Note

Seasonal Changes in Water Temperature, pH, Dissolved Oxygen and Transparency in a Japanese High Mountain Lake, L. Mikuriga-ike

Susumu TANAKA and Hiroyuki TOMINAGA

Abstract

Water temperature, pH, dissolved oxygen and transparency of a small Japanese high mountain lake, L. Mikuriga-ike, were measured from May to November 1974-1978. The lake formed winter stratification until about the middle of July. Measurements in May and the middle of June showed that the water temperature from the surface to about 8 m deep was below 1°C, and that the water near the bottom was approximately anoxic with a slightly higher pH. Subsequently the lake water overturned at 2.5°C in the middle of July, and the circulation period continued to the end of July with the temperature rising to 4°C. Lake surface of the summer stratification had a temperature of over 15°C. In summer stratification, the water near the thermocline was supersaturated with oxygen. This study found that autumnal circulation began at the end of October (1974, 1976) or in the middle of November (1977) at about 5 or 6°C. The pH value of the lake water showed weak acidity between 5.2 and 6.6. Transparency changed from 1.0 m to 12.0 m in depth during the investigation.

Key words: high mountain lake, Lake Mikuriga-ike, vertical profiles, dimictic lake

Lake Mikuriga-ike is a small volcanic maar. It is rare among Japanese high-altitude lakes (above the timberline) in that it is deep enough to form thermal stratification. This lake is located just below the summit of Mt. Tateyama in the Hida mountain range of central Japan (36°35'N, 137°36'E). In and around Mt. Tateyama the snow accumulates to depth of 10 m or more in winter during which the lake surface is covered with ice and thick snow for about half the year. The water of the lake surface is partly visible in areas of relatively light snow in early June and completely visible in early August. From August to October the surface is open, and plankton organisms occur and reproduce rapidly (TANAKA *et al.*, 1975, TOMINAGA and TANAKA, 1981). In December the lake is frozen over, and snow accumulates on the ice again.

The seasonal cycle of the limnological pro-

files in high mountain lakes of Japan has been little studied until now. In this paper, we intend to describe seasonal changes in water temperature, pH, dissolved oxygen and transparency of L. Mikuriga-ike observed from May, when the water surface is covered with ice and snow, to November before the lake freezes over.

Study site. The altitude of the lake surface is 2,404 m above sea level. The lake is approximately avoid in shape, 246m long and 160m wide with a maximum depth recorded as 15.3m measured by TAKAKURA *et al.* (Toyama Prefecture, 1976) (Fig. 1). Its surface area is 27,400 m². The bottom materials near shore are composed of rock and gravel, while the deeper deposits are mud and silt. The lake has two small temporary inflow streams but no visible outlet. Water level is comparably high in July and August and declines 1-2m after September.

Methods of measurement. Field surveys

Fig. 1. Location (A) and bathymetric map (B) of L. Mikuriga-ike. In Fig. A, narrow dotted lines show trails for mountain climber and thick dotted one shows a tunnel bus line. Alphabetical symbols show; a: Lake Mikuriga-ike, b: Lake Midoriga-ike and c: Bus terminal. Bathymetric map is redrawn from the figure of Toyama Prefecture (1976).

were carried out at the following frequencies: five times in 1974 (10 June, 23 July, 1 August, 21 August and 1 October), four in 1975 (13 June, 7 July, 28 August and 30 October), five in 1976 (22 May, 29 July, 4 August, 3 September and 27 October), nine in 1977 (5 June, 4 July, 21 July, 5 August, 19 August, 3 September, 18 September, 11 October and 10 November) and seven in 1978 (30 June, 9 July, 7 August, 5 September, 26 September, 14 October and 10 November). In 1974 and 1975, only the water temperature was measured.

Water temperatures were measured at intervals of 1m from surface to bottom by a thermometer thermometer (Toho Dentan E-5 type). Water samples for measurements of pH and dissolved oxygen were taken every two meters with a C-type water bottle (Rigosha & Co.) and analyzed for pH by colorimetric analysis and oxygen content according to the Winkler titrametric method. Measurements of transpar-

ency were done by Secchi disk. All measurements were carried out in the deepest part of the lake. The measurements in May and June, when the surface was covered with thick snows, were carried out through a hole made by a boring machine.

Water temperature. Water temperature changed seasonally in the same pattern every year during the investigation (Fig. 2). Winter stratification beneath the ice and snow cover persisted until about the middle of July. Water temperature beneath the thermocline was 4°C, and that of the epilimnion was 0-1°C. The thermal gradient was small, but thermocline clearly occurred at depths from 7 m to 11 m between May and mid-July. Spring overturn began at 2.5°C at the end of July and continued until the temperature went up to 4°C.

Summer stratification was observed from early August to the end of October. The maximum water temperature observed was

Fig. 2. Seasonal change of water temperature in L. Mikuriga-ike. The temperature was expressed as vertical distribution.

17.4°C at the surface layer, measured on 21 August 1974. Water temperature above 15°C in the lake surface began in early August and continued to the end of September. The thermocline shifted gradually to deeper layers as the surface temperature went down. Autumnal

circulation began in the middle of November when water temperature from surface to bottom was constant at 6°C. The autumn circulation may continue until a film of ice cover forms, though we were unable to verify this because the mountain pass was closed. The isotherms measured most frequently in 1977 are shown in Figure 3.

pH. The pH values of the lake water fluctuated between 5.2 and 6.1 throughout the investigation except for the bottom in the winter stagnation period. The low pH of L. Mikuriga-ike was already known (UENO and TANAKA, 1960). Since the substances which ordinarily lower pH values were not observed, it may be attributed to carbonic acid derived from carbon dioxide in the atmosphere. A slightly higher pH value (6.6) was observed only in the bottom layer on 22 May 1976 when the

Fig. 3. Isotherm of L. Mikuriga-ike in 1977.

Fig. 4. Seasonal and vertical distribution of dissolved oxygen gas based on the measurements of 1977. Numbers show the degree of saturation (%).

lake was in the winter stagnation period.

Dissolved oxygen (DO). Figure 4 shows the vertical and seasonal change in dissolved oxygen as the degree of saturation (%) in 1977. Concentrations of DO were distributed vertically under three patterns. One occurred during both circulation periods (mid-July and early November) and was a nearly straight line. In this condition, the oxygen was vertically contained more or less uniformly from top to bottom. Overturn from the oxygen rich surface water to the bottom may bring about the orthograde distribution. The second pattern was observed under summer stratification, and showed that the vertical profile of oxygen had a small swelling near the thermocline. This is called a heterograde distribution, and is caused by supersaturation of oxygen gas. It is generated by *Dinobryon sertularia* which reproduces abundantly in the dim light of the metalimnion (TOMINAGA and TANAKA, 1981).

The third pattern, which showed a sudden decrease of oxygen near the bottom, is called a clinograde distribution. This pattern was observed at the end of May or the beginning of June just when the winter stratification began to change. Decreases in oxygen near the bottom may not be attributed solely to chemical oxidation, but mainly to the respiration of aerobic bacteria of decay.

Transparency. Transparency fluctuated widely between 1.0 and 12.0 m during the inves-

Fig. 5. Seasonal change of the transparency.

tigation (Fig. 5). The greatest transparency was observed on 5 June 1977, and the least on 4 August 1976. The water during the spring circulation and the summer stratification had a tendency to be less transparent and, as the end of summer stratification approached, the lake water became more transparent again. Since silt-laden influents are absent in the lake, the decrease in transparency during the spring circulation may be caused exclusively by the supply of seston derived from minute particles contained in the snows on and around the lake. The condition of limited transparency continued until the snows surrounding the lake had completely melted.

Conclusion. Lake Mikuriga-ike, at a high altitude of 2,400 m, is found to be a dimictic lake circulating twice a year. This fact corroborates the known relationship between geographical limits and the effect of altitude on dimictic temperature regimes (HUTCHINSON, 1957). However, the lengths of summer and winter stagnation periods, *i.e.*, summer lasting about three months and winter about seven months, are different from lakes located in lowlands at the same latitude. *L. Mikuriga-ike* is characterized by the low water temperature of the epilimnion in summer and by the anoxic condition of the bottom layers at the end of the winter stagnation period. Higher water levels of the lake in July and August are caused mostly by melting water from lingering snows around the lake and as well as precipitation during the rainy season in Japan. Both the snowmelt water and the rainfall carry various

particles into the lake such as soil, remains of microorganisms, dust, *etc.*, and the water becomes less transparent. The water level in lowered in autumn when rainfall is reduced.

The anoxic condition is caused by a gradual decrease in dissolved oxygen concentration near the bottom during the long winter stagnation. This suggests that microbial activity in the bottom sediments consumes the oxygen over a long period under conditions of low temperature and the absence of oxygen gas from the upper layers.

Acknowledgements

We are grateful to many students of Toyama University for their assistance in field surveys. The research was partly supported by a Grant-in-Aid (No. 254215) from the Japan Ministry of Education, Science and Culture.

摘 要

高山湖沼ミクリガ池における水温, pH, 溶存酸素量, 透明度の季節変化

立山山頂近く室堂平(標高 2,400 m)に位置するミクリガ池の水温, pH, 溶存酸素量, 透明度を調べた。調査は 1974 年から 1978 年にかけて, 5 月から 11 月の間に行った。水温の変化から, ミクリガ池は年 2 回の循環期をもつ二循環性湖(温帯湖)であることが明らかとなった。7 月中旬まで冬期停滞期が続き, 5・6 月の観測では表層から水深約 8 m までは水温が 1°C 以下の低温にあり, 水温 4°C の底近くは無酸素でやや pH の高い状態であった。7 月中旬から下旬にかけて水温 2.5°C で循環期に入り, 水温が 4°C になる 7 月下旬まで続く。夏期停滞期に入ると表層の水温は急速に上昇し, 最高 15°C 以上になる。この時期, 水温躍層の近くの溶存酸素は過飽和となる。秋の循環期は水温が全層 6°C となる 11 月中旬頃にはじまる。冬期停滞期

の始まりは, 立山一帯の山岳に入ることが困難になるため確認されていない。pH 値は, 冬期停滞期の底層を除き, 5.2 から 6.1 の間の弱酸性を示した。透明度は 1.0 m から 12.0 m までの間を変化し, 融雪と降雨後の 7 月~8 月初に低く, 秋に高い傾向を示した。

References

- HUTCHINSON, G. E. (1957): A treatise on limnology. Vol. 1, Geography, physics, and chemistry. John Wiley & Sons.
- TANAKA, S., K. SATO, M. UKIHASHI and M. INAGAKI (1975): The plankters of four alpine lakes at Murodo-daira area on Mt. Tateyama in the Japanese Alps. Mem. Fac. Educ. Toyama Univ., 23: 97-106. (In Japanese with English summary)
- TOMINAGA, H. and S. TANAKA (1981): Limnological studies of a Japanese high mountain lake, Lake Mikuriga-ike. Verh. Internat. Verein. Limnol., 21: 611-612.
- TOYAMA PREFECTURE (1976): Tateyama Koshou Rikusuiseibutu Chousa Houkoku. (Report on the hydrobiology of the lakes on Mt. Tateyama), Toyama Prefecture. (In Japanese)
- UENO, M. and M. TANAKA (1960): The daphnid inhabiting the alpine lakes on Mt. Tateyama. Jpn. J. Limnol., 21: 293-306. (In Japanese with English summary)

(著者: 田中晋, 富山大学教育学部生物学教室, 〒930 富山市五福 3190; 富永裕之, 武蔵丘短期大学, 〒355-01 埼玉県比企郡吉見町大字南吉見 111-1; Susumu TANAKA, Department of Biology, Faculty of Education, Toyama University, Gofuku 3190, Toyama, 930; Hiroyuki TOMINAGA, Musashi-ga-oka College, Minami-yoshimi 111-1, Yoshimi, Saitama, 355-01)

Received: 4 August 1993

Accepted: 12 October 1993