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Phytoplankton Community at the Surface Microlayer in the North Basin of Lake Biwa

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Abstract

The phytoplankton community and their nutrient environment in the surface microlayer and the subsurface layer were studied in the north basin of Lake Biwa. Concentrations of ammonia, nitrate and urea were higher at the surface microlayer than 1.0 m depth. The photosynthetic rate and chlorophyll-a concentration showed no difference with depth. Diatoms were present in high numbers at the surface microlayer.

Key words: surface microlayer, phytoplankton community, photosynthesis, Lake Biwa

Introduction

Previous studies of the surface microlayer (at the air-water interface) of natural waters demonstrated the enrichment of particulate and dissolved compounds at this layer (e.g., NISHIZAWA, 1971[1]; SAIJO *et al.*, 1974[2]; MITAMURA and MATSUMOTO, 1981[3]; DANOS *et al.*, 1983[4]; WILLIAMS *et al.*, 1986[5]). The enrichment of algae at the surface microlayer has been reported by several workers in the sea and freshwater lakes (e.g., HARDY, 1973[6]; GALLAGHER, 1975[7]; PARKER and HATCHER, 1974[8]; DANOS *et al.*, 1983[4]; ESTEP and REMSEN, 1984[9]; CATALAN, 1986[10]). HARDY (1973)[6], GALLAGHER (1975)[7] and MITAMURA and MATSUMOTO (1981)[3] measured the photosynthetic activity of phytoplankton and then suggested the existence of active phytoneuston at the surface microlayer. For the physiological advantages due to the enrichment of nutrients and the disadvantages by higher solar irradiance and ultraviolet radiation, the surface microlayer is one of the interesting habitats from the view point of freshwater algal ecology. However, a few reports have been presented on community structure and physiological activity of the surface microlayer algae. We report here the species composition and photosynthesis of phytoplankton at the surface microlayer in the north basin of Lake Biwa.

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Method

The samples were collected at three stations in the north basin of Lake Biwa in the morning (calm day) on 24 June, 1991. Sta. A (40 m depth) locates in a deep area of Shiozu Bay. Sta. B (7 m depth) is a littoral zone, and Sta. C (50 m depth) is found in pelagic zone (Fig. 1). The surface microlayer samples were taken from around 200 μm layer of water surface using the 16-mesh stainless-steel screen which was cleaned by rinsing with acetone and distilled water to eliminate contaminants, using the technique of GARRETT (1965)[11]. The subsurface sample waters from 0.3 m and 1.0 m depths were taken with a Van-Dorn sampler. It was used at a horizontal position to collect from 0.3 m.

For the determination of nutrients and particulate matters, the water samples were filtered through/on Whatman GF/C glass-fiber filters preignited at 450℃ overnight. The filters and filtrates were stored at -20℃ until chemical analyses. Ammonia was determined by the method of SAGI (1966)[12], nitrite after BENDSHNEIDER and ROBINSON (1952)[13], nitrate after WOOD *et al.* (1967)[14], urea by the method of NEWELL *et al.* (1967)[15], and phosphate by the method of MURPHY and RILEY (1962)[16]. Particulate carbon (PC) and nitrogen (PN) were determined with a CHN Corder (Yanagimoto MT-3 type), and chlorophyll-a corrected for phaeopigments was measured by the method of LORENZEN (1967)[17] after extraction in 90% acetone with ultrasonication.

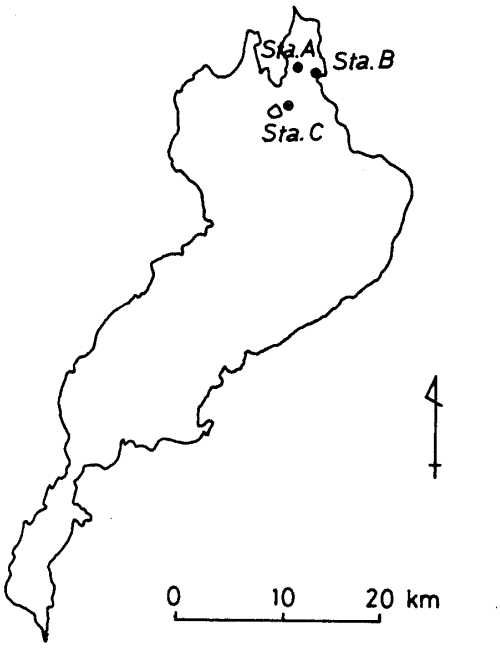

Fig. 1 Sampling stations in the north basin of Lake Biwa.

To determine photosynthesis, the water samples were dispensed in light and dark bottles. After the addition of ^{14}C-bicarbonate solution, the samples were incubated in a water tank at a temperature similar to the *in situ* condition under the illumination (1.5x 10^6 quanta · sec^{-1} · cm^{-2}) of daylight-type fluorescent lamps. After two hours incubation, biological activity was stopped by adding formaldehyde solution to each bottle. The samples were filtered through Millipore HA filters. The radioactivity of the filter was measured with a liquid scintillation spectrometer (Aloka Model LSC-651), as described by STEEMANN NIELSEN (1952)[18]. Total CO_2 in the sample water was determined with an infra-red CO_2 analyzer (SATAKE *et al.*, 1972)[19].

For microscopic examination of species composition of phytoplankton, the aliquots of water samples were preserved with formaldehyde (at a final concentration of 0.5%) and stored in refrigerator. 50 ml of samples was concentrated by centrifugation with 2,000 rpm for 20 minutes. The identification and cells (or colonies) counts for algal species, except for the identification of diatom species, were carried under 400x magnification. For the identification

and estimation of relative abundance for each diatom species, samples were treated with sulphuric acid to remove organic matter, and washed with water several times to clean off diatom frustules. The cleaned diatom samples were then dried on coverglasses, fixed to slides, and examined microscopically.

Results and discussion

Table 1 shows the vertical distribution of nitrogenous and phosphorus nutrients, PC, PN and chlorophyll-a concentration in the upper 1.0 m at each station. The concentrations of ammonia, nitrate and urea were higher at 0.0 m depth than at any other layer at every station. Urea was the most enriched compound among nitrogenous nutrients, and the ratio of the concentration at 0.0 m to that at 1.0 m depth (hereafter we refer this ratio as the concentration factor) was 5 to 11 for three stations. MITAMURA and MATSUMOTO (1981)[3] obtained similar results for urea in Lake Biwa, and suggested that the marked enrichment of urea at the surface microlayer was mainly supplied by dissolved or particulate organic nitrogen through decomposition and excretion. In the present study, any zooplankton species were not observed in water samples from the surface microlayer. Phosphate showed no apparent change in the concentration with depth at any stations.

Table 1 Concentration of nitrogenous and phosphorus nutrients, particulate carbon, nitrogen and chlorophyll-a in the upper 1.0 m at three stations.

	Sta. A			Sta. B			Sta. C		
	0.0	0.3 (m)	1.0	0.0	0.3 (m)	1.0	0.0	0.3 (m)	1.0
Ammonia (μg at. N · l^{-1})	4.5	0.5	0.3	1.1	0.4	0.2	0.7	0.4	0.2
Nitrite (μg at. N · l^{-1})	0.15	0.09	0.10	0.11	0.11	0.09	0.13	0.09	0.09
Nitrate (μg at. N · l^{-1})	3.5	0.6	0.7	1.2	0.7	0.6	0.9	0.6	0.7
Urea (μg at. N · l^{-1})	2.1	3.3	0.2	0.8	0.1	0.1	1.5	0.4	0.3
Phosphate (μg at. P · l^{-1})	0.11	0.10	0.09	0.10	0.17	0.08	0.11	0.08	0.08
Particulate carbon (μg C · l^{-1})	610	460	550	700	960	590	1020	460	540
Particulate nitrogen (μg N · l^{-1})	68	61	73	90	132	85	136	67	68
Chlorophyll-a (μg chl.a · l^{-1})	4.7	6.8	7.2	6.3	6.3	5.0	6.9	5.1	6.3

No appreciable difference was found in the concentration of PC, PN and chlorophyll-a between depths, except for Sta. C. At Sta. C, the enrichment of PC and PN at the surface microlayer was observed, showing 1.9 and 2.0 of the concentration factor. SAIJO *et al.* (1974)[2] reported higher values of the PC/PN ratio and low concentration factors of chlorophyll-a in Sagami and Suruga Bays. They suggested that the concentrations of particulate organic matter at the surface microlayer were caused by the accumulation of detrial matter, and not by active phytoplankton. In the present study, there was no apparent difference in PC/PN ratios, a similar tendency to the results of MITAMURA and MATSUMOTO (1981)[3].

The photosynthetic activity (photosynthetic rate by unit amount of chlorophyll-a) at the

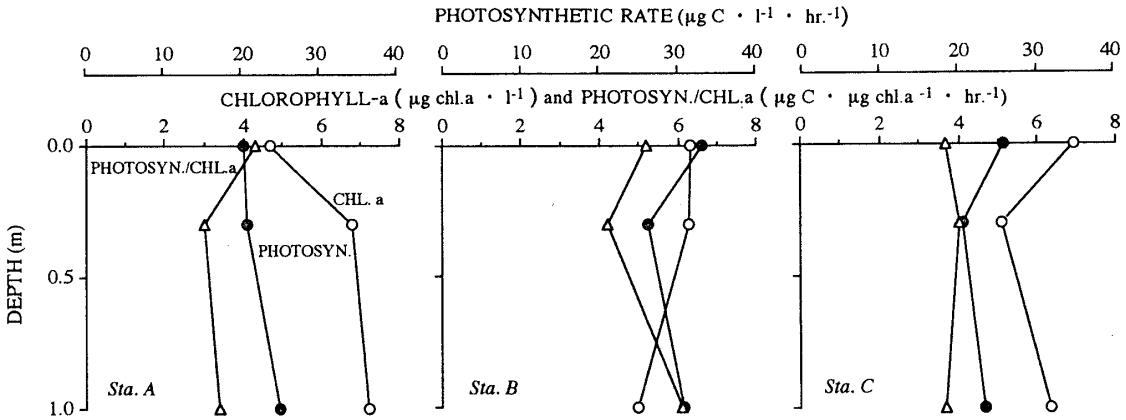

Fig. 2 Vertical distribution of chlorophyll-a, photosynthetic rate and the photosynthetic rate by unit amount of chlorophyll-a in the upper 1.0 m at three stations.

surface microlayer was 3.7 to 5.2 μg C · μg chl. a^{-1} · $hr.^{-1}$ (Fig. 2). There was no appreciable difference in photosynthetic activity between the surface microlayer and the subsurface layers. This suggests that phytoplankton was photosynthetically active not only in the surface layer but also at the surface microlayer.

PARKER and HATCHER (1974)[8], in their study of three freshwater environments in Virginia, demonstrated that the significant and striking differences frequently occurred in algal community structure and densities at the surface microlayer relative to subsurface water. ESTEP and REMSEN (1984)[9] found a similarity in species composition between the surface microlayer and the subsurface layer, and the difference in the relative abundance of species between the surface and subsurface in a small Wisconsin pond. They also reported that diatoms showed a specific affinity for the surface microlayer. We did not find significant difference in species composition between phytoplankton community at the surface microlayer and the other layer, although the algal biomass, especially diatom biomass, was abundant at the surface microlayer (Table 2). At Stas. A and B, diatoms were generally the most dominant algae. *Stephanodiscus carconensis,* mixed with *Stephanodiscus carconensis* v. *pusilla,* accounted for 55-65% of total cell numbers of diatom at the surface microlayer. The sum of the values in Bacillariophyceae listed in Table 2 accounts for 75-90% of total diatom cell numbers. At the surface microlayer of pelagic Sta. C, a significant accumulation of *Eudorina elegans* was observed. LAZINSKY *et al.*(1982)[20] indicated that flagellates and some diatom species were common at the surface microlayer in Lake Michigan. ESTEP and REMSEN (1984)[9] proposed that *Chlamydomonas* sp. may be a "surface microlayer specialist", an organism adapted to the surface microlayer having an unique ecosystem. In the present study, the enrichment of *Eudorina elegans* and diatoms (*Stephanodiscus carconensis* was dominant) was observed at the surface microlayer, although there was no appreciable difference in the chlorophyll-a concentration and photosynthetic rate between the surface microlayer and subsurface layer. One of the reasons seems to be the existence of ultraphytoplankton such as *Synechococcus* spp. in the sample waters, which were not examined microscopically. Further studies on the relation between the physiological properties of each species and the environmental parameters at the surface microlayer are required.

Table 2 Dominant phytoplankton species at the surface microlayer and the subsurface layers, in $x10^2$ cells or colonies (*C*) per liter of the sample water.

species	Sta. A			Sta. B			Sta. C		
	0.0	0.3 (m)	1.0	0.0	0.3 (m)	1.0	0.0	0.3 (m)	1.0
Cyanophyceae									
Anabaena macrospora				4	10	1			
Chroococcus dispersus (C)			+						
Euglenophyceae									
Trachelomonas sp.	4	3	+	9			17	1	
Dinophyceae									
Ceratium hirundenella			2		+	3	3	2	2
Chlorophyceae									
Sphaerocystis schroeteri (C)		4	6	5	+	1	8	5	
Eudorina elegans (C)	4	2	2				90	33	
Closterium aciculare							2	1	
Staurastrum dorsidentiferum v. *ornatum*		2	2				2	4	
Bacillariophyceae									
Melosira granulata	7		4	15		4			
Melosira solida				9	2	3	11	3	
Stephanodiscus carconensis	135	19	64	124	26	85	148	55	53
Fragilaria construens		4		20					
Fragilaria crotonensis	8	1	6	7					
Cocconeis placentula v. *leneata*		1	5	5					
Achnanthes spp.	35	13	25	19	18	9	11	19	5
Cymbella minuta v. *silesiaca*	6	2			2			4	3

+ : $< 10^2$ cells or colonies $\cdot l^{-1}$

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摘　　要

琵琶湖北湖における極表面水中の植物プランクトン群集

琵琶湖北湖において，極表面水中の植物プランクトンの種類構成と栄養塩現存量を調べた．極表面水中のアンモニア，硝酸，尿素態窒素の現存量は水深１ｍに比べ高かった．光合成，クロロフィル量には深度に伴っての相違は認められなかった．珪藻の細胞密度は極表面水中で高かった．

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