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Growth Dynamics of *Microsystis* spp. in Lake Taihu*

CHEN Weimin, CHEN Yuwei and GAO Xiyun

Taihu Lab for Lake Ecosystem Research, CAS
Nanjing Institute of Geography & Limnology, CAS,Nanjing 210008, China

Abstract: *Following the development of local industries, agriculture and the increase of living standard of people, Lake Taihu is in the meso-eutrophication stage. The main eutrophication part in this lake is the Meiling Bay. The dominant phytoplankton species are* Microcystis, Anabena, Melosira, Cyclotella *and* Cryptomonas. *In summer, Microcystis spp. occupys 85 % of algae biomass and form the water bloom. This causes the trouble for the people lived around the lake, especially for the drinking water of Wuxi City.*

The Microcystis intrinsic rate was high, the Max. growth rate 1.27. Besides Microcystis own characteristics, its growth depended on irradiation, temperature and nutrients, especially the phosphorus. This paper also discussed the possibility of biomanipulation for restoration of lake ecology and the control strategy of lake eutrophication.
Keywords: *Lake Taihu,* Microcystis *spp., Growth*

1. Introduction

Lake Taihu is the third largest freshwater lake in China. It is located between 30°5′-32°8′ N and 119°8′ -121°55′ E, with an area 2 338 km^2 and mean depth 1.9 m. Its catchment is 36 500 km^2 with a population of 31 milliion. The lake plays an important role in the local economic development. Following the development of industries and agriculture, as well as the increase of living standard of people in this region, the water quality of this lake now becomes worse than that of before.

Condition of Lake Taihu is belonging to meso-eutrophication stage. Since the end of 1980' the algae bloom can been observed obviously every year. The period of the bloom occurres from about April to December yearly. It reduces the drinking water quality for the residences around the lake and the people of Wuxi City and brings a lot trouble for industries and municipal activities. The dominant algae are *Microcystis* spp. A lot researches have been done on its structures

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within its cells and its poison. It is very important to study the growth dynamics of *Microcystis* for understanding the mechanism of Lake Taihu eutrophication.

2. Methods

2.1 Sampling and counting

The partial parts of Lake Taihu have been eutrophicated, especially the Meiliang Bay situated near Wuxi City with an area 100 km^2. There are two main rivers entering to this bay. They are the Meiling River and the Lujiang River. In order to study the eutrophication of the lake, 9 stations have been monitored monthly in Meiling Bay and open area of Lake Taihu since 1991 (Fig.1).

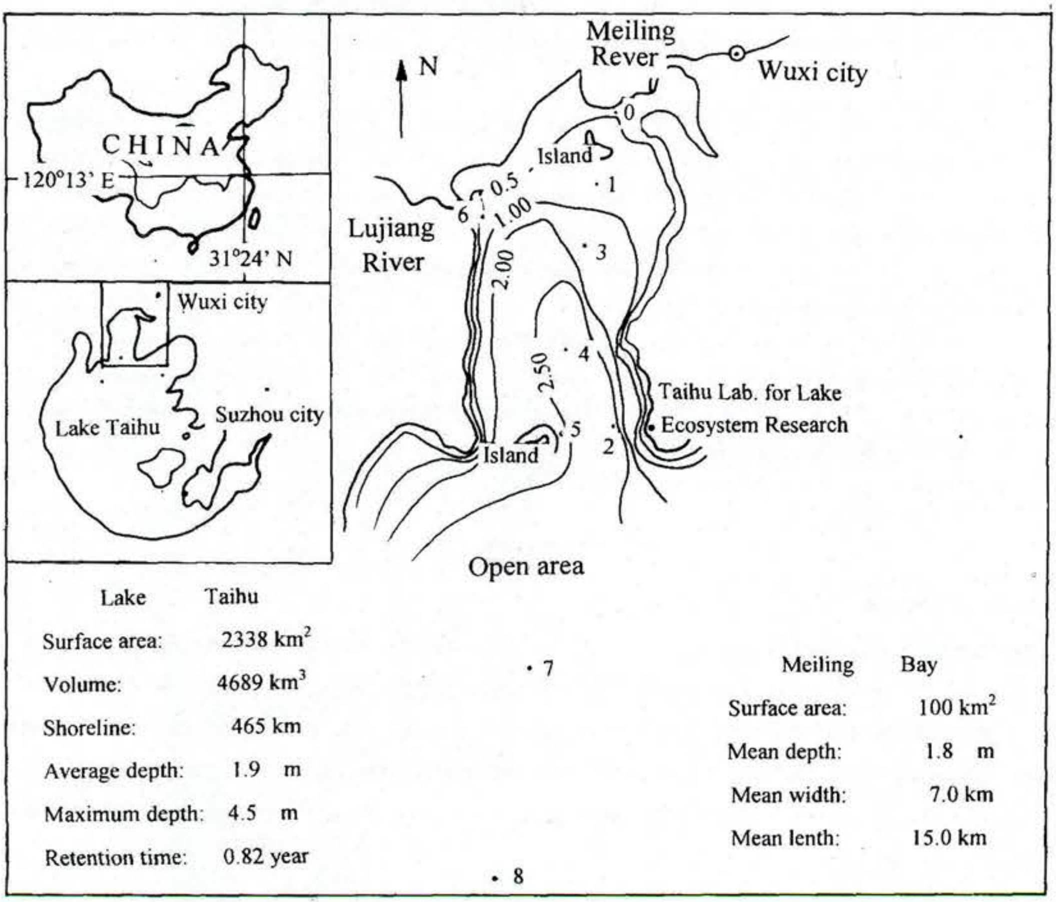

Fig. 1 The mophological properties of Meiling Bay and the Sampling Station

Phytoplankton samples were collected by cylinder sampler and fixed by Lugol's solution from 9 stations. Samples were precipitated for more than 24 hours and concentrated into 30 ml from 1 liter of sample. The identification and counting of phytoplankton were done under microscope. The algae abundance was converted from counting data.

2.2 Lake enclosure experiment

In order to estimate the algae bloom distribution influenced by the wind, the enclosure experiment was done in Lake Taihu near field station. There were 6 enclosures used during 19-24 June, 1993. Chlorophyll-*a* was measured for estimating *Microcystis* biomass every day. The wind direction and velocity were measured at same time.

2.3 Ecological experiments

(1) Based on the tests, the BG-11 medium was chosen for ecological experiments of *Microcystis* spp . culture.

(2) Microcystis spp. acts as ecological species. The inoculating *Microcystis* were from the lake. The procedures were as follows: a) *Microcystis* spp. were collected by phytoplankton net, put in a bottle , brought into lab. in light place. More than 95 % of them were *Microcystis* spp. Sample was set for several hours for *Microcystis* floating and animals separating. b) Using dropper, *Microcystis* spp. were isolated from the rest and put it into a triflask. The colonies were be separated by mechanism with small pieces of glass and filtered by 10 μ net and cultured for 2-3 days for further inoculation. c) The culture were conducted in the shaking bed at ca 30℃, with 6 fluorescent lamps (40 W/lamp). A serial ecological experiments were done concerning the growth, as well as the physco-chemical factors which affected the growth.

(3) Chlorophyll-*a* concentration was measured by spectrophotometer after the acetone extraction (Vollenweider, R.A.). The growth rates were estimated by the formula:

$$r=(\ln c_1-\ln c_0)/\Delta t$$

where r- growth rate, c_1 the final concentration of Chl-*a*, c_0 the original concentration of Chl-*a*, Δt is the time difference between the original and the final. The diameters of colonies were measured by Elzone particle account.

3. Results

3.1 Dynamics of phytoplankton in Meiling Bay

Meiling Bay, there is only one peak of phytoplankton biomass in summer in every year. It appears around June or July. The Max. biomass was 84 $mg\cdot L^{-1}$ in June 1992 and Min. biomass 0.24 $mg\cdot L^{-1}$ in February 1993. The mean biomass in 1993 was 4.45 $mg\cdot L^{-1}$. The fluctuation of chlorophyll-a concentration was similar to the change of phytoplankton biomass.

The dominated algae were *Microcystis, Anabena, Melosira, Cyclotella, Cryptonomas* and *Scenedesmus*. Among them, *Microcystis aeruginosa* and *M. flos-aquae* were main eutrophication algae in Lake Taihu and can be observed in water samples nearly the whole year. In summer, they always formed the thick scums, the so-called water bloom. Its abundance can reach to 99 % of the total algae $cells\cdot L^{-1}$ and occupy 85 % in biomass within summer period. *Microcystis* could be found in the surface layer of the lake sediments (Reynolds C. S. *et al.*).

The seasonal succession of phytoplankton was very clear. The algae, mentioned above alternate to be the seasons dominate species (Fig.2). The annual succession trended to be going to change. From the curve in Fig.3, the monthly mean biomass of *Microcystis* gradually reduced from 1992 to 1994. The mean biomass of *Microcystis* in 1992 was 10 mg · L^{-1} and 5×10^8 cells · L^{-1}. In 1993, it reduced to 6 mg·L^{-1} and 3×10^8 cells·L^{-1}, and in 1994 2.5 mg·L^{-1} as 25 % in 1992. The water bloom stretched to south area gradually. Along the shoreline area and in the northern part of Meiling Bay, the biomass of *Cryptomonas ovata, C. erosa* and *Chroomonas acuta,* as well as *Anabena, Oscillatoria* and *Cyclotella* were increasing. The similar phenomenon had been observed in Lake Donghu, China. Wang Jian and Lin Wanlian described In Lake, the small-sized algae had replaced the blue-green algae as the dominant species during 1979-1986. The small-sized algae include *Merismopedia glauca, Cryptomonas ovata, C. erosa,* several speceis of *Cyclotella* (Wang Jian *et al*). Such kind succession of algae had also been observed in Lake Kasumigaura, Japan (Fukushima T. *et al*). A nutrient competition hypothesis was proposed to explain the reason of the disappearance of blue-green algae bloom.

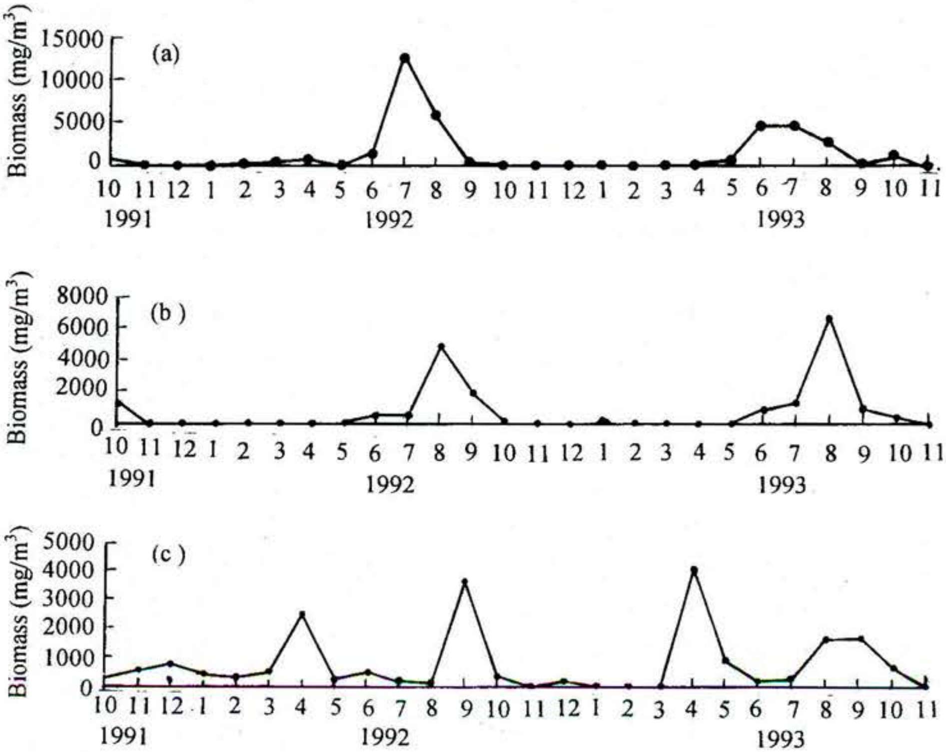

Fig. 2 Seasonal succession of dominant algae in Meiling Bay (a *Microcystis,* b *Melosira,* c *Cryptomonas*)

The annual changes of *Microcystis* abundance could be divided three periods. The first period was from December to next April. Few *Microcystis* could be observed in water samples. Some of them were on the sediments surface. The second period was from April or May. The beginning

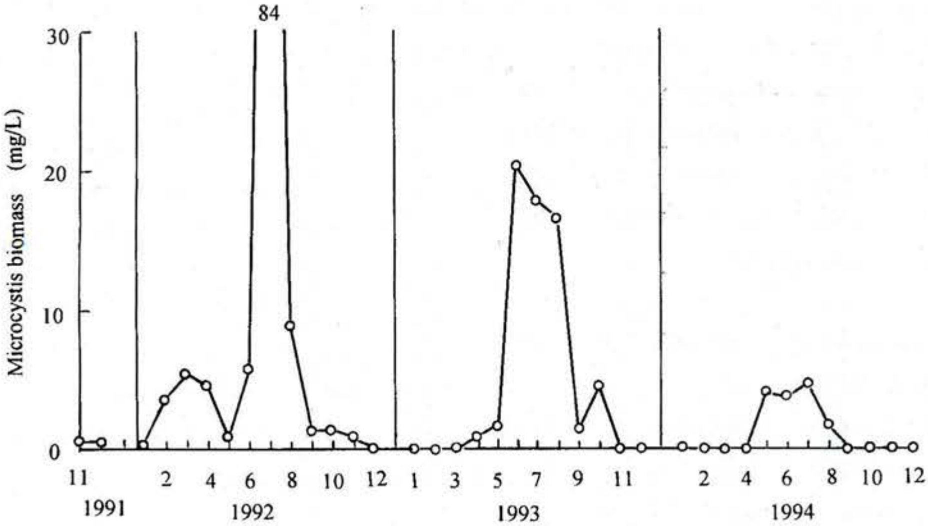

Fig. 3 Time sequence of *Microcystis* biomass in Meiliang Bay of Lake Taihu

time is dependent on the water temperature. During this period, *Microcystis* grew very fast. It grew in exponentially. A lot dividing cells could been watched under microscope. The algae bloom formed within this period. It could last tc September. The third period was from October to December, *Microcystis* biomass was reducing within October and November, the bloom still could be seen. The dividing cells were seldom observed.

3.2 Morphology of *Microcystis* spp. and its colonies

Six species of *Microcystis* had been observed in Lake Taihu. They were *Microcystis aeruginosa, M. flos-aquae, M. pulverea, M. pseudofilamentusa, M. incerta* and M. *marginada.* Main species were *Microcystis aeroginosa* and *M. flos-aquae*. They always formed colonies of irregular shape and size. The colonies were embedded in a distinct hyaline mucilage layer in which colony's cellls were arranged more or less compactly. The cells were spherical and had gas vacuoles in cells. Its diameter was between 4-5μ, with a mean volume 85μ^3. In fresh samples the cells showed bright color.

In cultured samples, the colonies were also got. The cell-diameter in cultured colonies was litter smaller than that of natural colonies. In both of cultured and natural colonies there were some bacteria and protozoan cells attached in the colonies.

Microcystis colonies could be observed in sediments surface in the whole. Some precipitated cells showed yellow color or empty, due to "hunger". The same phenomenon was watched while the some nutrients in medium was consumed in the culture.

3.3. Growth of *Microcystis* spp.

The *Microcystis* intrinsic rate was high. The max. growth rate was measured in culture experiments under the condition mentioned in 2.3. It was 1.27. The cultured data showed that the region of growth rates within 0.6 to 0.8 was 55.7 %. (Fig. 4)

According to measure diameters of cultured *Microcystis*, the colonies diameter was larger under dark period than under light period. The diameter range were 7.47-8.95 μ and 7.57-13.7 μ respectively.

3.4 *Microcystis* growth and the environmental factors

The growth of *Microcystis* spp. was influenced by irradiation, temperature, and nutrients. Based on stimulation experiment in laboratory, the relationship between photosynthetic rate and light intensity was linear below 500 $\mu E \cdot m^{-2} \cdot s^{-1}$ (Fig.5) The majority of light intensity in Meiling Bay was between 500-1 000 $\mu E \cdot m^{-2} \cdot s^{-1}$. Nearly all of the light intensity were light limit. Only a few periods, the light intensity in this area reaches to 2000-2 500 $\mu E \cdot m^{-2} \cdot s^{-1}$.

Growth rate	n	%
0<r<0.2	13	13.4%
0.2<r<0.4	24	24.7%
0.4<r<0.6	25	25.8%
0.6<r<0.8	29	29.9%
0.8<r<1.27	6	6.2%

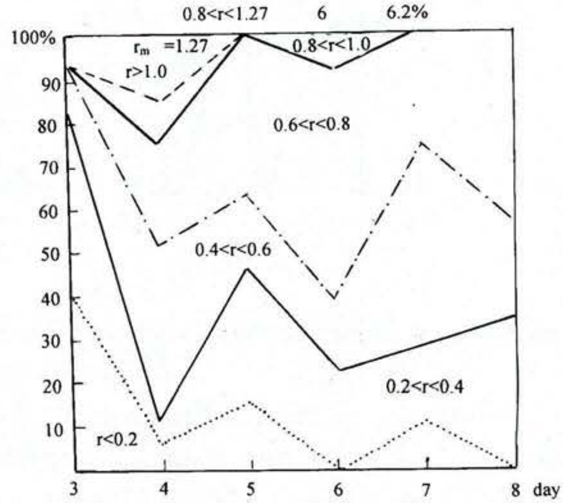

Fig. 4 Percentage of growth rate of *Macrosystis* spp.

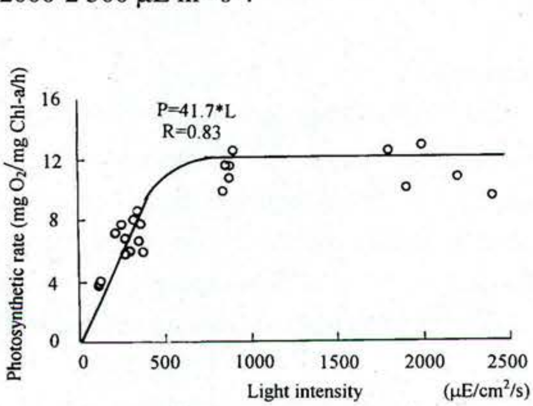

Fig. 5 Relationship between *Microsystis* photosynthetic rate an^d light intensity

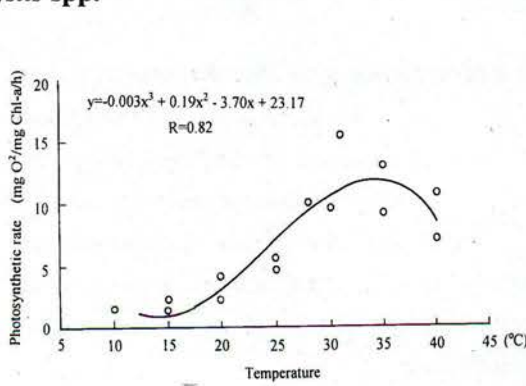

Fig. 6 Relationship between *Microsystis* photosynthetic rate and temperature

The result of study on the relationship between photosynthetic rate and temperature was pretty well. (Fig.6) *Microcystis* could not bear low temperature (Reynolds C. S. *et al*). It would not grow

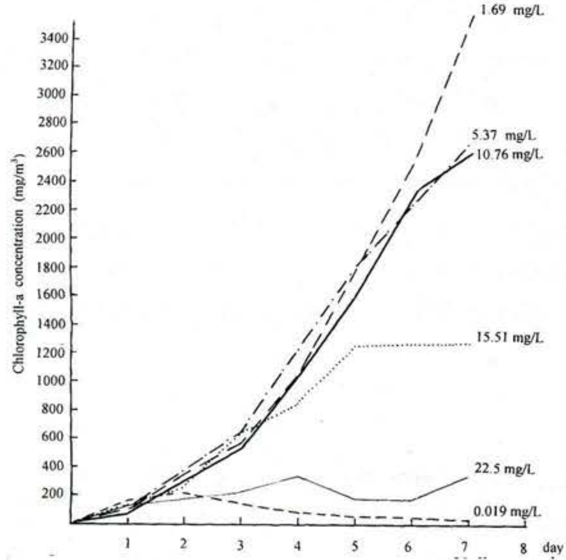

Fig. 7 Daily change of chlorophyll-*a* concentration of *Macrosystis* cultured in medium with different concentration of PO_4^{-3}

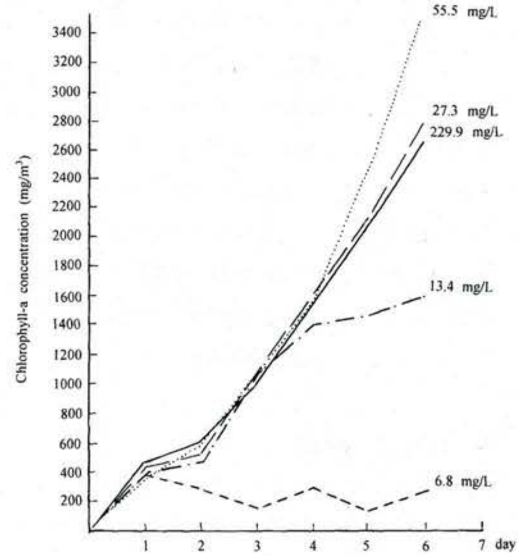

Fig. 8 Daily change of chlorophyll-*a* concentra tion of *Macrosystis* cultured in medium with different concentration of total dissolved nitrogen

below 13℃. The optimum temperature is ca 30℃. The temperature of Lake Taihu in summer was just within this range. This was very suitable for the *Microcystis* growth. Its regression equation was:

$$P=0.365*e^{0.112T} \quad (r=0.95).$$

Where *P*- the photosynthetic rate (mg $O_2 \cdot \mu g^{-1}$ Chl*a*$\cdot h^{-1}$), *T* temperature (℃).

During the *Microcystis* growth period, the difference among absorption of orthophosphate by unit Chlorophyll-*a* was large. It was 0.000058-0.0115 mg·μg^{-1} Chl-*a*, the mean value 0.0026 mg·μg^{-1} Chl-*a*. For total dissolved nitrogen (TDN), the range and mean value were 0.0015-0.1 mg·μg^{-1} Chl-*a* and 0.030 mg·μg^{-1} Chla respectively. Reaction of *Microcystis* to orthophosphate was more sensitive than it to TDN. (Fig. 7, 8) The TDN/PO_4^{-3} was 11.5. This figure was similar to the ratio of TN/TP 1992, in that year the algae bloom was the worst (Fig. 9).

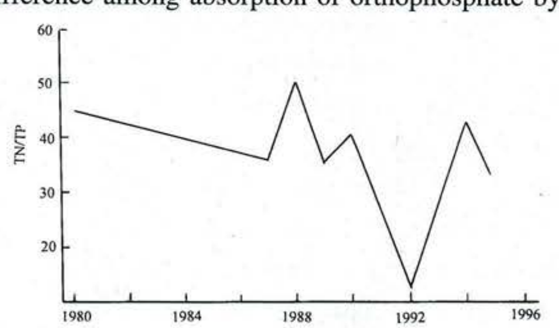

Fig. 9 Change of TN/TP in Lake Taihu during 1980-1996

The relation between chlorophyll-a and NH_4^+, NO_3^-, PO_4^{-3} could be illustrated by the curve of station 2 (Fig. 10). *Microcystis* preferred to use NH_4^+ as the source of nitrogen. The orthophosphoric phosphorus was as the source of phosphorus. It can be estimated that P 1 mg·L^{-1} can produce chlorophyll-*a* 384.6 μg·L^{-1}, corresponding biomass of *Microcystis* 128.3 mg·L^{-1}.

The enclosure experiments Shaw that the *Microcystis* chlorophyll*a* was 31.1 μg·L^{-1}, which was 5 times higher than that in enclosure on 23 June, 1993. The wind direction and its speed played a role in the forming of water bloom. If the wind velocity was less than the critical value (3 m·s^{-1}). It accumulated the *Microcystis* colonies to high density to be the water bloom. The Meiling Bay is just situated in north part of Lake Taihu. The dominant wind direction was the southwest. This kind wind blows the *Microcystis* colonies accumulation, this bay is the serious place suffered by the unpleasant water bloom.

4. Discussion

Lake eutrophication is an ecological disease. The nutrients enter the water bodies beyond its purification capability. The phosphorus is considered as the limiting factors. In Lake Taihu, the mean value of total nitrogen (TN) was 1.84 mg·L^{-1} in 1987 (Sun Shuncai, *et al*), and 3.93 mg·L^{-1} in 1995 (Meiling Bay). It means that TN increased 2.14 times within 8 years. In Lake Taihu the mean value of total phosphorus (TP) was 0.032 mg·L^{-1} in 1987 and 0.107 mg ·L^{-1} in 1995 (Meiliang Bay). It increased 3.34 times at the same period. The increasing rate of TP was higher than that of TN. This makes the ratio of TN to TP decreased. From the monitor data in 1992 and the experimental data, the ratio trends to 11.5, it will accelerate the lake eutrophication.

Temperature is the key factor. Lake Taihu is situated in the north temperate zone. The mean water temperature is 16.4 ℃ with a month average range between 1.5-27.4 ℃. This is favorable for *Microcystis* growth.

Lake Taihu is a large shallow lake. It is characterized by permanent circulation and high turbidity. Inorganic sediment particles are present in high amount in water in nearly anytime. This makes suitable underwater climate for *Microcystis* growth and prevents the light inhibition for this alga.

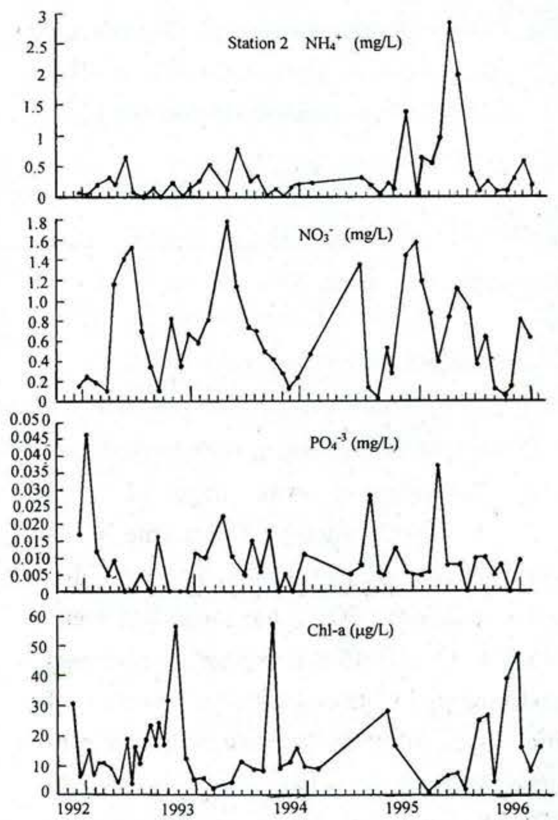

Fig. 10 Variation of concentrations of NH_4^+, NO_3^-, PO_4^{-3} and Chl-a with time in station

Microcystis spp. have comparative high growth rate, this is one of the reasons why algae bloom is so serious. From food chain, the relationship between *Microcystis* spp. and bacteria is not known but during the aerobic decomposition of *Microcystis*, the water quality and the cycling of nutrients, especially the release of PO_4^{3-} may not overlook (Chen Weimin, *et al.*) For the control of *Microcystis* by zooplankton, with the given zooplankton and *Microcystis* concentrations in the lake community, clearing rate can never reach values high enough to control *Microcystis* production and to produce clear water situations in the lake (Chen, W., *et al.*) . Fish's consumer also can not exceed the growth rate of *Microcystis*. Thus the function of biomanipulation is limited for restoration of lake ecology.

In order to control the eutrophication and restore the environment of Lake Taihu, the main points are as follows:

* to reduce the outer loading especially phosphorus;
* to suck the upper layer sediment, where a lot of phytoplankton including *Microcystis* lays to spend cold winter;
* to dig sediments for removing the inner loading;
* to harvest algae bloom and algae for reducing its density and changing the water quality;
* to recover the macrophyte in the lake;
* to develop the ecological fisheries.

After these comprehensive treatments are applied, Lake Taihu will recover its original beautiful face.

Acknowledgment

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