

Note

**Physicochemical and Biological Characteristics of  
Lake Bishamon-numa in Urabandai,  
Fukushima Prefecture\***

Kotaro SUGAWARA, Shuji HINO, Ryoji NAKAZATO, Masahiro OCHIAI  
and Yasuhiro SATOH\*\*

**ABSTRACT**

The first record of depth-time profiles for some physicochemical and biological parameters of Lake Bishamon-numa based on periodic observations during the ice-free season of 1996 are reported. Throughout the observed period, the thermocline was either absent or very weak. In accordance with this structure of water temperature, the dissolved oxygen was distributed uniformly in the water column at above a 90 % saturation level. The average and standard deviation of transparency was  $5.1 \pm 1.1$  m. On the assumption that the trophogenic zone is from the surface to a depth of twice the transparency, the whole water body of the east basin in which the sampling station is located, constitutes the trophogenic zone. pH was fairly constant from July to December with an average and standard deviation of  $6.2 \pm 0.1$ . Compared with past data, the pH of Lake Bishamon-numa has changed greatly within a relatively short time period in the past and has lately stabilized around pH 6. The concentrations of Na, K, Mg, and Ca were in the order of  $\text{m mol l}^{-1}$ , while those of Fe and Mn were of  $\mu\text{mol l}^{-1}$ . Ranked in descending order of concentrations, they are Na, Ca, Mg, K, Mn and Fe. The annual maximum of Chl. *a* was  $1.5 \mu\text{g l}^{-1}$  in May. Though there were slight maxima and minima, the Chl. *a* concentration was below  $1 \mu\text{g l}^{-1}$  in most seasons and averaged  $0.51 \mu\text{g l}^{-1}$ . This Chl. *a* level corresponds to those of other oligotrophic lakes. Nanophytoplankton ranging from 2 to 20  $\mu\text{m}$  predominated, and macrophytoplankton greater than 20  $\mu\text{m}$  were relatively scarce.

**Key words :** Goshiki-numa Lake Group, depth-time profiles, metals seasonal trend

**INTRODUCTION**

The lakes of the Urabandai Lake Group in Fukushima Prefecture were

---

\* Contribution No. 22, from Urabandai Limnological Station, Yamagata University.

\*\* Author to whom correspondence should be addressed.

formed at the time of an eruption of volcanic Mt. Bandai in July, 1888. A part of the summit, 1.7 km<sup>3</sup> in volume, was blown away by the eruption, resulting in large-scale mudflows (MURAYAMA, 1973). The mudflows had dammed many rivers and resulted in the moderately sized basins of Lakes Hibara, Onogawa and Akimoto. The depressions on the surface of the mudflows formed about 80 additional smaller lakes and ponds including Lake Bishamon-numa (NAGAOKA, 1991).

Within the Urabandai Lake Group, Lake Bishamon-numa belongs to a sub-group called the Goshiki-numa Lake Group. One of the earliest studies on this lake was conducted by YOSHIMURA (1935), who measured some physicochemical parameters including water temperature, pH, dissolved oxygen and transparency. Since then, pH, dissolved oxygen and/or some metals were measured by YOSHIMURA *et al.* (1937a, b, c), TANABE and KANAZAWA (1964) and KATO and AITA (1970). Plankton were studied by TANAKA (1992). However, most of these studies collected samples only once or twice, mostly in summer. No data are available on depth-time profiles of any kind of limnological parameters. This study features the first record of the seasonal distributions of some physicochemical and biological parameters in a water column of Lake Bishamon-numa in an ice-free season.

## MATERIALS AND METHODS

Lake Bishamon-numa (37°39'N, 140°05'E) lies 770 m above mean sea level. The lake covers 0.15 km<sup>2</sup> and contains 0.0005 km<sup>3</sup> of water. Its maximum depth is 13 m and it has a mean depth of 3.3 m (HORIE, 1962). The deepest point in this lake is located in a rather isolated small sub-basin called the Ido-numa basin. The lake has one inflowing river and one outflowing river. The water samples were taken at 1-m intervals from a station 7.5 m in water depth located in the deepest part of the east basin (Fig. 1). The samples were collected with a 6-liter Van Dorn sampler about every 3 weeks from 10 May to 12 December 1996. Water temperature was measured with a thermistor thermometer. Transparency was measured by a secchi disc. pH was measured using a pH meter (HACH ONE, HACH Co.) until 12 June, and after that with another pH meter (IM-20E, Toadenpa Co.). Dissolved oxygen was determined by the Winkler method. Aliquots of water samples for the analyses of metals (Mn, Fe, Na, K, Mg and Ca) were acidified with 0.1 M-HCl to a pH below 2. The acidified samples were stored at room temperature until the chemical analyses for metals were conducted by atomic absorption spectrophotometry (Perkin Elmer 3100). With the exception of Fe, the precision of the determination was 1-2 % (that for Fe was 15 %).

Water samples for Chl. *a* analysis were filtered through nylon nets of 20  $\mu$ m porosity. An aliquot of this filtrate was further filtered through 2  $\mu$ m nuclepore filters. Particles contained in 100 ml of unfiltered water, and filtrates of the nylon nets and the nuclepore filters were collected on Whatman GF/F glass fiber filters (mean porosity, 0.7  $\mu$ m) and then anal-

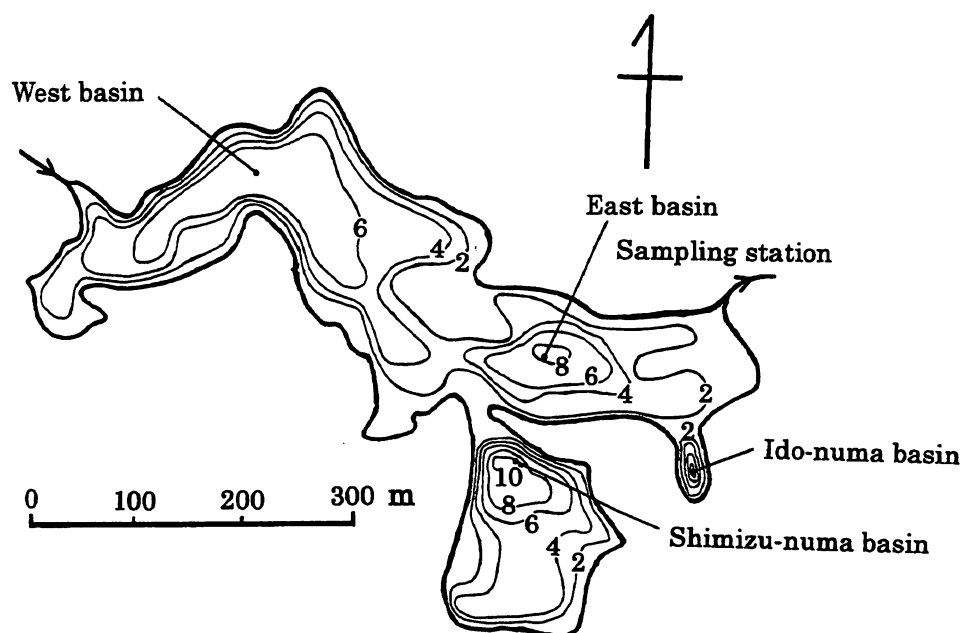


Fig. 1. Map showing station location in Lake Bishamon-numa.

alyzed for Chl. *a* by fluorophotometry (Turner 111) after cold methanol extraction for 12 hr. Total Chl. *a* denotes Chl. *a* contained in the unfiltered water samples. Chl. *a* contained in the filtrate of the nuclepore filters is expressed as  $< 2 \mu\text{m}$ . Chl. *a* ranging in size from 2 to  $20 \mu\text{m}$  and  $> 20 \mu\text{m}$  were arithmetically calculated.

## RESULTS AND DISCUSSION

YOSHIMURA (1937a) divided Lake Bishamon-numa into 4 sub basins : the west basin, east basin, Shimizu-numa basin, and Ido-numa basin. The latter two basins are much smaller than the former two. The west and east basins constitute the main body of the lake. Since the water chemistry of the west basin differed from that of the east basin due to an acidic spring on the bottom of the west basin (YOSHIMURA *et al.*, 1937a, b), the following results and discussion will be limited to the east basin of this lake.

### Water temperature, dissolved oxygen, transparency and pH

Water temperature was about  $9^\circ\text{C}$  throughout the water column at the beginning of our observation, 10 May 1996, and rose until summer. The annual maximum was  $20.5^\circ\text{C}$  at the surface on 8 August. The isotherms were nearly vertical even in summer, indicating that the thermocline was either absent or very weak throughout the observed period (Fig. 2A). Rapid water exchange may prevent the development of the thermocline in the lake, as suggested by YOSHIMURA *et al.* (1937a).

The isopleths of dissolved oxygen concentrations are roughly vertical throughout the year (Fig. 2B) in accordance with the temperature structure

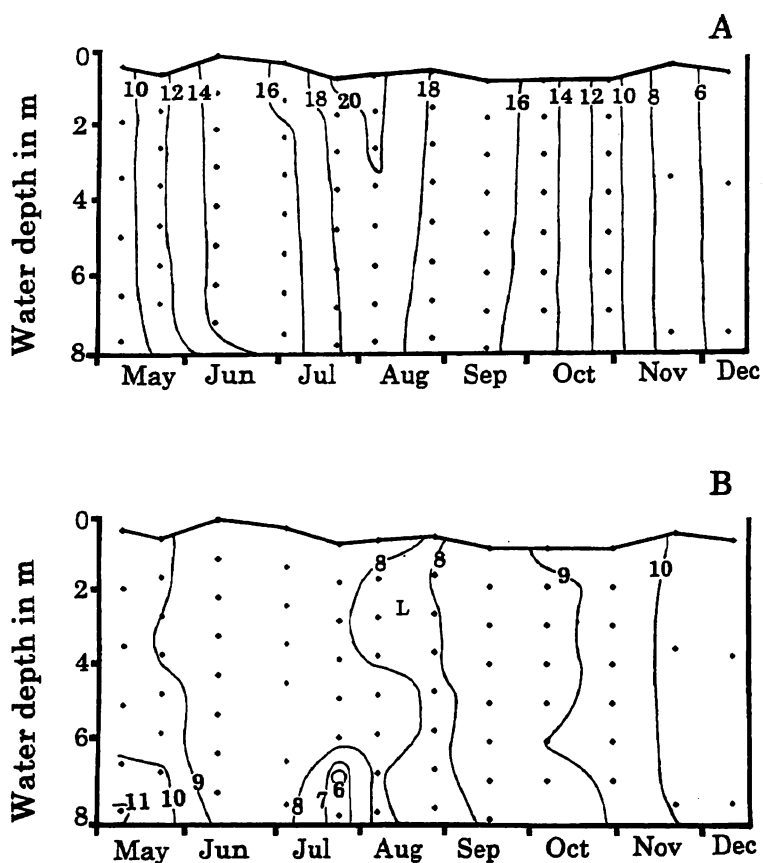


Fig. 2. Depth-time diagrams of A) water temperature in °C, and B) dissolved oxygen in mg l<sup>-1</sup> for Lake Bishamon-numa in 1996.

(Fig. 2A), except for a maximum just above the bottom in May and a minimum near the bottom in July. The mechanisms underlying such a maximum or minimum are not yet clear. YOSHIMURA *et al.* (1937b) measured the vertical distribution of dissolved oxygen in this lake at a station near the present one on 20 August 1935. It ranged from 7.83 to 8.01 mg l<sup>-1</sup> or from 93 to 99 % saturation level. In the present study, the concentrations of dissolved oxygen ranged from 7.59 to 8.02 mg l<sup>-1</sup> or from 90 to 96 % saturation on 29 August, a date comparable to that of YOSHIMURA *et al.* Both results are almost the same.

The transparency ranged from 2.4 m on 10 May to 6.5 m on 18 September with an average and standard deviation of  $5.1 \pm 1.1$  m. On the assumption that the trophogenic zone extends from the surface to a depth of twice the transparency, the whole water body of the east basin is regarded as the trophogenic zone.

Vertical profiles of pH were fairly uniform throughout the observed period, and pH was fairly constant from July to December, ranging from 6.0 to 6.3 with a mean value and standard deviation of  $6.2 \pm 0.1$  (Table 1). However, pH from May to June was lower, ranging from 5.1 to 5.8 with an average and standard deviation of  $5.5 \pm 0.2$ . This difference is significant at

Table 1. pH of Lake Bishamon-numa during ice-free season in 1996.

Depth(m)	10 May	23 May	12 June	5 July	25 July	8 Aug.	29 Aug.	18 Sept.	8 Oct.	31 Oct.	22 Nov.	12 Dec.
0	5.7	5.2	5.6	6.3	6.2	6.2	6.3	6.1	6.1	6.3	6.2	6.2
1	5.4	5.3	5.6	6.2	6.1	6.2	6.3	6.2	6.3	6.3	-	-
2	-	5.1	5.6	6.2	6.1	6.2	6.3	6.2	6.2	6.3	-	-
3	5.4	5.3	5.7	6.3	6.0	6.0	6.2	6.2	6.3	6.3	6.1	6.2
4	5.7	5.2	5.7	6.2	6.0	6.1	6.2	6.2	6.2	6.3	-	-
5	5.8	5.3	5.7	6.0	6.0	6.0	6.2	6.1	6.2	6.3	-	-
6	5.5	5.5	5.7	6.1	6.2	6.0	6.2	6.2	6.2	6.3	-	-
7	-	-	5.7	6.1	6.0	6.1	6.1	6.3	-	-	6.2	6.1

the level of 1 % risk. The spring pH shock of snow melt water (*e.g.* SAKATA, 1994) seems to be the most probable reason for these low pHs from May to June, because the low pH is restricted to spring. Usually, snow remains around the lake, and the snow on the surrounding mountain does not yet melt significantly in early May. The pH minimum on 23 May likely coincided with an intensive snow melt of the surrounding mountain region. Since the water of Lake Bishamon-numa changes quickly (YOSHIMURA *et al.*, 1937a), if the pH of inflowing water declines due to the pH shock of snow melt water, the pH of lake water would also fall.

Some previous results of pH measurements taken in Lake Bishamon-numa are available (Table 2). YOSHIMURA and his colleagues (1935, 1937a, c) reported pH values of 5.0 in 1931, 4.5 in 1935, and 6.2 in 1937. TANABE and KANAZAWA (1964) reported a pH value of 4.8 in 1964. KATO and AITA (1970) recorded the pH to be 6.2 in 1968. Since then, reported pH values have been around 6. It is worthy of note that the pH in 1937 by YOSHIMURA *et al.* (1937c) is more than one pH unit higher than those in 1931 by YOSHIMURA (1935) and in 1935 by YOSHIMURA *et al.* (1937a). This is also true if one compares the pH in 1964 by TANABE and KANAZAWA (1964) with that in 1968 by KATO and AITA (1970). These results show that the pH of Lake Bishamon-numa changed greatly within relatively short time periods in the past, but has recently stabilized at around 6. However, we have to pay

Table 2. Comparison of the present pH values with those from the previous studies.

pH	Date	Method	References
5.0	July 1931	Colorimetry	YOSHIMURA 1935
4.5	August 1935	Colorimetry	YOSHIMURA <i>et al.</i> , 1937a
6.2	September 1937	Colorimetry	YOSHIMURA <i>et al.</i> , 1937c
4.8	July 1964	Colorimetry	TANABE and KANAZAWA, 1964
6.2	June 1968	Not clear	KATO and AITA, 1970
5.8-6.4	June 1980	Colorimetry	TANAKA 1992
6.5	October 1986	Glass electrode	TANAKA 1992
5.6-6.3	June-October 1996*	Glass electrode	Present study

\* The period, from June to October, is selected in order to cover the sampling dates of the previous authors.

attention to the difference in the methods of pH measurement. Colorimetry sometimes tends to give lower pH values as compared with the glass-electrode method (HANYA and OGURA, 1995). However, at least the pH change from 4.5 in 1935 to 6.2 in 1937 are likely to be realistic, because such change are based on the results from the same authors using the same method (Table 2). Furthermore, both the colorimetry and glass-electrode methods have yielded similar pH values of around 6 since 1968, suggesting that the recent stabilization of pH values are also likely to be realistic.

### Metals

The concentrations of measured alkaline (Na and K) and alkaline earth metals (Mg and Ca) were in the order of  $\text{m mol l}^{-1}$ , while those of Mn, and

Table 3. Concentrations of metals in Lake Bishamon-numa in August 1968 by KATO and AITA and in 1996 by the present study. Present data given are the average  $\pm$  standard deviation of all data collected.

Year	Na ( $\text{m mol l}^{-1}$ )	K ( $\text{m mol l}^{-1}$ )	Ca ( $\text{m mol l}^{-1}$ )	Mg ( $\text{m mol l}^{-1}$ )	Fe ( $\mu\text{mol l}^{-1}$ )	Mn ( $\mu\text{mol l}^{-1}$ )	References
1968	1.91	0.17	1.78	1.05	1.1	23.7	KATO and AITA, 1970
1996	$2.01 \pm 0.26$	$0.22 \pm 0.02$	$1.60 \pm 0.07$	$1.00 \pm 0.06$	$2.4 \pm 1.1$	$26.1 \pm 3.0$	Present study

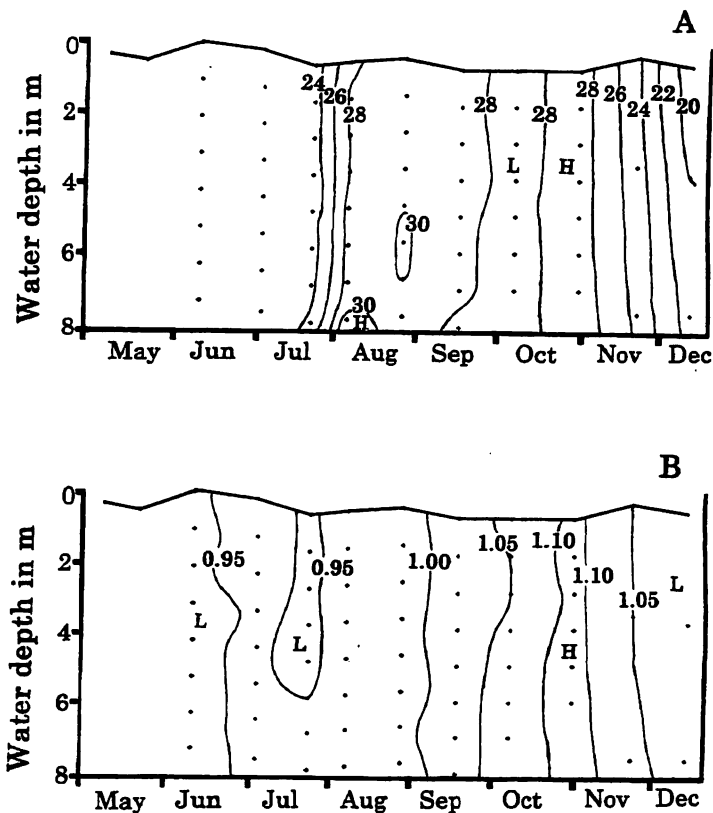


Fig. 3. Depth-time diagrams of A) Mn in  $\mu\text{mol l}^{-1}$ , and B) Mg in  $\text{m mol l}^{-1}$  for Lake Bishamon-numa in 1996.

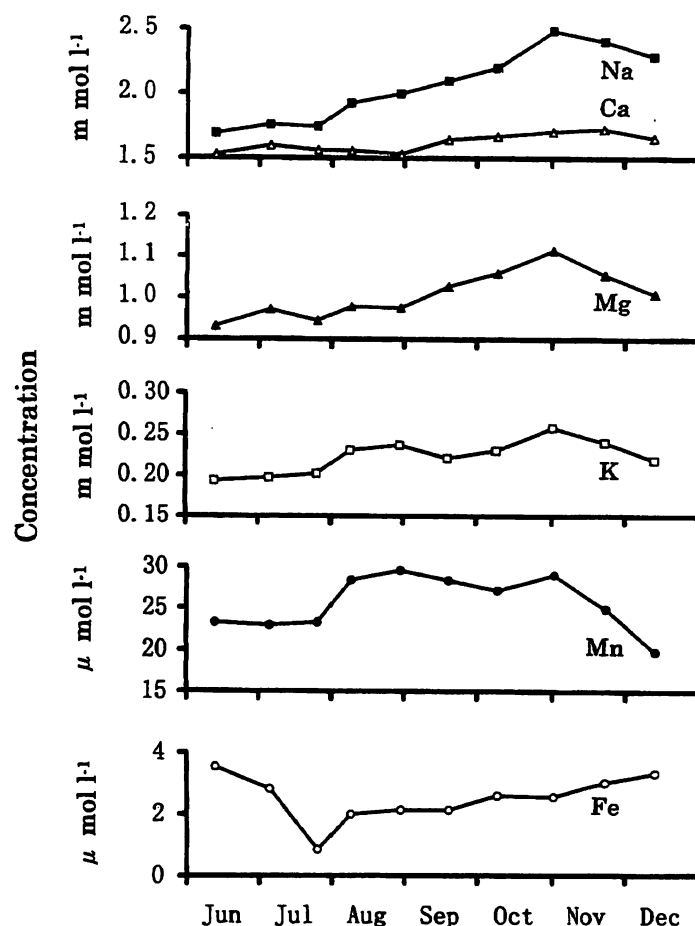


Fig. 4. Seasonal changes in the average metal concentrations in the water column.

Fe were of  $\mu\text{mol l}^{-1}$ . Ranked in descending order of concentration, they are Na, Ca, Mg, K, Mn and Fe (Table 3). KATO and AITA (1970) measured metal concentrations in August 1968, and the present results agree well with their results (Table 3). Mn and Fe are subject to redox reaction in natural waters while the other metals are not. The solubility of the oxidized forms of both Mn and Fe is very low, and both occur at low concentrations in oxygenated water like that of Lake Bishamon-numa. Highly mineralized water of volcanic origin seeps into the lakes of the Goshiki-numa Lake Group, resulting in high metal concentrations in these lakes (JIBP-PF Research Group of Acid Lakes in Urabandai, 1975).

Depth-time profiles of measured metals show that their vertical distributions in the water column are fairly uniform in accordance with that of water temperature. As typical examples of  $\mu\text{mol l}^{-1}$  order metals and  $\text{m mol l}^{-1}$  order metals, the depth-time diagrams of Mn and Mg are shown in Fig. 3A and 3B, respectively. Because of their uniform distribution, the mean concentrations in the whole water column at the sampling time are useful for a comparison of their trends in seasonal change. The seasonal trends of measured metals are roughly classified into three types (Fig. 4) : 1) Metals

having their concentration maxima in autumn. Na and Mg are typical of such metals, and Ca is also included in this category. 2) Metals having two broad maxima one in summer and another in autumn. K and Mn belong to this class. 3) Metals having a minimum in early summer. Fe is the only element showing this trend. How these trends originated remains to be determined.

### Chlorophyll *a*

Chl. *a* was relatively high near the bottom in May, at the surface in June, and at 5 m depth at the end of August, and low at the surface except in June (Fig. 5A). The peak in the bottom layer on 8 August was probably due to a contamination of Chl. *a* from the re-suspended bottom sediments due to a sampling miss. If we neglect this peak, the annual maximum of Chl. *a* was  $1.5 \mu\text{g l}^{-1}$  at 6 m on 10 and 23 May. Though there were slight maxima and minima, the Chl. *a* concentration was below  $1 \mu\text{g l}^{-1}$  during most seasons and averaged  $0.51 \mu\text{g l}^{-1}$ . This level of Chl. *a* corresponds to those of other oligotrophic lakes (FORTHBERG and RYDING, 1980).

Though unfortunately we did not size fractionate Chl. *a* in spring, based

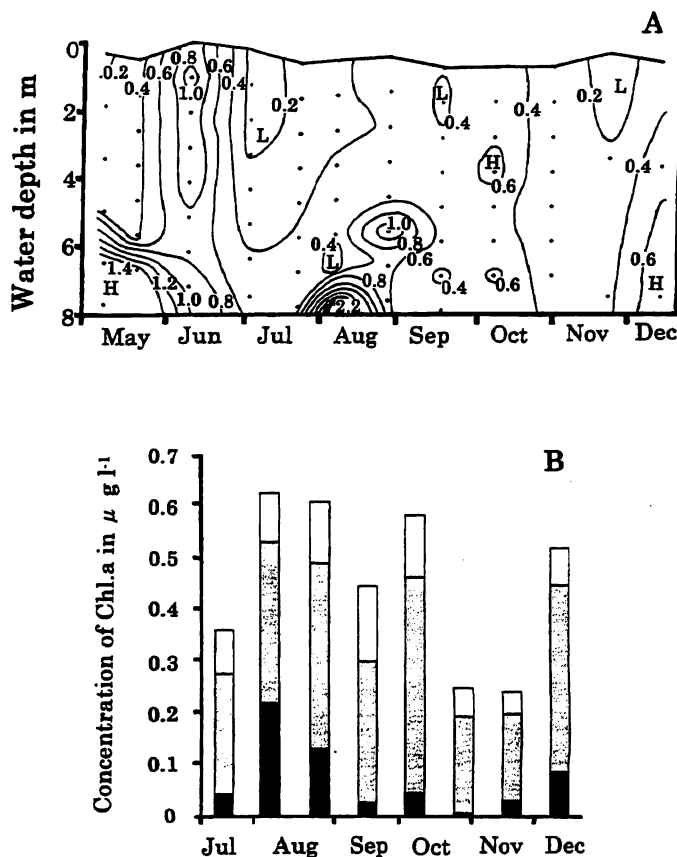


Fig. 5. A) Depth-time diagram of Chl. *a* in  $\mu\text{g l}^{-1}$  for Lake Bishamon-numa. B) Seasonal change in the average concentrations of Chl. *a* in the fraction greater than  $20 \mu\text{m}$  (solid bar), in the  $2-20 \mu\text{m}$  fraction (gray bar), and in the fraction less than  $2 \mu\text{m}$  (open bar) in the water column.



on the results of size fractionated Chl. *a*, nano-phytoplankton ranging from 2-20  $\mu\text{m}$  predominated and macro-phytoplankton greater than 20  $\mu\text{m}$  were relatively scarce at least from early summer to early winter in Lake Bishamon-numa, *i.e.*, 50 to 76 % of total Chl. *a* was found in the 2-20  $\mu\text{m}$  fraction, whereas only 15 % was in the >20  $\mu\text{m}$  fraction (Fig. 5B). These results are quite different from those of adjacent Lake Onogawa in that though Chl. *a* in the 2-20  $\mu\text{m}$  fraction predominated there from July to August 1996 as it did in Lake Bishamon-numa, the >20  $\mu\text{m}$  fraction dominated with up to 83 % in autumn and early winter (SATO *et al.*, unpublished data).

We tried to measure nutrients such as ammonia, nitrite, nitrate, and reactive phosphorus. However, the analytical methods used were interfered by abundant minerals, especially the formation of bulky precipitates during the sample storage in freezers and/or chemical reactions. We tried to remove the precipitates by filtration. However, we are skeptical about the results thus obtained, because the concentrations of reactive phosphorus was sometimes much higher than those of total phosphorus. For this reason, we did not show the results of nutrients. However, the Chl. *a* level of the lake mentioned above is very much lower than those of adjacent oligo- to mesotrophic Lakes Hibara and Akimoto (0.7-15  $\mu\text{g l}^{-1}$  and 0.4-8.9  $\mu\text{g l}^{-1}$ , respectively) and meso- to eutrophic Lake Onogawa (0.7-48  $\mu\text{g l}^{-1}$ , SATO and SAGISAKA, 1997), suggesting that the nutrients levels of Lake Bishamon-numa might be extremely low.

#### ACKNOWLEDGEMENTS

We are grateful to Goshiki-Sou, a hotel by Lake Bishamon-numa, for providing boats free of charge. We also thank Dr. R. JORDAN for his valuable comments on an earlier draft of this paper. Thanks are extended to the many students in our laboratory who helped us with sample collection.

#### REFERENCES

- FORSBERG, C. and S-O RYDING (1980) : Eutrophication parameters and trophic state indices in 30 Swedish waste-receiving lakes. *Arch. Hydrobiol.*, 89 : 189-207.
- HANYA, T. and N. OGURA (1995) : *Handbook of Natural Water Analysis* (3rd ed.), Maruzen Publishing (in Japanese).
- HORIE, S. (1962) : Morphometric features and the classification of all the lakes in Japan. *Mem. Coll. Sci. Univ. Kyoto (B)*, 28 : 189-207.
- JIBP-PF Research Group of Acid Lakes in Urabandai (1975) : *Productivity of the community of acidic lakes in Urabandai, with special reference to Lake Tatsu-numa, one of the disharmonic lakes*, p. 150-197, In MORI, S. and G. YAMAMOTO (eds.), *Productivity of Communities in Japanese Inland Waters*, University of Tokyo Press.
- KATO, T. and N. AITA (1970) : Geochemical investigation of the lakes in Urabandai district. Report of JIBP-PF in 1969 - Biological productivity of

- disharmonic lakes 53-59 (in Japanese).
- MURAYAMA, I. (1973) : *Volcanic Activity and Morphology*, Taimeido Publishing (in Japanese).
- NAGAOKA, M. (1991) : *Urabandai Lake Group*, In OKUDA, S., R. KURATA, M. NAGAOKA and K. SAWAMURA (eds.) *Aerial Views of Japanese Lakes*. Maruzen Publishing (in Japanese).
- SAKATA, K. (1994) : *Monitoring of Inland Waters*, p.271-274, In FUWA, K. (ed.), *Handbook of Global Environment*, Asakura Shoten Publishing (in Japanese).
- SATOH, Y., S. NAKAMURA, K. KATOH and H. SAGISAKA (1996) : Distribution of some physicochemical parameters and trophic status of Lake Onogawa. *Jpn. J. Limnol.*, 57 : 145-152.
- SATOH, Y. and H. SAGISAKA (1997) : Trophic status of Lake Akimoto and physicochemical comparison with two sister lakes of the same age. *Jpn. J. Limnol.*, 58 : 259-372.
- TANABE, K. and K. KANAZAWA (1964) : pH of Urabandai Goshiki-numa and other lakes. *Tohoku-Chiri*, 16 : 205 (in Japanese).
- TANAKA, M. (1992) : *The Lakes in Japan*, Nagoya University Press (in Japanese).
- YOSHIMURA, S. (1935) : Preliminary study on the local limnology of volcanic lakes around Volcano Bandai (1). *Chirigaku-Hyoron*, 8 : 782-802 (in Japanese).
- YOSHIMURA, S., K. NEGORO and S. YAMAMOTO (1937a) : Preliminary limnological study on Urabandai Goshiki-numa I. *Chirigaku-Hyoron*, 12 : 1-17 (in Japanese).
- YOSHIMURA, S., K. NEGORO and S. YAMAMOTO (1937b) : Preliminary limnological study on Urabandai Goshiki-numa II. *Chirigaku-Hyoron*, 12 : 126-152 (in Japanese).
- YOSHIMURA, S., K. NEGORO and S. YAMAMOTO (1937c) : Supplement of preliminary limnological study on Urabandai Goshiki-numa III. *Chirigaku-Hyoron*, 13 : 1147-1152 (in Japanese).

---

Kotaro SUGAWARA : Faculty of Science, Yamagata University, Yamagata 990-8560 (菅原幸太郎 : 〒990-8560 山形市小白川町 1-4-12, 山形大学理学部)

Shuji HINO : Faculty of Science, Yamagata University, Yamagata 990-8560 (日野修次 : 〒990-8560 山形市小白川町 1-4-12, 山形大学理学部)

Ryoji NAKAZATO : Faculty of Science, Yamagata University, Yamagata 990-8560. Present address : Center for Water Environment Studies, Ibaraki University, Ohu, Itako, Ibaraki 311-2402 (中里亮治 : 〒990-8560 山形市小白川町 1-4-12, 山形大学理学部. 現住所 : 〒311-2402 茨城県行方郡潮来町大生 1375, 茨城大学広域水圏環境科学教育センター)

Masahiro OCHIAI : Department of Chemistry, Faculty of Science, Tokyo Metropolitan University, Minamiosawa, Hachioji, Tokyo 192-0397 (落合正宏 : 〒192-0397 東京都八王子市南大沢 1-1, 東京都立大学理学部)

Yasuhiro SATOH : Faculty of Science, Yamagata University, Yamagata 990-8560 (佐藤泰哲 : 〒990-8560 山形市小白川町 1-4-12, 山形大学理学部)

---

(Received : 27 October 1998 ; Accepted : 19 May 1999)

## 福島県裏磐梯昆沙門沼の物理化学的, 生物学的特徴

菅原幸太郎・日野修次・中里亮治・落合正宏・佐藤泰哲

## 摘 要

1996年春から初冬にかけ, 昆沙門沼東湖盆の最深部, 水深 7.5 m の観測点でいくつかの物理・化学的, 生物学的因子を定期観測した。観測期間を通じ, 水温躍層は形成されないか, 形成されても微弱であった。この水温構造に呼応し, 溶存酸素は全水柱でほぼ均一に分布し, 飽和度 90 % 以上であった。透明度は平均  $5.1 \pm 1.1$  m であった。栄養生成層を透明度の 2 倍の深度までとすると, 東湖盆の全ての水体は栄養生成層となる。pH は 7 月から 12 月までかなり一定で, 平均および標準偏差  $6.15 \pm 0.08$  であった。過去のデータと比較すると, 昆沙門沼の pH は, 過去, 比較的短期間にかなり変動したが, 近年は pH6 前後で安定している。Na, K, Mg, Ca の濃度は  $\text{m mol l}^{-1}$  オーダーで, Fe と Mn は  $\mu\text{mol l}^{-1}$  オーダーであった。それらの濃度は高い方から順に, Na, Ca, Mg, K, Mn, Fe であった。Chl. *a* の年間の最大値は, 5 月に  $1.5 \mu\text{g l}^{-1}$  であった。小さな極大や極小を除くと, Chl. *a* 濃度はほとんどの季節  $1 \mu\text{g l}^{-1}$  以下で, 平均は  $0.51 \mu\text{g l}^{-1}$  であった。この Chl. *a* 濃度は貧栄養のレベルである。Chl. *a* のサイズ分画より, 昆沙門沼では 2-20  $\mu\text{m}$  のナノプランクトンが優先し, 20  $\mu\text{m}$  以上のマクロプランクトンは余り重要ではなかった。

# 3. 研究実績

この章に収録した論文は、いずれ学術雑誌に原著等として発表される予定です。  
特に引用を希望される方は、引用の可否について下記へお問い合わせ下さい。

## 問い合わせ先

名前：原 慶明

住所：990-8560 山形市小白川町1-4-12 山形大学理学部生物学科

電話：023-628-4610

Fax：023-628-4625

e-mail:hara@sci.kj.yamagata-u.ac.jp