ON THE PHYTOPLANKTON POPULATION IN THE FISH PONDS AT TAINAN

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Not much work has been done on the fresh water algal flora of the island of Taiwan. What has been done has been of a qualitative character rather than a quantitative one. Up to the present time nothing has been known about the population and the periodicity of the freshwater phytoplankton on this island. Since Taiwan is located in the subtropics and is geologically new, it has quite a different appearence in its algal flora from that of the British Islands. Although the island is small yet there are high mountains separating the land into quite complicated ecological environments. Thus the study of plant ecology on this island is very interesting, For the busy individual, with multifarious duties to perform, it is by no means an easy task to make collections at frequent intervals throughout the year. It is desirable that pioneer work should be undertaken to gain a sound knowledge of Taiwan freshwater phytoplankton.

In the year 1956, the writer had the privilege of visiting Tainan frequently and of making a quantitative study of the phytoplankton of the fish ponds in the Tainan Fish Cultural Experimental Station of the Taiwan Fisheries Research Institute. A special acknowledgment is due to Mr. Y. H. Tong, the director, for by his assistance and cooperation this work was made possible.

Material and Method

Water sample were collected each time from each of the ponds in large ten liter glass bottles and to each 300 ml. of formalin was added. After shaking, the bottle was allowed to stand for one week until all the solid particles had settled to the bottom and then by using a siphon tube the clear liquid on the upper layer was withdrawn. Finally the remaining fluid was centrifuged with an electric centrifuge and the solid sediment (total productivity) was measured in milliliters. The fixing fluid was 5% Formalin; it was again added to the sample to make up the volume up to ten milliliters and this was kept in a small glass bottle. A few collections, being of a larger amount of solid sediment, were kept in larger bottles and with more fixing fluid being added, but the volume was always calculated in a special proportion to the original volume of water collected.

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From each bottle 0.01 ml. of the sample was transferred by a pipette to a slide, and was covered by a square cover glass and examined under a microscope and the number of the algae present on that square was counted by the aid of a mechanical stage. The above countings were repeated ten times and the total amount was then multiplied by one hundred; this gave the total number of organisms in the ten liters of water examined.

Pools Investigated

Collections of plankton algae were made from January to December in 1956. Repeated collections were made from the same bodies of water each month continuously all through the year. Twenty three different collections were made. The data on which the collections were made are as follows: January 26, February 10, February 23, March 9, March 23, April 6, April 20, May 4, May 18, June 11, June 29, July 14, July 28, August 25, September 8, September 22, October 20, November 3, November 17, December 1, December 15, December 29.

All bodies of water investigated are fish ponds in or near the Fish Cultural Experiment Station of the Taiwan Fisheries Research Institute on Li Ren Street, Tainan.

The following is a list of the ponds investigated:
North Pond No. 1 with 0.42 hectare (4,230 sq. ft.)
Central Pond No. 1 With 0.04 hectare (396 sq. ft.)
Frog Pond No. 2 With 0.0025 hectare (25.4 sq. ft.)
(the above three ponds are all on the inside of the Fisheries Experiment Station)
Stone Bridge Fish Pond with 6.6 hectare (65,839 sq. ft.)
(which is located on the west side of the Station)

"Frog Pond No. 2" is a small concrete rectangular pond used for frog cultivation. It is shaded by a screen and by climbing vines so that less than one-third of the sunlight can pass through. The information regarding the weather data is taken from the Tainan Fish Cultural Experiment Station of the Taiwan Fisheries Research Institute. The average temperature for each month throughout the year is listed in the following table and chart. (Table 1 & Fig. 1).

The temperature is quite warm from May to October. The coldest month is January, but it still has an average temperature of above 18°C.

Thirty-nine different genera of algae were counted to ascertain their relative population and seasonal variations. They are: *Euglena, Phacus, Trachelomonas, Botrydiopsis, Tribonema, Rhizochrysis, Diatoms, Chroococcus, Cyanarcus, Aphanocapsa, Microcystis, Dactylococcopsis, Gomphosphaeria, Rhaphidiopsis, Merismopedia, Spirulina, Pelogloea, Anabaena, Anabaenopsis, Pseudoanabaena, Oscillatoria, Phormidium, Lyngbya, Chlamydomonas, Scenedesmus, Tetraedron, Crucigenia, Golenkenia, Actinastrum, Ankistrodesmus, Selenastrum,*

Table 1. The average of the Atmospheric Temperature and the Water Temperature of the four fish ponds

			January	February	March	April	May	June	July	August	September	October	November	December
Atmospheric Temperature		A. M.	14.41	15.8	20.15	22.79	26.36	27.4	27.45	26.2	26.8	25.4	20.7	17.9
		P. M.	21.8	23.2	26.35	29.46	31.41	30.5	30.99	35.8	29.6	29.4	26.4	23.1
Water Temperature	Central No. 1	A. M.	17.72	19.2	22.19	25.07	28.97	29.22	29.38	30.2	28.8	27.6	23.3	20.3
		P. M.	21.31	23.7	28.03	29.8	32.38	33.5	33.95	33.9	30.8	30.1	27.2	23.3
	North No. 1	A. M.	14.9	19.2	22.5	29.78	29.74	29.2	31.28	31.1	29.7	28.5	23.0	20.8
		P. M.	20.58	23.5	25.3	29.32	31.74	34.0	33.06	33.4	31.1	30.5	27.2	22.0
	Stone Bridge	A. M.	17.84	19.1	22.69	25.17	29.24	30.0	30.47	30.0	29.0	27.6	23.3	20.2
		P. M.	20.84	23.6	28.13	29.99	32.41	33.9	32.81	34.4	31.0	29.9	27.4	22.9
	Frog Pond	A. M.	15.95	16.98	20.57	24.01	26.62	27.4	27.56	27.5	27.2	25.2	21.1	18.3
		P. M.	17.16	19.97	22.75	26.19	28.43	29.8	28.47	28.1	28.4	27.3	23.3	20.2

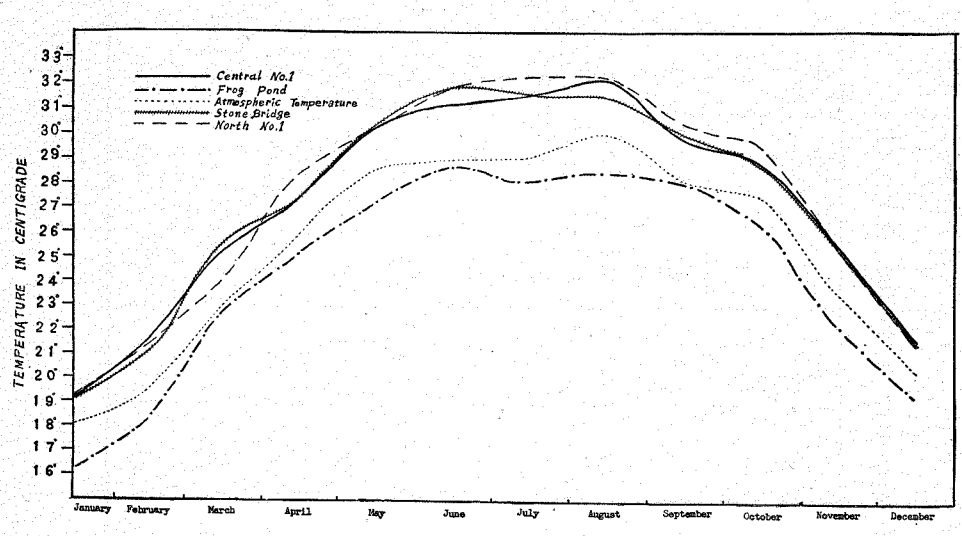

Fig. 1. Temperature chart of the year—Atmospheric temperature and water temperature of the four ponds.

Tetrastrum, Chlorococcum, Pediastrum, Closterium, Cosmarium, Staurastrum, Glenodinium, Peridinium.

The above algae belong to the five following divisions: Euglenophyta, Chrysophyta, Cyanophyta, Chlorophyta, and Pyrrhophyta. Algae belonging to the Chlorophyta are mostly of the Chlorococcales group. The Desmid count was low.

The bodies of water examined were small and stagnant, and the plankton investigated in them belongs to the helioplankton. They are located near to each other and the weather is about the same for each pond, but there are some important factors which make the environment different. One is the light factor, it is especially different in the "Frog Pond No. 2" from the rest of the ponds investigated. The water in "Frog Pond No. 2" has less light intensity than any of the others, because it is shaded by screen. "North Pond No. 1" is situated at the side of a house, therefore a small part of which is shedded for a period each day. "Stone Bridge" is a private fish pond with trees on its bank. "Central Pond No. 1" receives the most direct sunlight.

The Total Population of Phytoplankton Throughout the Year

The total plankton materials were quantitatively removed from the water samples (after they had been fixed, allowed to settle and had been centrifuged). The following figures are the number of ml. present in ten liters of water sample.

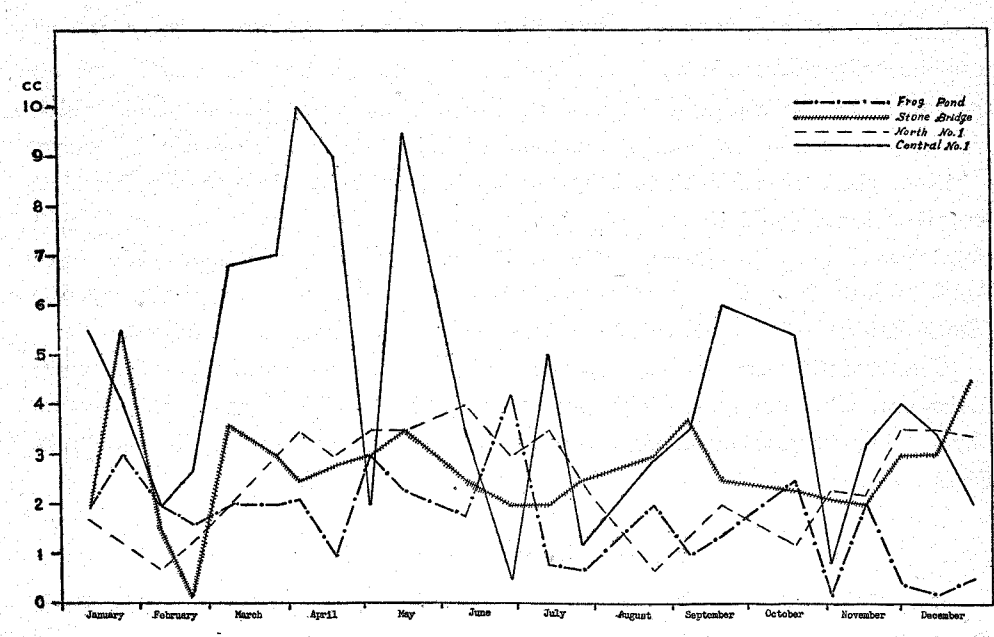

Fig. 2. Chart of the periodicity of total population of the phytoplankton in each of the four ponds.

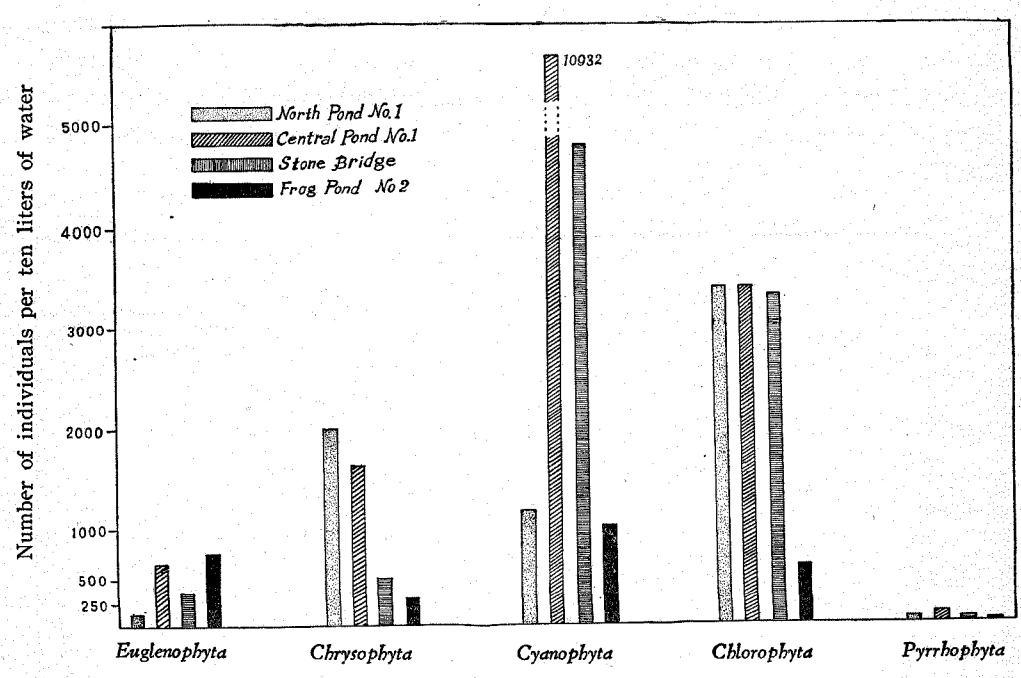

Fig. 3. The average population of the five main divisions in four fish ponds (number of individuals per ten liters of water).

Among the four ponds investigated "Frog Pond No. 2" gave the lowest productivity of phytoplankton, and the "Central Pond No. 1" gave the highest

productivity of phytoplankton. The highest yield in the "Frog Pond No. 2" was the collection made on June 29, which has 4.2 ml. per ten liters. But on the same day the water in "Central Pond No. 1" gave the lowest yield, which was only 0.5 ml. in ten liters. The population in "Central Pond No. 1" shows a higher yield from March to May and again from September to October, but it gave a lower yield in the mid-summer season. The population for "North Pond No. 1" gave its highest yield on June 11 and had a higher yield from April to July than in any other period of the year. The population of the "Stone Bridge" Fish Pond showed less variation than that of the others.

The constituents of the phytoplankton can be separated into five main divisions: Euglenophyta, Chrysophyta, Cyanophyta, Chlorophyta and Pyrrhophyta. The average population of these algae in the four ponds is shown in Figure 3.

The Population of Euglenoids

Three genera of the Euglenophyta have been counted, but only the genus *Euglena* is common. *Trachelomonas* is very rare. The average number of Trachelomonas to be found in "Frog Pond No. 2" is three per ten liters of water and in "Cetral Pond No. 1" is four per ten liters of water. The average number of *Phacus* to be found in the "Frog Pond No. 2" is 22 per ten liters of water; 43 per ten liters of water in the "Stone Bridge" Fish Pond; 12 per ten liters of water in "North Pond No. 1"; and 38 per ten liters in "Central Pond No. 1".

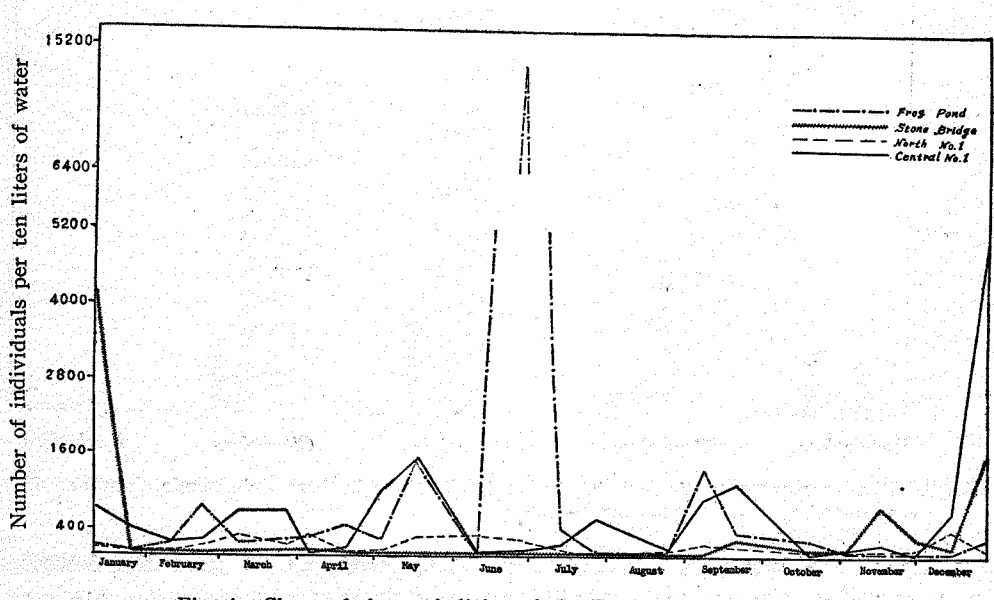

Fig. 4. Chart of the periodicity of the Euglena in each pond.

Euglena has its highest population in the "Frog Pond No. 2" where the average number in ten liters of water is 937; the second in "Central Pond No. 1" which has 325 per ten liters of water; and the lowest in "North Pond No. 1" which has 130 per ten liters of water. The highest yield of *Euglena* was in "Frog Pond No. 2" on June 29, which had 14,910 per ten liters of water. The periodicity of *Euglena* present in the four ponds is shown in Figure 4.

The Population of Chrysophyta

Three types of Chrysophyta have been counted. They are: *Botrydiopsis*, a spherical unicellular form; *Tribonema*, a filamentous form; and the *Diatoms*. Among these the Diatoms are the most abundant form. The average population of *Botridiopsis* is 7.8 per ten liters of water in "Frog Pond No. 2"; 8 per ten liters in "Stone Bridge" fish pond; 15 per ten liters in "North Pond No. 1" and 78 per ten liters in "Central Pond No. 1."

The average population of *Tribonema* was 58 per ten liters in "Frog Pond No. 2"; 41 per ten liters in "Stone Bridge" fish pond; 87 per ten liters in "North Pond No. 1"; and 771 per ten liters in "Central Pond No. 1". It shows a high production in "Central Pond No. 1". As to its seasonal distribution, it seems to favor the colder weather. The population of Diatoms found in these ponds is highest in "North Pond No. 1"; its average population per ten liters of water is 1945. The next is "Central Pond No. 1"; which has an average population of 747 per ten liters. The lowest population is found in "Frog Pond No. 2", which has 320 per ten liters. In "Stone Bridge" fish pond there were 426 per ten liters. The periodicity of Diatoms and Chrysophyta are shown in Figure 5 and Figure 6.

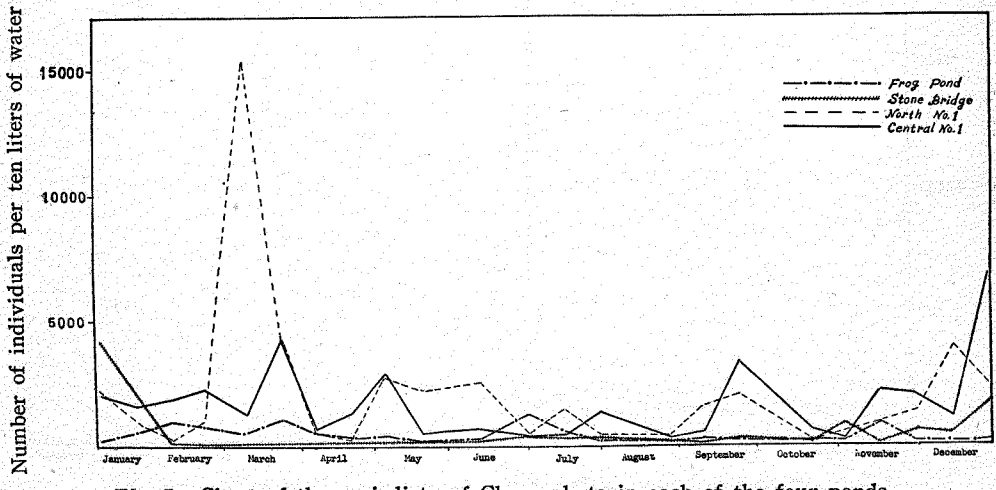

Fig. 5. Chart of the periodicty of Chrysophyta in each of the four ponds.

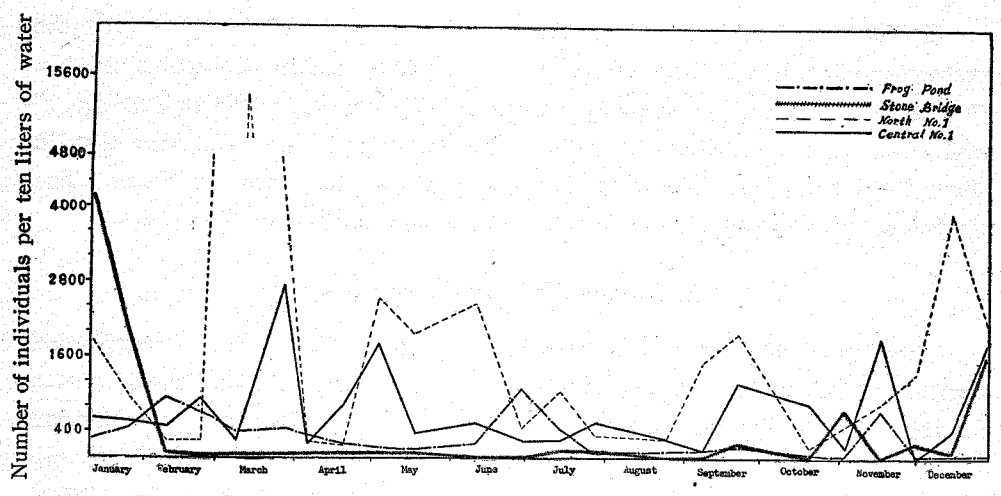

Fig. 6. Chart of the periodicity of Diatoms in each of the four ponds.

Population of Cyanophyta

Cyanophyta is the most abundant vegetation in these fish ponds. The highest number appeared on April 20th and May 4th in "Central Pond No. 1"

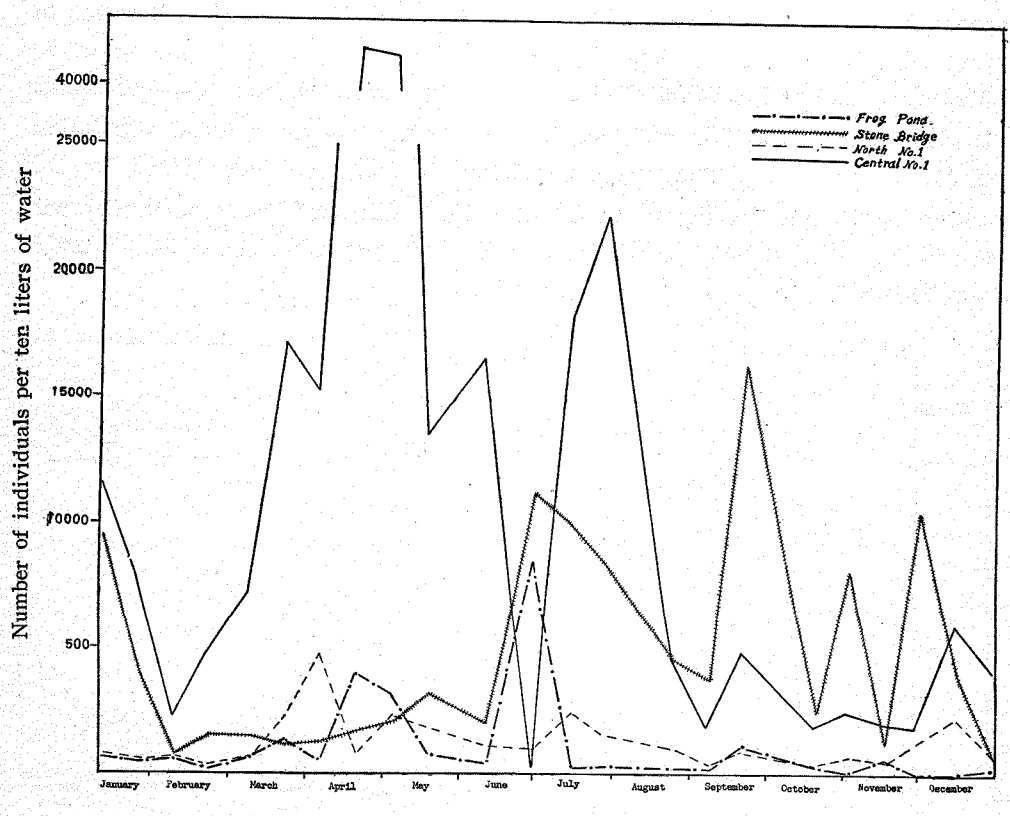

Fig. 7. Chart of the periodicity of Cyanophyta in each of the four ponds.

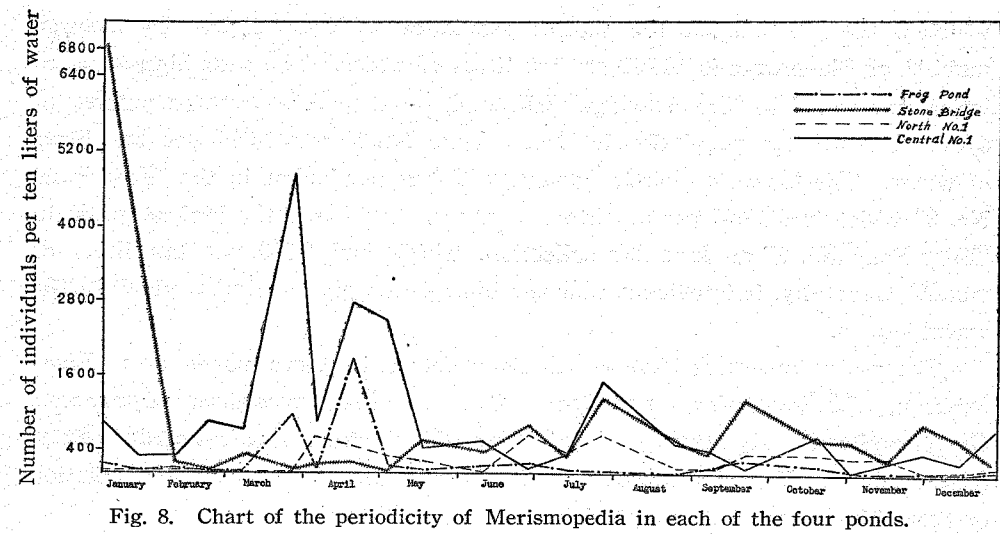

Fig. 8. Chart of the periodicity of Merismopedia in each of the four ponds.

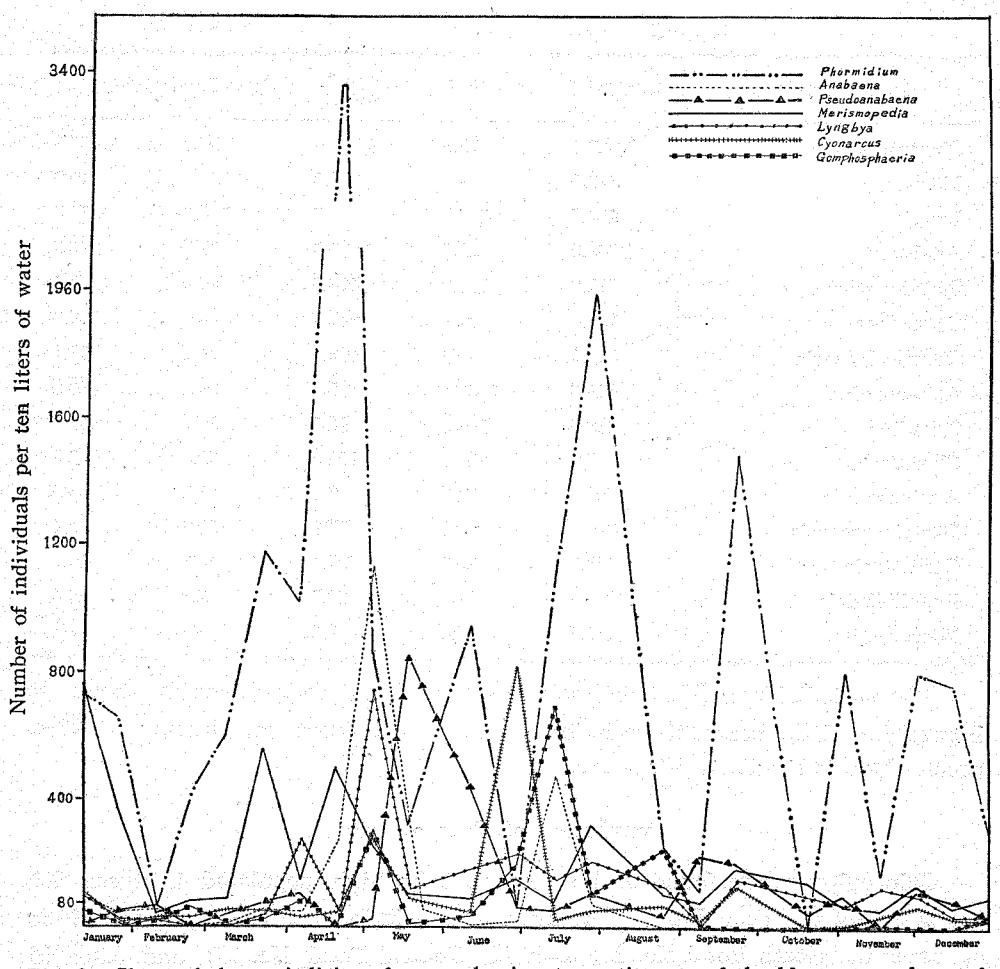

Fig. 9. Chart of the periodicity of seven dominant constituents of the blue green algae of the four ponds.

which is the one that had the highest population of Cyanophyta. Its average number of Bluegreens is 10,932 per ten liters of water. The next biggest population was found in "Stone Bridge" fish pond, which had an average number of 4,836. The average population in "North Pond No. 1" was 1,306 per ten liters of water. The lowest population among the four ponds was in the "Frog Pond No. 2" which had 1,086 per ten liters of water. We found the highest peak in "Frog Pond No. 2" on June 29's collection, which had 8,560 per ten liters of water. Generally, it is evident that the blue-greens give a higher yield in the warm season.

The major genera of blue green algae found in these ponds are: *Phormidium, Merismopedia, Lyngbya, Anabaena, Pseudoanabaena, Cyanarcus, Gomphosphaeris, Aphanocapsa, Spirulina, Chroococcus, Anabaenopsis, Dactylococcopsis, Oscillatoria, Rhaphidiopsis, Microcystis.* The average population of these blue-greens in each pond is given in Table 2.

Table 2. The average population of the blue-greens in each pond

Name of Algae	Central 1	North 1	Stone Bridge	Frog Pond	Average
Phormidium	5,980.4	75.6	1,716.9	97.3	1,967.5
Merismopedia	820.8	182.4	907.3	353.0	540.9
Lyngbya	624.7	256.5	331.7	138.6	337.8
Anabaena	1,007.3	22.6	19.5	97.8	286.8
Pseudoanabaena	513.0	100.0	408.6	46.9	267.1
Cyanarcus	158.2	71.7	643.4	73.9	236.8
Gomphosphaeria	312.1	40.4	425.6	78.2	214.1
Aphanocapsa	448.6	30.4	9.5	33.4	130.5
Spirulina	268.6	102.6	96.9	34.7	125.7
Chroococcus	7.8	223.9	198.6	63.4	123.4
Anabaenopsis	269.5	93.9	6.9	97.3	116.9
Dactylococcopsis	178.2	66.5	57.8	95.2	99.4
Oscillatoria	144.7	20.4	29.1	44.7	59.7
Rhaphidiopsis	—	17.8	64.7	3.0	21.4
Microcystis	15.6	4.3	8.6	—	7.1

The periodicity of *Merismopedia* in each of the four ponds is shown in Figure 8, and the seasonal variation of seven dominant constituents of blue-green algae is shown in Figure. 9.

Population of Chlorophyta

Chlorophyta were found to be more evenly high populated in these fish ponds except the Frog Pond. The average population was 3,461 per ten liters of water in "North Pond No. 1"; 3,456 in "Central Pond No. 1"; and 3,318 in

"Stone Bridge" fish pond. But there were only 639 per ten liters of water in "Frog Pond No. 2". The highest number was found in "North Pond No. 1" on June 11th, which was 11,920 per ten liters of water. The seasonal variation in the productivity of the green algae of these ponds is shown in the chart of Figure 10.

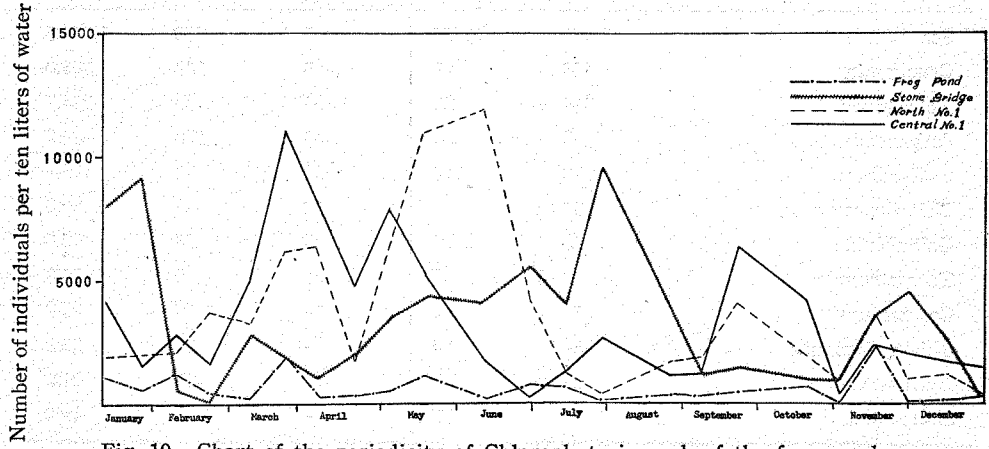

Fig. 10. Chart of the periodicity of Chlorophyta in each of the four ponds.

The predominant green alga in these ponds is Scenedesmus, and the periodicity of it is shown in Figure 11 below.

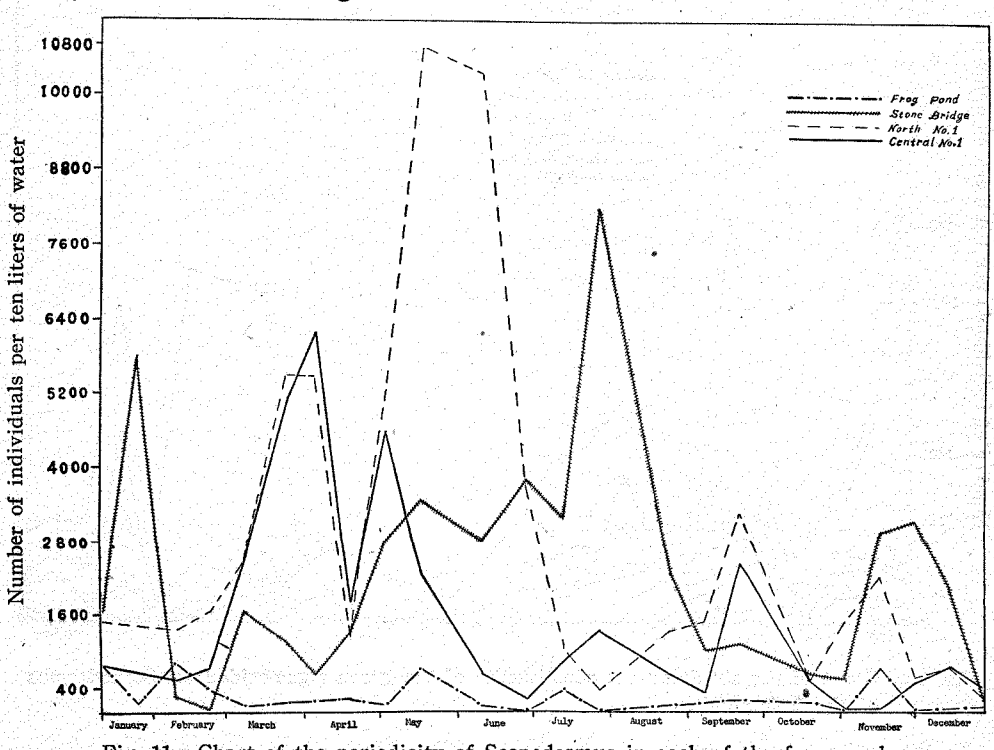

Fig. 11. Chart of the periodicity of Scenedesmus in each of the four ponds.

The average population of the different genera of green algae in each pond is show in Table 3 below.

Table 3. The average population of green-algae in each pond

Name of Algae	Central 1	North 1	Stone Bridge	Frog Pond	Average
Scenedesmus	1,463	2,778	2,202	255	1,674.5
Crucigenia	466	421	185	148	305.0
Tetraedron	314	28	468	89	224.7
Ankistrodesmus	69	34	65	170	84.5
Pediastrum	192	112	91	32	106.7
Chlorococcum	265	—	13	—	69.5
Golenkinia	176	53	9	16	63.5
Tetrastrum	52	38	48	9	36.8
Cosmarium	56	30	23	10	29.7
Chlamydomonas	59	10	—	26	23.8
Actinastrum	23	9	17	35	21.0
Selenastrum	54	22	—	3	19.0

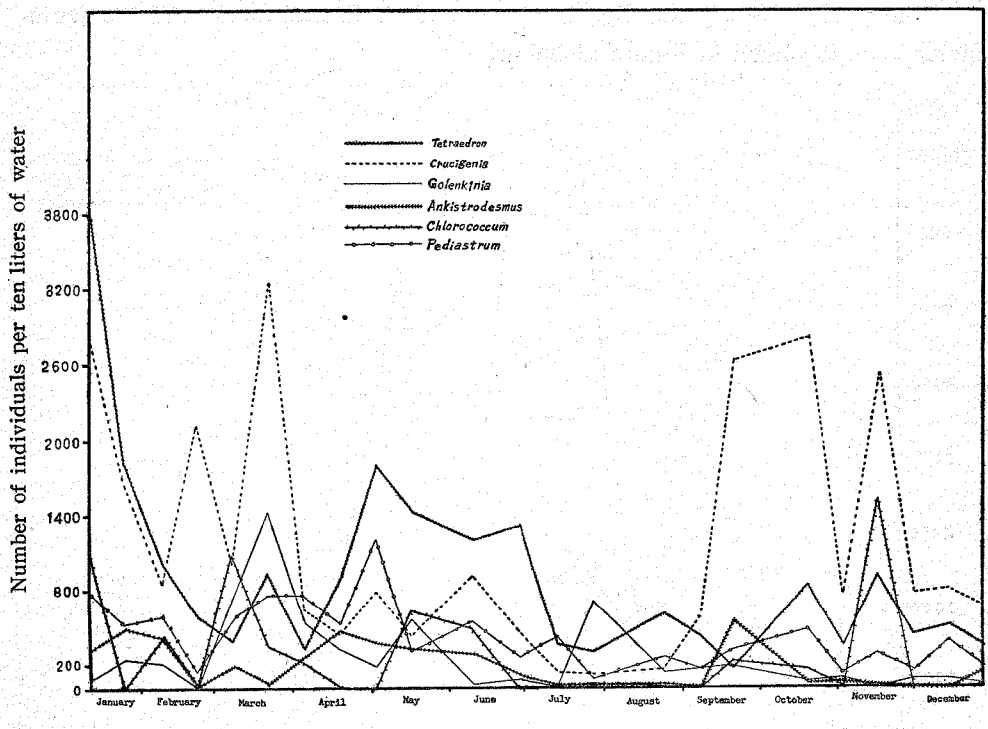

Fig. 12. Chart of the six dominant constituents of the green algae aside from Scenedesmus of the four ponds.

The green algae present in these ponds belong mostly to the Chlorococcales

group. Desmids are very few in number. A chart of the six dominant genera of green algae aside from Scenedesmus is given in Figure 12.

The periodicity of Pediastrum is shown in Figure 13 below.

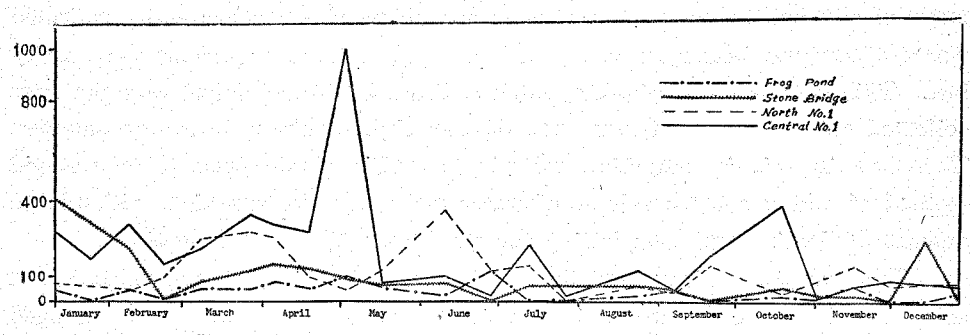

Fig. 13. Chart of the periodicity of Pediastrum in each of the four ponds.

Population of Pyrrhophyta

Since these ponds investigated were relatively small, we never observed the presence of *Dyanobrium.* We only found two dinoflagellates, namely *Glenodinium* and *Peridinium.* "Central Pond No. 1" has a relatively larger population than others. There were 198 per ten liters on the average in "Central Pond No. 1". The average number of Chrysophyta in "North Pond No. 1" was 82 per ten liters, and in "Stone Bridge" fish pond was 46. The lowest number to be found in "Frog Pond No. 2" was 31. The highest number found was on July 28's collection in "Central Pond No. 1". Generally speaking, the population of Pyrrhophyta is low in all these Ponds.

Table 4. Average population of Pyrrhophyta in each pond

Name of Algae	Central 1	North 1	Stone Bridge	Frog Pond	Average
Glenodinium	84.7	22.6	—	3.4	27.7
Peridinium	113.4	59.5	46.0	27.8	61.7

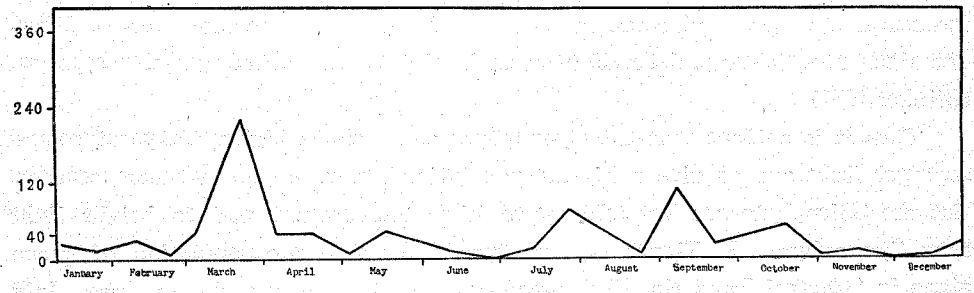

Fig. 14. Chart of the periodicity of Pyrrhophyta in the four fish ponds, showing the Changing in number of individuals per ten liters of water through a year.

Discussion and Conclusion

When the writer first started to make collections he used a plankton net made of silk bolting-cloth. But it was soon observed that the quantity collected was not accurate, because a great number of the minute organisms were easily lost. This is true, since Bigelow, Illick & Sears (1940) had found that the nets collected only one to ten per cent of the phytoplankton in water samples. Therefore in this investigation we adopted what would seem to be a stupid method of taking a large volume of water and fixing the organism with a large amount of fixative and then letting the plankton settle for a long time.

When we are talking about the periodicity of the phytoplankton, the first thing that occurs to our minds is that the population is likely to be changed directly in proportion to the temperature changes. But it has been shown in this experiment that this is not the case. There are other important factors which determine the growth of phytoplankton, and temperature is not the only factor. A too high or too low a temperature would inhibit the growth but when one studies the temperature curve of Tainan one realizes that even in the winter season the average temperature is still not too cool. A warm climate favors the growth of algae; but if the temperature is too high, it inhibits the growth. Another very important factor which is always closely related to temperature is light. Light seems even more important than temperature. The "Central Pond No. 1" which received more light intensity than the others had a relatively higher population of phytoplankton, while the "Frog Pond No. 2" receiving less light intensity, had a relatively lower population of phytoplankton. This is a strong evidence for proving the importance of light intensity in natural condition. But if the light is too strong, and the temperature is too high, it is also unfavorable to the growth of phytoplankton. This can be seen from the total productivity curve of the "Central Pond No. 1" which shows a decrease in productivity for the months of June and August. In most algae, respiration increases very rapidly when the temperature is above 25°C. The mechanism of heat injury is also possible for the melting of certain lipids with structural changes of plasmamembrane or plastids. But the characters of different algae are different, depending on their pigmentations and enzyme systems. (Blinks, 1951)

Thus it is evident that the Cyanophyta can resist a higher temperature and stronger light and so give a higher population count in the warmer seasons. But the Chlrophyta are less tolerant to high temperature and to bright light than Cyanophyta. In Figure 10, the curve shows that the population of green algae in "Central Pond No. 1" dropped down during the months of June, July and August. When we examine the curve of Diatoms we find that it seems to

favor a colder season. The Frog Pond is the place which always contains a high concentration of organic material, because people feed the frogs with meat and there is always some decaying meat left in the water. Euglenophyta seems to grow better in water rich in organic materials. When it gets enough light intensity it grows quickly. This can be proved by the rapid increase of *Euglena* in the end of June in "Frog Pond No. 2".

The changes in the production of phytoplankton gives less variation in "Stone Bridge" fish pond. The reason for this may be due to its being larger in size. Whenever changes do occur, either nutritional or of other environmental factors, it is not as sensitive as smaller bodies of water.

When we compare the total productivity of the five divisions of algae in each pond, we find that the Chlorophyta seems best able to survive. This group gave a very similar amount of average yield in each of the three fish ponds and only appeared low in frog pond which had a very different environment from the others. The Frog Pond differs from the others by having: (1) less light intensity by shadings; (2) high concentration of organic material in the water for the residual remains of the fodder of frogs; (3) higher acidity and lower oxygen content by the action of the bacterial decay of the meat left in the water. This shows that the Chlorophyta appear the better adapted to different environments. The cause for low count in the Desmid flora in this investigation as well as the investigations made by the writer before is probably due to the fact that Taiwan is geologically new.

臺南魚池中浮游藻類產量之研究

沈 毓 鳳

本實驗之目的，在觀察自然環境下浮游藻類在淡水魚池中生長情形及產量之變化。受試驗之魚池爲臺南水產試驗所之"中一號"，"北一號"，"牛蛙池"及其西隣"石橋魚池"四處；由于此四處之大小，和環境之不同，其生長及產量亦因之而有差異。

此實驗進行于1956年一至十二月，每月採集標本二次，其結果列入各圖表內，顯示光照爲最重要因素，光照與浮游藻類之產量成正比，溫度之影響不及光照顯著，但太大或太低均不適於浮游藻類之生長及繁殖，在一年中，三月至五月，九月至十月爲最適宜季節，產量較高，在寒暑季節，均不適當，故產量亦低。

實驗顯示，綠藻較能適應各種不同環境。藍藻能抗高溫。黃藻不能抗熱，在寒冷季節，產量反而較高。雙鞭藻適宜於較大之水池。游藻繁盛於有機物豐富之處。(摘要)

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