Korean J. Limnol. 38 (Special issue): 12~16 (2005)

Horizontal Distribution and Seasonal Change of Picophytoplankton in Surface Water of Lake Biwa

Kihira, Masaki*, Naoshige Goto and Osamu Mitamura

(Limnological Laboratory, School of Environmental Science, University of Shiga Prefecture, Hasska 3165, Hikone, Shiga 522-0057, Japan)

Seasonal change in cell number and biomass expressed as chlorophyll *a* of picophytoplankton community in surface waters was investigated in the north basin of Lake Biwa from September 2001 to November 2002. Two main peaks, in May and summer (from July to October), were observed by change of the cell density of picophytoplankton. It is considered that peak in May was due to water temperature rise and summer peak was attributed to mass-specific nutrient uptake by picophytoplankton. Horizontal distribution in cell number and biomass of picophytoplankton community in surface water of Lake Biwa was investigated at 56 stations on June 6~7 2002. DIN and DIP concentrations were lower in the north basin than in the south basin. The cell density and chlorophyll *a* of picophytoplankton were distributed almost uniformly in all area. The contribution of picophytoplankton to total phytoplankton chlorophyll *a* was higher in the north basin than in the south basin. These results suggest that picophytoplankton is important as a primary producer in low nutrient periods and areas of Lake Biwa.

Key words : picophytoplankton, nutrients, chlorophyll *a*, Lake Biwa

INTRODUCTION

Photoautotrophic picoplankton (i.e., the fraction of cells 0.2~2.0 μm in size; Sieburth *et al.*, 1978) are ubiquitous contributors among primary producers in lakes and marine ecosystems (Stockner and Antia, 1986; Weisse, 1988; Nagata *et al.*, 1996). Extremely high density of picophytoplankton occurred in Lake Biwa from the second half of the 1980s to the first half of the 1990s and the cell density of picophytoplankton was up to 10^6 cells mL^{-1} during a summer season (Maeda *et al.*, 1992). After that, there have been various investigations of picophytoplankton, for example long term seasonal and vertical distribution (Wakabayashi *et al.*, 1994), ecophysiological characteristic (Maeda *et al.*, 1992), relation to grazer (Nagata *et al.*, 1996) and photosynthetic activity (Mitamura *et al.*, 1999) in Lake Biwa. However, there is little information about the seasonal and horizontal distribution of picophytoplankton in Lake Biwa for the last decade. The purpose of our study are to elucidate 1) the seasonal changes in the picophytoplankton from pelagic to littoral zone in Lake Biwa and 2) to determine the horizontal distribution of the picophytoplankton in the surface water in Lake Biwa.

MATERIALS AND METHODS

Lake Biwa is the largest lake in Japan, covering an area of 669 km^2 with a maximum depth of 104 m. Seasonal change in the picophytoplankton biomass was investigated from September 2001 to November 2002 at six stations once a month. The sampling stations [T2 (35° 21′N, 136°

* Corresponding Author: Tel: +81-749-28-8263, Fax: +81-749-28-8247, E-mail: v10mkihira@ec.usp.ac.jp

08′E) to T7 (35° 15′N, 136° 13′E)] were located in the north basin (Fig. 1). Their horizontal distribution in all areas of Lake Biwa was investigated for 2 days (June 6～7, 2002). The sampling stations for that investigation were located at points that divided the latitude and longitude into 2-minute segments. Water samples were collected from the surface layer (0.5 m) of each station with a plastic pail. To measure the concentration of nutrients, a portion of the water samples were filtered through glass fiber filters (Whatman GF/F) treated by ignition at 420°C. The filtrates were stored at −20°C until chemical analysis. Ammonia was measured by the method described by Sagi (1966), nitrite after Bendschneider and Robinson (1952), nitrate after Mitamura (1997), and phosphate after Murphy and Riley (1962). To measure the cell density of picophytoplankton, a portion of each water sample was fixed with glutaraldehyde (final concentration of 1%) and kept cool (4°C) in the dark until measurement. The samples were filtered using 0.2 μm pore size Nuclepore filters, and the filters were counted by epifluorescence microscopy (OLYMPUS IX70 G-excitation, BP520-550, DM 565). Therefore, the cell density of picophytoplankton seems to be unestimated since what we counted are only picocyanobacteria which is a portion of picophytoplankton. To size phytoplankton, we used two kinds of glass fiber filters, i.e., Whatman GF/D (approximately 2.7 μm pore size) and GF/F (approximately 0.7 μm pore size). Water samples were first filtered through the Whatman GF/D, and the filtrates were filtered again through a Whatman GF/F. In the present study, the phytoplankton on the GF/D were defined as larger phytoplankton, while the smaller phytoplankton on the GF/F were defined as picophytoplankton. The concentrations of chlorophyll *a* of both larger phytoplankton and picophytoplankton were measured with a Turner 10-AU, using 90% acetone as the extraction solvent according to the method of Holm-Hansen (1965).

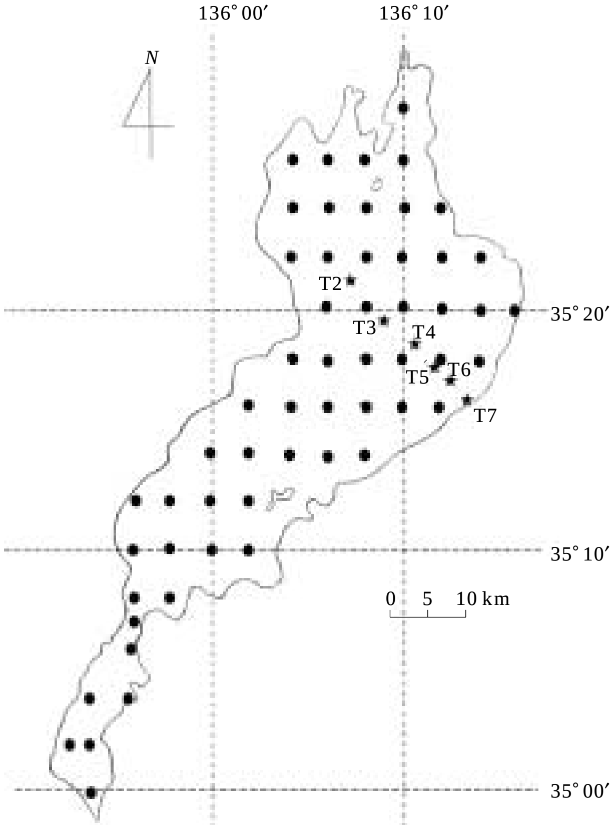

Fig. 1. Sampling station. Filled circle is samling station in horizontal distribution. Filled star is sampling station in seasonal change.

RESULTS AND DISCUSSION

1. Seasonal changes in biochemical parameters and picophytoplankton

Figure 2 shows the seasonal changes in water temperature, concentration of dissolved inorganic nitrogen (DIN: sum of ammonia, nitrite and nitrate nitrogen) and phosphate phosphorus (DIP) along the transect (T2 to T7) in the north basin of Lake Biwa. Water temperature ranged from 7.6 to 29.7°C, and the maximum value in August and the minimum value in February. The concentrations of DIN ranged from 1.1 to 24.1 μM. The concentration of DIN mostly varied depending on change in the concentration of nitrate nitrogen (data not shown). The concentrations of DIN were low from August to October 2002. The concentrations of DIP ranged from 0.01 to 0.16 μM. The DIN : DIP ratio ranged from 31 to 3790, indicating that phosphorus is one of the limiting parameters for phytoplankton growth in the north basin of Lake Biwa. Tezuka (1985) reported that the growth of phytoplankton was phosphorus limitation in all season.

Figure 3 shows seasonal changes in the cell density of picophytoplankton, and chlorophyll *a* of pico- and larger phytoplankton along the transection (T2 to T7). The cell density of picophytoplankton ranged from 0.8×10^4 to 47×10^4 cells mL^{-1}. That density increased from April to May reaching a maximum value in May, decreasing from May to June 2002, and increasing again from June to July. Thereafter, the high density of picophytoplankton cells was maintained until fall. The picophytoplankton chlorophyll *a* ranged from 0.07 to 1.89 $\mu g\ L^{-1}$, the pattern of seasonal change was similar to that of the cell density of picophytoplankton. Larger phytoplankton chlorophyll *a* ranged from 0.70 to 9.13 $\mu g\ L^{-1}$. It increased from September to December 2001 and from September to November 2002, and decreased from May to August 2002. The contribution of picophytoplankton to total phytoplankton chlorophyll *a* ranged from 1 to 41%, and the seasonal pattern was also similar to that of the cell density and picophytoplankton chlorophyll *a*.

In seasonal change of the cell density of picophytoplankton, two main peaks were observed in May and in summer (July to October). The summer peaks consistent with the results obtained by Maeda *et al.* (1992) and Wakabayashi *et al.* (1994). Although in summer the picophytoplankton was high, the concentration of DIN and DIP were very low (Fig. 2). Mass-specific nutrient

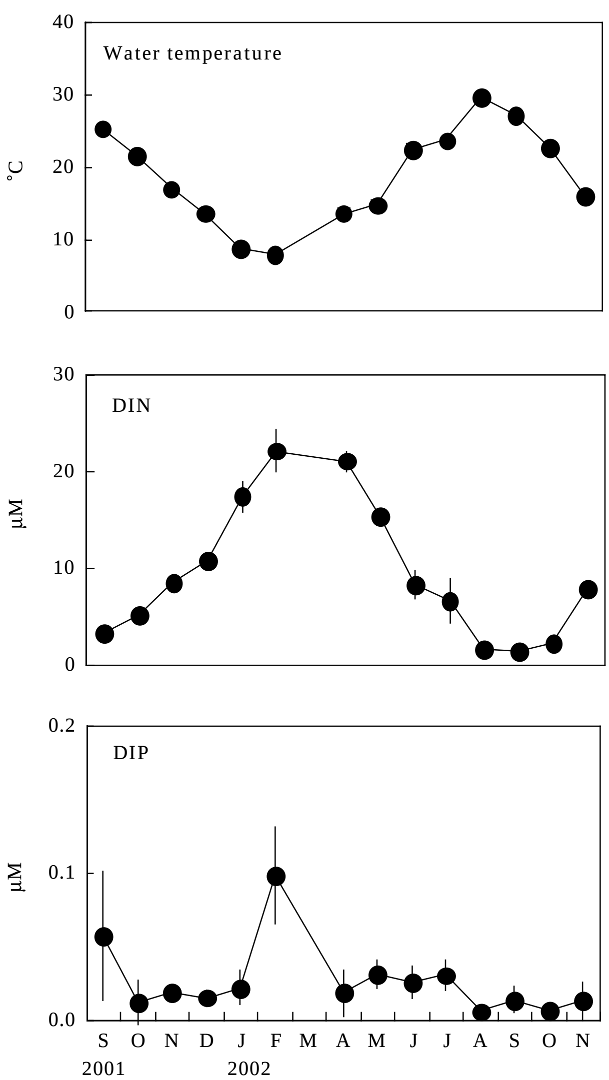

Fig. 2. Seasonal changes in water temperature, DIN and DIP at 6 stations in the north basin Lake Biwa. Vertical bars represent the standard deviation.

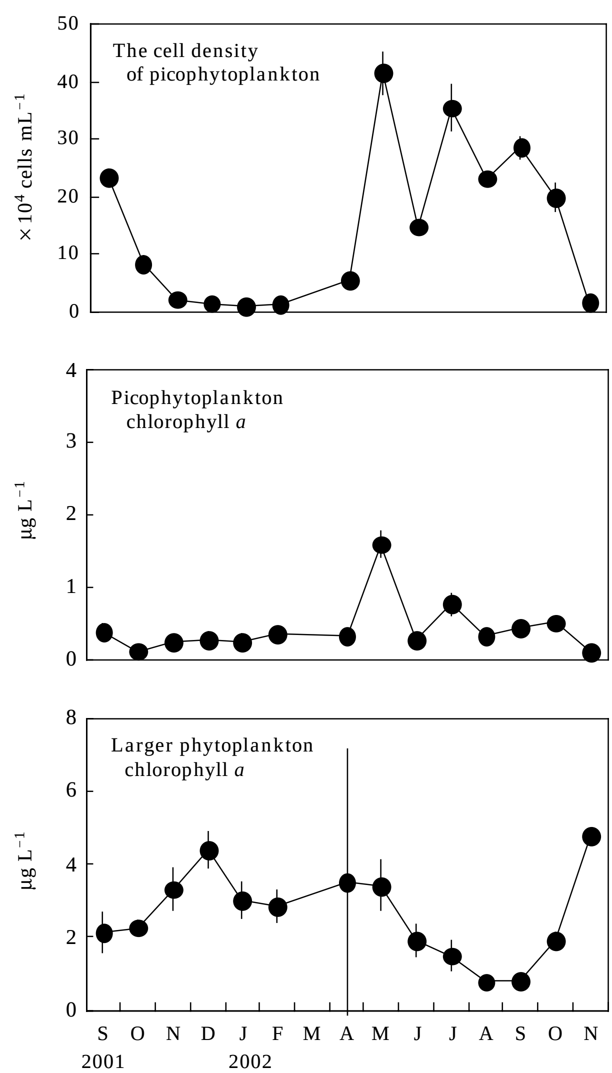

Fig. 3. Seasonal changes in the cell density of picophytoplankton, picophytoplankton chlorophyll *a* and larger phytoplankton chlorophyll *a* at six stations in the north basin of Lake Biwa. Vertical bars represent the standard deviation.

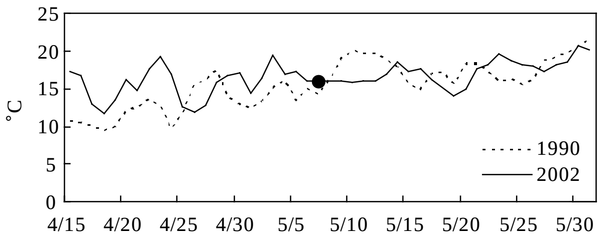

Fig. 4. Temporal changes in the average air temperature from April 15 to May 31 both 1990 and 2002 in Hikone city. Filled circle represents the sampling day in this study. This quoted the data of the Meteorological Agency.

uptake by phytoplankton increases with decreasing algal cell size (Raven, 1998). The nutrient uptake of picophytoplankton is more advantageous than larger phytoplankton in nutrient uptake during low nutrient periods. Moreover, it is considered that photosynthetis activity of picophytoplankton is higher than larger phytoplankton in summer (Mitamura *et al.*, 1999).

The peak in May is not confirmed by investigation of past in Lake Biwa. This is thought to be due to the difference of various conditions, for example weather, water temperature, nutrient and grazing, in about ten years ago and this time. In this study, comparison weather conditions were carried out. Figure 4 shows change of the average air temperature from April 15 to May 31 both 1990 and 2002 in Hikone city. For several weeks by our sampling day in May, the average air temperature in 2002 was about 3°C higher than in 1990. As a result, it is considered that water temperature rose with the rise of the average air temperature and photosynthetic activity of picophytoplankton went up. Mitamura *et al.* (1999) reported that the assimilation numbers of picophytoplankton were somewhat related to water temperature. Possibly these stimulated the increase in the cell density of picophytoplankton.

2. Horizontal distribution of picophytoplankton in Lake Biwa

The concentration of DIN and DIP were distributed almost uniformly throughout the lake except in some areas (data not shown). The concentration of DIN exceeded 10 μM in a part of south basin. This suggests that the south basin

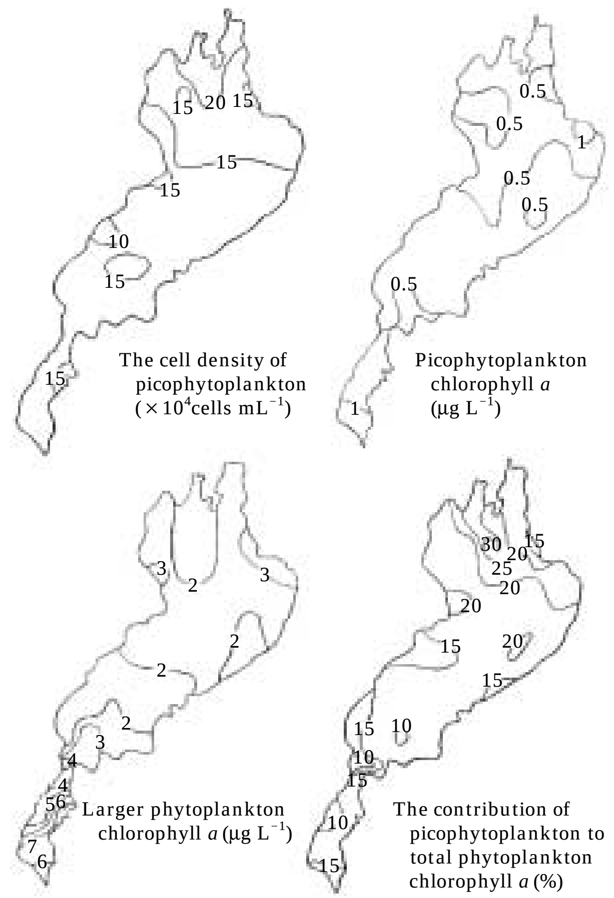

Fig. 5. Horizontal distribution of the cell density of picophytoplankton ($\times 10^4$ cells mL^{-1}), picophytoplankton chlorophyll *a* ($\mu g\ L^{-1}$), larger phytoplankton chlorophyll *a* ($\mu g\ L^{-1}$) and the contribution of picophytoplankton to total phytoplankton chlorophyll *a* (%) in all area of Lake Biwa.

was more eutrophic than the north basin.

Figure 5 shows horizontal distributions in the cell density of picophytoplankton, chlorophyll *a* of pico−and larger phytoplankton, and the contribution of picophytoplankton to total phytoplankton chlorophyll *a*. The cell density of picophytoplankton ranged from 9.4 to 24×10^4 cells mL^{-1} and was distributed almost uniformly over all areas. This results were consistent with that obtained by Nakano *et al.* (1996). The contribution of picophytoplankton to total chlorophyll *a* ranged from 7 to 32% and was higher in the north (18%) than in the south basin (13%). In particular, the contribution of picophytoplankton to total phytoplankton chlorophyll *a* was high in the northern part of the north basin, because the concentration of chlorophyll *a* in the larger phytoplankton had declined in that area while the concentration of chlorophyll *a* in picophytoplankton was almost uniformly in all areas.

In the northern of north basin, the concentration of DIN and DIP were lower than the south basin. It is considered that the nutrient uptake of picophytoplankton is more advantageous than larger phytoplankton in nutrient uptake in lower nutrient areas since the picophytoplankton cell size is smaller than larger phytoplankton. These results suggest that the picophytoplankton play a more important role primary producer in the northern part of the north basin of Lake Biwa with a little nutrient supply.

ACKNOWLEDGEMENTS

We are gateful to Captain B. Kaigai of the R/V *Hassaka* of University of Shiga Prefecture for his help and cooperation and to members of the Limnological Laboratoly of University of Shiga Prefecture. We also thank Dr. K. Nozaki for discussing the results in this study.

LITERATURE CITED

Bendschneider, K. and R.J. Robinson. 1952. A new spectrophotometric method for the determination of nitrite in sea water. J. Mar. Res. **11**: 87−96.

Holm−Hansen, O., C.J. Lorenzen, R.W. Holmes and J.D.H. Strickland. 1965. Fluorometric determination of chlorophyll. *J. Cons. perm. int. Explor. Mer*. **30**: 3−15.

Maeda, H., A. Kawai and M.N. Tilzer. 1992. The water bloom of cyanobacterial picoplankton in Lake Biwa, Japan. *Hydrobiologia* **248**: 93−103.

Mitamura, O. 1997. An improved method for the determination of nitrate in freshwaters based on hydrazinium reduction. *Memoirs of Osaka Kyoiku University, Ser III* **45**: 297−303.

Mitamura, O., H. Maeda and M. Kawashima. 1999. Seasonal change in photosynthetic activity of photoautotrophic picoplankton in Lake Biwa. *Jpn. J. Limnol*. **60**: 453−467.

Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta* **27**: 31−36.

Nagata, T., K. Takai, K. Kawabata, M. Nakanishi and J. Urabe. 1996. The trophic transfer via a picoplankton−flagellate−copepod food chain during a picocyanobacterial bloom in Lake Biwa. *Arch. Hydrobiol*. **137**: 145−160.

Nakano, S., K. Tanaka, T. Sono, T. Wakabayashi, S. Ichise, S. Yamanaka, E. Kaneda, M. Yamada, M. Naito, K. Kawabe, K. Maehata, N. Fujiwara, N. Maeda, K. Nomura and M. Nakanishi. 1996. Seasonal changes in horizontal distribution of algal picoplankton in Lake Biwa with special reference to water temperature, nutrient levels and heterotrophic flagellates. *Jpn. J. Limnol*. **57**: 49−55.

Raven, J.A. 1998. The twelfth Tansley Lecture. Small is beautiful: the picophytoplankton. *Functional Ecology* **12**: 503−513.

Sagi, T. 1966. Determination of ammonia in sea water by the indophenol method and its application to the coastal and off−shore waters. *Oceanogr. Mag*. **18**: 43−51.

Sieburth, J. McN., V. Smetecek and J. Lenz. 1978. Pelagic ecosystem structure: heterotrophic compartments of the plankton and their relationships to plankton size fractions. *Limnol. Oceanogr*. **23**: 1256−1263.

Stockner, J.G. and N.J. Antia. 1986. Algal picoplankton from marine and freshwater ecosystems: a multidisciplinary perspective. *Can. J. Fish. Aquat. Sci*. **43**: 2472−2503.

Tezuka, Y. 1985. C : N : P ratios of seston in Lake Biwa as indicators of nutrient deficiency in phytoplankton and decomposition process of hypolimnetic particulate matter. *Jpn. J. Limnol*. **46**: 239−246.

Wakabayashi, T., S. Ichise, N. Fujiwara, N. Maeda, K. Maehata, K. Kawabe, M. Naito, E. Kaneda, M. Yada, S. Yamanaka, T. Sono, K. Tanaka and K. Nomura. 1994. Picoplnakton in recent years in Lake Biwa 1991−1993. *Rep. Shiga. Pref. Inst. Pub. Hlth. and Environ. Sci*. **29**: 95−100.

Weisse, T. 1988. Dynamics of autotrophic picoplankton in Lake Constance. *J. Plankton. Res*. **10**: 1179−1188.

(Manuscript received 25 December 2004,
Revision accepted 20 February 2005)