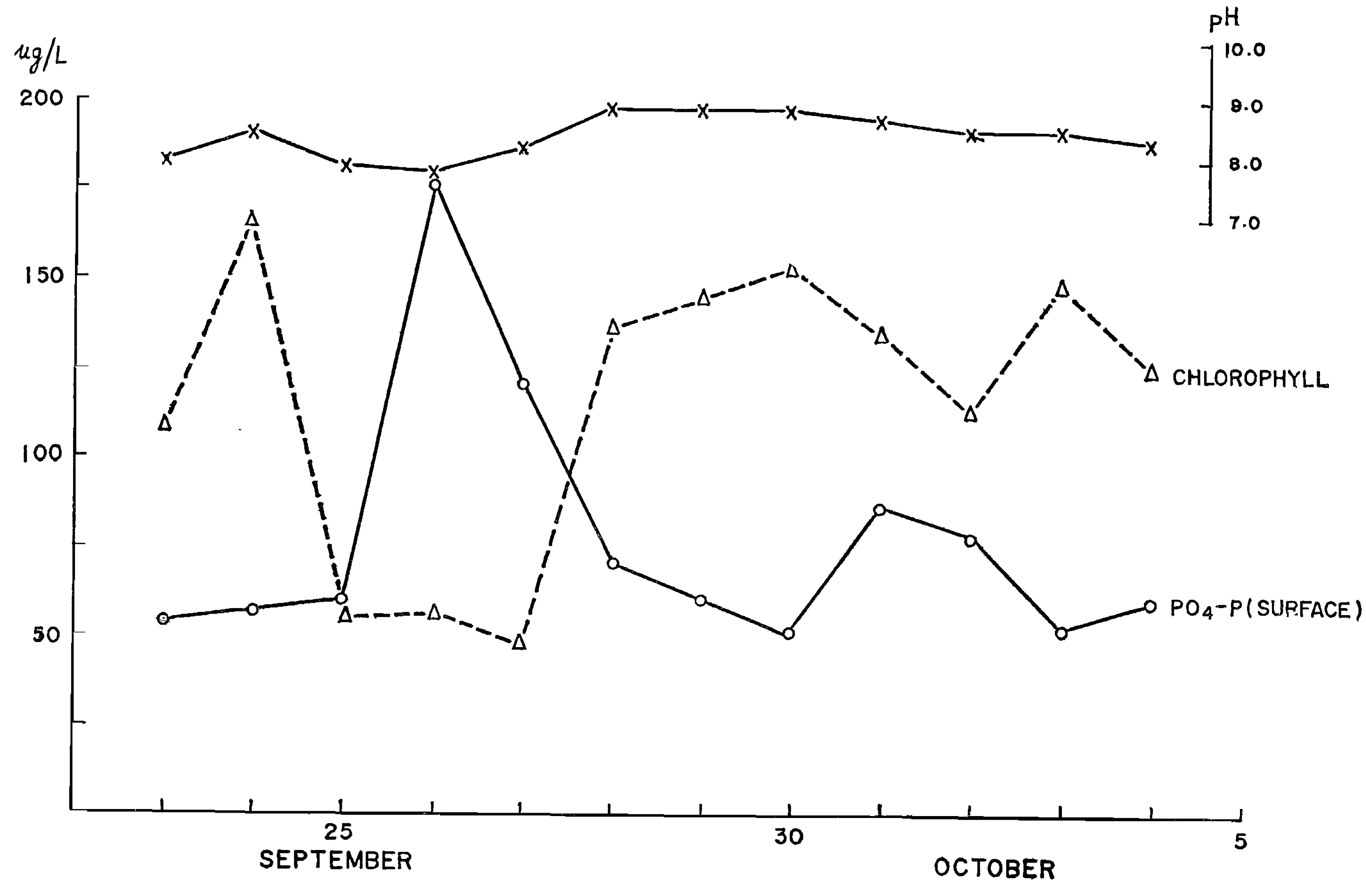

Figure 1. Changes of PO_4-P and chlorophyll concentrations in Taoyuan fish pond No. 5017.

Table 1. Changes of pH, phosphorus and chlorophyll concentrations in Taoyuan fish pond No. 5017.

Date	9-23	9-24	9-25	9-26	9-27	9-28
Water level, m	1.50	1.50	2.26	2.00	2.67	2.70
Superphosphate applied, kg				50		
pH (at 1200 hr)						
Surface	8.0	8.5	7.9	7.7	8.2	8.9
Bottom	7.9	8.3	7.7	7.8	—	8.3
PO_4-P, mg/l						
Surface	0.053	0.058	0.060	0.176	0.121	0.071
Bottom	0.055	0.056	0.064	0.184	0.132	0.077
Inflow	—	—	0.063	0.085	0.155	0.223
Chlorophyll a+b, mg/l	0.111	0.168	0.056	0.057	0.049	0.137

Date	9-29	9-30	10-1	10-2	10-3	10-4
Water level, m	2.68	2.54	2.51	2.56	2.64	2.78
Superphosphate applied, kg			25	25		
pH (at 1200 hr)						
Surface	8.9	8.9	8.7	8.5	8.5	8.3
Bottom	8.3	8.1	8.5	8.0	8.0	7.8
PO_4-P, mg/l						
Surface	0.060	0.051	0.087	0.079	0.051	0.062
Bottom	0.064	0.057	0.136	0.063	0.058	0.081
Inflow	0.178	0.113	0.148	0.121	0.159	0.147
Chlorophyll a+b, mg/l	0.146	0.153	0.135	0.115	0.149	0.125

(3) Changes of pH value

The pH value was always above 7.5 during the observation period. After fertilization, the phytoplankton population increased and so did pH value. The pH reached its maximal value of 8.9 on September 28.

The pH of bottom layer was often lower than that of surface layer. This is probably due to the combined effect of less phytoplankton concentration and richer decaying organic substance present in the bottom layer.

B. Chupei pond No. C3

The results of the observations are listed in Table 2, and shown in figure 2.

Table 2. Changes of pH, and phosphorus concentrations in Chupei pond No. C3 after application of superphosphate.

Date	10–17	10–18	10–19	10–20	10–21	10–22	10–23
pH	8.6	8.6	8.8	8.9	9.2	9.8	10.1
PO_4-P	0.062	0.166	0.150	0.107	0.079	0.069	0.073
Date	10–26	10–27	10–28	10–29	10–30	10–31	11–1
pH	9.9	9.6	9.9	9.7	10.1	10.0	9.6
PO_4-P	0.162	0.347	0.306	0.262	0.226	0.214	0.195
Date	11–1	11–2	11–3	11–4	11–5	11–6	11–7
pH	9.6	9.7	9.7	9.9	9.6	—	—
PO_4-P	0.195	0.225	0.202	0.200	0.200	0.189	0.195

(1) Changes of phosphorus concentrations

The changes of phosphorus concentrations after application of superphosphate was similar to that observed at pond No. 5017. For example, after fertilization on October 18, the phosphorus concentration increased from 0.062 to 0.166 mg/l and then decreased to 0.069 mg/l 5 days later (October 22).

The phosphorus content on October 26 was 0.162 mg/l. This high concentration was due to the addition of high phosphorus water (0.085 mg/l) from rice field on the night of October 25. After fertilization on October 27, the phosphorus content increased to 0.34 mg/l and then declined to 0.195 mg/l on November 1.

On November 2, more superphosphate was applied and the phosphorus concentration increased to 0.225 mg/l. But the decline of phosphate slowed down after this fertilization. After 5 days, the phosphorus only decreased to 0.196 mg/l. The possible reason for this slow decline will be explained later.

(2) Changes of pH

The pH value of this pond was often above 8.5 due to the high phytoplankton concentration.

After fertilization on October 18, the pH slightly increased. On October 23, the pH reached its maximal value, 10.1 and then remained between 9.6 to 10.0 though fertilizations were made again on October 29 and November 2.

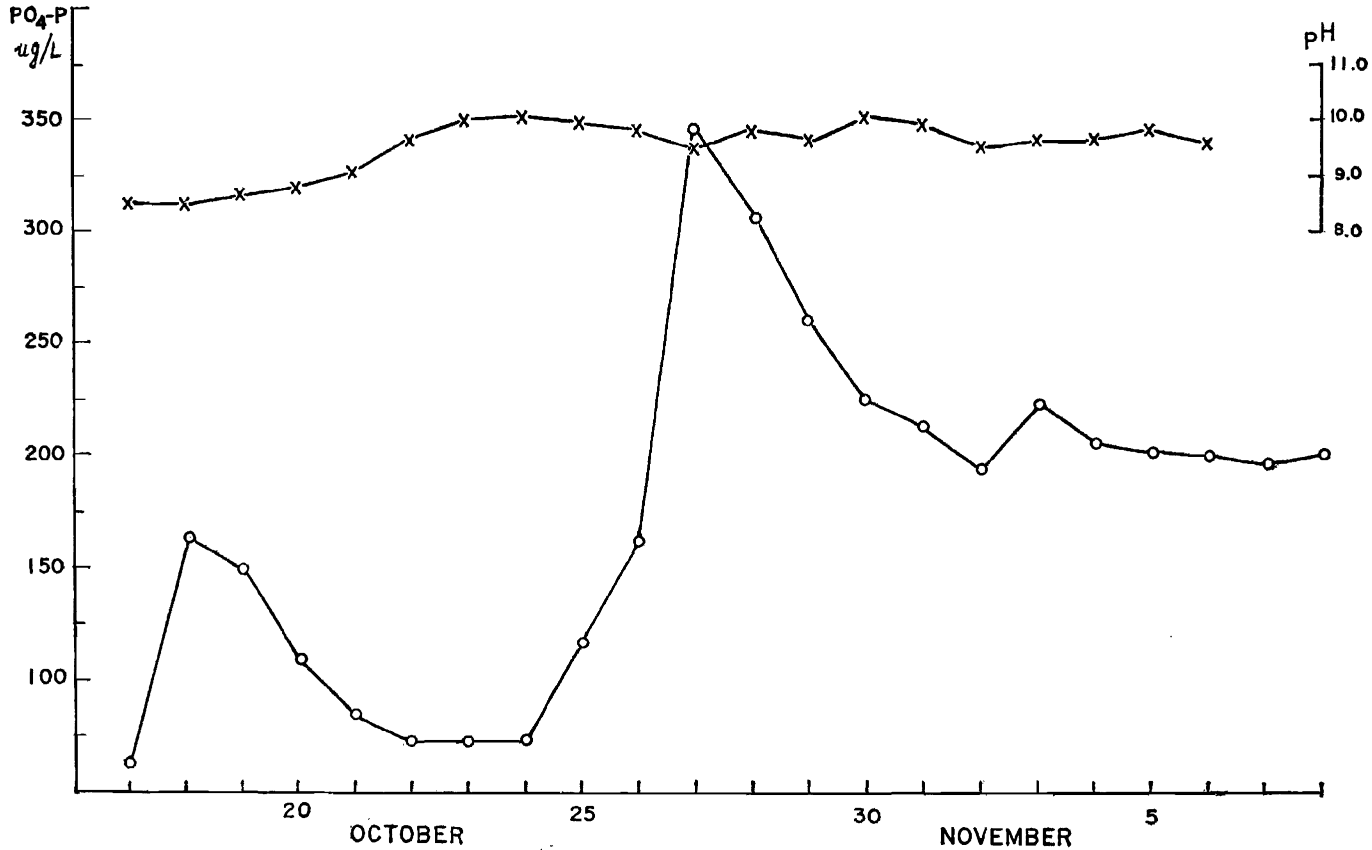

Figure 2. Changes of pH and PO_4-P concentrations in Chupei experimental pond No. C-3 after application of superphosphate.

Discussion

From the experiments described above, we find out that after application of phosphorus fertilizer, the soluble phosphate content tends to decline to the lowest level before fertilization. There are two reasons which may cause the decline of soluble phosphate. One is the uptake of phosphorus by phytoplankton, and the other is the chemical reactions in water and bottom mud which remove some parts of the added phosphate from the water.

1. Uptake of phosphorus by phytoplankton

Phosphorus is the major nutrient element required for normal growth of algae. The planktonic algae in fish ponds absorbed phosphate during photosynthesis (Kuhl, 1966), thereby some parts of the added phosphate was quickly removed.

It is obvious that there exists a negative relationship between phosphorus and chlorophyll concentrations as Table 1 and Figure 1 show. After the application of superphosphate on September 26, the chlorophyll contents increased gradually while phosphate concentrations decreased. When the phosphate concentration declined to the low concentration before fertilization (0.06 mg/l), the chlorophyll content reached its maximal value (0.153 mg/l). Similarly, after fertilization on October 1, the chlorophyll content increased from 0.115 to 0.149 mg/l while the phosphorus concentrations decreased from 0.087 to 0.051 mg/l. This indicates that after fertilization, the phytoplankton population, being supplied with enough phosphate, increased gradually, therefore the chlorophyll increase followed while phosphate was absorbed and declined.

Furthermore, the pH of fish pond is influenced mainly by the CO_2 dissolved in water (Hutchinson, 1957). The phytoplankton absorbs free CO_2 and HCO_3^- during photosynthesis. When phytoplankton population increases, more free CO_2 is absorbed resulting in higher pH. Hence a higher chlorophyll concentration is always followed by a higher pH value.

2. Chemical reactions in water and bottom mud

Generally speaking, the physico-chemical system between pond water and bottom mud is in an equilibrium state. Nutrient elements added externally to fish pond in the form of fertilizers upset the equilibrium. But as the physical and chemical reactions in water and bottom mud can remove some quantities of the added material, the equilibrium can be re-established (Hepher, 1966). Thus parts of phosphate added to fish ponds are lost in two ways, (1) the adsorption of bottom mud and (2) formation of insoluble $Ca_3(PO_4)_2$ with $CaCO_3$.

2.1 Adsorption of bottom mud

Oxidized ferric compound such as ferric hydroxide, ferric phosphate, and ferric-organo-complex compounds adsorb some quantities of phosphate.

But phosphate adsorption to these compounds can take place only when pH is below 8 (Hepher, 1958).

In fish ponds the pH of bottom layer (often below 8) is generally lower than that of upper layer because of smaller algal population and higher CO_2 concentration due to the decomposition of organic subtances (Hutchinson, 1957). Similar conditions are observed in pond No. 5017. Some of the added phosphate when diffusing into bottom layer, might be adsorbed by the ferric compound in bottom mud. But as to Chupei pond No. C3, the pH of bottom layer was often higher than 8 because of the shallowness of the water and high phytoplankton concentration. Therefore, phosphate adsorbed by the bottom mud must be comparatively small.

2.2 Precipitation by calcium carbonate

Hepher (1958) proved that in Israel a lot of added phosphate was precipitated as $Ca_3(PO_4)_2$ by $CaCO_3$. He also pointed out that when the photosynthetic activity of phytoplankton increased and raised the pH, the precipitation of phosphate by $CaCO_3$ also increased especially in pond water with high calcium content.

The total alkalinity of pond No. C3 is 166 mg/l $CaCO_3$ and the pH of surface layer is often above 8.5. With such high pH and calcium content, precipitation of phosphate must be large. In pond No. 5017 with a total alkalinity of 44 mg/l $CaCO_3$ and lower pH value, the precipitation of phosphate by $CaCO_3$ must be small.

After continuous fertilization with superphosphate, the adsorption of phosphate and the precipitation of phosphate by $CaCO_3$ have been saturated, thus leaving phytoplankton uptake the only way to remove surface phosphate from water. As a result soluble phosphate can stay in water for a longer period. Perhaps, this is the reason why phosphate concentration of Chupei pond No. C3 declined slowly after application of superphosphate on November 1 (fig. 2). It is possible also that low temperature in November (19.0°C) may slow down the phosphorus uptake by phytoplankton.

Summary

After application of superphosphate in fish ponds, the soluble phosphorus increased abruptly and then decreased steadily to the lowest level before fertilization if no more fertilizer is added.

The decreasing rate of phosphate content can be slowed down by continuous application of fertilizer and other factors.

Both pH value and chlorophyll concentration increase after application of superphosphate.

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斑節蝦的人工繁殖及其養殖試驗

臺灣省水產試驗所臺南分所

黃丁郎、丁雲源、謝錫欽

Artificial Propagation and Culture Experiments of Penaeus japonicus

By

T. L. Huang, Y. Y. Ting and S. C. Hsieh

前　　言

斑節蝦〔*Penaeus japonicus* BATE〕爲本省沿海蝦船的主要漁獲物之一，但尙未被列於養殖對象之中。在日本則放養人工繁殖之蝦苗作大量養殖[3,4]，已成爲企業化之經營。最近因蝦的國際市場價格日漸升高，使斑節蝦的養殖成爲很有前途的事業。查本省氣候適於斑節蝦的成長，如能施行集約養蝦外銷，可增加外滙，充裕國庫財源，省水產試驗所臺南分所，過去曾作斑節蝦的人工繁殖試驗，但僅止於後期幼蟲(Post larva)[6]，這次筆者等於57年2月至9月間，作此蝦之人工繁殖，育成大量之蝦苗，並移至曾文海埔地及民間魚塭養殖獲得若干成果，故玆將其方法，經過及結果報告如下，作爲今後斑節蝦養殖之參考。

蝦苗繁殖

1. 材料及方法

①實施期間：1968年2月27日至1968年5月31日。

②種蝦：

從臺南市安平港陳德輝先生的斑節活蝦蓄養槽中，挑選卵巢成熟者，以虱目魚苗籮盛海水，一籮收容9～10尾而以機車運回臺南分所，作爲產卵種蝦之用。該槽的活蝦係委托蝦船，以活艙或水桶帶回以便銷售日本。

③產卵、孵化及幼生飼育方法：

企業化的蝦苗繁殖，已證實使用大型的200噸水泥池較小型者爲佳[3]，但此次筆者等爲配合東港蝦苗繁殖中心在尙未建立前，作預備試驗爲目的，在氣温較低之4月間，利用半噸及一噸容量的圓形硬質塑膠製水槽五個，置於恒温玻璃室內進行〔圖1〕。

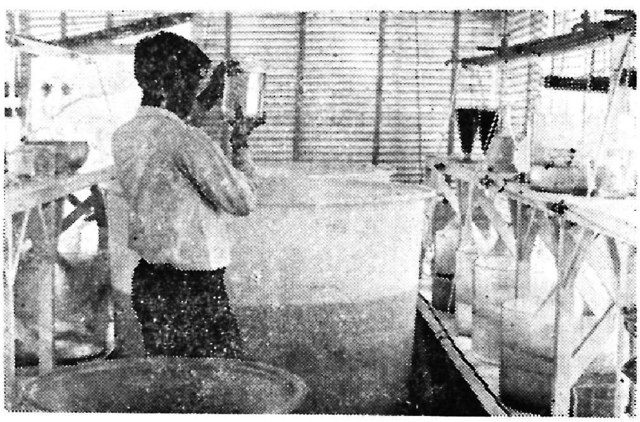

圖 1　恒温玻璃室內

爲恐該槽有毒物質溶出，曾先試行豐年蝦的孵化飼育，確認無害後才使用。使用之海水是取自臺南分所虱目魚塭外水路於漲潮時用二分之一馬力的抽水機直接抽入約半槽水，而以尼龍布在注水口過濾動物性浮游生物，其鹽分濃度爲 31 至 33‰，水温保持 22 至 28° C 之間，一噸槽收容種蝦 4 至 5 尾，半噸槽 3 尾，並以空氣壓縮機在水槽中不斷打氣，由產卵至後期幼蟲（Post-larva）一直在此槽止水狀態下飼育。而後期幼蟲期才移入 3.7×1.9×0.5 公尺的水泥池（圖 2），池底舖砂厚約 3 公分，注入魚塭外水路海水約40公分．在止水狀態下飼育2至3週後，體長約 3 公分，體重約0.15公克時作爲蝦苗放養於魚塭。四月十日以後，因水温上昇曾在野外水泥池（圖 2 中的蝦苗飼育池加高40公分而成）進行繁殖。產卵數與各期幼生的生存率計算是用燒杯搯取一定量的池水計數其中之卵或各期幼蟲，作數次取其平均値換算其總數。

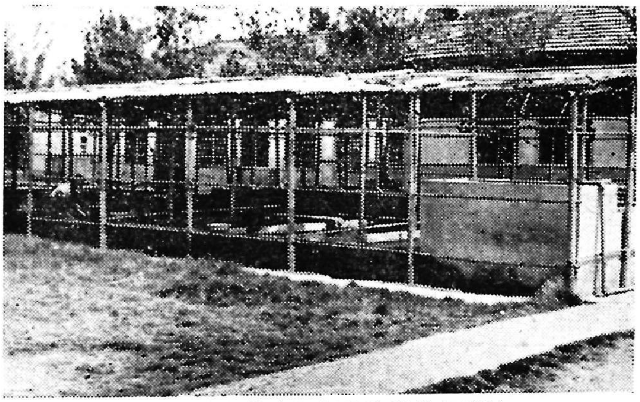
圖2.　後期幼蟲期以後的蝦苗飼育池

④餌料：

班節蝦苗之餌料，在 Zoea 期一般是投飼人工培養的矽藻 *Skeletonema* SP，Mysis 期以後則投飼剛孵化的 Brine shrimp，及至 Post-larva 即由浮游生活轉變爲底棲生活時，投飼切碎的貝肉[3,5,8]。筆者等爲明瞭虱目魚塭的浮游生物，對蝦苗繁殖上有何利用價値，除按照上述方法飼育外，曾採集虱目魚養成池中之於春季注水後大量繁生的矽藻（以*Nitzschia closterium*爲主，圖 3），作爲 Zoea 的餌料，Mysis 以後投以輪蟲及劍水蚤，Post-larva 1 週後移入水池者則僅靠池中的藻類及底棲生物，並以浮游生物網由魚塭內水路，每兩天採集活的劍水蚤投入，或以凍結的劍水蚤解凍後投飼，而不另外投飼任何貝、蝦肉爲餌料。*Skeletonema costatum* 由高雄港採集，純種分離培養用 A S P 6 的人工海水，大量培養則取魚塭的澄清海水，調節其鹽分至30‰左右，經加熱殺菌放冷後，利用直徑45公分、深40公分的玻璃水槽，於其中接種，並加數滴 Miquell-Allen-Nelson 液，及 Pl. solution，夜間以40W的螢光燈，不斷打氣進行培養。*Nitzschia* 在春初虱目魚塭，每多異常繁殖，在日間水温高時，可能因同化作用，藻體表面形成許多的小氣泡而浮於水面，被南風吹集於池邊，此時可用燒杯連表水一起採集，然後以××7規格（網目徑 195μ）的浮游生物網布過濾雜物後投給。動物性浮游生物是用××17規格（網目徑 64μ）的浮游生物網採集後，以××7 規


圖3.　虱目魚塭大量繁生的 Nitzschia closterium

格的網布濾出較小型的輪蟲，作爲 Mysis 的初期餌料，剩下較大型的 Copepoda 則作爲 Post-larva 之飼料。另外大量採集輪蟲，劍水蚤等盛入鉛製飯盒中，置於 —15°C 下急速凍結以便來日投飼。

2. 結　果

①產卵與孵化：

安平一帶在 2 月中旬以前獲得成熟種蝦之機會極少，2 月下旬增多，3 至 5 月最多，6 月以後又逐漸減少，此季排卵後的種蝦佔大多數，而且水溫上昇，活蝦的船上蓄養困難，無法獲得種蝦，故停止繁殖試驗。此次供試產卵之種蝦如表 1 所示；2 月下旬與 3 月上旬的產卵率較低，3 月中至五月較高，此可能因初期水溫較低以及成熟度較差外，筆者等對選擇種蝦卵巢成熟程度或有不妥所致。在產卵的盛期如果能嚴密地選擇，其產卵率可提高到70%以上。

表 1　供試種蝦的產卵情形

次　數	月　日	採集種蝦尾數	產卵尾數	種蝦之產卵率	備　　考
No 1	2. 27	10	2	20%	在室內水槽產卵
2	3. 1	9	2	22.2	〃
3	3. 7	6	2	33.3	〃
4	3. 14	9	6	66.7	〃
5	4. 10	28	4	14.3	野外池放17尾產2尾，室內水槽放11尾產2尾
6	4. 15	26	17	65.4	野外池放18尾產10尾，室內水槽放8尾產7尾
7	5. 1	18	12	66.7	在室內水槽產卵

此次試驗種蝦是於下午 3 至 5 時放入產卵槽，並將窗簾放下使室內暗些，夜間熄燈，如此大部分將於翌晨產卵，沒有延到第三天產卵之例，但在21個產卵例中，有 5 次是在當天傍晚就發現產卵者，產卵後的水槽，水面會發生許多泡沫及污物，附着於周圍，一見即知已產卵，而且池水腥味濃厚，必須除去此泡沫及污物，以免染污水質，此次雖無正確測定孵化率，但正常卵一般孵化率都很高，依多次的經驗半噸水槽，可得 120,000～380,000 的 Nauplius。

② Zoea 的飼育：

因利用魚塭外水路的海水，富於營養塩，且含有許多浮游生物的關係，產卵後池水多逐漸變爲黃綠或暗褐色，一直至Zoea期不投任何餌料，可發現其拖着糞便，證明 Zoea 已攝食此自然繁殖的浮游生物，筆者等曾作投飼 Skeletonema 與不投飼比較結果，不投飼者亦可變態成Mysis，但其生存率較投 Skeletonema 者爲少。投魚塭採集的 Nitzschia 者雖能被攝食，但因Nitzschia closterium 的長刺易纏着 Zoea 的付屬肢，阻礙其游泳故不甚理想，投以其他不帶長刺的矽藻，較能經正常的變態而成長。斑節蝦的繁殖期正適春初虱目魚塭注水後矽藻異常繁殖季節，故這些矽藻大爲可利用。

③ Mysis。Post-larva 的飼育：

Mysis 以後的餌料， 主投以孵化後的豐年蝦幼蟲， 此外爲明瞭虱目魚塭內水路饒產的輪蟲(80～250μ)、劍水蚤(250～450μ)能否代替豐年蝦起見，曾以××17 規格的浮游生物網採集後，再以×× 7 規格的網布濾出輪蟲，作爲 Mysis 初期的餌料， Mysis 後期以後則不經篩別直接投

入，試驗結果，雖不如投豐年蝦的生存率高，但半噸水槽可得 P7*者 5,000尾以上（投豐年蝦者為12,000多尾），在野外的 6 噸容量水泥池，曾得19,200尾（表 2）。

表 2　不同餌料別的飼育例

半噸塑膠製水槽（在恒溫室）					3.7×1.9×0.9公尺水泥池（在野外）				
月　日	水　溫	期別	飼育經過		月　日	水　溫	期別	飼育經過	
	AM　PM					AM			
3. 14	26.0～27.0		下午放入3尾		4. 10	24.5		下午放入17尾	
15	25.0～27.5		產卵2尾(未完全排完)		11	25.0		產卵2尾	
16	25.0～26.0	N			12	24.2	N	估計28萬尾	
17	25.0～27.0	N	估計有12萬尾		13	23.0	N		
18	25.5～26.5	Z_1	投入 Skeletonema		14		Z_1	投魚塭的矽藻	
19	25.0～27.0	Z_2	〃		15	23.2	Z_1	〃	
20	25.0～27.0	Z_2	〃		16		Z_2	〃	
21	26.5～27.0	Z_3	估計有4萬尾		17		Z_2	〃	
22	25.0～25.5	Z_3	投入 Artemia		18		Z_3	〃	
23		M	〃		19		Z_3	投輪蟲	
24	25.0	M	〃		20		Z_3.M	〃	
25		M	〃		21		M	〃	
26	21.5	M	〃		22	20.6	M	〃	
27	23.0	M	〃		23		M	投輪蟲及劍水蚤	
28		P_1	投貝肉		24		M	〃	
4. 3	24.2	P_6	得12.500尾放砂池		25		P_2	〃	
					26		P_3	得19.200尾放砂池	

④ P7（The 7th Post-larva）以後的飼育：

一般 Post-larva 以後仍在原池以碎貝肉飼育至 P 20 後，直接放入養成池，或再移入砂池飼育至體長約 3 公分，體重約 0.25公克後始作為蝦苗。筆者等用 3.7×1.9×0.5公尺的水泥池，舖砂厚約 3 公分，注入魚塭外水路的海水（鹽分31‰），使砂面發生底藻，水質澄清後，放入 P 7 者約15,000尾，並採集活的劍水蚤等投入後，隔 3 ～ 5 天注入一部份新水，而在不打氣，不另外投飼的狀態下，飼育 3 ～ 4 週結果生存率為45%，其體長為 2.9公分，體重為 0.15克，而較投貝肉飼育者為瘦。

⑤ *Skeletonema Costatum* 的培養：

原種由高雄港內，於漲潮時用××17規格的浮游生物網採集後帶回臺南分所分離培養，該港除盛夏（7 、8 月）採集量較少外，斑節蝦繁殖期間的 2 至 6 月及 9 至12月，其天然的發生量相當多，有時海水呈微褐色，在採得的浮游生物中 Skeletonema 幾乎佔80%以上，而由15～52個羣體連成長條狀，（圖 4）最長者達 1,300μ ，分離是在顯微鏡下，用毛細吸管挑選細胞較大而且長直者，以 200cc 的三角燒杯培養（用 ASP6 培養液），約經三次分離後可得較純的原種，

*係指變成後期幼蟲後第七天者

因爲臺南分所近旁無法得到淸淨的海水，因此從事大量培養時是用澄淸了的虱目魚塭水，加上Miquell-Allen-Nelson培養液，以及P1. solution幾滴培養結果，繁殖密度高達 54×10⁴cell/ml，但利用未曾加熱殺菌的魚塭水時，其繁殖密度僅達24×10⁴cell/ml。所用的培養槽是玻璃製的，其直徑爲40公分，深36公分，以20公升培養液中接入 40×10⁴ cell/ml 濃度的原液 1,000ml，水塭 25～28.5°C 時5至6天達最高密度，以後則革體彎曲、沉澱而死亡（圖5、6）。

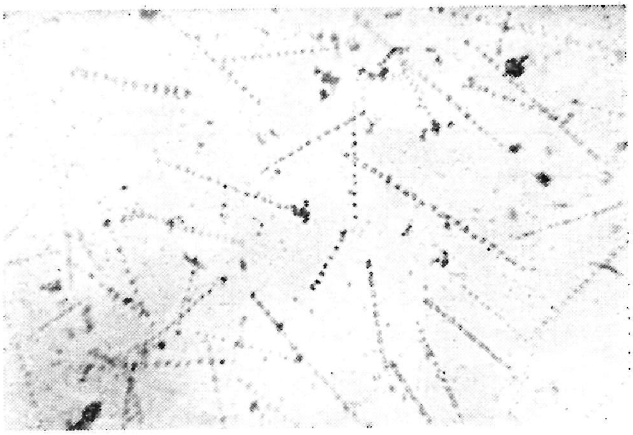

圖4　高雄港採集的 *Skeletonema costatum*

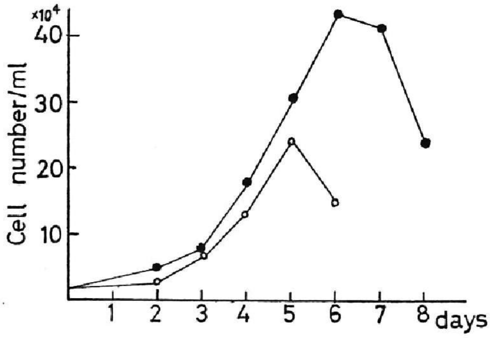

圖6　Miquell-Allen-Nelson+P1. solution 對 Skeletonema costatum 大量培養時的繁殖情形
•—•—• 培養用水曾加熱殺菌
○—○—○ 不經加熱

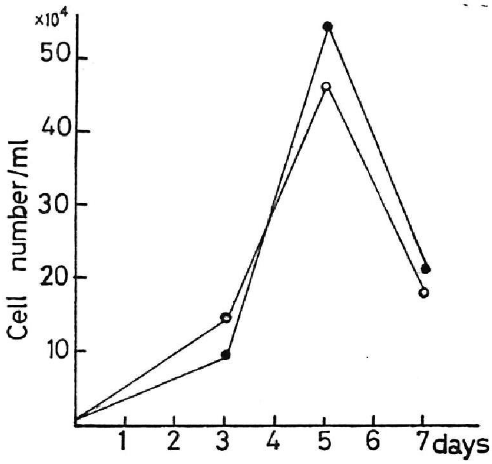

圖5　不同培養液對 Skeletonema costatum 的繁殖情形
•—•—• Miquell-Allen-Nelson+P1. solution
○—○—○ ASP6

養殖試驗

爲探討斑節蝦在含砂較多的虱目魚塭，以粗放式方法是否可以養殖，特作此試驗。

1. 方法及經過

此試驗是在三個地方分別進行，一在曾文海埔地實驗魚塭（稱A池），面積爲 1,000m²，底質爲砂，放養 1,000 尾。二在東港劉坤玉魚塭（稱B池），底質爲壤土，面積 1,050m²，放養 3,000尾，另加入草蝦苗25尾。三在東東港林雨水魚塭（稱C池），面積約 2,000m²，底質爲半

砂泥，放養3,000尾。蝦苗是筆者等所人工繁殖者，而在水泥池飼育2～3週，體長約2.9公分，體重約0.12公克左右者盛入裝有氧氣之塑膠袋中，而由臺南分所以汽車運至各池放養。放養前各池塘都曾排水晒乾，注入海水使池底形成薄薄的底藻，並施茶粕殺除害敵後始放養。放養期間除B池設有注排水口經常交換池水外，A、C池則因注排水不方便始終不曾換水。此試驗期間三池均不投任何飼料，僅靠池中繁生的藻類及底棲生物及紅筋蟲、輪蟲及劍水蚤等類之浮游生物。水溫是在上午8時及下午2時測定，鹽分則用赤沼式比重計在上午測水溫時一道測定。成長度原擬每二週任意採集10尾測定，但未能按原定計劃進行，而僅作三次的中間測定。

表3　斑節蝦養殖池別的放養與收獲情形

池別		曾文海埔地魚塭（A池）	東港劉坤玉魚塭（B池）	東港林雨水魚塭（C池）
面積 m^2		1,000	1,030	2,000
放養	年月日	1968. 5. 24	1968. 5. 9	1968. 4. 25
	平均體重	0.12g	0.015g	0.15g
	平均體長	2.9cm	1.5cm	3.0cm
	尾數	1,000尾	3,000尾另放草蝦25尾	3,000尾
	每 m^2 尾數	1尾	3尾	1.5尾
收獲	年月日	1968. 9. 13	1968. 9. 23	1968. 9. 24
	平均體重	12.6g	草蝦14尾	
	平均體長	12.9cm	平均體重45g	全無收獲
	尾數	308尾		
	重量	3.88kg		
	生存率	30.8%		

2. 結果及檢討

A池

此年五月適值雨季，池水鹽分降至24.9‰，池底由藍色藻類及矽藻形成厚約1～2 mm 的藻床，池水澄清，在顯微鏡觀察結果此等藻類主爲 *Lyngbya*、*Oscillatoria*、*Spirulina*、*Phormidium*、*Pleurosigma*、*Navicula* 及一些纖蟲，纖毛蟲類，紅筋蟲等，此外有輪蟲及劍水蚤等浮游生物，放養後第三天因大量降雨，池水鹽分下降至17.2‰，以後也因此年雨量特別多，7月中旬降至11.8‰，7月底爲10.7‰，此時在池邊曾發現死蝦，8月間之鹽分爲10.9～12.5‰，而9月收成時已降至7.8‰（圖7），且70%以上均患上輕微的鰓腐病，甚者鰓葉腐爛，鰓上的胸甲破裂呈如石川[2]所指出之鰓黑變病症（圖8），此病之原因據石川[2]稱爲一種無色糸狀細菌 Leucothrix 寄生於鰓組織所致，不過此病之遠因或可歸因於長久棲息於低鹽分的水域所致。養殖期間的水溫是在25～35°C 之間，最熱的7、8月，下午最高水溫雖有數天高達35°C以上（圖9），但亦未見池蝦呈任何異常現象。依圖10的成長情形來看，放養後31天（6月24日測定）體重達5.75公克，81天10.32公克（8月14日測定），第111天（9月13日）結束此試驗，排乾池水捕捉結果共獲308尾，生存率爲 30.8%，平均體長爲12.9公分，體重爲12.6公克。日本的集約養殖，每m^2

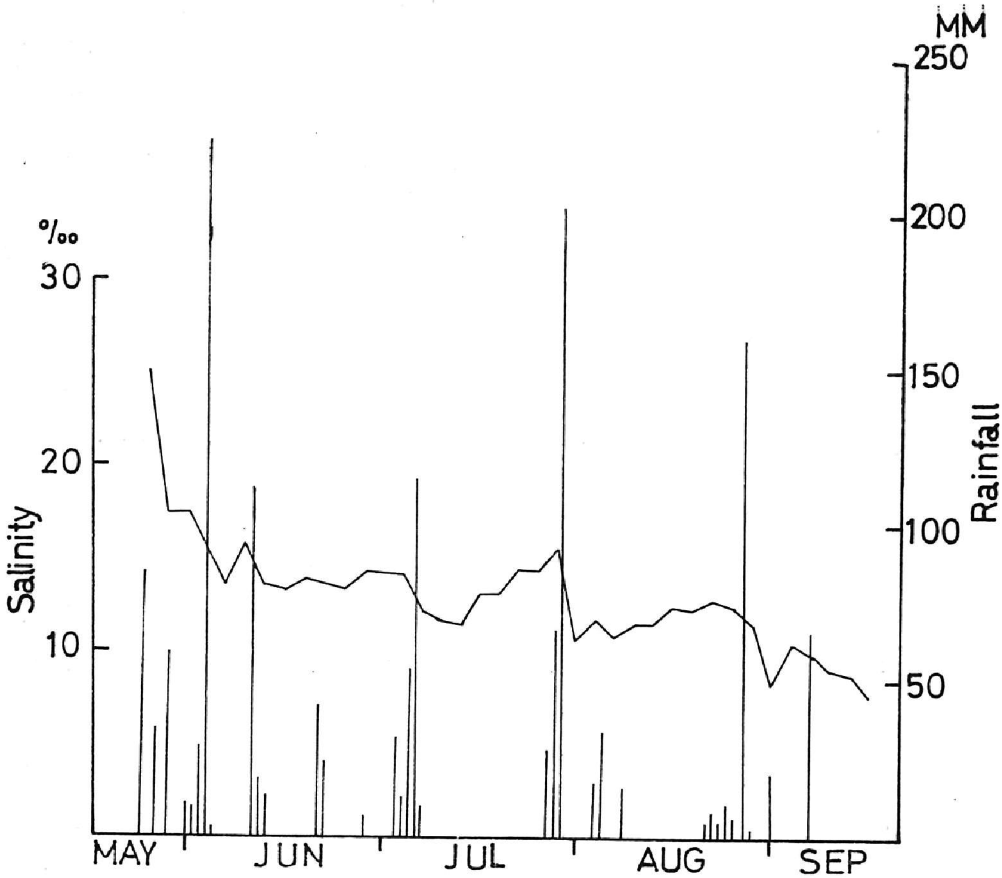

圖 7　斑節蝦養殖池之鹽分、雨量變化情形

放養20～30尾，7月以前放養者須4個月以上（11月以後）才能成長至10～18公克，而7月以後放養者無法達上市體型，須經越冬[1,9,10]。此次試驗以每m^2放養一尾，不投任何飼料，不換池水，且長期在低鹽分的環境下，竟有如此的成長結果這是值得重視的。考察此次生存率僅爲 30.8％ 的原因可歸因於池水鹽分過低，據廖之報告[7] 此蝦在鹽素量 6‰以下則其攝餌量會降低，鹽素量降低至 3‰以下則將於2週內會斃死，而此次養殖期間已數日達此危險範圍，另外由於不投任何飼料以致食物缺乏，在極端饑餓狀態下或許有互相殘食之現象。排乾池水捕獲此蝦時發現有潛伏於池底高砂堆之習性，曾在寬約一公尺的砂堆中捕獲28尾，而

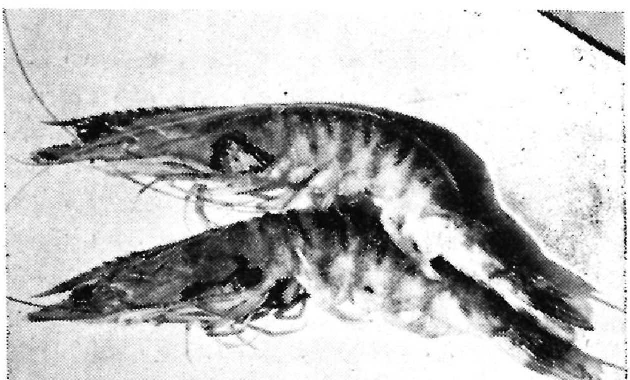

圖8.　養殖斑節蝦的鰓黑變病症

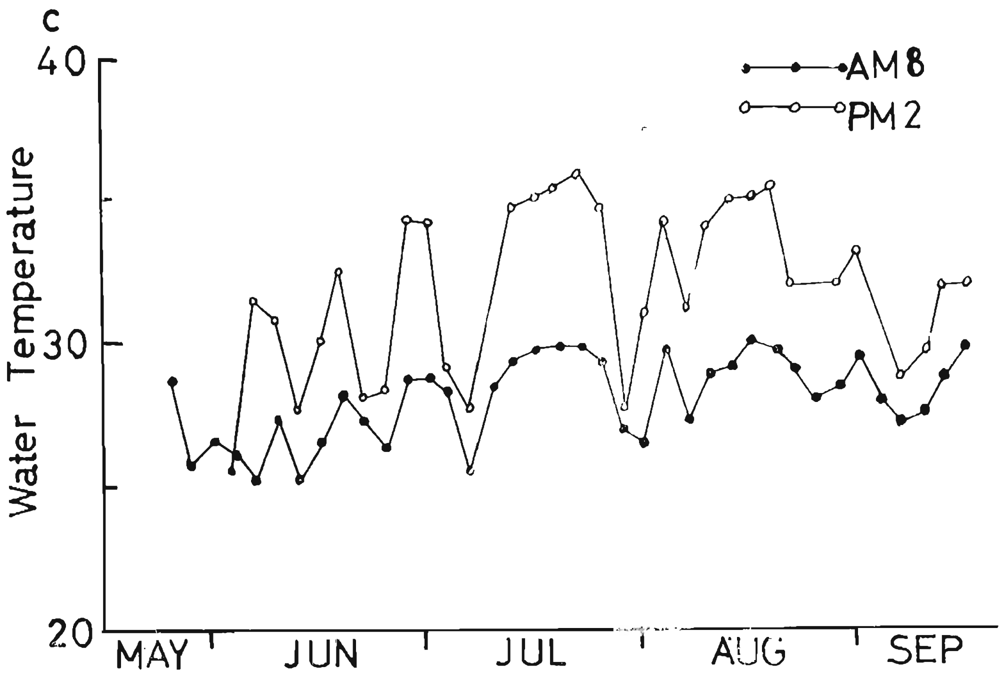

圖 9. 斑節蝦養殖池之水溫變化情形

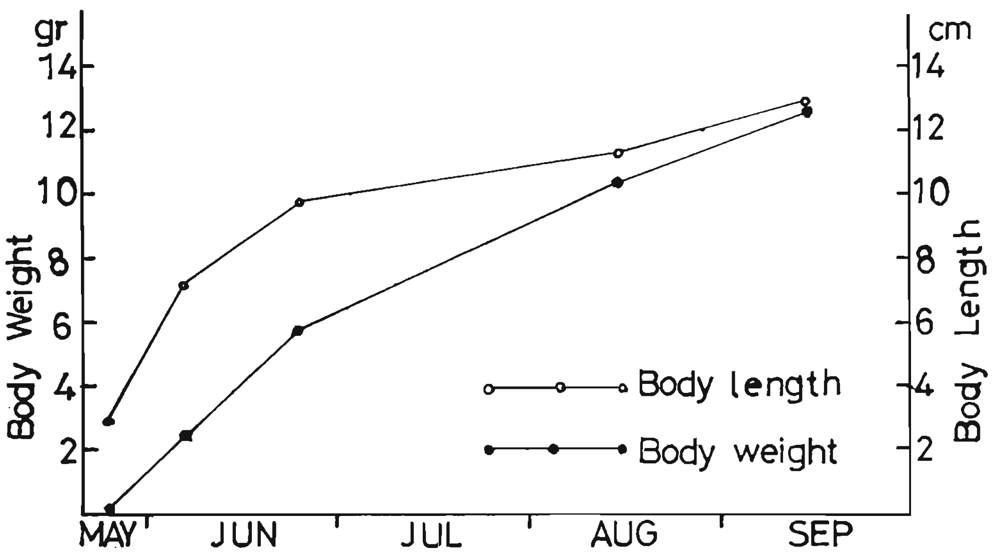

圖10 養殖斑節蝦之成長情形

在凹處的潛伏者則極少，此兩處之主要不同點在於前者被污染程度遠較後者來得輕微。依筆者等之推算，如利用較爲易於交換海水的虱目魚塭，用推土機推去上層含有機物較多的表土，然後處處堆放寬約一公尺的小砂丘，或在魚池四週圍舖成砂床，使其所佔的面積約爲20％左右，保持水深30～50公分，每 m^2 放養 5 尾，放養初期靠天然餌料，隨着此蝦成長天然餌料不够供應時，酌

投螺貝及什蝦魚肉等。養殖 3 個半月（4 月放養 7 月中旬收成），生存率以 70%，每尾體重 20g 計算，每公頃可收成700公斤，一年養殖二次，可收 1,400公斤，以每公斤活蝦外銷價格 150元計算，年可收入 210,000元，較虱目魚養殖收入高出 4 至 5 倍，且成本遠較虱目魚養殖爲低廉。

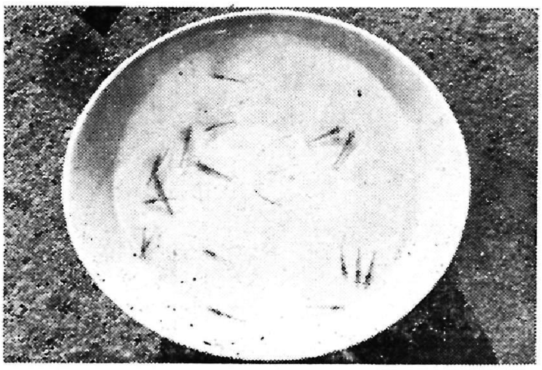

圖11　放養前之斑節蝦苗

圖12　蝦苗裝箱運送

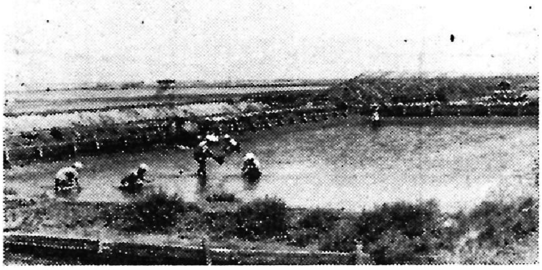

圖13　斑節蝦養殖池之收獲

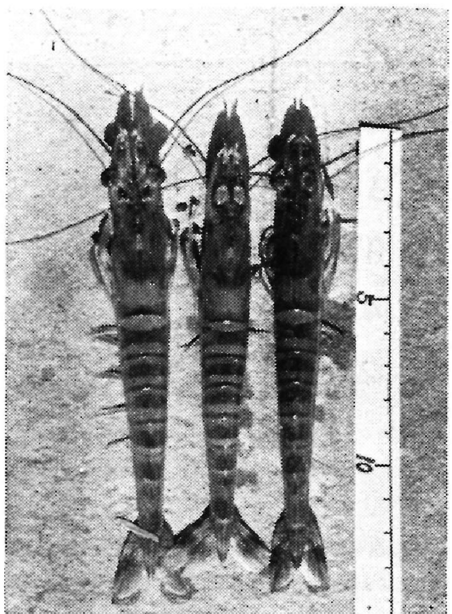

圖14　收獲時之體型

圖15　養殖之斑節蝦

圖16　潛伏在砂中的斑節蝦

B池

因此池爲古老的虱目魚塭，含泥較多，雖設有注水口與排水口每天通水一次，但池底難免污染，放養後38天（6月16日測定）的平均體重3.1公克，體長7.2公分，於該晚10時以手電燈在池邊照明捕捉游泳中之此蝦，解剖其胃與腸的內容物結果示於第5表。7月中旬，因周圍農田的雨水聚集，使溝通外海的水路成爲淡水，池水鹽分雖無測定記錄，但以舌舐試結果遠較A池的7.8‰爲淡，夜間已不見其游泳，日間下池捕捉未能發現，於9月23日乾池結束此試驗，結果僅捕獲草蝦14尾，平均體重爲45公克，生存率爲56%，由此可見草蝦對低鹽分及底土污染的適應，遠較斑節蝦爲强。

表4.　斑節蝦收獲時的體型

全長 (cm)	殼長 (cm)	體重 (g)
12.6	2.8	10.8
12.9	2.9	12.1
12.9	3.0	13.5
12.7	2.9	12.0
13.1	3.1	14.0
12.7	2.9	11.0
12.8	2.9	12.5
12.8	2.9	12.5
13.6	3.2	14.3
12.6	3.0	11.9
平均12.9	2.95	12.6

表5.　粗放式養殖池斑節蝦消化管內容物種類

1, Cyanophyta 之碎片
2, Bacillariophyta
   Melosira sP.
   Navicula sP.
   Cymbella sP.
   Nitzschia sP.
3, Copepods 付屈肢等破片
4, Rotatoria 循甲之一部破片
5, Chironomid eggs
6, 貝類（卷貝）之破片
7. 其他稚貝類之表皮及破片

採集地：東港劉坤玉魚塭（B池）
採集時間：1968年6月16日 PM10.00
體重：2.5~3.1克者

C池

池底與A池同，含砂較多，但與B池一樣因位置離海岸遠，雨季中外水路上層水變淡，無法導進海水，致長期困於鹽分過低的環境下而全部死亡。

摘　　要

1. 爲探討本省斑節蝦人工繁殖，以及此蝦在虱目魚塭與海埔地養殖之可能性，利用魚塭通水路之海水作此蝦的產卵，孵化試驗，而採集魚塭中的矽藻，輪蟲，劍水蚤等天然餌料，與人工培養的 *Skeletonema costatum* 與 Brine shrimp 等餌料作培育試驗，並於含砂較多的曾文海埔地魚塭，泥土質的東港劉坤玉魚塭，及東港林雨水魚塭，作養殖比較試驗。
2. 臺南安平一帶，2月中旬至5月底，爲此蝦產卵盛期。半噸及一噸圓型硬質塑膠水槽，盛入虱目魚塭外水路漲潮時的海水，作產卵試驗結果，如能選擇成熟度較好的種蝦，其產卵率可提高到65%以上。
3. 採集春初虱目魚養成池內大量發生的矽藻類作爲此蝦 Zoea 期之餌料，並以魚塭內水路饒產的輪蟲，劍水蚤等作爲 Mysis 及 Post-larva 期之餌料飼育結果，雖較投飼人工培養的 *Skeletonema* 及 *Brine shrimp* 者生存率低，但半噸塑膠製水槽，曾養獲 P7 者5,000尾，6噸的野外水泥池獲19,200尾之多。
4. 在3.7×1.9×0.5公尺的水泥池舖砂厚約3公分，注入魚塭外水路的海水，使砂面發生底藻，水質澄清後，放入 P7 者約 13,500尾，而給予所採集的劍水蚤此外不投予任何餌料，不打氣的狀態下飼育約3週結果，成長至體重約0.15公克，體長約2.9公分，生存率爲45%，但其體形較投貝肉者爲瘦。
5. *Skeletonema costatum* 在高雄港除盛夏（7、8月）採集量較少外，斑節蝦繁殖期間的2～6月及9～12月，其天然發生量相當多，有時海水爲之呈微褐色。利用魚塭的澄清池水加熱放冷後，加入數滴 Miquell 液及 Pl. solution 作大量培養結果，水溫 25～28.5°C時，5～6天即可達最高密度 54×10^4 cell/ml.
6. 放養人工繁殖的斑節蝦苗（平均體重 0.12克）1,000尾，於含砂較多的曾文海埔地虱目魚塭 1,000m²（A池），經111天不投任何飼料，不換池水的粗放方式養殖結果，其生存率爲30.8%，平均體重爲12.6公克，體長12.9公分，養殖期間因雨量過多，池水鹽分爲之低降，將近收獲的9月上旬曾降至7.8‰，而所收成之蝦之70%以上均患有輕微的鰓腐病，其甚者鰓葉腐爛呈鰓黑變病症。
7. B、C兩池因溝通海水的水路離海岸較遠，周圍農田的雨水聚集，致使池水過淡（曾降至7‰以下）並池底有機物之含量較多，易呈缺氧現象，而導致全部死亡。唯B池與斑節蝦混養的草蝦，尚有56%的生存率，且每尾體重達45公克以上，由此可見草蝦對於低鹽分與惡劣環境的抵抗力遠較斑節蝦爲强。

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ARTIFICIAL PROPAGATION AND CULTURE OF PENAEUS JAPONICUS BATE

Ting-Lang Huang, Yun-Yuan Ting and Si-Chin Hsieh

Tainan Fish Culture Station

Penaeus japonicus is a prawn of high market value. Its culture has recently been intensively practiced and promises to become an important industry.

The writers undertook the various experiments on the artificial propagation of this prawn in the hope of establishing similar culture industry in Taiwan and the results obtained so far are summarized as follows:

1) In Anping, Tainan, the period from mid-February to the end of May is the high spawning season of *Penaeus japonicus*.

2) Live mature female prawns were collected from shrimp trawlers and placed in plastic tanks of 0.5 to 1 ton capacity filled with sea water for spawning. Aeration was necessary for this phase of work.

3) Spawning usually took place the next day after introduction of the female prawn. The naupli did not eat, but the next stage of development, the zoea, fed on diatoms, preferably *Skeletonema costatum* which had to be cultivated in separate tanks for feeding the larvae. The mysis fed on zooplankton. The naupli of the brine shrimp, *Artemia salina*, were the most convenient, nutritious but expensive food for the mysis of the prawn. Copepoda and zooplankton from milkfish ponds were not so good as *Artemia* as food for the mysis.

4) Post-larva of the prawn required clam meat in addition to *Artemia* as food, but the rotifera and copepoda collected from the milkfish ponds and canals were also eaten by the mysis and post-larvae. However, the survival rate of mysis and post-larvae was better when fed with *Artemia* and clam meat than with zooplankton from the milkfish ponds.

5) *Skeletonema costatum* was collected at Kaohsiung Harbor in July and August. Fortunately, during the propagation period of this prawn, i.e. February to July and September to December, *Skeletonema* was also naturally abundant. In laboratory culture by adding a few drops of Miquell solution and Pl solution into sterilized clear pond water the pure culture of *Skeletonema costatum* had grown to the highest density of 54×10^4 cell/ml in 25-28.5°C after 5-6 days.

6) Commercial culture experiment of *Penaeus japonicus* was carried out by stocking 1,000 young prawns (average weight 0.12 gr) in a sandy pond A (1,000m^2) on tidal land. In 111 days of culture the prawns grew to an average weight of 12.6 gr and body length 12.9 cm with a survival rate of 30.9%. This low survival rate is probably due to heavy rainfall and consequently low salinity

(even down to 0.8% in early September just before harvest).

7) For comparison, 3,000 young *Penaeus japonicus* were stocked in a pond of $1030m^2$ together with 25 young *P. monodon*. In a culture period of four months, all the *P. japonicus* died, but the *P. monodon* had a survival rate of 56%. Low oxygen content, heavy rainfall and low salinity were responsible for the disappearance of the *japonicus*. This proves that *monodon* is more adaptable to low salinity than *japonicus*.

8) In another pond of $2,000m^2$, 3,000 young *P. japonicus* were stocked, but all of them died after four months.

9) From the above experiment it becomes evident that commercial culture of *P. japonicus* may become practical if among many other conditions efficient and cheap food for the mysis, post-larvae and juvenile prawn can be found and the salinity in the production ponds must be kept constant at 2 to 3.5% throughout the culture period.

臺南虱目魚之生態研究

林 晃 生

Some Aspects of Milkfish Ecology

By H. S. Lin

一、前　　言

虱目魚 *Chanos chanos* (Forskal)，爲廣鹽性之温水魚類。據 Schuster (1960) 記載，此魚分佈於紅海、非洲東部、桑吉巴、亞丁、馬拉加西、印度半島之南部、西部及西南部、錫蘭、馬來亞、泰國、越南、臺灣、日本南部諸島、菲律賓、印尼、澳洲、紐西蘭、新幾內亞、三毛亞，飛枝、社會島、吉耳貝特、土木土、夏威夷，美國西岸舊金山以南至墨西哥等地之沿海或海灣。此區位於地球之東經 40°至西經100° 之間，包括北緯30°～40°至南緯30°～40°之亞熱帶與熱帶海域及海口河流。

此魚之養殖歷史頗久，在臺南市已有三百多年之記載。據臺灣漁業年報 (1966) 其養殖面積約爲15608.87公頃，幾全部分佈於西南沿海北緯23° 40′以南。平均年產量每公頃約1,800公斤。其所佔之面積佔臺灣總養殖面積之40.54%，而產量則佔49.72%，由此可見其重要性。

此魚的生長環境與其他魚類之養殖環境差異很大，據陳同白 (1953) 及蘇國珍 (1957) 等略述如下：虱目魚養殖一年中大概可分爲兩個時期：

(一)準備時期：十一月至翌年三月之間：

(1)魚苗之越冬：將養成池內所剩下的小魚引入那東西向的越冬溝；水深約150～180公分，其上架設面向西北傾斜的稻草棚以避寒流，其間留數處小通風窗，晝間時常打開以免池水缺氧。此溝之前有育苗池，以便魚苗覓食與運動。夏季也以此養育三點花 (1.5 cm 之幼苗)。

(2)整理養成池：曝晒池底，積蓄海鹽，施放有機肥料，培育藻床，毒殺雜魚。主要雜魚，據黃英武等 (1964) 報告，有吳郭魚 (*Tilapia mossambica*)，唐郭魚 (*T. zilli*)，夏威夷海鰱 (*Elops saurus*)，大眼海鰱 (*Megalops cyprinoides*)，鰕虎科 (Gobidae)，彈塗科 (Periophthalmidae) 等等；同時毒殺無脊椎動物如鹽水蜈蚣 (*Nereis glandicincta*) 等。

(二)飼養時期：四月至十一月，其間分批放養大小不同的魚苗，投飼料，毒殺紅筋蟲 (*Chironomus longilobus* 之幼體) 與 *Berosus* sp.，並分批以刺網捕獲大魚。水位以不超過 40cm 爲宜，情況特殊則可降低水位至 15cm 左右。如底藻敗壞則可暫停飼養，排水曝晒約兩星期後重新放魚飼養。

虱目魚苗的來源由環島沿海附近捕獲而來。漁期爲四月至十月。此魚之育成率可高達90%以上。

Warren 與 Doudoroff (1962) 首先提出溶氧量減少對魚之食物消耗量，攝食活動與食慾有抑制的現象。據 Stewart 等 (1967) 有關鱸魚對不同溶氧濃度與食慾之報告。筆者鑑於虱目魚塭之生物羣落特殊，始於1967年 5 月至10月從事於虱目魚的生態研究。本文著重溶氧量的晝夜變化與魚體內食物含量多寡相互間的關係。

二、材料與方法

於省水產試驗所臺南分所選擇3號（2.03公頃）、4號（2.05公頃）、5號（3.27公頃）、6號（3.14公頃）逢機採樣，每月調查一晝夜，每三小時取樣一次，連續八或九次，其項目如下：

1.捕魚與消化道內含物量的測定：

自上午九時起至翌日六時止共八次，每次於一池中採樣，其樣品不得少於五尾，至實驗室內，先行測定體長與體重，立刻剖腹取出消化道，分成前後兩部份量其長度，並剖開消化道取出其內含物。前部份爲咽喉至幽門垂（Pyloric caeca），後部份爲幽門垂以後至肛門。其前部之內含物取出放入已裝好固定液（FAA）的離心機 10cm 量管，其刻度致 0.1ml，視其增高的格數而記錄之，並保存於茶色標本瓶內。後部量少時由離心機量管處理，量多時則以刻度至 0.5ml 的30ml量筒處理。先裝入5ml 的水放入腸含物後記錄其昇高之格數。再者用靈敏天秤測其所增加的重量而求得平均比重，以此比重轉化體積成爲重量。

2.溶氧量之測定：

每次於四個或二個魚池*各以二瓶250ml 深茶色的玻璃瓶取樣，依Strickland and Parsons（1965）著海水分析手册中的 Winkler 法，立刻固定之並保存後處理，以數次滴定的結果所求得的平均值以 ml/l 之單位表示其溶氧量。

3.氣壓與日照時間：

氣壓以自動記錄器與水銀氣壓計校正後求得之海平面的氣壓 mm Hg 。日照時間以圓筒日照計記錄之。此資料爲臺南測候所之記錄。

4.溫度之測定：

(1)水溫以 Foxboro Portable Indicator 測定各池底之溫度。

(2)氣溫以水銀溫度計測定之。

5.鹽度之測定：

以天秤式比重計測定後又以溫鹽曲線求得鹽度。

6.混濁度：

以美製 HACH 水質分析（化學）箱中的光電器測得混濁度（JTU）之單位來表示。此一單位爲 SiO_2 1 mg/l，即一百萬分之一的二氧化矽溶液來表示。

7.藻床量之測定：

各池取出三處 100cm² 面積的底藻，置於約 45°C 的溫室內一星期後刮下上層的藻類，置於坩堝在溫箱 105°C 下過夜，取出在乾燥器內冷却後由靈敏天秤稱重，復置於高溫爐內過夜。溫度可達 680°C左右。取出放入乾燥器內冷却後測重，兩者差異即爲藻類及有機物的燒失重。

三、結　　果

1.氣壓與虱目魚池溶氧量的關係：以六號池求出氣壓與溶氧量的週日變化之相關係數如表一。溶氧量的多少與氣壓的大小並無一致有規律的關係。

* 五月六月七月爲四個魚池，八月九月十月爲兩個魚池。

表 1　溶氧量與氣壓週日變化的相關係數

日　　　期	30-31/5	27-28/6	25-26/7	24-25/8	30-31/9	27-28/10
相關係數 r	0.7027	0.4661	-0.1269	0.0008	-0.3850	-0.7464*

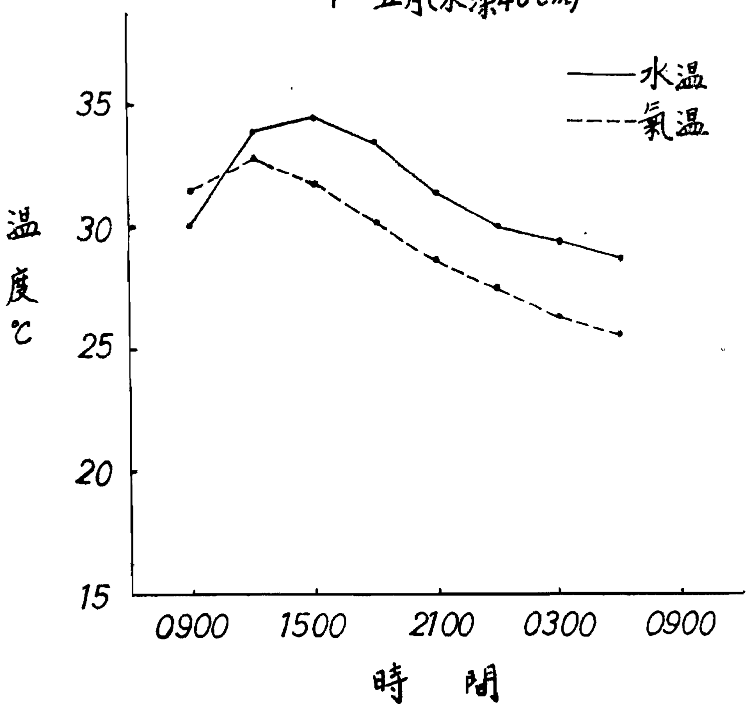
5 月 $r\binom{n-2=6}{p=0.05}=0.7067$

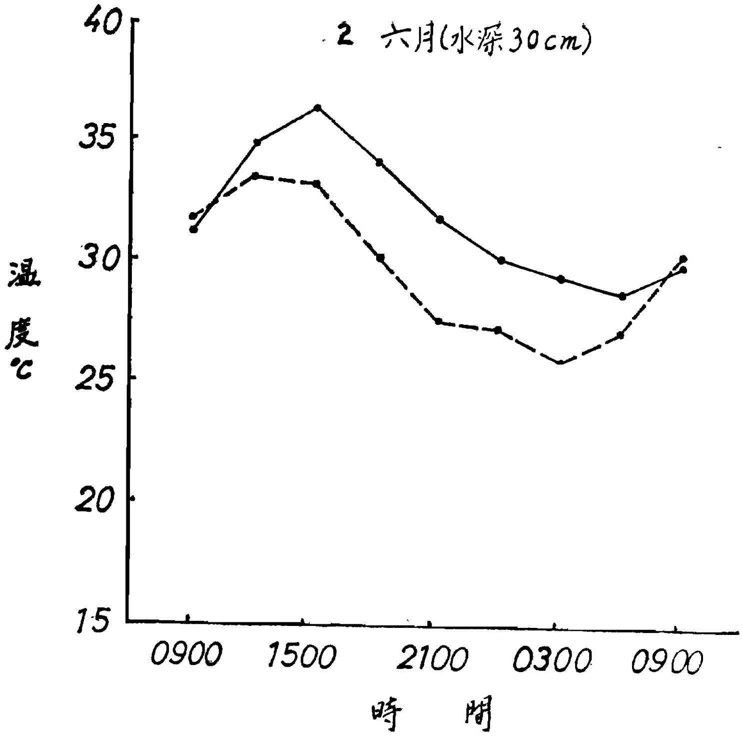
6 月至10月 $r\binom{n-2=7}{p=0.05}=0.6664$

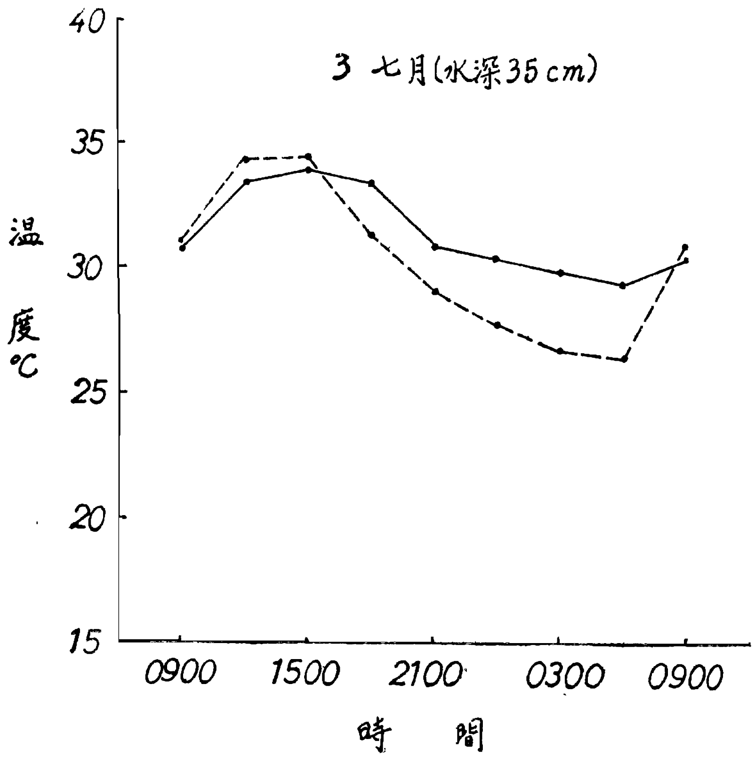
2.水温與氣温週日變化與池水深度之關係如圖(一)。水温高於氣温的時間長。池水深度較淺者水温與氣温較接近。如九、十月之曲線。

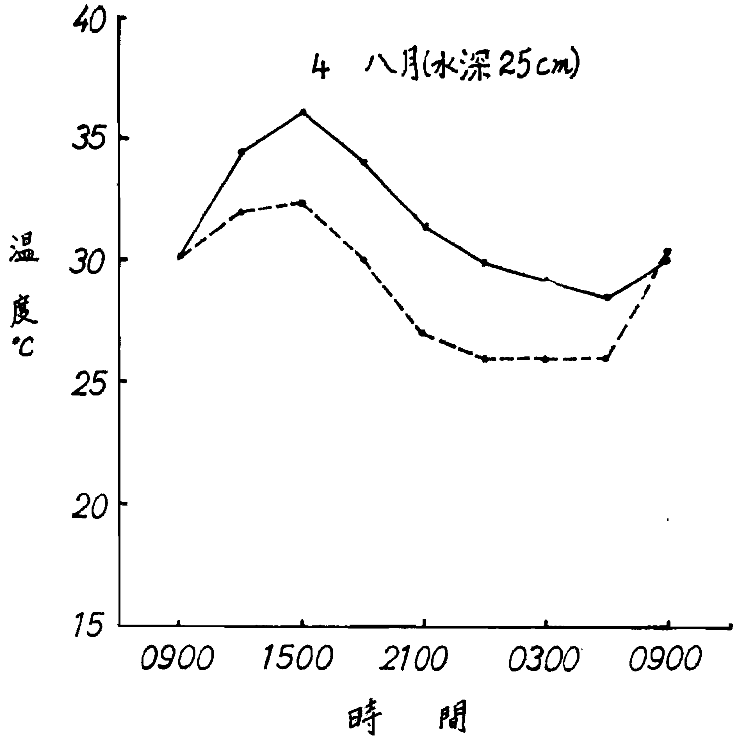
圖一　水温与氣温之比較

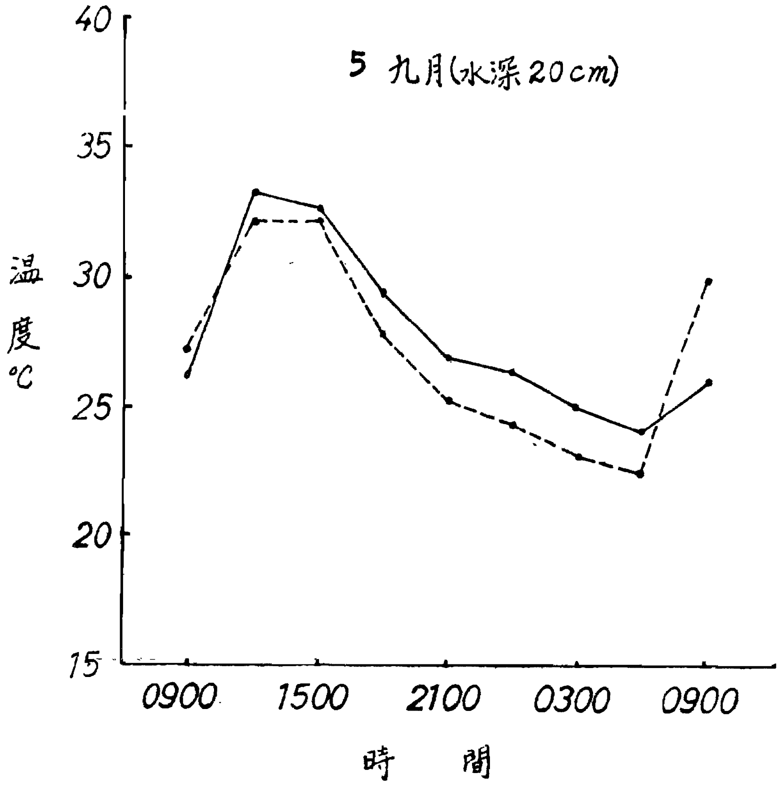
1　五月(水深40 cm)

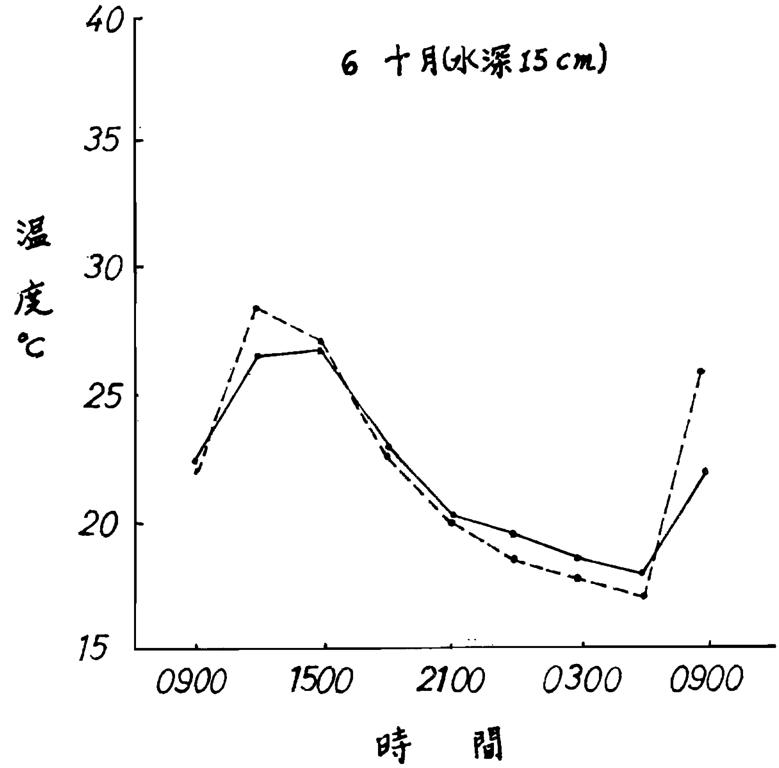



2 六月(水深30cm)
40
35
30
25
20
15
温
度
℃
0900
1500
2100
0300
0900
時　間


3 七月(水深35cm)
40
35
30
25
20
15
温
度
℃
0900
1500
2100
0300
0900
時　間


4 八月(水深25cm)
40
35
30
25
20
15
温度℃
0900
1500
2100
0300
0900
時 間


5 九月(水深20cm)
40
35
30
25
20
15
温度℃
0900
1500
2100
0300
0900
時 間



3.溶氧量與水溫的週日變化關係：在六號池測出溶氧量與水溫之週日變化相關係數如表二，爲顯著相關或極顯著相關。即一日之內當水溫升高則溶氧量隨着增加。

表2　溶氧量與水溫週日變化的相關係數

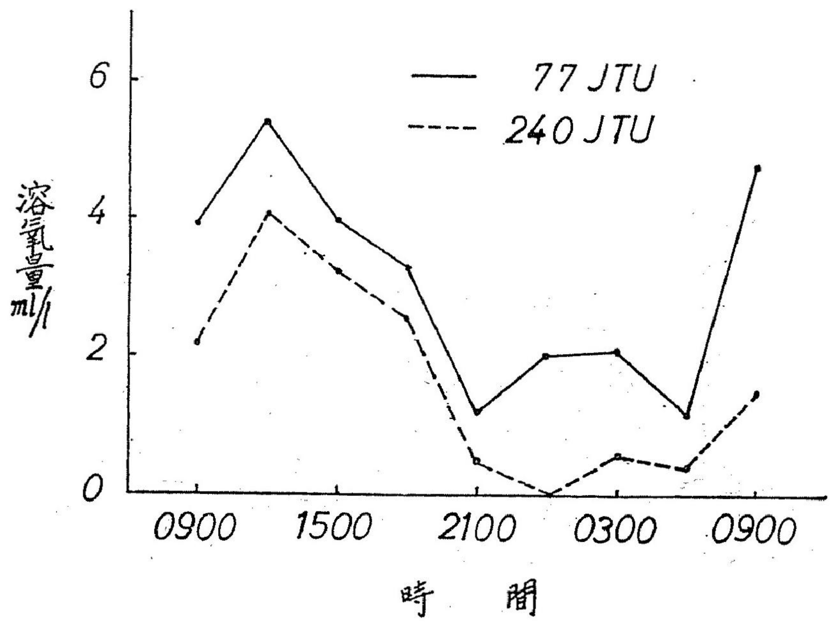
日　　　期	30-31/5	27-28/6	25-24/7	24-25/8	30-31/9	27-28/10
相關係數 r	0.8198*	0.9577*	0.9181**	0.7844*	0.8353**	0.8712**

5月 $r\binom{n-2=6}{p=0.05}=0.7067$　　　　$r\binom{n-2=6}{p=0.01}=8343$

6月至10月 $r\binom{n-2=7}{p=0.05}=0.6664$　　　　$r\binom{n-2=7}{p=0.01}=0.7977$

4.溶氧量與混濁度的關係：於10月27—28日所測的五號池〔77 JTU〕與六號池〔240 JTU〕其溶氧量之週日變化如圖二。混濁度高者溶氧量低。

圖二　溶氧週日變化與混濁度之比較



註：溶氧量的測定有零值的出現，是因 Winkler 法的澱粉指示劑無法使試液顯色時之值。

5.比較六月至十月連續兩天上午六時的溶氧量，日照量，水溫與混濁度之間的關係如表三。日照量多，水溫高，溶氧量也高。混濁度大則影響溶氧量。

表三　各月各池溶氧量、水溫、混濁度與日照量之關係

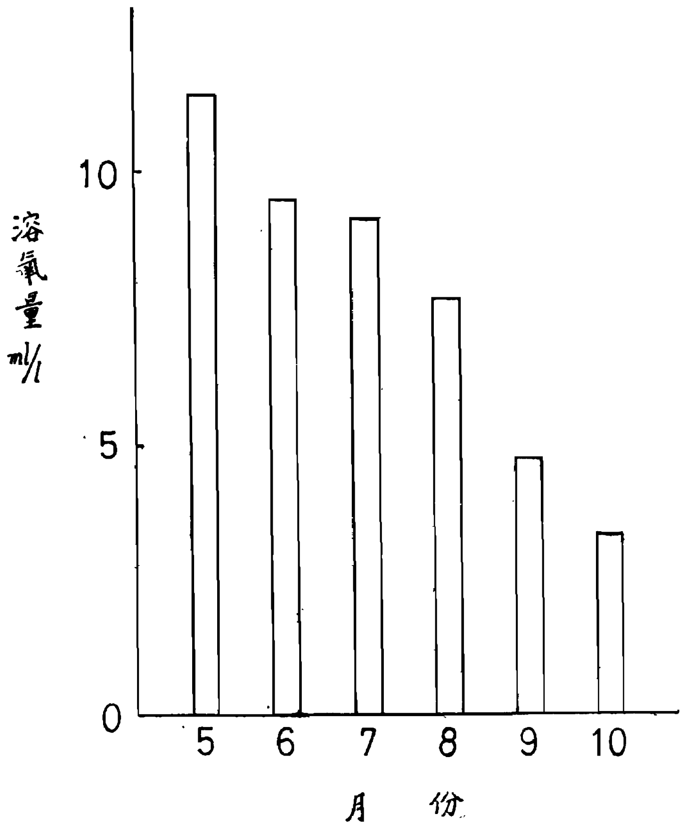
池號	項目＼日期	27/6	28/6	25/7	26/7	23/8	24/8	30/9	31/9	27/10	28/10
	日照量 Ⅰ	0.2	0.3	1.0	0.0	0.3	0.4	0.2	0.5	0.0	0.0
	日照量 Ⅱ	1.0	0.8	1.0	1.0	1.0	0.8	1.0	1.0	0.0	0.6
	日照量 Ⅲ	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0	0.0	1.0
	日照量 和	2.2	2.1	3.0	2.0	2.1	2.2	2.2	2.5	0.0	1.6
3號池	溶氧量 ml/l	3.91	2.69	0.93	0.82						
	水温 °C	31.0	29.8	30.8	30.8						
	混濁度 JTU	18	18	30	30						
4號池	溶氧量 ml/l	5.05	4.03	0.48	0.00						
	水温 °C	31.1	29.8	30.8	30.0						
	混濁度 JTU	13	13	62	62						
5號池	溶氧量 ml/l	4.10	3.19	0.00	0.19	1.42	2.62	1.75	2.22	3.91	4.84
	水温 °C	30.9	30.2	30.8	30.3	30.0	30.0	26.2	26.0	22.5	21.5
	混濁度 JTU	20	20	50	50	35	35	25	25	77	77
6號池	溶氧量 ml/l	5.16	3.66	3.19	2.79	2.65	2.76	3.09	0.42	2.21	1.53
	水温 °C	31.3	30.6	30.8	30.3	30.3	30.3	26.2	26.0	20.0	20.0
	混濁度 JTU	14	14	29	29	8	8	60	60	240	240

註：Ⅰ爲6—7時Ⅱ爲7—8時Ⅲ爲8—9時的日照量。日照量等於1：爲一小時內全部均能使日照計反應者。日照量等於0：爲一小時內全陰天，不能使日照計反應者。

6.溶氧量的週日變化隨着時間而變，以五月與六月的溶氧量數值經變方分析得； 五月 F＝28.9584**六月 F＝111.5355**。即各時間之間與溶氧量之間有極顯著之差異。

7.六號池15：00時溶氧量各月測定值的變化如圖三，因養殖日期之延續而溶氧量遞減。

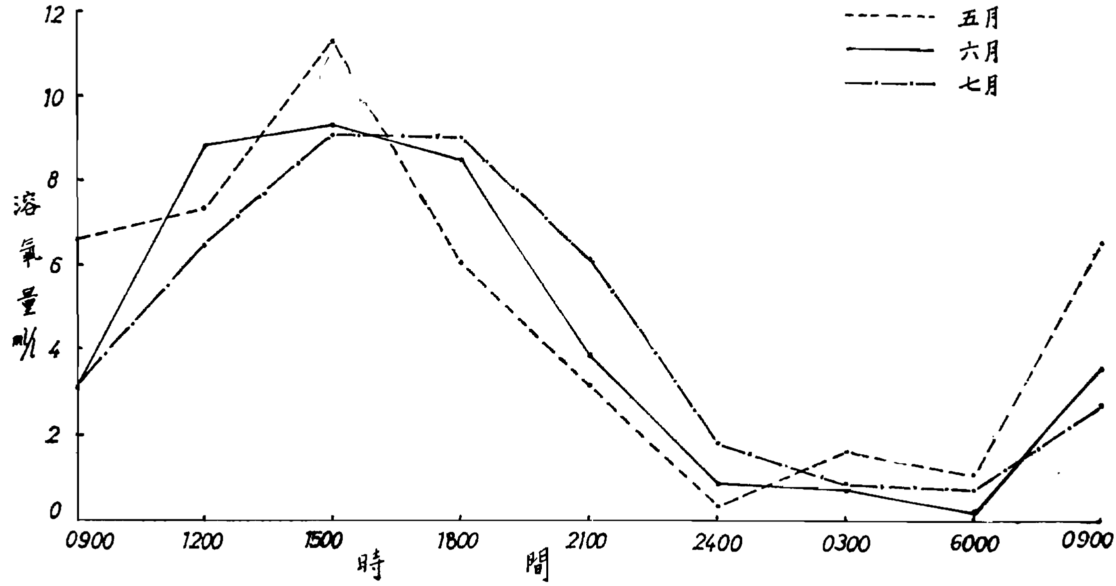
圖三　六号池15:00時之溶氧量之月變化



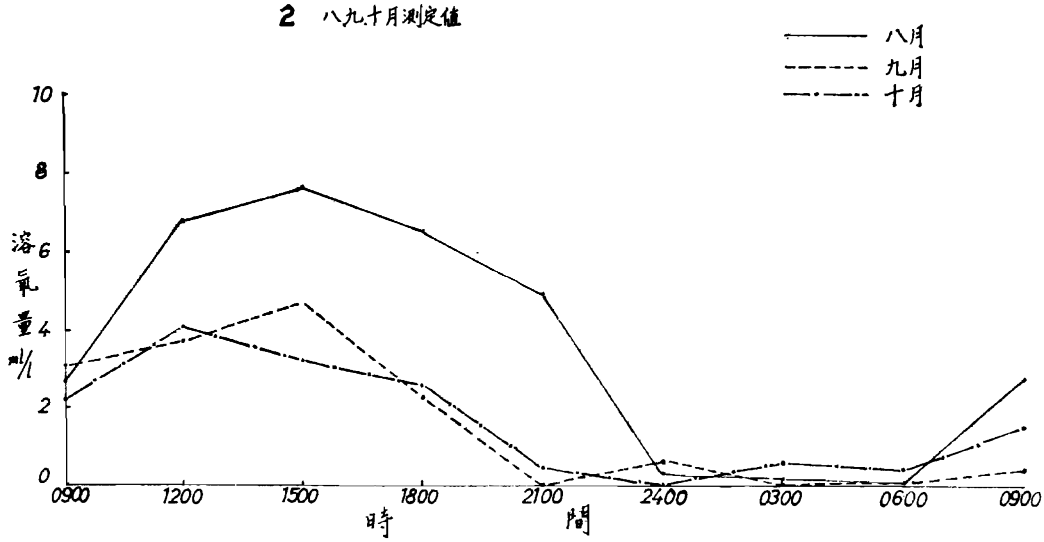
六號池的溶氧量五月至十月測定值的週日變化如圖四。溶氧量晝間 15:00 最高，十月則十二點最高，夜間24:00至清晨6:00均極低。

圖四　六号池溶氧量之週日變化

1　五六七月測定值



2　八九十月測定值



8.各月測定日取面積 300 平方公分的底藻以測其燒失的重量：單位爲克結果如下表。其燒失重量因隨養殖月份而遞減。

表4　各月測定日底藻面積300平方公分之燒失量（克）

池號 \ 燒失重量 \ 日期	30/5	27/6	25/7	23/8	29/9	27/10
3 號 池	9.232	6.402	2.854	—	—	—
4 號 池	4.607	10.928	2.537	—	—	—
5 號 池	10.921	8.608	2.542	1.717	1.237	1.053
6 號 池	8.580	10.921	5.607	1.612	1.198	0.937

9. 15:00時溶氧量與底藻燒失重量的關係。由五、六號池測定值的溶氧量與底藻燒失量以求兩者間的相關係數。五號池因七月測定時的情況極爲特殊經 t 值測驗有顯著差異故去除之。其他資料得 $r=0.9276>r\binom{n-2=3}{p=0.05}=0.8783$爲顯著之正相關。六號池的資料求得 $r=0.8181>r\binom{n-2=4}{p=0.05}=0.8114$。兩者亦爲顯著的正相關。

10.虱目魚苗對溫度的忍耐力：

將虱目魚苗置於燒杯中，原來溫度爲 28—29°C，鹽度爲 33‰，約每五分鐘升高或降低攝氏溫度一度。熱死溫度試驗的虱目魚苗共6尾，體重界於1.9至3.2克之間，平均體重爲 2.5±0.49 克。冷死試驗的魚苗共10尾，體重界於 2.3 至 8.9 克平均體重爲 5.9±2.32 克。分別試驗結果如下：

魚之活動狀態	攝氏溫度	鰓蓋跳動率（次數/分鐘）
熱死	42.7*	
熱昏	41.5—42.6	38
極力活動	39.0—41.5	240
快速活動	34.0—39.0	205—215
正常活動	19.5—34.0	142—180
低溫微動	13.0—19.5	78—130
低溫開始運動	11.0—13.0	（瞬間而已）
冷昏	9.5—11.0	20
冷死	8.5—9.5	

* 水溫 42.7°C 時的溶氧量爲1.5 ml/l.

於熱昏時返回原來溫度（28°C）的水中即可完全復甦，於冷昏時讓水溫逐漸昇高，5.6 克之魚苗至13.5°C可復蘇，5.7克之魚苗至14.0°C復蘇，6.5克之魚苗至 14.5°C 復蘇，8.3與8.9克之魚苗至19°C始復蘇。較大的魚苗需較高的溫度才能復蘇。

11.虱目魚的氧氣消耗量：

將虱目魚置於密閉的玻璃瓶中測定其氧氣的消耗量。

其結果如下：

(1)虱目魚的體重　g　　172.0　130.0　116.0　平均體重 139.33 g

虱目魚的體長 (F.L.) cm	22.3 20.5 20.0
水　　温：	25.2°C
鹽　　度：	27.4‰
氧氣消耗量：	426.755 ml/hr/kg
死亡界限的溶氧濃度：	0.25 ml/l
(2)虱目魚的體重 g	31.2 26.3 23.5 22.7 平均體重 25.93 g
虱目魚的體長 (F.L.) cm	13.1 12.3 12.1 12.0
水　　温：	23.0°C
鹽　　度：	27.2‰
氧氣消耗量：	208.921 ml/hr/kg
死亡界限的溶氧濃度：	0.116 ml/l
(3)虱目魚的體重 g	30.5 28.9 17.6 平均體重：25.66 g
虱目魚的體長 (F.L.) cm	13.1 12.9 11.3
水　　温：	23.0°C
鹽　　度：	27.2‰
氧氣消耗量：	210.788 ml/hr/kg.
死亡界限的溶氧濃度：	0.135 ml/l
(4)虱目魚的體重 g	21.7 18.5 13.2 12.8 11.3 11.2 10.9 10.8 平均體重：13.80 g
虱目魚的體長 (F.L.) cm	11.9 10.7 9.7 9.7 9.6 9.5 9.3 9.1
水　　温	23.0°C
鹽　　度	27.2‰
氧氣消耗量：	198.809 ml/hr/kg.
死亡界限的溶氧濃度：	0.145 ml/l.

由上得知，虱目魚的致死溶氧濃度約 0.11至 0.25 ml/l，在自然環境下所測得之值零時虱目魚只浮頭，而不致於死亡，因池水水面與大氣相接觸其表面能吸收大氣參入的氧氣。

12、虱目魚苗的抗鹽性試驗所得資料如下：

虱目魚苗的體重 (g)	2.15	2.50	2.70	3.70	5.00	7.40	8.20	11.70
虱目魚苗的體長 F.L. (cm)	5.95	6.30	6.40	7.00	7.95	8.70	9.10	10.20
失去平衡時的鹽度‰	93.7	101.0	93.7	100.1	107.6	114.3	103.6	112.4
死亡時的鹽度‰	104.3	105.6	95.7	103.6	113.0	119.4	110.4	117.0

失去干衡時的平均鹽度：　103.3±7.76‰

死亡時的平均鹽度：　108.6±7.82‰

其魚苗體重與失去平衡時之鹽度的相關係數爲 $r=0.7993^{*}>r\binom{n-2=6}{p=0.05}=0.7067$

其魚苗體重與致死鹽度的相關係數爲 $r=0.7724^{*}>r\binom{n-2=6}{p=0.05}=0.7067$爲顯著即正相關。故魚苗的體重愈大則抗鹽力愈高。

13、虱目魚之消化道與體長的比值因生長的階段而有不同。於五、六月的資料， 分成五組，每組由逢機取樣各得20尾資料，其各組比值的結果如下：

體長〔cm〕	消化道長〔cm〕／體長 F.L.〔cm〕
30～25	8.5680±1.5091
25～20	7.8028±1.3149
20～15	7.1407±1.2735
15～10	6.8410±1.0919
9.7～8.2	4.2163±0.6902

魚體愈長則消化道爲體長之倍數愈大。

14. 虱目魚的消化器官與胃含物。

虱目魚的口吻小，口腔無牙齒。四對全鰓，一對半鰓，鰓弧上有兩排鰓耙呈深溝狀。於體長〔F.L.〕16.8cm 的魚體，其鰓耙長爲 2100μ，寬爲156μ。似呈百葉窗之相錯緊密排列。從口望入，則見上下各四對溝狀鰓耙伸入口腔至咽之前端。咽以下則有一小段斜紋而較厚的括約肌，在體長〔F.L.〕15公分之小魚其括約肌長約 1.5公分，其後袋狀縱走的食道平滑肌約3.3公分，砂囊約 1.6公分，幽門垂至肛門爲 51.0公分。在大魚中食道呈赤紅色，其管道外表皮有兩條金黃色的帶狀分佈。食道內含物分析晝間主要食物爲底藻，夜間與淸晨通常只有少量的胃含物，混濁度小的情況下多數爲橈脚類，輪蟲類與其卵，也有很少量的矽藻。未發現底棲性的藍綠藻類。然混濁度大時則除橈脚類外還有少量的藍綠藻。此魚的食物隨其生活環境而有所變化，其主要食物各月份所分析的結果如下：

五月：以 *Lyngbya*, *Microcoleus* 爲主，也有少量的 *Navicula*, *Amphora*, *Pleurosigma*, *Chroococcus*, *Chlorella* 以及動物性的輪蟲類中的 *Brachionus*, *Dipleuchlanis*, 與線蟲類並有少量的 *Brachionus* 的卵。

六月：以 *Lyngbya* 與腐敗物爲主，*Chroococus*, *Microcoleus* 爲次，*Phormidium*, *Oscillatoria*, *Amphora* 與 *Navicula* 又次之。動物性的有 *Dipleuchlanis*, *Brachionus* 及其卵，還有 Cyclops 與 Nauplius。

七月：以 *Chroococcus* 爲主。腐敗物，*Lyngbya*, 與 *Microcoleus* 次之。*Navicula*, *Amphora* 又次之。及極少量的 *Phormidium* 與 *Spirulina*.

八月：以 *Chroococcus* 與腐敗物爲主，及少量的 *Lyngbya*, *Chlamydomonas*, *Navicula*, *Microcoleus*, *Pleurosigma*, *Oscillatoria*.

九月：以腐敗物與 *Chroococcus*, 爲主 *Lyngbya* 次之，*Microcoleus* 又次之，與極少量的 *Oscillatoria*, *Phormidium*, *Surirella* 與 *Navicula*。

十月：以腐敗物爲主，*Lyngbya* 與 *Chroococcus* 爲副，*Navicula* 次之，及極少量的 *Pleurosigma* 與 *Microcoleus* 以及動物性的 Cyclops.

15. 消化道內含物與體重的百分比與水溫的週日變化的相關係數如下：

表五　消化道內含物與體重百分比及水溫週日變化的相關係數

日　　期	30-31/5	27-28/6	25-26/7	23-24/8	29-30/9	27-28/10
相 關 係 數 r	0.7128*	0.9328*	0.8608**	0.8696**	0.6729	0.6866

$r\binom{n-2=6}{p=0.05}=0.7067$　　$r\binom{n-2=6}{p=0.01}=0.8343$

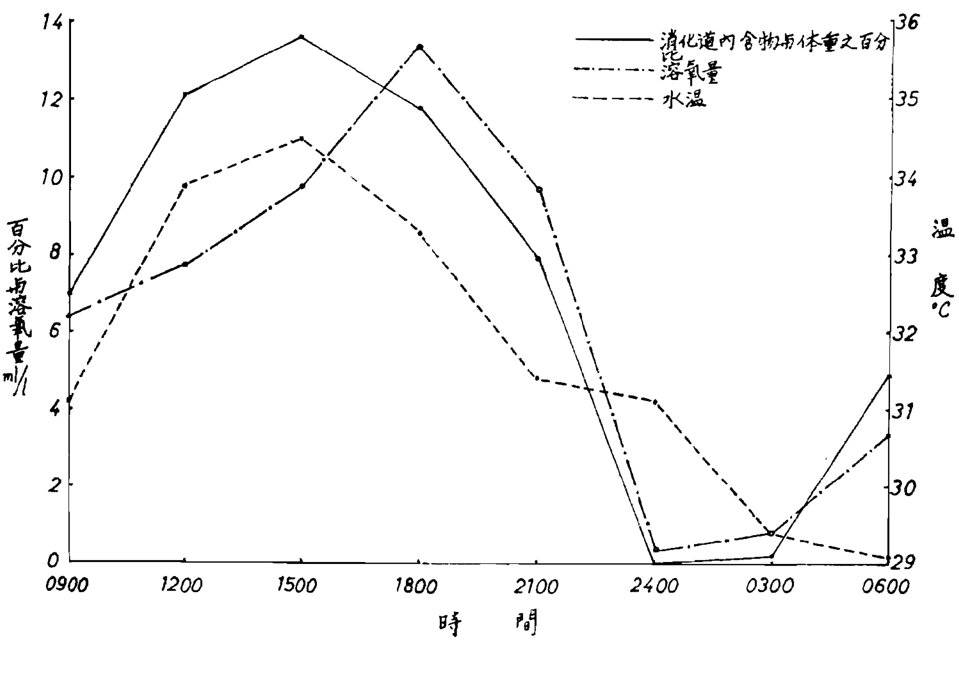
5 月消化道內含物與體重的百分比與水溫間有顯著正相關而 6 、7 、8 月有極顯著正相關。9 、10月則無顯著的正相關。

16. 消化道內含物與體重之百分比與週日中各時間之間或各月之間的關係。

將五月至十月全部資料經 Bliss 氏的轉化使百分數變爲角度。又經變方分析而得各時間之間 $F=17.7539^{**} > F\left(\begin{matrix} df1=6 & p=0.05 \\ df2=35 & p=0.01 \end{matrix}\right)\begin{matrix}=2.48\\=3.59\end{matrix}$ 即週日中各時間之間有極顯著之差異。各月間經變方分析得 $F=4.5902^{**} > F\left(\begin{matrix} df1=5 & p=0.05 \\ df2=35 & p=0.01 \end{matrix}\right)\begin{matrix}=2.49\\=3.59\end{matrix}$ 即各月間有極顯着的差異。因情況特殊將七月與十月除掉不參與計算，則各時間之間也有極顯著之差異，$F=19.8155^{**} > F\left(\begin{matrix} df1=6 & p=0.05 \\ df2=21 & p=0.01 \end{matrix}\right)\begin{matrix}=2.57\\=3.81\end{matrix}$ 而各月之間無顯著差異 $F=1.0014 < F\left(\begin{matrix} df1=3 & p=0.05 \\ df2=21 & p=0.01 \end{matrix}\right)\begin{matrix}=3.07\\=4.87\end{matrix}$ 無顯著之差異。即五、六、八、九 四個月資料，攝食量與時間的週日變化有一致的關係存在。

17. 五月所測得之消化道內食物與體重之百分比，溶氧量與水溫的關係如圖五，水溫，溶氧量和消化道內含物與體重之百分比大略有一致的現象。

圖五 消化道內含物與体重之百分比、溶氧量、與水溫之關係



18. 五、六月各型越冬苗已在虱目魚池中生長一、二個月，由所捕獲的資料體長由 93mm至268mm共82尾，以分組法分成十一組處理得一體長與體重的關係式如下：

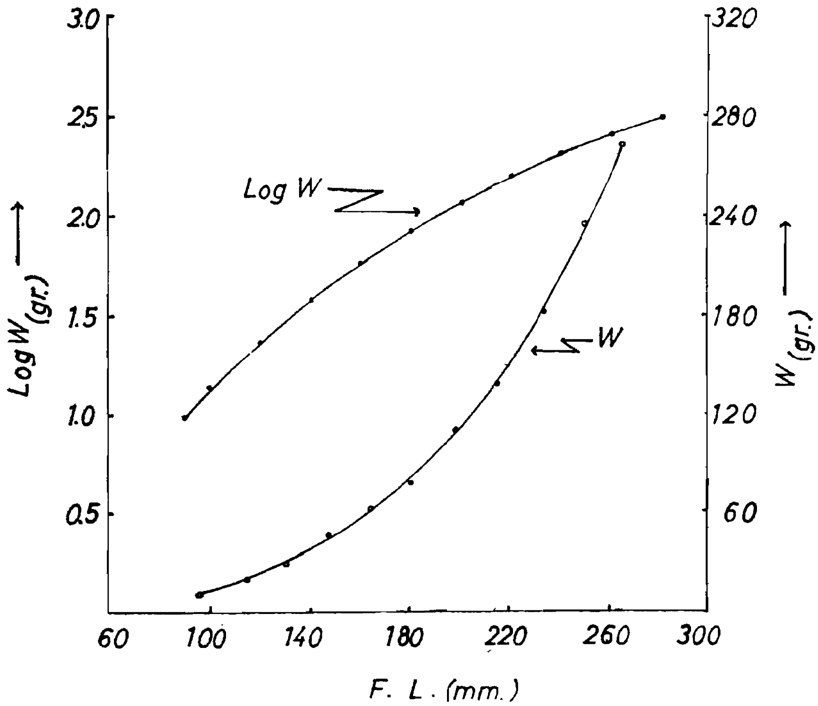
$$W=0.0000009811 \cdot (F.L.)^{3.07299316}$$

即 $\log W=-5.00832737+3.07299316 \log (F.L.)$ W以克 (gm) 爲單位

F.L. (尾叉長) 以耗米 (mm) 爲單位。

以圖六表示體長與體重的關係：

圖六　虱目魚体重與体長之關係



19. 五、六月間虱目魚池水況良好與十月水況惡劣兩種不同的環境下所捕獲的虱目魚，體長〔F.L.〕界於 25.2 與 27.0cm 之間的肥滿度相比較。十月所得的資料共17尾，五、六月間所得的資料共26尾，依相川廣秋〔1940〕求肥滿度的公式經修正使適合於求虱目魚的肥滿度其公式如下：

$$F=\frac{W}{L^3}\times 10^b$$

W：爲魚體重〔腹內無食物的魚〕單位：公克〔g〕

L：爲魚體長〔口吻至尾叉長〕　單位：釐米〔mm〕

b：爲正整數：6

由十月的資料所求得的肥滿度　$F=14.027\pm 0.72615$

其樣品間的變異係數　$CV=5.18\%$

由五、六月的資料所得的肥滿度　$F=14.7238\pm 1.2683$

其樣品間的變異係數　$CV=8.61\%$

五、六月所得資料肥滿度的變異係數略大於十月所得肥滿度的變異係數。

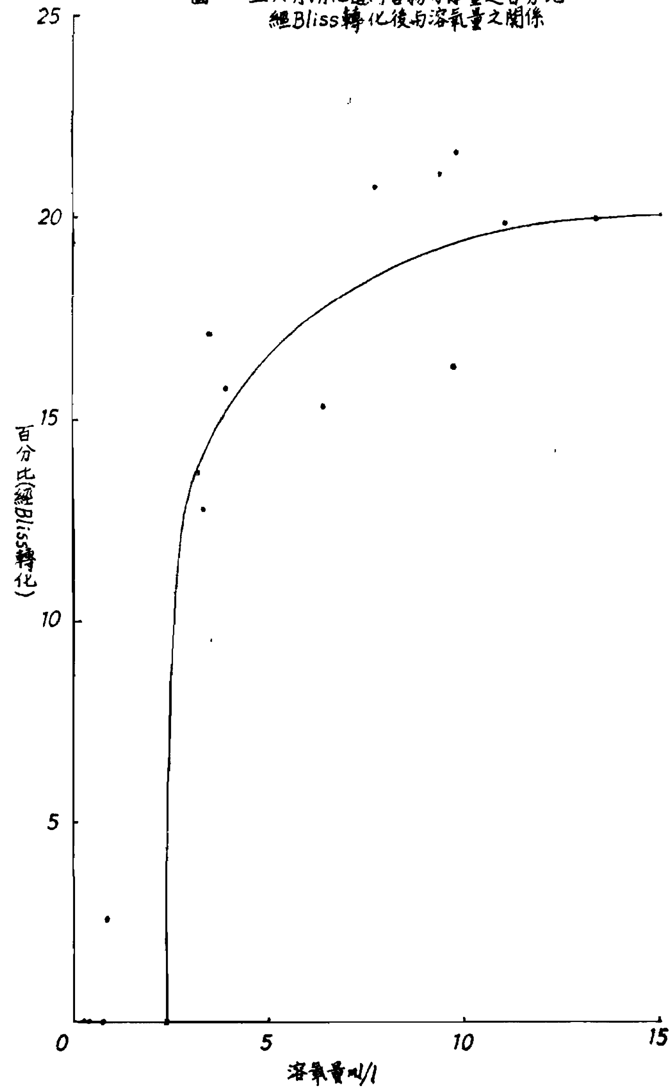
五、六月與十月所得的平均肥滿度經 t 值測驗得 $t=2.0575^*$ 有顯著的差異。

$$t\left(\begin{matrix}n-1=40\\ p=0.01\end{matrix}\right)=2.7012>2.0576>t\left(\begin{matrix}n-1=40\\ p=0.05\end{matrix}\right)=2.0224$$

註：自由度〔df〕本應n－1＝42，因 Fisher 之 t 分佈表只有 df＝40 與 df＝45 的數值，故取數值較接近而其值較大的 df＝40。以此做顯著性測驗。

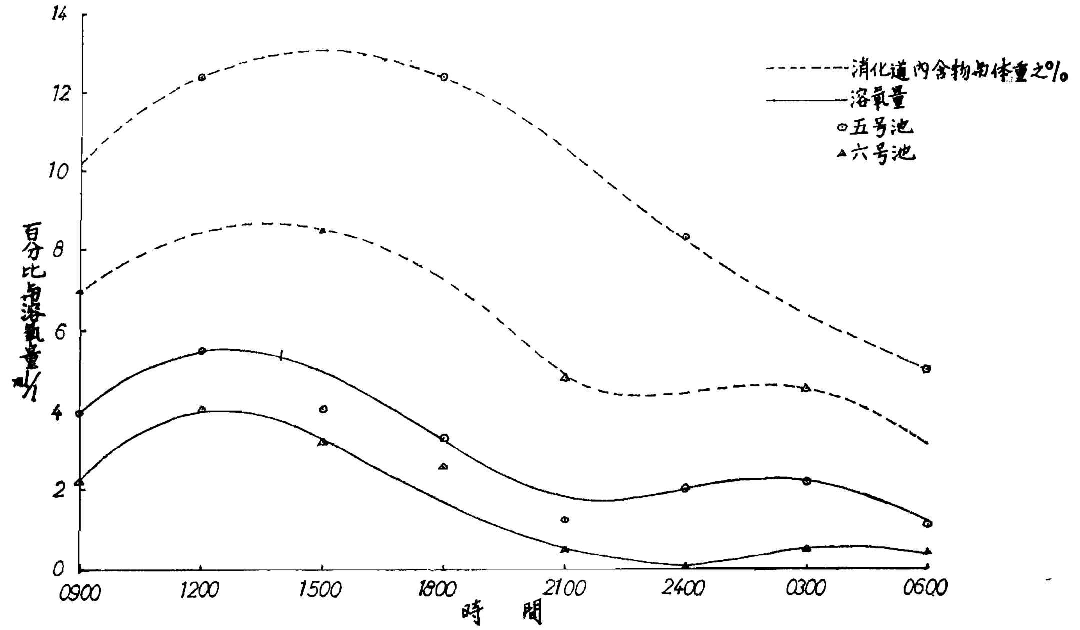
20．五月與六月各池水況良好，池與池之間的溶氧量無顯著差異，其各測定時間之消化道內含物與體重的百分比經 Bliss 表轉化成角度，其與溶氧之相關係數 $r=0.8777^{**} > r\binom{n-2=14}{p=0.01} = 0.6226$ 有極顯著的正相關。然此並非直線相關，於圖七顯示為曲線相關。溶氧量大於3.23ml/l則食量大增，以後曲線斜率小，即溶氧量再增加其食量增加率小。

圖七　五六月消化道內含物与体重之百分比經Bliss轉化後与溶氧量之關係



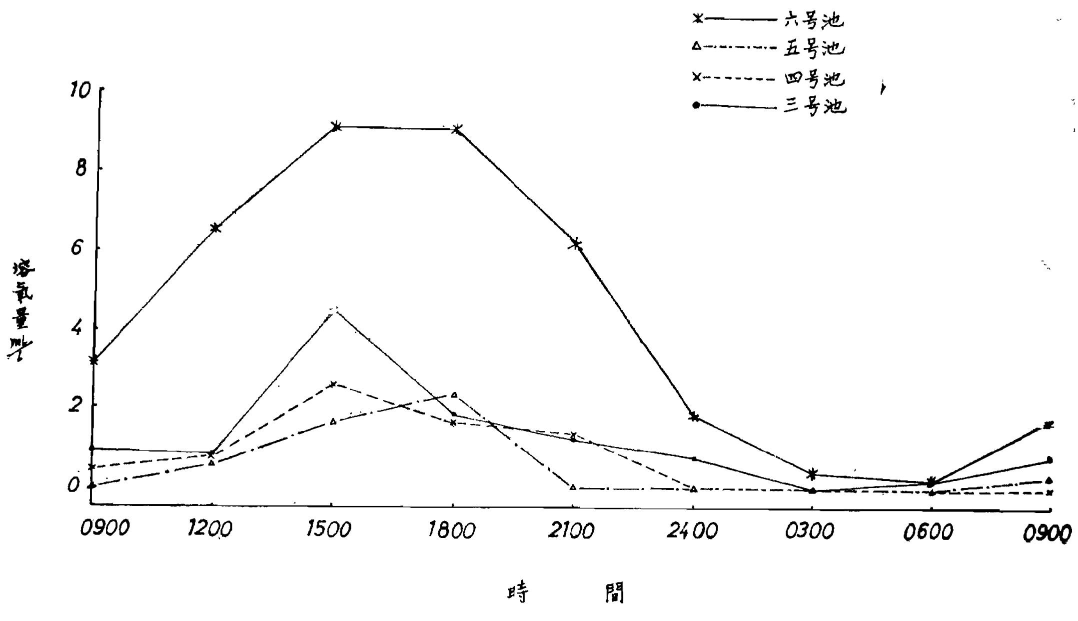
21．十月所得資料五號池溶氧量比六號池溶氧量較高，而消化道內含物與體重的百分比與其溶氧量的多少有一致的相互關係。如圖八所示。

圖八　消化道內含物与体重之百分比及溶氧量之關係(十月)



22. 七月廿七至廿八日所測得三、四、五、六號四個池的溶氧量週日變化如圖九。除六號池外，其他三個魚池的池水呈褐色。此三個魚池自深夜至清晨虱目魚只浮頭。四號池於七月卅一日死魚19尾，三號池於八月五日死 689 尾，翌日又死12尾。於八月六日以後三、四號池排水重新曬坪，以恢復魚池底藻的生產力。五號池因數日後情況轉佳而無需重新曬坪。

圖九　七月測定日之各池之溶氧量



四、討　　論

水中的溶氧濃度與氣壓本應有正相關，然於虱目魚塭的溶氧量因動物羣與植物羣密度很大而使氣壓不足以影響池水的溶氧量。臺南地區通常夏季晝間爲西南海風，入午夜以後逐漸轉爲陸上風，其氣壓較晝間爲低。九月十月因西北季風來臨，夜間氣溫低，氣壓較晝間爲高，故十月之資料顯示氣壓與溶氧量有顯著之負相關。氣壓對虱目魚池水中溶氧濃度無顯着的影響。

水温與氣温之間的關係如圖一；池水深度 15cm至 40cm 不等。如爲 15cm則水温與氣温極相近。除上午九時至十二時氣温常較水温爲高外，水温通常高於氣温，但也有水温較氣温爲低者。於黃英武〔1963〕兩天的測定中也有此現象。於八月廿三日照强度較其他測定日爲大，混濁度較小故氣温與水温只在上午九時相接近而已。其他則水温均高於氣温。

水温與溶氧量的週日變化均有顯著或極顯著之正相關，此與物理學上的觀點相反。由於晝間因陽光的照射使水温昇高，生物體的代謝作用因而增加，藻類光合作用產生的氧氣遠超過動物的耗氧量，於下午十五時以後溶氧量下降。於 Herrmann 等〔1962〕測定鮭魚苗(Coho salmon〕連續16小時的氧氣消耗量。以早上未進食前最少，於下午至旁晚最大，約增加最少時的80%甚至於 200%，以後則有顯著的下降。故十五時以後除了光合作用減少外，同時也可能因虱目魚的氧氣消耗激增所至。黃英武〔1963〕所述氣壓於六月十八日從十二時至十九時劇烈下降，且降得甚低故溶存氧量變化劇烈。經筆者多次重複測定結果證明其所得的資料，溶氧量的下降實因水温的劇烈下降。

於圖二兩池混濁度 77 JTU 與 240 JTU 所得溶氧量的週日變化，混濁度較大者溶氧量較低。又於表三所示連續兩天上午九時的溶氧量與水温因日照量較多而較高。然於混濁度大而池水呈褐色的則有例外，如七月廿五日的七號池，九月卅日的六號池，及十月廿八日的六號池。筆者認爲日照量多促進浮游動物與魚類之耗氧量，而使溶氧量低於日照量較少者。於八月廿三日上午五時四五分至六時半下一陣 12mm 小雨，又於八點至九點間有0.2小時的陰天，故雖然日照時間的總和較翌日爲長，其溶氧量反而略低。溶氧量除與日照量關係外，還有當時藻床量的多寡。藻床量與溶氧量兩者間有顯著之正相關。

虱目魚爲熱帶與亞熱帶之温水魚，其能活動的温度介於11.0～41.5°C。據 Allee〔1949〕一般冷血動物能活動的温度範圍爲6～35°C. Leathes & Paper〔1925〕謂動物對於高温的忍受力受其體內脂肪質的影響大於蛋白質的影響，含有較多油質肪脂者對於低温的忍受力較大，含較多固體性質的脂肪者則對高温的忍受力大。虱目魚的腹腔壁上介於黑色腹膜與膜肌之間有一層半固態狀的脂肪層，此罕見於其他養殖魚類，虱目魚對高温的忍受力較强高温界限達42.7°C.據 Fry 等〔1942〕金魚〔*Carassius auratus*〕的高温界限爲 41.0°C。據 Doudoroff〔1942〕對海中綠魚〔*Girella nigeicans*〕的高温界限爲31.4°C。據繆端生〔1966〕吳郭魚〔*Tilapia mossambica*〕的高温界限則約爲 41.0～42.8°C與虱目魚甚接近。對於低温的忍受界限虱目魚爲 8.5～9.5°C，比一般魚爲高。據繆端生〔1966〕吳郭魚的低温界限爲6.8～8.0°C。據 Doudoroff〔1942〕海中綠魚的低温界限爲 5°C。一般學者認爲在高温時魚致死的原因常爲溶氧的缺少窒息而死。於虱目魚的實驗中測得42.7°C 時之溶氧濃度爲 1.5 ml/l，比其致死濃度的溶氧量還高故確實因高温熱死。據 Allee〔1951〕所述動物適應力，最高温度，最低温度與最適温度三者之間，最適温度往往接近最高温度。虱目魚之實驗結果也是如此。

虱目魚的抗鹽性較其他虱目魚池中的雜魚爲强，此魚能活在鹽度高達70‰的池水中。對低鹽度也極能適應，從 36‰ 的池水中移入自來水中可繼續生活。於實驗所得魚苗的平均死亡鹽度爲

108.6‰。

Viswanathan & Tampi (1952)對虱目魚幼苗在溫度介於28～31°C時的耗氧量得一方程式：$Q=1.829 \cdot W^{0.8342}$ Q 爲氧氣消耗量（cmm） W爲魚體重（mgm）每小時的消耗量， 由於其所用的材料非常小，其體長（全長）介於16與 40mm 之間，而其所用的水爲自來水故無從比較。照理論講；同一重量而個體數越多者即體積較小表面積較大，耗氧量也較多，本究研所得的結果却相反。此魚之致死濃度很低約在0.11～0.25 ml/l 之間。

虱目魚的消化道極長，通常均爲體長的倍數。此魚之口器與鰓耙的構造依 Lagler （1962）所述應屬於吃浮游生物與底棲生物的 "Grazers"。胃含物的觀察結果；在深夜與黎明時分攝食浮游動物最多。依浮游動物之習性黎明前與傍晚後各有一段浮游動物的垂直上昇活動之時間，以胃含物所得的觀察結果足以證明此魚有攝食浮游生物的習性。據山村牧夫（1942）也曾提到夜間虱目魚攝食動物性浮游生物較多而植物浮游生物較少。至於一天總食量的多少至今沒有比較正確而可靠的測定法。筆者曾依 Darnell 與 Meierotto（1962）的方法測定虱目魚的消化速率，在此魚捕獲後因受驚嚇而於六小時內相繼死亡而消化道仍存多量的食物，故此法不能應用於虱目魚。虱目魚的食物因生活環境的改變而異， 通常以 *Lyngbya* 爲主食， 也有以 *Chroococcus* 或腐敗物爲主食。此魚消化道的內含物與體重之百分比，水溫和溶氧量的週日變化如圖三。溫度高溶氧量多攝食量也大。

虱目魚體長與體重之關係由五、六月所捕獲的資料求得$W=0.0000009811\,(FL)^{3.07299316}$ 以此所畫出的曲線與 Viswanathan and Tampi（1952）的曲線相似而斜率略大，因其所用的資料爲海濱所捕獲的虱目魚比蓄養的虱目魚較瘦故其斜率較小。

虱目魚池的池水溶氧量週日間的變動很大。依 Harvey（1945）的海水飽和溶氧量表推知在五、六月之資料其最高溶氧量可高達飽和濃度的三倍左右，九、十月也在飽和溶氧量以上。夜間則溶氧量經常極低。據 Herrmann 等 （1962）， Fisher（1963） 及 Doudoroff & Warren（1962)測寬口鱸魚苗對食慾之最適合的溶氧濃度爲飽和溶氧濃度，太高或太低均會抑制魚體的食物消耗與成長，本研究爲溶氧量高時並無法證明此對食慾有不良影響。據 Doudoroff （1957）所述魚在太低的溶氧量3 mg/l左右經過長時期易引起死亡。如七月廿七、八日所得的資料；三號、四號、五號池的溶氧量極低故四號池於七月卅一日死 19尾，三號池至八月五日死 689尾，翌日又死12尾，五號池以後好轉而無死魚的現象。此證明虱目魚能忍受低溶氧濃度一段長時間後才死亡。Doudoroff（1957）述及低溶氧接近於 1 mg/l 或低於此濃度者對於數種魚可以忍受一段長的時間。於七月廿八日四號池的溶氧量從 0 時（24:00）至上午九時所測者均爲零 ，而虱目魚只浮頭而不致於死亡。 Doudoroff（1962）又述週日間很高與很低的溶氧濃度變化對魚的攝食與生長有良好的生理現象。於五月卅至卅一日最高者爲 14.78mg/l，夜間最低者爲0.36ml/l，而其消化道內所含食物的多寡有明顯的變化。反之十月廿七日至廿八日；五號池最高溶氧量爲 5.39ml/l.，最低溶氧量爲 1.20ml/l 六號池最高溶氧量爲 4.10 ml/l ，最低溶氧量爲 0.00 ml/l. 如此低的溶氧量而變動幅度又小，影響至其消化器官的功能。則魚一天廿四小時內消化道均有食物。而其所含的重量與體重的百分比也隨着溶氧量的多寡而變動。此時魚體肥滿度爲14.0247 ± 0.72615比五，六月所捕獲的魚體肥滿度 14.7238 ± 1.2683 較小，經 t 值測驗兩者有顯著的差異，即十月所捕獲的虱目魚消瘦得多。其所以瘦的原因除溫度較低與食物缺少外，最主要之原因爲溶氧量的減少影響及消化率的降低所致。 Herrmann 等 （1962）論及食物消耗量少至幾乎只足够維持現有體重所需要的消耗量，也許不能增加新的體素。但消化效力與同化效力可因食物消耗率的減少甚至溶氧量的減少而調整。維持現有體重所需要的食物也許會因溶氧量的缺少而增減。Stewart

等〔1967〕對於寬口鱸之實驗結果 4mg/l 以下的溶氧濃度時其食物轉化率會降低。由於氧氣的缺少而使鰓的活動增加，便需要更多的能量；同時食物的消化與同化作用或代謝作用也因此而減少食物的轉化效力。Bouck 與 Ball〔1965〕所述水質汚染使溶氧量降低至 4mg/l 以下可使魚血清蛋白的組成改變。在其實驗中以藍鰓魚〔Blue gill〕，寬口鱸魚〔Largemouth bass〕與黃鯰魚〔Yellow bullhead〕三種魚類在低溶氧量會吐出已吞入腹中長達 12 小時的食物，此食物僅略被消化而已，此證明低溶氧量對消化有不良的影響。於十月廿七～八日所採得消化道內含物觀察的結果悉知食物在消化道內停留甚久，並顯出消化不良而略有腐敗的現象。

五、摘　　要

1.氣壓變化與虱目魚池溶氧濃度無關。

2.氣溫與虱目魚池水溫間的差異因水深而增加。

3.週日間的溶氧濃度隨着溫度而增加。

4.混濁度較高者則溶氧濃度較低。

5.日照量多則溶氧量高。

6.溶氧量週日間的變化隨各測定時間而有極顯著的差異。

7.底藻的燒失量與溶氧濃度均因飼養日期愈久而愈少。

8.底藻的多寡與溶氧量有顯著的正相關。

9.虱目魚苗的致死溫度；高溫爲42.7°C以上，低溫爲8.5°C以下。

10.虱目魚的耗氧量因魚體的大小而有異，致死濃度約 0.11ml/l 至 0.25ml/l 之間。

11.虱目魚苗的抗鹽力極强，其致死鹽度大約爲108.6±7.82‰。

12.虱目魚之消化道爲體長的倍數，大魚較小魚的倍數爲大。

13.虱目魚的消化系統屬於攝食底藻與浮游生物者。夜間或清晨幾乎全攝食動物性浮游生物，晝間則主食 *Lyngbya*；於養殖期末主食 *Chroococcus*。

14.消化道內含物與體重的百分比和溫度的週日變化有顯著的正相關。

15.消化道內含物與體重的百分比經 Bliss 表轉化後隨時間的不同而有顯著的差異。

16.於五月所得的資料：溶氧量，水溫和消化道內食物與體重之百分比有正相關。

17.於五、六月所得的資料，虱目魚體長與體重的關係式爲 $W=0.0000009811\cdot(F.L.)^{3.07299316}$。

18.五、六月虱目魚的肥滿度較十月的略大，各爲14.7238±1.2683與14.0247±0.7262，兩者之間有顯著的差異。

19.於十月測得的溶氧量之週日變化較小〔0.00～5.36ml/l〕終日消化道內均有內含物。其含量之多寡與溶氧量的多寡有一致的趨勢。於五月溶氧量的週日變化大(0.36～14.78ml/l〕時，溶氧量 3.2ml/l 以下則食量極少以上則食量大增。

20.如七月資料所得，溶氧太低的魚池則虱目魚易於死亡。

六、誌　　謝

本文研究期間承蒙　繆端生教授的懇切指導和策勵，匡正糾謬，詳加改訂。並獲梁主任潤生教授、葉樹藩教授、林書顏兼任教授、鄧火土兼任教授、廖文光副教授、童逸修先生的多方督促，以及省水產試驗所臺南分所全體員工的從旁協助，或提供資料，或時予鼓勵，惠我良多。同時，

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八、英文摘要

Some Aspects of Milkfish Ecology

Summary

1. There is no correlation between the atmospheric pressure and dissolved oxygen concentration in milkfish pond.
2. The water temperature of shallow milkfish ponds is more easily influenced by air temperature than that in deeper ponds.
3. The diurnal fluctuation of dissolved oxygen concentration follows quite closely the water temperature.
4. The higher the water turbidity, the lower the dissolved oxygen concentration.
5. The greater the sum of the diurnal duration, the higher the concentration of the dissolved oxygen.
6. The dissolved oxygen concentration varies with the time of the day.
7. Bottom algae decreases with the advance of culture period, and so does the dissolved oxygen concentration.
8. The correlation of dissolved oxygen and abundance of bottom algae is significantly positive.
9. The lethal temperature for juvenile milkfish lies above 42.7°C and below 8.5°C.
10. The oxygen consumption of milkfish varies according to body weight; the lethal concentration is 0.11-0.25 ml/l.
11. Milkfish is euryhaline; the maximum lethal salinity for juvenile milkfish is 108.6±7.82 per mille.
12. The ratio of the alimentary canal and the body length of milkfish is smaller in juvenile than in adult.
13. The digestive system of milkfish is adapted essentially for benthic alga and plankton feeding. The food of milkfish varies with time; during night and early morning the milkfish feeds almost all on zooplankton. In day time it takes essentially *Lyngbya* and in the later part of the culture period *Chroococcus*.
14. The weight of the content of the digestive tract as percentage of the body weight is significantly correlated to the diurnal fluctuation of the water temperature.
15. The above percentage after transformed into degrees of angle by Bliss, shows a significant difference at different times of the day.
16. Data obtained in May show that dissolved oxygen concentration, water temperature and alimentary content in percentage of the body weight are positively correlated.
17. The relationship of body weight and body length (fork length) of milkfish

calculated from the data of May and June can be expressed by the equation: $W=0.0000009811 \bullet (F.L.)^{3.07299316}$

18. The degree of well being of milkfish in May and June is better than that in October, i. e. 14.7238 ± 1.2683 against 14.0247 ± 0.72615 respectively, this difference being statistically significant.
19. When the range of oxygen concentration is small during the month of October the alimentary canal content varies little showing poor digeston due to insufficient supply of O_2. But when the range of O_2 concentration is wider (for example between 0.36 and 14.78 ml/l)the content of alimentary canal varies to a great extent, signifying that the fish almost stop eating at low level of O_2 content and begin to eat vigorously and digest rapidly at higher level of O_2 concentration.
20. As shown by data obtained in July, the milkfish is apt to die gradually because of low dissolved oxygen concentration.

ALGAE OF TAINAN MILKFISH PONDS

By

Chang Tsang-pi

Department of Botany, National Taiwan University

In studying milkfish feeding, it is necessary, first of all, to identify the species of algae that are thriving in the ponds and that are found in the digestive tract of the milkfish. By comparison of the data obtained in this manner, the types of algae as food of preference to the milkfish can be determined. Lin[1] in reviewing the feeding habit of milkfish states that seven species of Cyanophyta, six species of Bacillariophyta and a few Chlorophyta were found in the stomach of milkfish by Yamamura[2], and Schuster[3] listed 20 species of Cyanophyta, 14 species of Bacillariophyta and 7 species of Chlorophyta in the Indonesian milkfish ponds. These findings together with the stomach content analysis hint to the possibility that milkfish prefers Cyanophyta and Bacillariophyta to any other types of algae and microfauna. Among the algae identified by Schuster, *Chroococcus turgidus*, (Kütz) Näg., *Lyngbya aestuarii* Mert., *Microcoleus chtonoplastes* Thuret, *Cyclotella meneghinian* Kütz. and *Nitzschia closterium* W. Smith, are also common in the Tainan milkfish ponds.

The salinity of the Tainan milkfish ponds ranges between 30 to 34 per mille most of the year. However, there are exceptions. During the dry season, salinity may rise to as high as 70 per mille due to continuous evaporation, and in the summer, heavy rain and typhoon may bring down the salinity of the milkfish ponds to below 15 per mille. As the Tainan milkfish ponds get their water from the canals which lead to the open sea and at the same time receive freshwater from the rice fields and city sewers, it is only natural to find both marine and freshwater algae therein. But, in reality freshwater forms are rare probably due to the high salinity of the water in the milkfish ponds.

Green algae usually constitute an active part of the algal community of the milkfish ponds. The motile unicellular algae such as *Platymonas* and *Chlamydomonas*, the non-motile unicellular alga, *Chlorella*, and also the *Euglena* and *Eutreptia*, however, appear only when the ecological conditions are favorable. The abundant growth of green algae and diatoms increases the turbidity of the water which hinders the development

1. Lin, S.Y. 1968. Milkfish farming in Taiwan. Fish Culture Report, No. 3. Taiwan Fisheries Research Institute.
2. Yamamura, M. 1942. Milkfish culture (unpublished, in Japanese).
3. Schuster, W.H. 1952. Fish-culture in brackish-water ponds of Java. Indo-Pacific Fisheries Council Special Publications No. 1. 143 pages.

of bottom algae, due to the reduction of light penetration. This condition is unfavorable for milkfish production. Non-motile algae such as *Tetraedron*, *Tetrastrum*, *Selenastrum*, *Kircheriella* and *Scenedesmus* are sometimes found in the water-supply canals after heavy rainfall. As they are freshwater species drifting in with the run-off water they cannot remain in the canal nor thrive in the salt-water ponds.

Enteromorpha and *Chaetomorpha* are the most common and abundant genera among the Chlorophyta in milkfish ponds of the Philippines[1], but both are not common in the Tainan milkfish ponds. *Enteromorpha compressa* grows abundantly in tufts on the cement banks of canals just at the water line from April through the summer, but it does not grow on the muddy banks of the milkfish ponds. Both *Enteromorpha* and *Chaetomorpha* first attach themselves onto some substrata in the running water, then they can float on the water surface or submerge in the shallow milkfish ponds[1]. *Enteromorpha compressa* sometimes floats here and there in small groups in the milkfish ponds and in the canals.

Due to my tight schedule of work the phase of study on the stomach content was not undertaken. So, the present report is only the result of a preliminary study carried out from September 1967 to June 1968, during which period algal samples were collected twice a month from the Tainan milkfish ponds for identification.

The algae found in the Tainan milkfish ponds can be grouped into five divisions, namely Cyanophyta, Chlorophyta, Euglenophyta, Pyrrophyta and Chrysophyta (Chrysophyceae, Bacillariophyceae).

Algae of Euglenophyta (e.g. *Euglena* and*Eutreptia*) and of Pyrrophyta (e.g. *Gymnodinium*) as plankters are abundant in the Tainan milkfish ponds. Chlorophyta and Bacillariophyceae are also common, while Cyanophyta are the most important algae in bottom community.

DIVISION CYANOPHYTA

CLASS MYXOPHYCEAE (Blue-green Algae)

Class Myxophyceae is divided into three orders, namely Chroococcales, Chamaesiphonales and Hormogonales. Cells belonging to Chamaesiphonales have not yet been found in the Tainan milkfish ponds.

Key to Tainan orders

1. Cells coccoid, solitary or united with many cells into a colony .... Chroococcales
1. Cells filamentous, with many filaments in tuft-like colony, or solitary .... Hormogonales

Order Chroococcales

There are six genera found in the Tainan milkfish ponds

1. Villadolid & Villaluz, Popular Bull, 30, Dept. Agr. Nat. Resou., Philippines.

Key to Tainan genera

1. Plants unicellular or forming a colony of 2-8 (rarely up to 32) cells 3
1. Plants composed of many cells in a common matrix or aggregated plant mass........ 2
   2. Cells aggregated closely into a mass, ball-like, solid or hollow .... *Microcystis*
   2. Cells arranged in pairs and in rows .... *Merismopedia* (in part)
   3. Cells arranged in pairs and in rows; colony plate-like...*Merismopedia* (in part)
   3. Cells arranged seldom in pairs; colony ball-like, solid 4
      4. Colony sheath absent (or invisible)........ *Synechocystis*
      4. Colony sheath present 5
   5. Cells spherical (according to Tainan alga), within watery matrix .... *Aphanocapsa*
   5. Cells hemispherical to angular, within thin laminate sheaths 6
      6. Cell contents always having pseudovacuoles........ *Chroococcus*
      6. Cell contents homogeneous .... *Pleurocapsa*

Microcystis Kützing 1833

Colony free-floating, or sedentary, with numerous spherical cells irregularly or ovately arranged in a copious matrix, some perforate or laceolate; cell contents pale or bright blue-green, or other colors, sometimes with pseudovacuoles.

One species has been found in the Tainan milkfish ponds.

Microcystis flos-aquae (Wittr,) Kirchner

Desikachary, 1959, Cyanophyta, p. 94, pl. 17, fig. 11; pl. 18, fig. 11.
Geitler, 1925, in Pascher's Süsswasserflora 12:60, figs. 41-2.
Lindau, 1914, Die Algen I, p. 14, fig. 13.
Tiffany & Britton, 1951, Algae of Ill., p. 336, pl. 91, fig. 1055.

M. aeruginosa.

Colonies roughly spherical, ellipsoid, or somewhat elongate or often squarish in optical section, not clathrate, with indistinct colonial mucilage; cells 3-7 μ in diameter, spherical, with pseudovacuoles.

Planktonic in lakes, tanks and ponds, often as a water bloom.

Tainan-Very rare.

Merismopedia Meyen 1839

Cells spherical, always in pairs, forming a flat plate, composed of one layer of many cells arranged in rows both transversely and longitudinally, enclosed in a common gelatinous, homogeneous matrix; colony quadrangular or with margins convolute; cell contents always homogeneous.

Three species have been found in the Tainan milkfish ponds.

Key to Tainan species

1. Cells more than 2 μ in diameter .... *M. punctata*
1. Cells less than 2 μ in diameter.. 2
   2. Colony always 4 celled.. *M. minima*
   2. Colony always 8 celled.....................................*M. tenuissimum*

Merismopedia minima Beck

Desikachary, 1959, Cyanophyta, p. 154, pl. 29, fig. 11.
Geitler, 1925, in Pasher's Süsswasserflora 12:106.

Cells pale blue-green 4 to many in small colonies, 0.5-0.6 μ broad, freely swimming, colony in group of four cells 2-3 X 3 μ.

Planktonic in artifical tank (India)

Tainan-Rather common.

Merismopedia punctata Meyer

Desikachary, I959, Cyanophyta, p. 155, pl. 23, fig. 5 & pl. 29, fig. 6.
Geitler, I925, in Pascher's Süsswasserflora I2:106, fig. 125.
Lindau, 1914, Die Algen, I, p. 15.
Prescott, 1951, Algae of Great Lakes areas, p. 459, pl. 100, fig. 10.

Colonies small, 4-64 cells, about 60 μ broad; cells not closely packed, spherical or ovoid, 2.5-3.5 μ broad, pale blue-green.

Plankton in stagnant and flowing waters or among other algae; in brackish ponds.

Tainan-Rather common.

The samples always present 8 cells in a colony, scattered among Tainan plankton; closely related to *Merismopedia glauca* (Ehr.) Näg.

Merismopedia tenuissimum Lemm.

Desikachary, 1959, Cyanophyta, p. 154-5, pl. 29, fig. 7 & pl. 30, figs. 8, 9.
Geitler, 1925, in Pascher's Süsswasserflora 12:106, fig. 123.
Lindau, 1914, Die Algen I, p. 16, fig. 16.

Prescott, 1951, Algae of Great Lakes areas, p. 459, pl. 100, fig. 17.
Tilden, 1910, Minnesota Algae I, p. 45, pl. 2, fig. 37.
Wille, 1903, Nordisches Plankton 20:7.

Cells pale blue-green, closely packed in colonies of 16-100 cells, subspherical, 1.3-2 μ broad, sometimes individual cells having distinct mucilaginous envelopes.

In plankton; floating in brackish waters; very common in acid habitats.

Tainan-Rare, only found in one site in February.

Synechocystis Sauvageau 1892

Cells spherical, solitary or forming a small colony, without visible individual cell sheath; cell simple division.

One species found in Tainan milkfish ponds. *Synechocystis* cells might have been confused with *Mesmopedia* or *Microcystis* because of their similarity.

Synechocystis aquatilis Sauvageau

Desikachary, 1959, Cyanophyta, p. 144-5, pl. 25, fig. 9.
Geitler, 1925, in Pascher's Süsswasserflora 12:110, fig. 130.
Tiffany & Gardner, 1951, Algae of Ill., p. 336, pl. 91, fig. 1056.
Tilden, 1910, Minnesota Algae I, p. 10, pl. 1, fig. 10.

Cells 4-6 μ in diameter, pale blue-green, usually with some pseudovacuoles in cell contents; solitary or in groups of two.

Planktonic in stagnant waters; in slightly brackish ponds.

Tainan-Common.

Sample cells in groups of two with few pseudovacuoles in each cell are scattered among marine *Chlorella* and other algae.

Aphanocapsa Nägeli 1849

Cells spherical, or hemispherical in pairs in a common colored matrix; cell contents pale blue-green, homogeneous or finely granulate. One species is found in a Tainan pond.

Aphanocapsa littoralis Hansgirg

Desikachary, 1959, Cyanophyta, p. 131, pl. 21, fig. 1.

Colony amorphous, without any definite shape, mucilaginous, blue-green or yellowish; cells spherical to subspherical, 4-6 μ in diameter, single or densely or loosely aggregated into a thallus or plant mass.

Planktonic in Indian Ocean; among other coastal algae; in brackish waters.

Tainan-Rare.

Chroococcus Nägeli 1848

Cells spherical, half-moon shaped or angular, forming various shapes, 2-64 or more celled colony; gelatinous matrix hyaline, homogeneous or laminate, cells blue-green or other colored, granulate, not vacuolate. Cell division and fragmentation.

Only one species is abundantly found in the Tainan milkfish ponds.

Chroococcus turgidus (Kütz.) Nägeli

Desikachary, 1959, Cyanophyta, p. 101-2, pl. 26, f. 6.
Geitler, 1925, in Pascher's Süsswasserflora Heft 12, p. 77, f. 71.
Hirose, 1937, J. Jap. Bot. 13:497, f. 9.
Prescott, 1951, Algae of Great Lakes areas, p. 450, pl. 100, f. 19.
Setchell & Gardner, 1919, Univ. Calif. Publ. Bot., 8(1):10.
Tilden, 1910, Minnesota algae I, p. 5-6, pl. 1, f. 3.
Umezaki, 1961, Mem. Coll. Agr. Kyoto Univ., 83:63-4, pl. 1, f. 1.
Yoneda, 1937, Acta Phytotax. Geobot. 6:187, f. 14

Plants colonial, spherical, lobed, or more or less angular from compression, solid or less hollow; cells spherical or ellipsoid when young, or angular by compression, singular or associated in colonies of two, four, rarely eight; sheath thick, often somewhat lamellate, always hyaline; cell wall thin, indistinct; cells 13-25 rarely 40 μ in diameter; cell contents vivid blue-green, but brownish and granulate when old, always homogeneous when young.

Growing in brackish water along high-tide line; common among various algae in lagoon; planktonic in mangroves; on slimy rocks and piers; terrestrial on moist rocks; common in many lakes and bogs. Tychoplankton.

Tainan-Common

This alga seems to be a species living in various habitats, marine and freshwater, even in hot springs and on soil. Cells in colony, mostly of 2-4, rarely more than 8. A single cell state is always comparatively larger than cells in colonies of more than two, up to 12 μ in diameter, but with sheath 12-16 μ broad. In Tainan this alga is found among the planktonic and bottom filamentous algae.

Pleurocapsa Thuret 1885

Cells spherical or nearly hemispherical in division; colony composed of many cells arranged more or less in rows; gelatinous matrix hyaline, becoming colored with age.

One species has been found in Tainan milkfish ponds.

Pleurocapsa fulginosa Hauck

Setchell & Gardner, 1919, Univ. Calif. Publ. Bot. 8(1):36-7.
Tilden, 1910, Minnesota Algae I, p. 48, pl. 3, fig. 3.

Colony forming a thin, coat-like crustose on wood or rocks, each colony 50-100 μ in diameter generally, but small one only 5-20 μ broad, with colorless membrane and homogeneous or colored cell contents.

Growing on piles; in salt water; in spas.

Tainan-Rare.

A small colony composed of 5 cells in a rounded hyaline envelope is found in Tainan ponds. It is only 8 μ in diameter.

Order Hormogonales

There are seven genera found in Tainan milkfish ponds.

Key to Tainan genera

1. Trichome solitary, with or without sheath 2
1. Trichomes many in a common sheath .... *Microcoleus*
    2. Trichome without sheath, twisted in spirals or bent regularly... 3
    2. Trichome with or without sheath, straight or bent irregularly... 4
3. Trichome unicellular .... *Spirulina*
3. Trichome multicellular .... *Arthrospira*
    4. Sheath thick, gelatinous .... *Lyngbya*
    4. Sheath thin, watery or invisible (or absent) 5
5. Trichome constricted strongly at the cross-walls; cells barrel-shaped to spherical .... *Anabaena*
5. Trichome constricted slightly at the cross-walls; cells always compressed or short, cylindrical 6
    6. Trichome without sheath; cells always compressed or cylindrical .... *Oscillatoria*
    6. Trichome with watery sheath, always invisible; cells more barrel-shaped .... *Phromidium*

Microcoleus Desmazieres 1823

Trichomes numerous and closely packed within a wide, hyaline, cylindric, mucous, open-ended sheath; apices rounded, attenuate, capitate or calyptrate.

Fragmentation by the formation of hormogonia.

One species has been abundantly found in Tainan milkfish ponds,

Microcoleus chthonoplastes Thuret ex Gomont
= *Chthonoblastus salinus* Kütz
= *Ch. Lyngbyei* Kütz.

Desikachary, 1959, Cyanophyta, p. 343, pl. 60, figs. 7-9.
Geitler, 1925, in Pascher's Süsswasserflora 12:436.
Setchell & Gardner, 1919, Univ. Calif. Publ. Bot. 8(1):86.
Tilden, 1910, Minnesota algae I, p. 155, pl. 6, fig. 27.

Filaments single, free out of algal mesh or among other algae, or forming a dull green, expanded, compact and stratified mass, made up of bundles of filaments, coiled, rarely branched, few found among other algae in the benthic community; sheath uneven, thick, cylindrical, with apex usually open, sometimes diffluent; trichome-green, nearly straight, or constricted at the cross-walls, 2.5-6 μ broad, not capitate; cells 3.6-10 μ in length.

Growing in salt marshes; on sea coasts; on brick walls; on soil with other algae in fresh-waters.

Tainan-Very common with other algae on muddy bottoms and in fish gut.

This widespread species is usually found in shallow pools, in salt marshes and prefers warm waters. It may be carried here and there by the feet of water-birds, It is one of the most important species in Tainan milkfish ponds as food for the fish, because many filaments were found in the fish gut. In general, filaments are surrounded by loosely thick sheath as a bundle that is always extended out of the sheath. Trichomes with sheath have been found in the samples also. These unsheathed trichomes could be easily treated as fragments of *Oscillatoria* or other filamentous blue-green algae.

Spirulina Turpin 1827

Trichome unicellular, spirally twisted, loose or tightly coiled, most species twisted, the spiral very regular. without tapering toward the apices, freely-floating, or among other algae.

Three species have been commonly found in Tainan milkfish ponds.

Key to Tainan species

1. Spirals tightly coiled .... *Sp. subsalsa*
1. Spirals loosely coiled.. 2
    2. Distance between the turns less than 6 μ .... *Sp. major*
    2. Distance between the turns more than 15 μ .... *Sp. laxissima*

Spirulina laxissima G.S. West

Desikachary, 1951, Cyanophyta, p. 196, pl. 36, fig. 5.

Geitler, 1925, in Pascher's Süsswasserflora 12:347, fig. 415.
West, 1907, Journ. Linn. Soc. (London) Bot. 38:78, pl. 9. fig. 6.

Trichome 0.7-0.8 μ broad, blue-green; spirals very loose, but regular, 4.5-5.3 μ broad; 17-22 μ distant from each other, apical cells rounded, obtused.

Tainan-Very rare.

Fresh-water algae (India).

Spirulina major Kützing

Geitler, 1925, in Pascher's Süsswasserflora Heft 12, p. 347.
Lindau, 1914, Die Algen I, p. 28, fig. 38.
Prescott, 1951, Algae of Great Lakes areas, p. 480, pl. 108, fig. 11.
Setchell & Gardner, 1919, Univ. Calif. Publ. Bot 8(1):56-7, pl. 1, fig. 5.
Tiffany & Britton, 1951, Algae of Ill., p. 354, pl. 97, fig. 1124.
Tilden, 1910, Minnesota algae I, p. 87-8, pl. 4, fig. 46.
Umezaki, 1961, Mem. Coll. Agr. Kyoto Univ., 83:65, pl. 10, fig. 8.

Trichomes pale blue-green, more or less flexuous, 1-1.7 μ in diameter, twisted in a regular and loose spiral, with a distance of 2.7-5 μ between the turns.

Forming a very slippery but firm brownish black stratum and also scattered among other algae; in warm sulphur springs. It is commonly found among *Oscillatoria* sp. on soil moistened by water or on muddy shores.

Tainan-Common, found in plankton and on bottom community.

The alga found in Taiwan spas is represented by two forms, both tightly and loosely coiled on a common plant, but the one from Tainan samples is only one form. The tightly coiled form is considered a subspecies, namely Sp. *subsalsa*.

Spirulina subsalsa Oersted

Desikachary, 1959, Cyanophyta, p. 193-4, pl. 36, figs. 3,9.
Prescott, 1951, Algae of Great Lakes areas, p. 480, pl. 108, fig. 14.
Tilden, 1910, Minnesota algae I, p. 89-90, pl. 4, fig. 49.
Umezaki, 1961, Mem. Coll. Agr. Kyoto Univ., 83:66, pl. 10, fig. 9

Trichome both closely and loosely spiralled in the same individual, 1-2 μ in diameter; spirals 3-5 μ wide, often tightly coiled, always entangled with other algae or isolated.

Growing mixed with other minute forms or among other algae; in spas; on the roots of mangroves; on rocks on shore; growing in cavities with brackish water; floating or expanding or expanding on pond-bottom.

Tainan-Common, planktonic or benthic in milkfish ponds; in fish gut.

The samples are very similar to the description of Setchell and Gardner 1919, as its forma *oceania* (Crouan) Gomont. Trichomes only 1 μ in diameter, somewhat straight in outline, twisted into regular, tightly coiled spirals. This forma grows especially well in brackish waters. In India, large variations of trichomes of various diameters have been reported, but the Tainan samples are of only one size.

Comparing *Sp. subsalsa* with *Sp. major*, the latter can be taken apart by its lax spirals while the former is tightly coiled.

Arthrospira Stizenberger 1852

Trichome multicellular, loosely spiralled, without sheath; cells quadrate or a little longer than wide; cross-walls sometimes granulate.

The genus is very similar to *Spirulina*, in which the trichome is unicellular.

One species has been found in Tainan milkfish ponds.

Arthrospira gomontiana Setchell
=*Spirulina gomontiana* (Setchell) Geitler

Geitler, 1925, in Pascher's Süsswasserflora Heft 12, p. 344.
Prescott, 1951, Algae of Great Lakes areas, p. 481, pl. 108, fig. 21.
Tiffany & Britton, 1951, Algae of Ill., p. 354, pl. 97, fig. 1126.
Tilden, 1910, Minnesota algae I, p. 86.

Trichomes 2.5-3 μ in diameter, regularly twisted into a rather loose spiral about 6 μ in diameter, the distance between the turns being 16-18 μ; apical cells not at all capitate; cells 4-5 μ long; cross-walls invisible, with few granules; cell contents usually showing large pseudovacuoles, light blue-green.

The alga is considered as *Spirulina gomontiana* by some algologists.*

Growing in verdigris-green patches, on the pool (India). Tychoplankter. Rare.

*Setchell, 1895, Bull. Torr. Bot. Club 22:430.
Tilden, 1910, Minnesota algae I, p. 86.

Lyngbya C.A. Agardh 1824

Trichomes solitary, with obtused or attenuated ends, sometimes constricted at the cross-walls, with tubular sheath, firm, hyaline or colored with age; filaments unbranched, straight, bent or twisted, solitary or meshed together, or epiphytic; cell contents homogeneous, granulate, or variously colored. Fragmentation by formation of hormogonia.

Four species have been found in Tainan milkfish ponds.

Key to Tainan species

1. Cross-walls usually pellucid·································· *L. lagerheimia*
1. Cross-walls not pellucid ··· 2
   2. Trichome scattered here and there, coarse granules ··· *L. confervoides*
   2. Trichome granulated always at the cross-walls or in every cell, 3
3. Cross-walls granulated, a layer of dense granules on either side·· *L. aestuarii*
3. Cross-walls granulated, few granules ························· *L. semiplena*

Lyngbya lagerheimia (Möbius) Gomont

Desikachary, 1959, Cyanophyta, p. 290-1, pl. 48, fig. 6, & pl. 53, fig. 2.

Geitler, 1925, in Pascher's Süsswasserflora Heft 12, p. 397, figs. 500, 506.

Lindau, 1914, Die Algen I, p. 32.

Prescott, 1951, Algae of Great Lakes areas, p. 501, pl. 111, figs 5, 6.

Tilden, 1910, Minnesota algae I, p. 111-2, pl. 5, figs. 22, 23.

Plant solitary or entangled with other algae; filaments bent and twisted, sometimes spiralled, occasionally straight, sheath distinct but thin, hyaline; trichomes pale aeruginous, apex not attenuate, but broadly rounded or convex, without calyptra; cross-walls not constricted, without granules, usually pellucid; cells 1.5-2.5 μ broad, 1.3-2.5 μ long; cell contents with or without a single granule on either side of the cross-wall; sheath thin, colorless; filaments 2-2.5 μ wide.

Growing on or among other *Lyngbya* (i.e. *aestuarii* and others); in shallow water of lakes and in roadside ponds; in brackish water; in small pool near the spray and on rocks in running water; in spas.

Tainan-Common among other filamentous algae; floating freely.

The sample from Tainan is quite similar to the Japanese plant, L. *pellucida* (Umezaki, 1955, Bot. Mag. Tokyo 68:68, fig. 1), because pellucid cross-walls have been identified easily except the presence of few coarse granules in cell contents. The homogeneous filaments have been definitely observed in some Tainan samples, they should be regarded as the young form of *L. lagerheimia*.

Lyngbya confervoides C. Ag.

Holmes, 1895, J. Linn. Soc. Bot. 31:257.

Tilden, 1910, Minnesota Algae I, p. 119, pl. 5, fig. 39.
Umezaki, 1961, Mem. Coll. Agr. Kyoto Univ. 83(8):53, pl. 8, fig. 2.

Filaments decumbent and entangled at the base, ascending above, elongate, straight, almost rigid, 12-30 μ in diameter; sheaths hyaline, homogeneous, later becoming thick, lamellate and rough on the surface, up to 6 μ in thickness; trichomes olive-green or blue-green, 9-25 μ mostly 10-16 μ broad, apex not attenuate; cross-walls not constricted, generally granulated, rarely not; cells 2-4 μ long; cell contents granulated; apical cells rounded, without calyptra.

Cosmopolitan. Growing on rocks in the lower or upper littoral belt, some in rock depressions in the supralittoral belt. This world-wide species is especially common in the warmer seas. It has been commonly found along the southern coasts of Japan, and only found on the northern coasts in summer (Umezaki, 1961). Sea shores or mud; in culture from salt basin.

Common in Tainan.

Gomont (1892, in Umezaki) placed *L. atrovirens* and *L. atropurpurea* under the name of *L. confervoides*. They are synonyms.

In Tainan samples, the large, dark granules are scattered here and there on trichomes. Filaments meshed themselves into net-like or plant mass, growing on the pond bottom.

Lyngbya aestuarii (Mertens) Liebmann

Desikachary, 1959, Cyanophyta, p. 305-8, pl. 52, fig. 8; pl. 51, figs. 9, 10.
Geitler, 1925, in Pascher's Süsswasserflora Heft 12, p. 436.
Lindau, 1914, Die Algen I, p. 35.
Prescott, 1951, Algae of Great Lakes areas, p. 499, pl. 111, fig. 8.
Setchell & Gardner, 1919, Univ. Calif. Publ. Bot. 8:78
Tiffany & Britton, 1952, Algae of Ill., p. 339, pl. 92, fig. 10.
Tilden, 1910, Minnesota algae I, p. 120-3, pl. 5, figs. 40, 41,
Umezaki, 1961, Mem. Coll. Agr. Kyoto Univ., 83:49, pl. 8, fig. 1.

Plant mass widely expanded, forming a dark green wool-like layer on the pond bottom or forming a small piece of blackish floccus where the white-colored fungi grow well upon the dying alga. It is the most important component in the bottom algal community, assumed to be the main food for milkfish.

Filament long, flexuous, densely interwoven, occasionally falsely branched, somewhat straight and loosely entangled, but most densely crowded to erect fascicles or triangular tufts; observed separately out of water with some mud substrata; sheaths around trichomes colorless, very thin, but roughened on the surface, becoming lamellate when old, pale or yellowish brown, sometimes in other colors; empty sheaths always extended very long, strongly twisted and entangled with other filaments; trichome blue-green, or olive green, 8-24 μ broad, not constricted at the cross-walls, always extended out of the sheath; cells 2.7-5.6 μ long only, compressed in shape; cell contents finely granular, mostly with a layer of coarse granules near to or at the cross-walls; apex of trichome slightly tapering and slightly capitate, truncate, rarely conical acute, apical cells always slightly thickened with outer membranes; cells in general 8-24 X 2.7-5.6 μ.

In brackish pond; very common in lagoon and salt marsh and in salty pool; abundant in quite brackish water, forming felt-like sheets; in mineral water; in mats on stones; in quite fresh-water; in old clay-pit; planktonic lakes, ponds, rivers and seas; on soil and epiphytic on sponges; in spas.

This alga is a species of the tropical warm waters, but it always invades into cooler waters and becomes widespread. Living in different habitats and under various temperatures, they adapt themselves to the changes of environmental factors by becoming polymorphic; therefore, some new varieties and forms of this plant make identification difficult.

Samples collected from Tainan were polymorphous, very abundant

Lyngbya semiplena (C. Ag.) J. Ag.

Desikachary, 1951, Cyanophyta, p.315, pl. 49, pl. 52, fig. 7.
Tilden, 1910, Minnesota algae I, p. 118-9, pl. 5, fig. 38.
Umezaki, 1961, Mem. Coll. Agr. Kyoto Univ., 83:51-2, pl. 7, fig. 4.

Filaments decumbent and entwined at the base, above flexuous, 5-12 μ broad, sheath hyaline, somewhat muscous, when young homogeneous, becoming lamellate with age, up to 3 μ in thickness; trichomes blue-green, 5-12 μ broad, generally 7-10 μ; apical cells slightly attenuate or sometimes not, but rounded; cross-walls not constricted, granulate or not; cells 2-3 μ long, 1/3-1/6 as short as the diameter of the cell; apical cell with a flat conical or round calyptra, but thin; plants caespitose, extensive, muscous, commonly dark yellowish-brown.

Cosmopolitan. Growing on rocks in the upper or lower littoral belt. or in supralittoral belt, sometimes associated with other algae or entangled on larger algae.

This alga is very similar to *L. aestuarii*. They grow together, but the latter is less in number. On the other hand, while the latter is predominant in one site, the former may disappear altogether, a condition possibly due to difference in growth period.

Anabaena Bory 1822

Trichomes free-floating, solitary or aggregated within a thin mucous sheath, straight or bent, spiral or irregularly twisted, with attenuate apices; cells spherical to barrel-shaped, homogeneous or granulate, sometimes with pseudovacuoles, colored with age according to species; heterocysts spherical, intercalary; akinetes variously shaped, solitary or series.

Multiplication by hormogonia and by akinetes.

Only one species has been found in Tainan milkfish ponds.

Anabaena planktonica Brunnthaler

Geitler, 1925, in Pascher's Süsswasserflora, Heft 12, p. 315-6, fig. 363.
Prescott, 1951, Algae of Great Lakes areas, p. 517, pl. 118, figs. 1-3.
Tiffany & Britton, 1951, Algae of Ill., p. 357, pl. 98, fig. 1128.

Cells 9-15 X 9-12 μ, round or broadly ellipsoid, usually with numerous pseudovacuoles: hetercysts spherical, 12-14 μ broad; akinetes 12-20 X 12-30 μ, solitary, remote from or adjacent to heterocysts, spherical to elongate; trichomes enclosed by a hyaline, thin sheath; filaments free-floating, solitary, straight or slightly bent.

In fresh-waters (U.S.A., Europe).

Few filaments were found in Tainan. They float freely among other algae. Trichome bent, without sheath; apical cells tapered attenuated; heterocysts spherical; cell contents having pseudovacuoles; all these are quite similar to *Anabaena planktonica*, though the alga is a freshwater species unexpectedly found in this area. It may have been driven from its freshwater habitat into the milkfish ponds by rain-flood.

Oscillatoria Vaucher 1903

Trichomes unbranched, without evident sheaths or gelatinous matrix, solitary or intertwined, straight or bent and contorted, sometimes tapering very gradually toward the ends, with or without capitate calyptrae; cell contents homogeneous, granular or colored; filaments keeping oscillating or gliding movements.

Fragmentation by the formation of hormogonia.

One species has been found in Tainan milkfish ponds.

Oscillatoria boryana Bory

Desikachary, 1959. Cyanophyta, p. 218, pl. 38, fig. 12.
Geitler, 1925, in Pascher's Süsswasserflora Heft 12, p. 367, fig. 443.
Tilden, 1910, Minnesota algae I. p. 83, pl. 4, figs. 37, 38.

Trichomes 6-8 μ broad, forming a loose and regular spiral through their entire length, or straight and hooked at the apex, flexuous, constricted at the cross-walls; apex of trichome more or less pointed, without calyptra; cells 4-6 μ long; cross-walls here and there finely granulated; cell contents showing a few protoplasmic granules.

In hot springs; in a waste-water drain; on rocks in a river; on moist soil.

Tainan-Rare.

Phormidium Kützing 1843

Trichomes unbranched, enclosed by watery gelatinous sheaths or invisible matrix; filaments solitary or in mass which is made up of parallel or densely interwoven trichomes, apex various, sometimes capitate, often with calyptra.

Fragmentation by the formation of hormogonia.

Four species have been found in Tainan milkfish ponds.

Key to Tainan species

1. Cross-walls not constricted, with 2 coarse granules on either side .... *Ph. laminosum*
1. Cross-walls constricted distinctly at least slightly 2
   2. Cell quadrate, or near spherical .... *Ph. fragile*
   2. Cell cylindrical or at least short rod-like........................ 3
3. Trichomes less than 2 μ in diameter .... *Ph. tenue*
3. Trichomes more than 2.5 μ in diameter .... *Ph. molle*

Phormidium laminosum Gomont

Desikachary, 1951, Cyanophyta, p. 259, pl. 44, fig. 6.
Geitler, 1925, in Pascher's Süsswasserflora 12:382, fig. 482.
Lindau, 1914, Die Algen I, p. 29.
Tilden, 1910, Minnesota Algae I, p. 96-7, pl. 4, fig. 62.

Filament flexuous. densely entangled; sheath thin, mucilaginous; trichome not constricted at the cross-walls; cross-walls usually inconspicuous, with four granules, 1-1.5 μ broad; cell length longer than its diameter, 2-4 μ long; apical cells acute-conical, with calyptra.

In spas (Taiwan); on water-logged soil in rice fields (India).

In Tainan sample cells up to 2.5 μ broad, 3-5 μ long; inconspicuous cross-walls with 2 granules on either side. The trichome is quite similar to *Phormidium purpurascens*, but it has no visible sheath like the latter. Filaments found in Tainan are fragments of the species only; they cannot give us the information of what their apical cell looks like. Trichome is somewhat straight and 4 granules at the cross-walls are clearly seen. Rare.

Phormidium fragile (Meneghini) Gomont

Desikachary, 1959, Cyanopyta, p. 253, pl. 44, figs. 1-3.
Geitler, 1925, in Pascher's Süsswasserflora Heft 12, p. 378, fig. 470.

Trichomes more or less flexuous, entangled or nearly parallel, distinctly constricted at the cross-walls; cells quadrate, 1.2-3 μ long; apical cell acute conical, without calyptra; tapering at the apex; sheath diffluent, not colored.

On moist soil; floating in shallow fresh water and estuary; in spas.

Tainan-Rare.

Phormidium tenue (Meneghini) Gomont
=*Leptothrix subtilissima* Kütz.
=*Hyphaeothrix subtilissima* Rabh.

Desikachary, 1959, Cyanophyta, p. 259, pl. 43, figs. 13-5 & pl. 44, figs. 7-9.
Geitler, 1925, in Pascher's Süsswasserflora 12:381, fig. 478.
Lindau, 1914, Die Algen I, p. 29.
Prescott, 1951, Algae of Great Lakes areas.
Tiffany & Britton, 1951, Algae of Ill., p. 347-8, pl. 95, fig. 1098.
Tilden, 1910, Minnesota algae I, p. 98, pl. 4, figs. 63-5.
Umezaki, 1961, Mem. Coll. Agr. Kyoto Univ., 83:60, pl. 9, fig. 5.

Filaments elongate, somewhat straight, densely intricate; sheath thin, mostly diffluent; trichomes 1-2 μ in diameter, slightly constricted at cross-walls, but always pellucid; apex without calyptra; cells 2.5-5 μ long; cell contents homogeneous, pale blue-green.

On moist surface and among other algae in freshwater and salt-water bodies, also in hot-springs; on pot in greenhouse.

Tainan-Common.

Filaments from Tainan samples are always broken as fragments scattered among other algae. Some trichome cells are comparatively longer than the freshwater form found. Of course, normal forms are found together in brackish ponds also. Trichomes appear naked without sheaths and have pellucid cross-walls where the fragments can easily break into pieces. A long, straight filament is difficult to find in the samples.

Phormidium molle (Kütz.) Gomont
=*Anabaena mollis* Kütz

Desikachary, 1959, Cyanophyta, p. 255, pl. 59. fig. 8.
Geitler, 1925, in Pascher's Süsswasserflora 12:378, fig. 471.
Lindau, 1914, Die Algen I, p. 28.

Trichome straight, or very slightly bent, distinctly constricted at the cross-walls, not attenuated at the ends, 2.7-3.3 μ broad, light bluegreen, cross-walls not granulated; cells quadrate, cylindrical, or pressed barrel-shaped, 3-7.8 μ long; apical cells rounded, without calyptra.

On mud, in rice-field soils, in waters.

Tainan-Very rare.

DIVISION CHLOROPHYTA

(Green Algae)

Ten genera have been found in Tainan milkfish ponds. Most of these green algae except *Enteromorpha* are planktonic.

Key to Tainan genera

1. Plant macroscopic, seen with eyes .... *Enteromorpha*
1. Plant microscopic, seen only under microscope 2
    2. Cells motile, with flagella 3
    2. Cells non-motile, without flagella 4
3. Flagella, two each cell .... *Chlamydomonas*
3. Flagella, four each cell .... *Platymonas*
    4. Cells spherical, without spines .... *Chlorella*
    4. Cells lunate, oblong or angular (even spherical, but having spines) 5
5. Body-form lunate-arcuate 6
5. Body-form, other forms 7
    6. Cells lunate, all cells with convex faces apposed, without sheath .... *Selenastrum*
    6. Cells arcuate, 4 or 8 in groups with convex apposed within a wide homogeneous gelatinous matrix .... *Kirchneriella*
    7. Cells ellipsoidal or oblong 8
    7. Cells angular or arranged in plate form 9
        8. Colony commonly of 4 celled in a series .... *Scenedesmus*
        8. Colony always solitary, rarely in 2, 3 or 4 .... *Franceia*
    9. Cell solitary, with or without processes .... *Tetraedron*
    9. Cells always four in quadrate arrangement, spines only on convex surface of triangular cells .... *Tetrastrum*

Enteromorpha Link 1820

Mature thalli are always hollow tubes with a wall of one cell in thickness, attached to the substrate by a basal rhizoidal cell or by basal multicellular rhizoids; cells angular by mutual compression, and irregularly disposed or with a tendency to lie in vertical series; cell uninucleate, with a single parietal chloroplast which contains one pyrenoid, some more than one.

Asexual reproduction is by means of vegetative multiplication of shoot abscission or by means of quadriflagellate zoospores produced in a number of 4, 8, 16, or 32 in a cell. Sexual reproduction is by means of biflagellate gametes, the union of isogametes. This genus has an isomorphic alternation of generations.

It has been collected from inland brine lakes and salt sprlngs; common in rivers flowing into the ocean. The general habitats of growth of *Enteromorpha* species vary very much in different environments.

One species has been found in tufts on the banks of canals of Tainan milkfish ponds.

Enteromorpha compressa (L.) Grev.

Lindau, 1914, Dle Algen II. p. 126.
Okamura, 1956, Japan marine algae, p. 16, figs. 5(1), 6(3,4).
Setchell & Gardner, 1919, Univ. Calif. Publ. Bot. 8:251, pl. 14, figs. 7,8; pl. 16, fig. 3.

Frond tubular, more or less compressed, sometimes constricted at the middle, varying much in dimensions; branches usually simple, cylindrical or expanding laterally and upward, in either case narrowed at the base, similar in appearance to the main axis; cells in no definite order; membrane rather thin.

Along seashores, on rocks, washed by seawater; growing in the middle and lower littoral belts.

Tainan-Growing on cement banks of trenches and water gates.

Chlamydomonas Ehrenberg 1833

Vegetative cell unicellular, actively motile, with ovoid, spherical, fusiform or ellipsoid and triangular shapes, sometimes with 1 or 2 apical papillae from which the 2 equal-lengthed flagella arise; often with a mucilaginous sheath; chloroplast a densely padded body filling the entlre cell, or a thin parietal cup; pyrenoids 1 to many, basal or bilateral and scattered; eyespot lateral and anterior; 2-4 apical contractile vacuoles usually discernible.

There are two species found in Tainan milkfish ponds.

Key to Tainan species

1. Cell short, lanceolate to obovoid.................................. *Ch. mucicola*
1. Cell depressed globose .... *Chlamydomonas sp.*

Clamydomonas mucicola Schmidle

Prescott, 1951, Algae of Great Lakes areas, p. 71, pl. 46, fig. 20.

Cells narrowly elliptic or narrowly ovoid, attenuate to a blunt point anteriorly, broadly rounded posteriorly; flagella two, $1^1/_2$ times the body length; chloroplast a lateral plate with a single pyrenoid; eyespot and 4 contractile vacuoles in the anterior end; cells 3-4 X 6-10 μ.

Tychoplankter.

Tainan-Very common, abundant among the plankton of several ponds.

The sample cells are ovoid to short, lanceolate, with a small, apical papillae from which 2 flagella extend either side and bent backward. Their chloroplasts are massive or parietal, occupying almost the whole cell except the lower part with a large pyrenoid expanded. In February, this alga is dominant in some ponds, but rarely found near the bottom. Some cells in pair as in process of gamete conjugation have been observed in the samples.

Chlamydomonas sp.

Smith, 1950, Freshwater algae of U.S., p. 75-7.

Cells ovoid or nearly rectangular, with 2 flagella each cell; chloroplast one, parietal or cup-shaped; pyrenoid one, embedded in the chloroplast, invisible, flagellum as long as the cell; cells 3-4 X 3-5 μ.

Tainan-Rare.

Platymonas G.S. West 1916

Cells quadriflagellate, compressed, subrectangular to broadly elliptical (in vertical view); contractile vacuoles at the base of the flagella, eyespot always present; chloroplast cup-shaped, massive or delicate, and entire, or with the anterior end incised into four lobes, with or without a pyrenoid.

Asexual reproduction: longitudinal division.

Samples from Tainan are very similar to *Carteria*.

One species has been found in Tainan milkfish ponds.

Platymonas subcordiformis Wille
=*Carteria subcordiformis* Wille
=*Carteria cordiformis* (Carter) Dill-Lemm., 1903, Nordisches Plankton 21:10, fig. 31.

I am not sure that the Tainan alga belongs to this taxa, but the explanation of *P. subcordiformis* by Smith is reasonable though still doubtful.

Smith, 1950, Freshwater algae of U.S., p. 85.

Wille, 1903, Nyt. Mag. Naturvidenskab. 41:89-94, pl. 1.

Cells ellipsoid or ovate, with 4 flagella; cell wall delicate; chloroplast one, massive; pyrenoid embedded in the chloroplast, invisible; an eyespot always present. When the cell becomes older, its flagella disappears, the cell wall thickens and chloroplast is reduced to granular mass escaping through the slit of the shell or cell wall.

P. subcordiformis if found on both the Atlantic and the Pacific coasts in brackish-water pools rich in droppings from the sea-birds. Brackish water species can also develop in freshwaters.

Tainan-Very common.

Chlorella Beyerinck 1890

Cells small, globose or rarely ellipsoid, solitary; chloroplast single, parietal, often cup-shaped, usually without pyrenoid. Formation of autospores in a mother cell.

One species growing abundantly in Tainan milkfish ponds.

Chlorella sp.

cells 3-15 μ in diameter, solitary or freely floating; chloroplast one, cup-shaped. Some cells are like *Chlorococcum*; some with 2-3-4 autospores.

Cosmopolitan. Air-borne species; in freshwaters.

Tainan-Very common.

Chlorella cells growing in Tainan milkfish ponds do not have the green chloroplast but only the pale green in cup-shaped form. These cells seem to be an intermedian form between *Chlorococcum* and *Nannochloris*. Some cells are really like free *Synechocystis*. If autospores in mother cell cannot be seen, these cells will not be considered as marine *Chlorella*. The species cannot be identified due to poor growth.

Selenastrum Reinsch 1867

Cells arcuate to lunate, with acutely pointed apices, of 4, 8 or 16 aggregated into a colony, without a colony matrix; chloroplast one, laminate, parietal, on the convex side of a cell, but entirely filling it when the cell is older, with a single pyrenoid.

Formation of autospores.

Planktonic in quiet waters, freshwater.

Possibly one species of this genus is present in Tainan milkfish ponds, but it cannot be definitely identified because only a few cells have been found.

Selenastrum sp.

Smith, 1950, Fresh-water algae of U.S., p. 266-7,

Cells arcuate to lunate, with attenuate poles; their convex surfaces apposed into an aggregation of 4-8-16 or more cells, without a gelatinous envelope; chromatophore single, parietal, with or without pyrenoids.

Fresh-water species.

Tainan-Very rare, only few cells found in a water-supply trench.

The lunate cells swim individually in the water without a gelatinous envelope. They cannot be easily identified by their actual name.

Kirchneriella Schmidle 1893

Cells arcuate or lunate, with attenuate or sub-acute poles. loosely arranged in a wide gelatinous matrix; chloroplast single, parietal on convex side of cell or entirely filling cell, with or without pyrenoid.

Formation of 4-8 autospores.

Only few cells freely scattered among other algae in Tainan milkfish ponds.

Kirchneriella obesa (West)
—*Selenoderma malmeana* Bohlin

Brunnthaler, 1915, in Pascher's Süsswasserflora 5(2):181, fig. 267.
Lindau, 1914, Die Algen II, p. 112, fig. 318.

Cells half-crescent, 2-4 μ in diameter.

A fresh-water species.

Tainan-Very rare, only found in water-supply trench, as plankton.

Scenedesmus Meyen 1829

Coenobia generally flat plates or ellipsoid, oblong, fusiform, acicular or ovoid cells in multiples of 2; cells contacting each other laterally in one series or in two series joined by apical contact (sometimes in quadrate arrangement): cell-wall smooth or variously ornamented, with or without terminal or lateral spines or teeth; chloroplast single, parietal, often filling the whole cell, with a pyrenoid,

Formation of 2-32 autospores.

There are six species and varieties found in Tainan milkfish ponds.

Key to Tainan species and varieties

1. Cells with spines or teeth 2
1. Cells without spines or teeth 3
   2. Inner cells with spines .... *S. abundans* var. *brevicauda*
   2. Inner cells without spines 4
3. Outer cells lunate, strongly curved, with acute apices; inner cells

with straight, sharp apices ······································ *S. dimorphus*

3. Outer and inner cells ovate or oblong; apices round only··· *S. bijuda*

4. Spine one on one pole of outer cells, the other pole none ·· *S. diagonalis*

4. Spines two on two poles of outer cell ···································· 5

5. Spine slightly curved, near to straight····················· *S. quadricauda*

5. Spine strongly curved ······················*S. quadricauda* var. *quadrispina*

Scenedesmus abundans var. *brevicauda* G.M. Smith

Prescott, 1951, Algae of Great Lakes areas, p. 274, pl. 61, figs. 26, 27; pl. 62, fig. 1.

Cells oblong or ovate, in a single series of 4, outer cells with 1 or 2 polar spines and 2 spines on the lateral wall, inner cells with a spine at each pole; cells 2.5-5 μ in diameter, 5-8 μ long; spines 1.5-3.5 μ long.

Plankter, freshwater species.

Tainan-Rare.

This alga was not found in Tainan brackish water ponds before. Its presence now must have been due to its having been carried by freshwater into the ponds.

Scenedesmus bijuda (Turp.) Lagerheim

Colony composed of 2-8 cells in a single flat series; cells ovate or oblong, without teeth or spines; cells 4-8 μ in diameter, 8-16 μ long.

Widely distributed; often appearing as a prominent component of the littoral plankton.

Tainan-Rare.

Cells in Tainan samples do not agree with descriptions in literature, for the opposition polar of small teeth found here, only two celled in a series. These samples could be an old form of *S. diagonalis*. *S. bijuda* seems like a rather brackish species living along the coast and in estuary. It has been recorded in the estuary region of Tamshui River (Chang, 1967, Taiwania 13:20).

Scenedesmus diagonalis S. Fang

Chang, 1967, Taiwania 13:20-21, pl. 1, fig. 23.

Colony composed of (2)-4-8 fusiform cells arranged in one series; outer cells with obliquely bent spines; inner cells none; cells 3-5 X 14-20 μ.

Freshwater species. Rare in estuary or in brackish water.

Tainan-Rare, only found in a water-supply canal once.

Scenedesmus dimorphus (Turp.) Kütz.

Prescott, 1951, Algae of Great Lakes areas, p. 277-8, pl. 63, figs. 8, 9.
Shen, 1956, Rept. Inst. Fish. Biol. Mini. Eco. Affairs & NTU I (1):51, pl.4, figs. 1, 2,

Colony composed of 4 or 8 fusiform cells arranged in a single or alternating series; inner cells with straight, sharp apices; outer cells lunate, strongly curved, with acute apices; cells 3-6 μ in diameter, 16-22 μ long.

Common and widely distributed in freshwater, never recorded in brackish water before.

Tainan-Very rare.

This alga may have come from the sewer of Tainan or from the rice-field, found only in water-supply canal once after rain.

Scenedesmus quadricauda (Turp.) de Bréb.
=*Achnanthes quadricauda* Thuret
=*Scenedesmus variabilis* De Wild. var. *cornutus* Francé

Brunthaler, 1915, in Pascher's Süsswasserflora 5(2):165.
Lemmermann, 1903, Nordisches Plankton 21:14, figs. 47-50.
Lindau, 1914, Die Algen II, p. 119, fig. 344.
Prescott, 1951, Algae of Great Lakes areas, p. 280, pl. 64, fig. 2.
Shen, 1956, Rept. Inst. Fish. Biol. Mini. Eco. Aff. & Nat'l Taiwan Univ., 1(1):50, pl. 2, figs. 4-6.

Colonies composed of 2-4-8 oblong-cylindric cells usually in one series (sometimes in 2 alternating series); outer cells with a long curved spine at each pole; inner cells without spines or with more papillae at the apex; cells variable in size, 3-18 μ in diameter, 9-35 μ long.

Freshwater species in general. Common and widely distributed in a variety of habitats; in North Sea.

Tainan-Rare. This alga has never been found in Tainan milkfish ponds except in the water-supply canal after heavy rain. However, in freshwaters of Tainan it is a common species, henceforth it is washed down to the brackish water canal.

Scenedesmus quadricauda var. *quadrispina* (Chod.)
(=*Scenedesmus quadrispina* Chod.)

Prescott, 1951, Algae of Great Lakes areas, p. 280, pl. 63, fig. 21.

Colony composed of 4-8 ovate cells with short spines, usually strongly recurved; cells 4-7.4 μ in diameter, 9-16 μ long; spines about 3 μ long.

Rare, but widely distributed in many lakes and ponds.
Tainan-Rare, only found in a water-supply canal.

Franceia Lemmermann 1898

Free-floating, ovate or ellipsoid cells, solitary or 2-4 celled together; cell walls covered with long, slender bristle-like setae which may show a basal swelling or tubercle; chloroplasts 1-4 parietal plates; pyrenoids present or absent.

Formation of autospores.

This genus could be compared with *Lagerheimia* in which the setae are confined to the polar or equatorial regions of cell walls.

One species has been found in Tainan milkfish ponds.

Franceia Droescheri (Lemm.) G.M. Smith

Prescott, 1951, Algae of Great Lakes Areas, p. 251, pl. 56, figs. 1-3.

Cells broadly ellipsoid, the wall covered with stiff, straight, spine-like bristles without particular hardenings at their bases; chloroplasts 2-4 parietal plates; cells 5-12 μ in diameter without setae, 9-16 μ long; setae 15-22 μ long.

Euplankter. A freshwater species. Very rare in Tainan.

Tetraedron Kützing 1845

Cells solitary and unattached, flat and angular or polyhedral; of various shapes; the angles entire, with or without spines, or variously lobed to form di- or trichotomous spine-tipped processes; chloroplasts one to many, parietal discs or plate; pyrenoid usually present.

Formation of 4-32 autospores.

Species with small cells are usually found among other algae in pools and ditches. Many species with large cells are always found in the plankton from freshwater.

One species has been found in Tainan milkfish ponds.

Tetraedron minimum (A. Braum) Hansgirg
=*Polyedrium minimum* A Braum

Brunnthaler, 1915, in Pascher's Süsswasserflora 5:(2):147, fig. 155.
Lindau, 1914, Die Algen II, p. 113, fig. 320.
Prescott, 1951, Algae of Great Lakes areas, p. 267, pl. 60, figs. 12-15.

Cells small, flat, tetragonal, the angles rounded and without spines or processes, lobes sometimes cruciately arranged; margins of the cell concave, with one frequently incised; cells (6)-14.5-20 μ broad.

Common in the tychoplankton and euplankter of many lakes and ponds; a freshwater species.

Tainan-Very rare, only found once in water-supply canal after rainy season, 1967.

Tetrastrum Chodat 1895

Coenbia free-floating, of 4 triangular, cruciately arranged cells (in quadrate plate), inner faces straight and adjoined to form a rectangular arrangement; outer convex and beset with 3 or 4 short setae; colony always enclosed by a thin sheath; chloroplasts 1-4 in each cell, parietal discs with pyrenoid, some species absent.

Formation of autospores.

This genus is very similar to *Crucigenia*, a genus with which it has much in common.

Tetrastrum is generally characterized by the setae.

One species has been found in Tainan milkfish ponds.

Tetrastrum staurogeniaeforme (Schröder) Lemm.
=*Cohniella staurogeniaeformis* Schröder
=*Staurögenia Schröderi* Schmidle

Brunnthaler, 1915, in Pascher's Süsswasserflora 5(2):177, fig. 259.
Prescott, 1951, Algae of Great Lakes areas, p. 286, pl. 66, fig. 3.

A colony of 4 triangular cells, cruciately arranged about a small rectangular plate; the latter furnished with as many as 6 fine, hair-like setae; chloroplasts 1-4 parietal discs, sometimes containing pyrenoids; cells 3-6 μ broad; colony 7-15 μ wide without setae which are 4-8 μ long.

Rare among the plankton of lakes.

Tainan-Very rare, only found in the water-supply canal once.

This species could be compared with *Crucigenia quadrata*.

DIVISION EUGLENOPHYTA

CLASS EUGLENOPHYCEAE

Order Euglenales

Family Euglenaceae

There are two genera found in Tainan milkfish ponds.

Key to Tainan genera

1. Flagellum one .... *Euglena*
1. Flagella two.. *Eutreptia*

Euglena Ehrenberg 1838

Cell elongate, oblong, lanceolate or spindle-shaped, twisted spirally or ridged, solitary, motile by a flagellum, sometimes attenuate at posterior; flagellum of varied length, extended from blepharoplast through the gullet, reservoir and out of gullet pore whipping outside; periplast more or less plastic and striated; chromatophores numerous, discoid to short rod-like, with or without pyrenoids; cells with an eyespot at the anterior end; one or more contractile vacuoles adjacent and opening to reservoir; formation of paramylum bodies of variable number and shape, attached to or free of chromatophores; nucleus relatively large and centrally located; some species having hematochrome granules.

Reproduction asexually by temporary cysts or just longitudinal division of motile cells, other species by union of isogametes.

So far only one species is recorded in Tainan milkfish ponds.

Euglena schmitzii Gojdics
=*E. geniculata* Schmitz

Gojdics, 1955, The genus Euglena, p. 75, pl. 5, fig. 2.

Cells 50-80 X 9.5-12.5 μ, bluntly spindle-shaped to nearly cylindrical; anterior end acute-conical; posterior end tapering gently to be a tailpiece; periplast striated finely and invisibly; chromatophores long, rodlike, somewhat pointed ends, in two groups, each converging toward paramylum bodies; paramylum short rectangular rods, about 3-5 μ long; pyrenoids small, disc-like; flagellum one, short, about 1/10 body length (only few cells show the flagellum, most samples show no flagella at all); eyespot small; nucleus between two chromatophore groups.

When it moves slowly, the posterior end is held down or bent. A C-shape is very common; it may show a reversed C, or even assume an S-shape. It crawls rather than swims.

A bottom species in brackish waters (salinity 1.5-1.6%).

Tainan-Very rare.

Eutreptia sp.

Smith, 1950, Fresh-water algae of U.S., p. 357.

Cells broadly fusiform to elongate, fusiform-cylindric in motion and when extended, broadly truncate at the anterior end or somewhat protruded at the apex; posteriorly tapering to bluntly rounded or somewhat protruded; flagella two, 2 times the cell length; periplast apparently smooth; chloroplasts numerous platelets scattered throughout the cell; pyrenoids two, being surrounded by paramylum bodies (about 4).

Cytological characters are very similar to *Euglena subthinophila* Prescott, 1955, Ohio J. Sci. 55(2):106-7, pl. 4, fig. 19, but *Euglena* has only one flagellum while the Tainan sample has two.

Tainan-Common.

Order Colaciales

Family Coaliaciaceae

An alga of this family is considered a species of *Colacium*, in Tainan milkfish ponds, but no definite identification can be made. The cell of this species is free from the substratum and is provided with gelatinous stalk.

DIVISION PYRRORHYTA

CLASS DINOPHYCEAE (DINOFLAGELLATES)

Order Gymnodiniales

Family Gymnodiniaceae

Genus *Gymnodinium* Kofoid & Swezy 1921

Cells ovoid, ellipsoid or pyriform, the transverse furrow complete, spirally turning to the left and dividing the cell into 2 equal (or slightly unequal), differently shaped portions; longitudinal furrow extending to the poles or only part way into the epicone and hypocone, but always farther into the latter than the former; pigmented species with numerous, golden-brown, elongate or ovoid chromatophores which are radially arranged; membrane smooth, or with longitudinal striations.

Gymnodinium species
=*Symbiodinium microadriaticum* Freudenthal, 1962, J. Protozool. 9(1):45-52.

This species is abundant in the yellow water of milkfish ponds in summer. The identification is not certain; it might be a species of *Chilomonas* and yet it fits into Freudenthal's description of *Symbiodinium microadriaticum* quite well (figure 1).

DIVISION CHRYSOPHYTA

SUB-CLASS CHRYSOPHYCEAE

Order Chrysomonadales

Family Ochromonadaceae

Only one genus, dinobryon of this division is found in Tainan milkfish ponds.

Dinobryon Ehrenberg 1835

Cells united in dentate or branching free-swimming colonies; cell attached to the bottom of a conical, campanulate or cylindrical lorica which is hyaline or colored, with pointed base and open at the top, its surface smooth or spirally scultured, cellulose; protoplast within the lorica spindle-shaped, conical or ovoid with 2 flagella equal-lengthed, attached to the base of the lorica by a short cytoplasmic stalk; chromatophores one or two, parietal, laminate; contractile vacuoles several, and 1 apical eyespot.

Reproduction: longitudinal division of cell content; palmelloid cysts; isogamy.

Only one species is found in Tainan milkfish ponds.

Dinobryon sertularia Ehrenberg

Lemmermann, 1903, Nordisches Plankton 21:4, figs. 11, 12.
Lindau, 1914, Die Algen I, p. 100, fig. 161.
Prescott, 1951, Algae of Great Lakes areas, p. 378-9, pl. 98, fig. 10.

Colonies slightly diverging; loricas fusiform-campanulate; posterior portion blunt-pointed; lateral margins smooth, convex, narrowed above the mid region and then slightly flaring to a wide mouth; loricas 10-14 μ broad, 30-40 μ long.

Common among the plankton of hard waters; frequently found with *D. sociale*; sometimes becoming the dominant species.

Tainan-Very rare.

The alga is rarely found in the brackish waters around Tainan; its protoplast is lost for some unknown reasons; because of this, *D. sertularia* may not be able to stand permanently in brackish-water. Some *Chlamydomonas* go in and out of *Dinobryon's* loricas would be *Chlamydomonas dinobryonii* G.M. Smith. This Chlamydomonas has been wrongly identified on account of the chloroplast shapes.

SUB-DIVISION BACILLARIOPHYCEAE

CLASS BACILLARIOPHYCEAE (Diatoms)

Diatoms are divided into two orders. There are 14 genera found in Tainan milkfish ponds.

Key to the Orders of diatoms

1. Valves mostly round, with radial or concentric ornamentation from central point; radially symmetrical, with marginal spines;

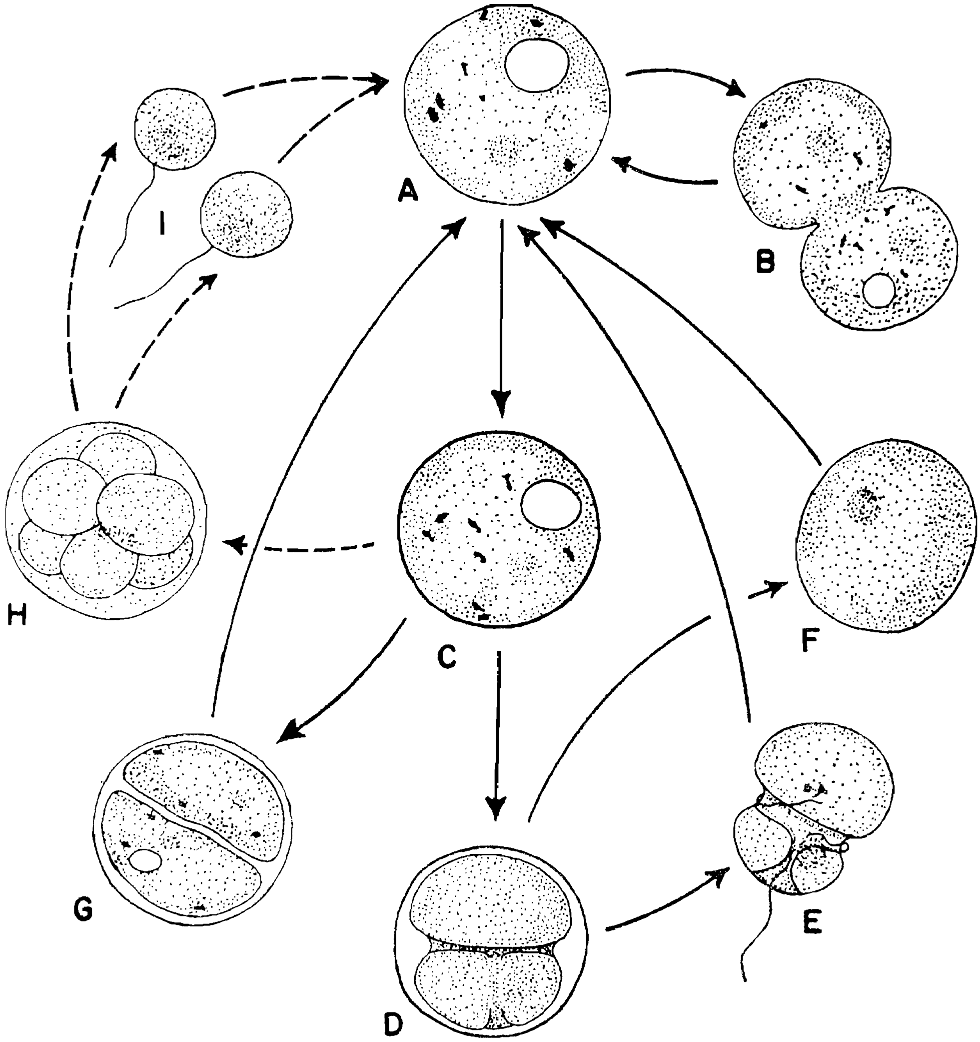

Fig. 1. Life cycle of *Symbiodinium microadriaticum* sp. nov. A. Vegetative cell. B. Vegetative cell undergoing binary fission, producing two daughter vegetative cells. C. Vegtative cyst, differing from the vegetative cell mainly in the thickness of the cell wall. D. Mature zoosporangium, containing a gymnodinioid zoospore. E. Gymnodinioid zoospore. F. Aplanospore. G. Cyst containing two autospores. H. Cyst containing developing isogametes (?). I. Liberated isogametes (?). Internal detail not shown. [from Freudenthal, J. Protozol. 9 (1)]

raphe or pseudoraphe none; cell immobile .... I. Centrales
1. Valves rarely round, with bilateral ornamentation; bilaterally symmetrical, without marginal spines; raphe or pseudoraphe present; cells mobile.. II. Pennales

Order I. Centrales

In this order, only four genera have been found in Tainan milkfish ponds.

Key to Tainan genera

1. Spaces present between cells 2
1. Spaces absent between cells 3
   2. Valve with angular processes, with spines extended within the space.. *Biddulphia*
   2. Valve without any processes, with spines extended angularly out of the space.. *Chaetoceros*
3. Cells drum-like .... *Cyclotella*
3. Cells cylindrical.. *Leptocylindrus*

Biddulphia Gray 1832

Frustules varying from species to species in shape, cells transversely compressed, with processes cylindrical, conical or globular at valve angles; frustules in girdle view elliptical or angular in outline, with centric ornamentation; cell walls highly silicified, coarsely areolate, smaller areolae on processes; girdle and intercalary bands conspicuously ornamented; chromatophores large or small; cells solitary or united into chains. Auxospores are formed singly within a cell; microspores divided from the protoplast into 32 or 64, are produced.

It is a genus of littoral marine diatoms growing chiefly on clayey banks or on seaweeds. Very few species are freshwater.

One species is found in Tainan milkfish ponds.

Biddulphia mobiliensis Bailey

Bailey, 1845, Amer. Jour. Sci., 48:336, pl. 4, fig. 24.
Cupp, 1943, Marine plankton diatoms of W. coast, p. 153, fig. 110.
Gran, 1911, Nordisches Plankton, 19:106-7, fig. 138.
Kokubo, 1965, Plankton diatoms, p. 219, fig. 236.
Lebour, 1930, Plankton diatoms of North Sea, p. 174, fig. 134.

Cells single or rarely united in short straight chains by the long spines; valves elliptical-lanceolate, convex, with a flat central part; valve processes slender, arising inside the margin of the valve, directed diagonally outward; two long spines placed far apart but equally far from the processes; cells thin-walled, without a sharp constriction between valve and girdle zone; scultering fine, reticulate, 14-16 areolae in 10 μ on cell shell, 17-18 on girdle band.

Neritic, truly planktonic. Temperate and south temperate species. Common off the coast but never in large numbers. Widespread.

Tainan-Very rare.

Chaetoceros Ehrenberg 1844

Frustules elliptical in valve view, each valve inserted by two horns being symmetrically disposed with respect to the median axis of a valve; horns solid or hollow, and smooth or ornamented with punctae or spines; girdles overlapping, without intercalary bands; cells jointed in straight or spirally twisted chains; cell walls silicified little and always without ornamentation; chromatophores different from species to species. Auxospores are formed; statospores have been found in several species; microspores are rarely found.

The genus has many species, and almost all are marine except the few found in slightly brackish water.

Key to Tainan species

1. Cells free in individuals 2
1. Cells united in chains.. *Ch. didymus*
   2. Chromatophore one in a cell .... *Ch. vistule*
   2. Chromatophores two in a cell .... *Ch. gracile*

Chaetoceros didymus Ehr.
=*Chaetoceros didymum* Ehr.

Cupp, 1943, Marine plankton diatoms of W. coast, p. 121, fig. 75-A.
Gran, 1911, Nordisches Plankton, 19:79, fig. 94.
Kokubo, 1965, Plankton diatoms, p. 188-9, fig. 196.
Yamaji, 1966, Ill. Mar. Plank. Japan, p. 29, pl. 15, fig. 3.

Chains straight, 12-34 μ in diameter; cells four-cornered in girdle view, with concave surfaces; apertures large, constricted in the middle; valves with a semicircular papilla in the center; setae arising from corners of cells, crossing at their base; some chains prolongating; chromatophores two per cell, pressed against the valve, each with a pyrenoid in the papilla.

Neritic. South temperate species. Common, sometimes abundant in marine plankton.

Tainan-Very rare.

Sample cells are few in a long chain, only found in a site once.

Chaetoceros gracile Schütt

Gran, 1905, Nordisches Plankton, 19:97, fig. 125.
Lebour, 1930, Plankton diatoms of North Sea, p. 168, fig. 130.
Lindau, 1914, Die Algen I, p. 136.

Cells solitary, not always united into chains, small, rectangular in girdle view; valves elliptical, surface weakly concave with slightly produced angles; setae arising just within the valve margins, short and directed outward; valve mantle shallow, very thin, without any obvious division between it and girdle; chromatophores two, small; valve 6-10 μ in width; pervalvar axis about the same.

Neritic in the northern part of the North Sea, Baltic and North Atlantic.

Tainan-Common.

Chaetoceros vistule Apstein

Cupp, 1943, Marine plankton diatoms of W. coast, p. 144, fig. 102

Cells solitary or in pairs, with small elliptical valve, apical axis 7-8 μ long; valves strongly concave; setae arising from projecting corners, slightly concave; chromatophore one, lying on girdle side.

Neritic. Also a brackish-water species.

Tainan-Very rare, only found in one site in October, 1967.

Cyclotella Kützing 1834

Cells drum-shaped, discoid, circular in valve view (some species, elliptical) solitary and free-floating, some united in straight or spirally twisted filaments by means of gelatinous threads from valve to valve, or of a common gelatinous envelope; ornamentation of a valve consisted of two regions: an inner smooth region and finely punctate, and an outer peripherical zone with radial striae or punctate; girdles of frustules smooth, no intercalary bands; chromatophore numerous, discoid. Auxospores are produced singly within a cell.

The genus is primarily marine, some species are found in freshwater and brackish water habitats.

One species has been found in Tainan milkfish ponds.

Cyclotella meneghiniana Kütz.

Hustedt, 1930, in Pasher's Die Süsswasserflora 10:100, fig. 67.
Lindau, 1914, Die Algen I, p. 130, fig. 228.
Tiffany & Britton, 1951, Algae of Ill., p. 218, pl. 58, fig. 660.

Cells 10-30 μ in diameter or up to 48 μ; outer zone broad, striae 8-9 in 10 μ; central zone smooth or finely radially punctate, often with a large isolated puncta.

Marine but always coastal, frequently found among the plankton of stagnant salt waters; also in freshwaters.

Tainan-Very common, frequently found among plankton and bottom algal society; sometimes dominant.

Cells newly formed from auxospores are bigger than older ones. Two forms have been found in Tainan milkfish ponds.

Leptocylindrus Cleve

Cells cylindrical, elongated, united into chains; valves flat; girdle with numerous intercalary bands; chromatophores usually two, some species numerous, small. Marine.

One species is found in Tainan milkfish ponds.

Leptocylindrus danicus Cleve
Rhizosolenia fragillima Bergon

Cupp, 1943, Marine plankton diatoms of W. coast, p. 78, fig. 39.
Gran, 1911, Nordisches Plankton, 19:49, fig. 54.
Kokubo, 1965, Plankton diatoms, p. 138, fig. 126.

Cells cylindrical, 7-10 μ in diameter, two to ten times as long; united in closed, straight chains; valves flat, without visible sculturings; an intercalary band present in the middle but always invisible; chromatophores few to numerous.

Neritic. Probably a north temperate species. Widespread in the seas.

Tainan-Rare.

Order II Pennales

In this order, ten genera have been found in Tainan milkfish ponds.

Key to Tainan genera

1. Valve sigmoid 2
1. Valve other forms 3
    2. Transverse striations crossing with longitudinal striae at right angles .... *Gyrosigma*
    2. Transverse striations crossing with oblique striae at about 60 degrees .... *Pleurosigma*
3. Valve linear, long rod-like, with a pseudoraphe .... *Synedra*
3. Valve ovate, lanceolate or other forms but not really linear 4
    4. Valve with keel .... *Nitzschia*
    4. Valve without keel 5
5. Cell in girdle view hour-glass shaped .... *Amphiprora*

5. Cell in girdle other forms ·· 6

6. Frustule in girdle view as "<" or lunate················ *Achnanthes*

6. Frustule in girdle view rectangular ································ 7

7. Chromatophore one·· 9

7. Chromatophores two ·· 8

8. Valve vaviculoid or linearly fusiform ······················ *Navicula*

8. Valve elliptical or sub-ovate ······································ 10

9. Chromatophore one only; intercalary bands absent.········ *Anomoeoneis*

9. Chromatophores 1, 2 or 4; intercalary bands present

10. Cell ovate in valve view ······································ *Amphora*

10. Cell elliptical in valve view································· *Diploneis*

Gyrosigma Hassall 1845; emend. Cleve 1894

Valves sigmoid, gradually attenuated toward acute or rounded poles; frustules in girdle view elliptical to lanceolate; intercalary bands and septa absent; raphe sigmoid, with small central and polar nodules; axial area narrow with small, rounded central area; transverse striations crossing longitudinal striae at right angles; chromatophores two. plate-shaped, generally with several pyrenoids.

Key to Tainan species.

1. Raphe straight either side of the central nodule········ *Gy. scalproides*

1. Raphe slightly sigmoid from the central nodule ··········· *Gy. balticum*

Gyrosigma balticum (Ehr.) Rabh.

Kokubo, 1965, Plankton diatoms, p. 295, fig. 339-c

Lindau, 1914, Die Algen I, p. 161.

Patrick & Reimer, 1966, Diatoms of U.S., p. 324-5, pl. 25, fig. 1.

=*Navicula baltica* Ehr.

=*Pleurosigma baltica* (Ehr.) W. Smith

=*Gyrosigma baltica* (Ehr.) Rabh.

Valve slightly sigmoid, linear, moderately arched, with bluntly rounded, subconical ends; valve margins straight, slightly incurved; axial area and raphe undulate, eccentric; central area elongate, diagonal, elliptical; transverse and longitudinal striae about equally as distant forming squares; transverse and longitudinal striae, 11-16 in 10 μ. Cells 200-400 X 20-32 μ.

Brackish water, coastal species.

Tainan-Common. This alga can be dominant in season.

Gyrosigma scalproides (Rabh.) Cleve

Hustedt, 1930, in Pascher's Süsswasserflora 10:226, fig. 338.

Lindau, 1914, Die Algen I, p. 161, fig. 322.
Patrick & Reimer, 1966, Diatoms of U.S., p. 318, pl. 23, fig. 7.
Tiffany & Britton, 1951, Algae of Ill., p. 269, pl. 66, fig. 762.

Cells 5-10 X 25-70 μ; valves lanceolate, sigmoid, gradually attenuated to rounded poles; ends scalpelliform; central area small, longitudinally elliptical or orbicular; transverse striae more distinct than longitudinal striae, transverse striations, usually perpendicular to the middle line, sometimes medianly radial, 22-24 in 10 μ; longitudinal striations about 28-30 in 10 μ.

A rather widely distributed species more characteristics of flowing water habitats in which the water is always alkaline.

Tainan-Rare.

Hustedt (1930) records this species as small as 25 μ long and 5.5 μ in diameter. This is the same as our samples from Tainan. The diatom is best identified by the subtle knob-like poles, the lateral raphe and the "T" shaped raphe ends.

Pleurosigma Wm. Smith 1852; emend. Cleve 1894

Cells solitary, elliptic-lanceolate in girdle view, intercalary bands and septa absent; valves sigmoid, gradually tapering toward the rounded or subacute ends; raphe sigmoid, with small central and polar nodules; central area small, round; axial area narrow; striations in three series; transverse, oblique and longitudinal; chromatophores two, four or more, plate-like. Two auxospores formed from the conjugation of two cells.

Most species are found in salt or brackish water.

Key to Tainan species and variety

1. Valve margins parallel, tapering very gradually toward poles .... *Pl. salinarum*
1. Valve margins expanded in the median, sharply tapering toward poles 2
    2. Median margins expanded angularly. oblique striae cross each other at an angle of about 90° .... *Pl. normanii*
    2. Median margins expanded very broadly round, oblique striae cross each other at an angle of about 60° .... *Pl. angulatum* var. *aestuarii*

Pleurosigma angulatum var. *aestuarii* (Breb.) V. Heurck

Patrick & Reimer, 1966, Diatoms of U.S., p. 332-3, pl. 27, figs. 3 a-c.
Tiffany & Britton, 1951, Algae of Ill., p. 267, pl. 68, fig. 791.

Valve sigmoid, rhombo-lanceolate, mediately angular and polarly sharply rounded; ends subrostrate to rostrate; axial area and raphe sigmoid;

striae slightly fine, oblique striations at an angle of about 60 with the transverse striae, transverse and diagonal striae 19-23 in 10 μ. Cells 70-132 X 17-22 μ. This alga is different from *Pl. angulatum* (Quekett) Wm. Smith in respect to slighter, finer striations (23 in 10 μ), narrower valve-margins and not so much protruded poles. This taxa could be compared with *Navicula aestuarii* Kütz. for the consideration of being synonyms of both algae. Someone has considered *Pleurosigma aestuarii* to be the same as this algae, the variety of *Pl. angulatum* (Patrick and Reimer, 1966).

A common marine species from temperate waters, frequent on all European coasts, planktonic.

Tainan-Common.

Pleurosigma salinarum Grunow
=*Pleurosigma pusillum* Grun.
=*Pleurosigma salinarum* var. *pusilla* (Grun. in Cl. & Grun.) Cleve

Hustedt, 1930, in Pascher's Die Süsswasserflora 10:228, fig. 344.
Lindau, 1914, Die Algen I, p. 162.
Patrick & Reimer, 1966, Diatoms of U.S., p. 333-4, pl. 27, figs. a-c.

Valve slightly sigmoid, lanceolate or linear-lanceolate with rather strongly attenuated, narrow, rounded obtuse ends; valve surface relatively flat; axial area and raphe slightly sigmoid, slightly eccentric toward the ends; central area small, elongate-elliptical or rhombic; transverse striae slightly coarse and somewhat more conspicuous than diagonal striae, 22-25 in 10 μ; diagonal striae 25-28 μ in 10μ. Cells 70-13- X 13-17 μ.

Euryhaline, nearly freshwater to moderately brackish water. A brackish water species.

Tainan-Common.

This alga can best be distinguished by the characteristics of the ends and the relatively fine striae. Longer forms are more frequently found in moderately brackish water, shorter forms are much more common in very slightly brackish or even in freshwater.

Pleurosigma normanii Ralfs
=*Pleurosigma affine* Grunow 1880

Hendy, 1961, Intro. Account of the smaller algae of British coastal waters, p. 244.
Kokubo, 1965, Plankton diatoms, p. 296-7, figs. 341-a.b.

Valves broad lanceolate, slightly sigmoid, with sub-acute ends; raphe nearly central, sigmoidi valve surface striate, striae punctate; oblique striae 16-17 in 10 μ; transverse striae 19-21 in 10 μ; central nodule sometimes slightly dilated transversely; cells 90-220 X 28-36 μ.

One of the commonest and the most widely spread of all *Pleurosigma* species and found from the tropics to the polar seas; frequently found in the plankton.

Tainan-Common.

Synedra Ehrenberg 1830

Cells narrow, elongate, solitary or united in radiating colonies; valves linear to lanceolate, straight or sometimes curved, with or without poles attenuated, often capitate; transverse striation lateral to a narrow pseudoraphe; central area smooth, present or not; cells elongate in girdle view, with truncate ends and striae; chromatophores two, plate-like, each usually with three or more pyrenoids. Auxospores 1-2 in a cell, without conjugation.

Synedra is a genus found in a great variety of habitats; smaller cells sessile and coating on substrata, the larger cells free-floating or epiphytic. They can be found among lake plankton.

One species has been found in Tainan milkfish ponds.

Synedra ulna (Nitzsch.) Ehrenberg

Hustedt, 1930, in Pascher's Süsswasserflora 10:151, figs. 158, 159.
Lindau, 1914, Die Algen I, p. 146, fig. 270.
Mizuno, 1964, Ill. Freshwater plankton of Japan, p. 137, pl. 50, figs. 1-11.
Tiffany & Britton, 1951, Algae of Ill., p. 237, pl. 63, fig. 713.

Cells 5-9 X 50-350 μ, solitary or planktonic; linear in girdle view; valves linear to lanceolate, very gradually narrowed toward the rounded or headed poles; pseudoraphe narrowly linear, with central area varying, but absent in sample cells, transverse striae 8-12 in 10 μ.

Very common in freshwater to marine.

Tainan-Very rare, only found in a site of fragments scattered among other algae.

This alga has many kinds of variation in body-form, therefore only typical cells have been identified.

Nitzschia Hassall 1845

Cells solitary and free-floating or densely clustered in a colony, with a common gelatinous tube; frustules elongate-rectangular, or sigmoid in girdle view, with somewhat attenuate poles, rhombic in cross-section; valves longitudinal asymmetric, variable in shape, some medianly constricted; keel with a raphe near one margin, having small nodules and a row of circular pores; striation transverse or punctate; chromatophores two, on the same girdle face.

Auxospores two, formed by the conjugation of two cells.

The genus is found in both freshwater and salt water. It is one of the most important diatoms in plankton, especially in freshwater.

Key to Tainan species and varieties

1. Valve apex forming hair-like awn, long .... *N. closterium*
1. Valve apex attenuated or obtused but not awn-shaped 2
   2. Valve sigmoid, linear 3
   2. Valve naviculoid, plate-like or others 4
3. Valve margin constricted little at the median .... *N. obtusa* var. *scalpelliformis*
3. Valve margins parallel at the median .... *N. sigma*
   4. Valve plate-like .... *N. constricta* var. *parva*
   4. Valve linearly naviculoid 5
5. Valve fusiform, without median constriction .... *N. lanceolata*
5. Valve lenticular, slightly constricted at the median 6
   6. Poles cuneate or somewhat capitate .... *N. palea*
   6. Poles sub-acute, or attenuate .... *N. frustulum* var. *subsalina*

Nitzschia frustulum var. *subsalina* Hust.

Chang, 1966, Taiwania 12:62.
Hendy, 1961, Account smaller algae of British coastal waters, p. 283.—the type, common in estuaries; frequent on muddy shores, a brackish species.
Hustedt, 1930, in Pascher's Süsswasserflora Heft 10, p. 415, fig. 796.

Valves linear to lanceolate, tapering to sub-acute apices; keel puncta distinct, 15 in 10 μ; valve surface finely striate, 29 in 10 μ, always invisible.

In salt-water; common in brackish water; in spas.

Tainan-Common, but not abundant.

Nitzschia lanceolata W. Smith

Synedra montana Foged, 1966, Freshwater diatoms from Ghana. Biol. Skr. Dan. Vid. Selsk. 15(1):52-3, pl. 1, fig. 11.

Kokubo, 1965, Plankton diatoms (2nd. ed.), p. 317.
Lindau, 1914, Die Algen, p. 199, fig. 466.
Yamachi, 1966, Ill. Mar. Plankton Jap., p. 57-8, pl. 28, fig. 17.

Valves long, lanceolate; ends somewhat pointedly rounded; cells 100-200 μ long, up to 17 μ broad; keel punctae clear, 5-7 in 10 μ striations fine, 29-30 in 10 μ; margins in the middle of girdle view somewhat swollen; girdle band having fine striations.

Along the coast; in the brackish waters.

Tainan-Very common.

The cells from the Tainan samples are short. This alga is easily identified as it has complicated ends with a special lobe longitudinally.

Cells are similar to *Synedra montana* Krasske with respect to the expanded central part of the valve which has a slight constriction at the poles of the transapical axis. The latter cells 60 X 2.7 μ, living in turbid ponds, and in the alps.

Nitzschia palea (Kütz.) Wm. Smith

Hustedt, 1930, in Pascher's Süsswasserflora 10:416, fig. 801.
Lindau, 1914, Die Algen, p. 200, fig. 470.
Mizuno, 1964, Ill. freshwater plankton of Japan, p. 176, pl. 67, figs. 16, 17.
Tiffany & Britton, 1951, Algae of Ill., p. 288, pl. 76, fig. 900.

Cells 20-65 μ; X 2.5-5 μ valves linear to linear-lanceolate, with cuneate poles; striations 35-40 in 10 μ; keel punctate, 10-15 in 10 μ.

Freshwater and brackish water; on moist walls and among mosses.

Tainan-Common.

The small form of *Nitzschia lanceolata* is now considered identical as this alga, and the shorter form of the alga is closely related to *Nitzschia kützingiana* with only the difference of polar form.

Nitzschia constricta var. *parva* Van Heurck

Mizuno, 1964, Ill. of freshwater plankton of Japan, p. 177, pl. 68, fig. 9.

Cells 20-22 X 8-10 μ; valves constricted in the middle as concave margins; ends sharply tapering to be triangular, polar end protruding slightly; cells slightly broadly linear; keel puncta 13 in 10 μ.

In salt fields (Japan).

Tainan-Rather common in May; and few in other months.

Cells of Tainan samples are smaller than the one described in literature. The sample may be the small type of the taxa. On valve surface, punctae crossed by longitudinal and transverse striations are easily seen.

Nitzschia sigma (Kütz.) Wm. Smith

Hendy, 1961, Account of smaller algae of British coastal waters, p. 281, pl. 42, fig. 1.
Hustedt, 1930, in Pascher's Süsswasserflora 10:420-1, fig. 813.

Kokubo, 1965, Plankton diatoms, p. 317, fig. 367.
Lindau, 1914, Die Algen I, p. 198, fig. 458.

Cells solitary, 50-240 X 4-12 μ; frustules linear, with weakly truncate ends; valves linear, gently sigmoid, curving to sub-acute poles; keel distinct, punctate 8 in 10 μ; valve surface striae, striae transverse, 20-21 in 10 μ.

Marine and brackish.

Tainan-Common.

The structure of this alga is very variable, and cells found in Tainan have two forms: short form less than 30 μ in length and long form more than 50 μ in length. These two forms do not appear together in one place at the same time.

Nitzschia obtusa var. *scalpelliformis* Grunow

Chang, 1967, Taiwania 12:62-3.
Hendy, 1961, Account of smaller algae of British coastal waters, p. 282.
Hustedt, 1930, in Pascher's Süsswasserflora 10:422, fig. 817 b.

Frustules linear, often slightly sigmoid at the ends; valves 60-170 μ long, with obliquely obtused poles, constricted very slightly in the middle; keel puncta 5-9 in 10 μ; striations about 30 in 10 μ; cells 6-13 μ broad.

Common in brackish water and in spas.

Tainan-Rare. Sample cell 60 X 7 μ.

Nitzschia closterium (Ehr.) Wm. Smith
Ceratoneis closterium Ehr.

Gran, 1911, Nordisches Plankton 19:129, fig. 172.
Hendy, 196, An introd. account of small algae of British coastal waters 5:283, pl. 21, fig. 8.
Kokubo, 1965, Plankton diatoms, p. 318, fig. 369.
Lindau, 1914, Die Algen I, p. 195, fig. 452.
Tiffany & Britton, 1951, Algae of Ill., p. 286, pl. 76, fig. 894.

Cells solitary, but usually found matted together in dense masses; central part of the valve weakly oblong, with tapering apex, forming hair-like awns or spines; apex sometimes reduced to form short crescentric or fusiform valves; chromatopores two, small, flattened bodies; valves 32-260 μ long; cells 2-6 μ broad.

Coastal species, found in lagoon; common in neritic plankton all around the British Isles, and Japan, and Taiwan marine waters; in brackish waters, mostly mixed with other algae on the bottom and plankton societies in Tainan ponds.

Samples from Tainan ponds have been found in two types of body-forms; short and long spined. The former is $1^1/_2$ times as long as the latter; both can be easily discovered together at the same site. Long-spined cells found at a single site are usually composed of two forms; straight and bent (up to 45 degrees).

It is very similar to *N. longissima*, but the length of the latter is longer (at least more than 110 μ). Sometimes the short spined cells have an S shaped polar just like *N. longissima* var. *reversa*. Short-spined and long-spined are considered as one species here.

Amphiprora Ehrenberg 1843; emend. Cleve 1891

Cells solitary, free-floating or sessile and attached to substrate by gelatinous envelope, naviculoid in valve view, with rather sharp poles; cells in girdle view with a sigmoid girdle; sigmoid raphe in outer margin of keel with small central and polar nodules; both valve surface and keel ornamented with parallel striae or rows of punctae; several intercalary bands, straight or sigmoid, cells broader in girdle view than in valve view; chromatophore one, sometimes two.

One species has been found in Tainan ponds.

Amphiprora alata Kütz.
Navicula alata Ehr.

Hendy, 1961, Account of smaller algae of British coastal waters, p. 253. pl. 39, figs. 14-6.
Hustedt, 1930, in Pascher's Süsswasserflora Heft 10:340, fig. 625.
Kokubo, 1965, Plankton diatoms, p. 300-1, fig. 347.
Lindau, 1914, Die Algen I, p. 157.

Frustules constricted in the middle and twisted in a "figure of 8" pattern; valves linear, with acute apices; axial area raised to form a sigmoid keel enclosing the raphe; valve surface striate, striae finely lineate; keel coarsely punctate; girdle composed of numerous narrow bands, finely striate; junction line not sinuose; chromatophores two, small. Cells 60-160 X 25-38 μ.

Common in water of lower salinity; in salt water; in estuary; in salt lakes.

Tainan-Rather common.

On Tainan cells, the two chromatophores are always condused into a lanceolate body.

Achnanthes Bory 1822

Cells somewhat rectangular and longitudinally bent in girdle view as

"<" shape, free or united into a ribbon-like chain; valves linear to elliptical, or lanceolate, with a raphe or a pseudoraphe or both; central area distinct, sometimes widened to margins, cross-shaped; transverse striation often radiate; chromatophores one, two or more, all discoid. Two auxospores formed from two cells by conjugation.

It is found in both freshwater and salt water.

Only one alga found in Tainan milkfish ponds seems to be in this genus.

Achnanthes sp.

Smith, 1951, Fresh-water algae of U.S., p. 484-5.

Cells broadly lanceolate in the valve view, slowly tapering toward cuneate obtuse ends; slightly C-shaped in girdle view; chromatophore one, H-shaped in valve view; nucleus in the middle of the cell.

Tainan-Common plankton and bottom society.

Navicula Bory 1822; emend. Cleve 1894

Cells always solitary or free-floating, sometimes aggregated into radiating tufts; frustules symmetrical in all three planes; valves elongate, commonly attenuated toward the poles, with capitate, rounded or rostate apices; raphe distinct, axial, straight, with a small central and polar nodules; axial area very narrow; central area small but smooth; transverse striae or rows of punctate parallel or slightly radial in the median; frustules rectangular in girdle view, with smooth girdles and without intercalary bands; chromatophores two, laminate, some four or eight.

Auxospores are formed by conjugation of two cells or just a division of a protoplast into two gametes which fuse to form two spores.

Most species are freshwater, few are marine.

Key to Tainan species and varieties

1. Valve without capitate poles, broadly rounded ends······*N. lagerheimii*
1. Valve with attenuate or head-like poles, protruded ends·················2
    2. Poles head-like, strongly capitate·········*N. anglica* var. *subsalina*
    2. Poles attenuate or weakly rostate ·····························*N. marina*

Navicula anglica var. *subsalsa* Grunow

Hustedt, 1930, in Pascher's Süsswasserflora 10:303, figs. 530-1.

Valves elliptical, with broadly swollen margins in the middle, with protruded ends or slightly head-like; cells 20-40 μ long, 8-14 μ broad; axial area narrow; central area small, rounded; transverse striation radiately, briefly arranged, 9-12 in 10 μ, but short near the middle nodule.

Widely distributed in freshwaters. Frequently found in salt waters here and there.

Tainan-Common.

Navicula lagerheimii

Chang, 1967, Taiwania 12:56.
Skvortzow, 1938, Phil. J. Sci., 64:446; 65:269.

Cells lanceolate to broadly elliptical; axial area narrow; central area rounded, transverse striations somewhat radial in the middle.

A brackish species (?).

Tainan-Very commonly found in the samples but not many in a single site. Cells about 5 X 10 μ.

Navicula marina Ralfs
=*Navicula punctulata* Wm. Smith

Hendy, 1961, Account of the smaller algae of British coastal waters, p. 207, pl. 31, figs. 1-3.
Patrick & Reimer, 1966, Diatoms of U.S., p. 449, pl. 41, fig. 1.

Valves broadly elliptic-lanceolate with very weakly rostrate apices; axial area narrow, slightly wider at the middle, a distance between the central and polar nodules; central area rounded; valve surface striate, striae punctate, 11-12 in 10 μ, radial in the middle as well as apices. Cells 50-90 X 30-33 μ; 39-65 X 25-30 μ (in Patrick & Reimer).

Littoral, mainly brackish. Common on the south coast of England and in the Thames estuary.

Tainan-Rare.

Cells larger than 34 X 15 μ are considered as the short form of this alga. This alga is often confused with *Navicula granulata* Bailey, which has more open punctation in the middle of the valve, but the former is more common in brackish waters. The size and shape of samples agree with the description of Patrick and Reimer.

Anomoeoneis Pfitzer 1871

Cells generally solitary, lanceolate to rhombic or elliptical in valve view; rectangular in girdle view; axial area with a median circular expansion but small, sometimes lyrate; raphe straight; transverse striations interrupted by smooth space-lines zigzagging longitudinally on valve surface; intercalary bands absent; chromatophore one, laminate.

Formation of two auxospores from the conjugation of two gametes from two sister cells enclosed in a common, gelatinous envelope.

Most species live in fresh waters, but some grow in spas and slightly brackish water.

Only one species is found in Tainan milkfish ponds.

Anomoeoneis exilis (Kützing) Cleve

Chang, 1967, Taiwania, 12:54.
Hustedt, 1930, in Pascher's Süsswasserflora Heft 10, p. 264, fig. 429.
Lindau, 1914, Die Algen I, p. 170.
Tiffany & Britton, 1951, Algae of Ill., p. 246, pl. 65, fig. 739.

Cells 4-6 X 15-35 μ; valves lanceolate, with capitate poles; raphe straight, central area small, circular; transverse striations radial, about 30 in 10 μ; crossed by longitudinal striations.

Common in freshwaters, ponds or lakes; in spas.

Tainan-Rather common but not abundant.

Amphora Ehrenberg 1840

Cells usually sessile with concave faces but attached in girdle view, broadly elliptical, with truncate ends, girdles usually separated by intercalary bands or punctate; valves lunate, longitudinally asymmetric; axial field area strongly eccentric; striations transverse; raphe gibbous, always with the central nodule close to the concave margin; chromatophores 1,2 or 4.

Auxospores formed in pairs by the conjugation of two cells or formed singly by the union of gametes which are produced by a single cell.

This is a large genus, only a few fresh-water species. Most of the marine species live in tropical waters.

One species is abundant in Tainan milkfish ponds.

Amphora lineata Greg.

Kokubo, 1965, Plankton diatoms, p. 303, fig. 351 a.

Cells broadly elliptical, with truncate ends in girdle view; valves lunate, with rather blunt poles, centrally concave, dorsally convex.

Marine.

Tainan-Common.

Diploneis Ehrenberg 1844

Cells free, solitary, rectangular in girdle view; valves elliptical or linear, with a median constriction; central area with a nodule, quadrate;

axial area narrow, with a raphe or furrow transverse costae or rows of punctate, radial, often crossed by longitudinal ones; chromatophores two.

Marine and freshwater.

One species is found in Tainan ponds.

Diploneis puella (Schumann) Cleve
=*Navicula elliptica* var. *minutissima*

Chang, 1967, Taiwania 12:54-5
Hustedt, 1930, in Pascher's Süsswasserflora 10:250, fig. 394
Tiffany & Britton, 1951, Algae of Ill., p. 249, pl. 65, fig. 751.

Cells 13-27 X 6-14 μ; valves elliptic; central area large and four-sided; raphe linear, narrow and distinct; furrow narrow and linear; transverse costae delicate, somewhat radial, 14-18 in 10 μ; with intermediate spaces very finely punctate; longitudinal costae indistinct.

Fresh-water, usually hard; in slightly salty water.

Tainan-Common, in some sites they are predominant at the right season.

There are two kinds of the algae in the Tainan samples: ovate and broadly lanceolate. A lobed chromatophore around the cell content has been observed in the ovate cell, on the other hand a small body of pale chromatophore is present in the broadly lanceolate cell. In this case I think the lanceolate form is an old form of the ovate cell. These two types of the algae have been treated as a single taxa.