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ZOOPLANKTON AND PHYTOPLANKTON IN ALL ANOXIC LAYERS OF LAKE FUKAMI-IKE

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ABSTRACT: Lake Fukami-ike is a small monomictic and eutrophic lake, located in southern Nagano Prefecture in Central Japan. An uncommon phenomenon of dissolved oxygen 0-1 mgL^{-1} from the surface to the bottom layer occurred on 16 November, 2013. On November 2, *Trichocerca similis* (Rotatoria) etc. dominantly distributed from 0-5 m depth depending on distribution DO concentration. *Tintinnopsis lacustris* (Protozoa) was found in the bottom layer (anoxic condition). The number of cells (*Fragilaria rumpens* (Bacillariophyceae) etc. abounded from the 0-5 m layer. On November 16, *T. lacustris* distributed from the surface to the bottom layer. Then, *T. lacustris* continued to distribute from the surface to the bottom layer, and the genus *Synedra* was found to have distributed uniformly from the surface to 6 m depth in the next investigation on 21 December, when the DO concentration was about 10 mgL^{-1} from the surface to the bottom layer. The changes in vertical distribution of *T. lacustris*, seemed to indicate that lake water was lifted from the bottom layer when shift stagnation periods to circulation periods.

Keywords: All layers, Anoxic condition, Zooplankton, Phytoplankton

1. INTRODUCTION

Lake Fukami-ike is a small monomictic and eutrophic lake. The studies in this lake were begun from 1978, and it is continuing now mainly about water quality roughly once a month. An uncommon phenomenon occurred due to dissolved oxygen 0 - 1 mgL^{-1} from the surface to bottom layer on 16 November, 2013.

This paper describes the results of zooplankton and phytoplankton distribution, nutrients, and Chlorophyll-*a* in all layers in the anoxic condition, compared with the previous investigation (on 2 November) and the following investigation (on 21 December).

2. METHODS

2.1 Study area

Lake Fukami-ike is a small monomictic and eutrophic lake, located in southern Nagano Prefecture in Central Japan; north latitude 35° 32′ 55″ 77, east longitude 137° 81′ 93″ 56, with a small diameter: 150 m, 300 m, area 2.1 ha, volume 1.0 × 105 m^3 and a maximum depth of 7.75 m (Fig. 1 and Fig.2) (Yagi, 2009, 2010).

Circulation periods were in November to March, and stagnation periods in April to October; the dissolved oxygen concentration was zero in about the 4 m to 5 m deeper layer in mid-summer (Yagi et al., 2009).

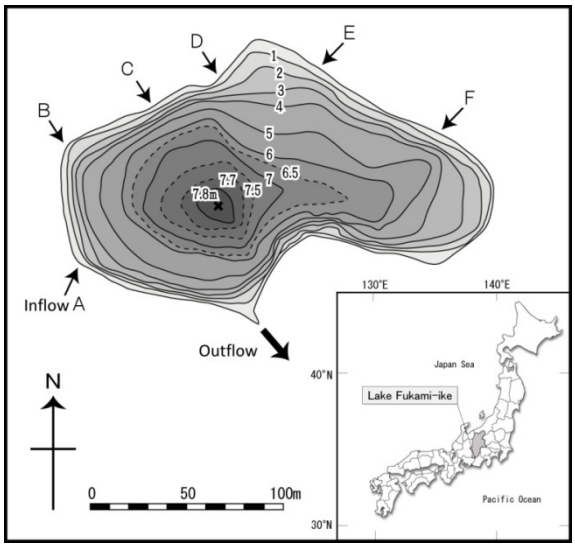

Fig. 1 Bathymetrical map of Lake Fukami-ike.

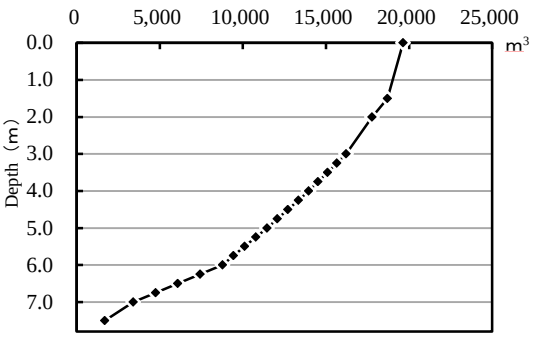

Fig. 2 Stratified volume amount of Lake Fukami-ike.

2.2 Sampling and analysis

Lake water samples were collected at the deepest point with a hand−operation water pump connected to a polyvinylchloride tube from every 0.25 m depth during the period of water stratification from April to October or from every 50 cm-1 m depth in other months.

A part of the water samples was filtered through a glass fiber filter (Whatman, GF/F, 47 mm) immediately after the sampling. The samples were stored at -20℃ until chemical analysis in the laboratory. The filtrate was used for the determination of ammonium, nitrate and nitrite and phosphorous. Inorganic nitrogen (ammonium, nitrate, and nitrite) was measured by ion chromatography analysis (DKK-TOA CORPORATION, PCI-311S). Total dissolved phosphorus was measured by the molybdenum blue colorimetric method (Murphy and Riley, 1962).

Chlorophyll-*a* was measured by the fluorometric method (Holm-Hansen et al., 1965). Water temperature was measured with a thermistor thermometer, and dissolved oxygen was determined with a DO meter.

Plankton samples were taken with a Van Dorn water sampler (10L, Rigo Co., Ltd., Tokyo Japan) every 1 m from the upper layer to the bottom layer. When the water sampling in 7 m layer, take a slight mud of bottom layer. All samples were preserved in 1% formalin in the field immediately, then counted and identified by optical microscope (BX51, OLYMPUS Optical Co., Ltd., Tokyo, Japan) in the laboratory. The cells of phytoplankton and individual zooplankton were counted using a ruled line glass slide. Dominance was shown by the numbers of cells and individuals.

3. RESULTS

3.1 Water temperature and dissolved oxygen

Vertical distributions of dissolved oxygen on 2 and 16 November, and 21 December were shown in Fig. 3. Vertical distribution of water temperature was shown in Fig. 4.

Dissolved oxygen decreased to about zero about 6 m deeper, water temperature decrease (<15.5 ℃) 6 m deeper on 2 November; meaning in stagnation periods.

On 16 November, the value were shown at nearly zero in all layer, water temperature were constantly at about 14 ℃ in all layers.

On 21 December, the value were constantly at about 10 mgL^{-1} in all layers, water temperature was constantly about 7 ℃ 1 m; meaning in circulation periods.

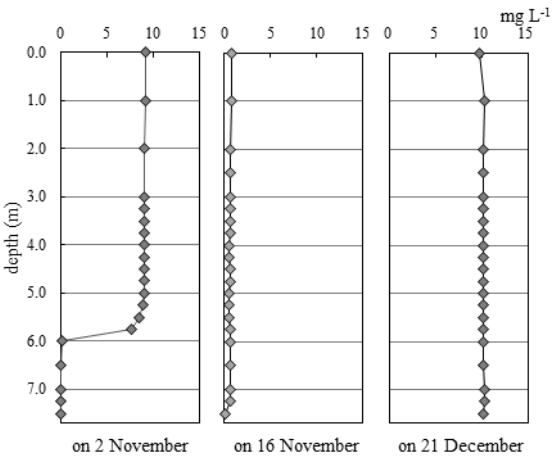

Fig. 3 Vertical distribution of dissolved oxygen on 2 and 16 November, and 21 December.

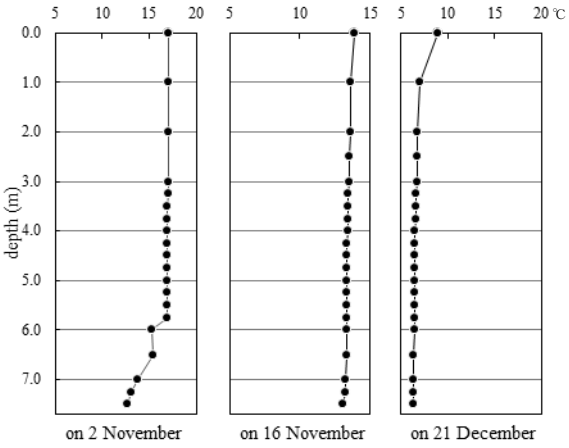

Fig. 4 Vertical distribution of water temperature on 2 and 16 November, and 21 December.

3.2 Zooplankton

Vertical distribution of zooplankton on 2 and 16 November, 21 December was shown in Fig. 5.

Trichocerca similis (Rotatoria) and *Bosmina longirostris* (Crustaceae) dominantly distributed from the surface layer to 5 m depth. They distributed depending on the sufficiently dissolved oxygen concentration layer. *Tintinnopsis lacustris* (Protozoa) distributed in the bottom layer (anoxic condition), on 2 November.

On 16 November, *Tintinnopsis lacustris* (Protozoa), which distributed only in the bottom layer on 6 November, distributed from the surface to the bottom layer. *Epistylis* sp. (Protozoa) was found in all layers the secondly.

On 21 December, *Tintinnopsis lacustris* continued to distribute from the surface to the bottom layer; density (ind. L^{-1}) was much the same

while dissolved oxygen was zero on 2 November. *Epistylis* sp. (Protozoa) and *Bosmina longirostris* (Crustaceae) etc. were found.

From 16 November to 21 December, for about one month, *Tintinnopsis lacustris* continued distribution in all layers. At the next investigation (on 18 January, after about one month), *Tintinnopsis lacustris* was not found.

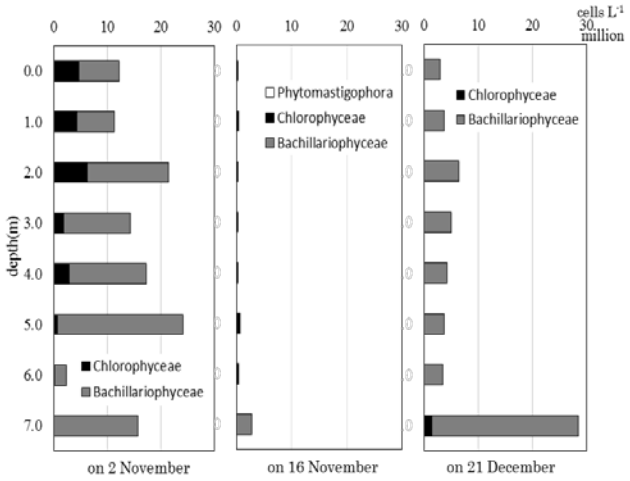

Fig. 5 Vertical distribution of phytoplankton on 2 and 16 November, and 21 December.

3.3 Nutrients

Concentrations in water column of ammonium (NH_4-N), nitrate (NO_2-N), nitrite (NO_3-N) and phosphorus phosphate (PO_4-P) were shown in Table 1-3.

On 2 November (during stagnation periods), NH_4-N and PO_4-P concentrations were high (6 m deeper layer), and the NO_3-N concentration was 0 in 6 m deeper layer. On 16 November, NH_4-N, NO_3-N, NO_2-N and PO_4-P concentrations were constant from 0 m to 7.5 m, except for NO_3-N and PO_4-P in 7.5 m.

On 21 December (during circulation periods), NH_4-N, NO_3-N, NO_2-N and PO_4-P concentration were constant from 0 m to 7.5 m.

The concentrations were highest on 16 November in the range 0 m from 6.5 m, on 2 and 16 November, and 21 December, except for release from bottom layer (in 6.5 m deeper layer) on 2 November (during stagnation periods).

Table 1 Vertical distribution of NH_4-N, NO_2-N, NO_3-N and PO_4-P on 2 November.

(mg l^{-1})

depth (m)	NH_4-N	NO_2-N	NO_3-N	PO_4-P
0	0.04	0.00	0.31	0.02
1	0.03	0.00	0.34	0.02
2	0.02	0.00	0.42	0.01
3	0.02	0.00	0.33	0.02
4	0.02	0.00	0.37	0.01
5	0.01	0.00	0.37	0.01
6	0.07	0.00	0.00	0.12
7	0.08	0.00	0.00	0.79
7.5	0.06	0.00	0.00	0.91

Table 2 Vertical distribution of NH_4-N, NO_2-N, NO_3-N and PO_4-P on 16 November.

(mg l^{-1})

depth (m)	NH_4-N	NO_2-N	NO_3-N	PO_4-P
0	0.90	0.00	0.30	0.01
1	0.19	0.00	0.26	0.02
2	1.00	0.00	0.29	0.01
3	1.05	0.00	0.28	0.00
4	0.95	0.00	0.27	0.03
5	-	0.00	0.28	0.05
6	0.75	0.00	0.30	0.01
7	1.10	0.00	0.43	0.02
7.5	-	0.01	0.07	0.19

Table 3 Vertical distribution of NH_4-N, NO_2-N, NO_3-N and PO_4-P on 21 December.

(mg l^{-1})

depth (m)	NH_4-N	NO_2-N	NO_3-N	PO_4-P
0	0.18	0.02	0.59	0.02
1	0.23	0.01	0.48	0.01
2	0.24	0.03	0.42	0.01
3	0.19	0.03	0.33	0.01
4	0.19	0.02	0.42	0.00
5	0.19	0.03	0.55	0.01
6	0.19	0.00	0.33	0.01
7	0.19	0.00	0.23	0.01
7.5	0.20	0.05	0.50	0.00

3.4 Chlorophyll-*a*

Vertical distributions of chlorophyll-*a* on 2 and 16 November, and 21 December were shown in Fig. 6.

The values were about 60 µg L^{-1} at 0 m to 5 m, about 200 to 400 µg L^{-1} (as bacterio chlorophyll-*c*) in 5 m deeper on 2 November. The values constantly ranged from about 10 to 20, except for about 200µg L^{-1} in 7.5 m on 16 November. The values constantly ranged from about 40 to 60 in all layers. The values of 16 November were low in the three investigations.

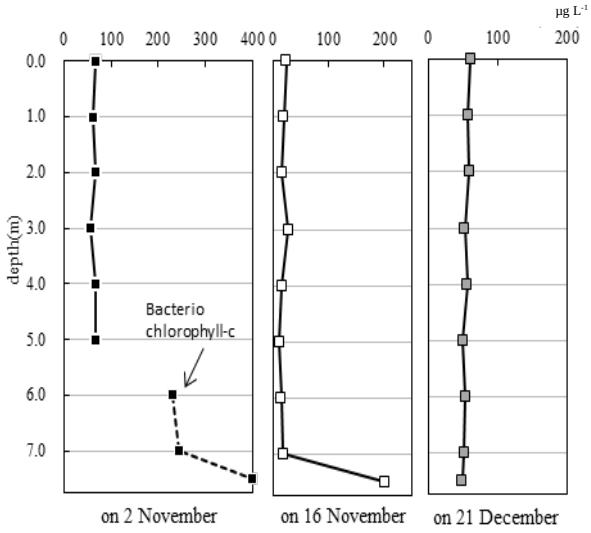

Fig. 6 Vertical distribution of Chlorophyll-*a* concentration on 2 and 16 November, and 21 December.

3.5 Phytoplankton

Vertical distribution of phytoplankton on 2 November, 16 November and 21 December were shown in Fig. 7.

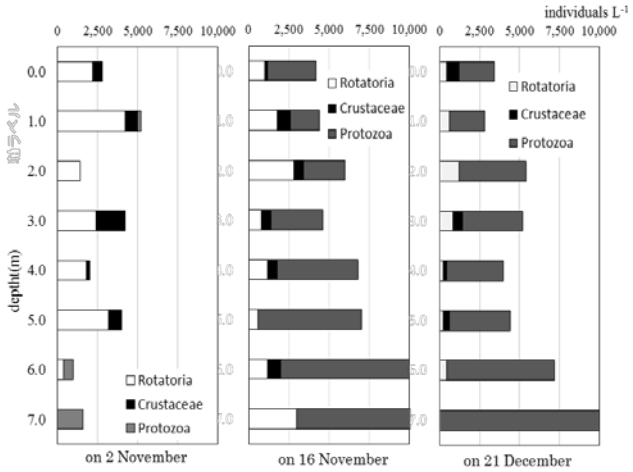

Fig. 7 Vertical distribution of phytoplankton on 2 and 16 November, and 21 December.

The number of cells abounded from the surface to 5 m layer; *Fragilaria rumpens* (Bacillariophyceae) and *Crucigenia tetrapedia* (Chlorophyceae) were dominant. It was the same as the vertical distribution of dissolved oxygen in the water column on 2 November. The peak in 7 m seemed to reflect sinking from the layer above and precipitated in the bottom layer.

On 16 November, phytoplankton were few in all layers. (The peak in 7 m seemed to constitute sinking from the layer above and precipitated in the bottom layer).

On 21 December, phytoplankton with genus *Synedra* (Bacillariophyceae) distributed uniformly from the surface to 6 m depth (The peak in 7 m seemed to constitute sinking from the layer above and precipitated in the bottom layer).

4. CONCLUSION

Phytoplankton were few in any layer under anoxic condition on 16 November. It seemed that phytoplankton cannot grow by exhaustion of nutrients in the water column because their concentration was highest under the anoxic condition. Dissolved oxygen in the water column was not enough to live and use for growth.

Tintinnopsis lacustris was found in all layers under anoxic condition. It seemed to have poor tolerance of dissolved oxygen because they were found the bottom layer on 2 November. The reason that individuals increased on 16 November, and continued on 21 December is not well understood.

The changes in their vertical distribution from 2 to 16 November, seemed due to the lake water lifting from the bottom layer (*Tintinnopsis lacustris* living) on November to all layers when shift stagnation periods to circulate on periods. There is little research on the vertical distribution of plankton, nutrient, and chlorophyll-*a*, in the anoxic condition. This paper is thus a valuable description of an uncommon phenomenon.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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