HOKKAIDO UNIVERSITY

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LIMNOLOGICAL INVESTIGATIONS OF THE TSUGARUJUNIKO LAKE GROUP, AOMORI PREFECTURE, NORTHERN JAPAN, WITH SPECIAL REFERENCE TO THE PLANKTON COMMUNITIES

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I. INTRODUCTION

THE Tsugarujuniko Lake Group is composed of many lakelets with small but comparatively deep basins. All these bodies of water are generally protected from the winds, keeping well-developed stratification of water in physical and chemical properties. That stratification is reflected on the vertical distribution of plankton.

Because of facilities for various fields of investigations, this lake group has long attracted the interest of geologists, limnologists and biologists. Although these lakelets are situated near each other in a restricted mountain area, there are considerably varying morphometric and physiographic features according to the lakelets. Each lakelet has somewhat its own characteristic hydrography and chemical properties, thus is provided with proper biotic communities to a certain extent; some are eutrophic, while others are mesotrophic or oligotrophic in productivity.

The investigators engaged in studying the present lake group are listed here with the years of publication of their works:

Arakawa (1933)
Takahashi (1933)
Yoshimura and Koba (1933)
Yoshimura (1934a)
Yoshimura, Koba and Osatu (1934)
Yoshimura, Koba, Obara and Osatu (1934)
Yoshimura (1935a)
Yoshimura (1935b)
Yoshimura (1937a)
Yoshimura (1937b)
Kokubo and Kawamura (1940a)
Kokubo and Kawamura (1940b)
Kokubo and Kawamura (1940 c)
Kokubo and Kawamura (1941a)
Kokubo and Kawamura (1941b)
Kokubo and Kawamura (1941c)
Kawamura and Kokubo (1941)
Kokubo (1941)
Kawamura and Kokubo (1942)
Kokubo (1942)
Matsuya and Kokubo (1942a)
Matsuya and Kokubo (1942b)
Kokubo and Nomura (1943)
Ishida, Kokubo and Kawamura (1944)
Kokubo, Ishida and Kawamura (1944)
Kawamura (1947)
Kawamura and Kokubo (1947)
Kokubo and Kawamura (1948)
Motoda (1953)
Nakano (1954)
Okitsu (1954)

The present investigation was attempted as a survey along the line of general limnology on several representative lakelets in the group as much in detail as possible. The changes in plankton communities according to the difference in nature of the bodies of water and changes accompanied with seasonal variation of hydrographic conditions were of particular interest to the present investigation. Stress was also laid on the relationship between the vertical distribution of plankton and physicochemical stratification of water. The productivity of the lakelets as estimated by quantitative measurement of plankton was also dealt with here from a practical point of view in fish-culture.

Before going further, the author wishes to express sincere gratitude to Prof. T. Inukai of the Faculty of Agriculture, Hokkaido University, at Sapporo for his kindness in encouraging the author to carry out the present investigation and in criticizing the data obtained. Cordial thanks are also due to Prof. T. Uchida, Faculty of Agriculture, and J. Tokida, Faculty of Fisheries, Hokkaido University, for their kind criticisms of the results in the present studies. He wishes also gratefully make acknowledgment to Emer. Prof. of Tohoku University, S. Kokubo, the former Director of the Marine Biological Station at Asamushi attached to the Tohoku University at Sendai, not only for his favours in giving untiring direction under which the research work on the biology and limnology of the present author was initiated in 1938, but also for his kindness in guiding throughout the present investigation.

The author is under great obligation to Mr. M. Watanabe, the Dean of the Faculty of Fisheries, Hokkaido University, at Hakodate at that time, for his encouragement and permission to undertake the present work. He also expresses deep gratitude to Prof. S. Motoda of the Faculty of Fisheries, for his generosity in providing facilities for the present investigation and in giving many invaluable suggestions during the work.

Thanks are also due from the author to the members of the Marine Biological Station at Asamushi, particularly to Mr. T. Okitsu and Mr. B. Tsubata, for the courtesy shown by them during his stay. Furthermore, the author wishes to thank Mr. K. Oshite, Mr. H. Takano and Mr. N. Ogawa for their help during the field observation, and also Mr. K. Shichinohe of the Fish Hatchery at Lake Tsugarujuniko for his kindness in supplying facilities for the field work.

The present investigation was rendered possible in part through the financial support of a grant-in-aid for Miscellaneous Scientific Research from the Ministry of Education, to which the author expresses his sincere thanks.

II. PHYSIOGRAPHY OF THE LAKE GROUP

BEFORE going further the general aspect in the geographical situation and morphological characters of the lake basins which have been subjected to the present study will be mentioned referring to the descriptions of previous workers.

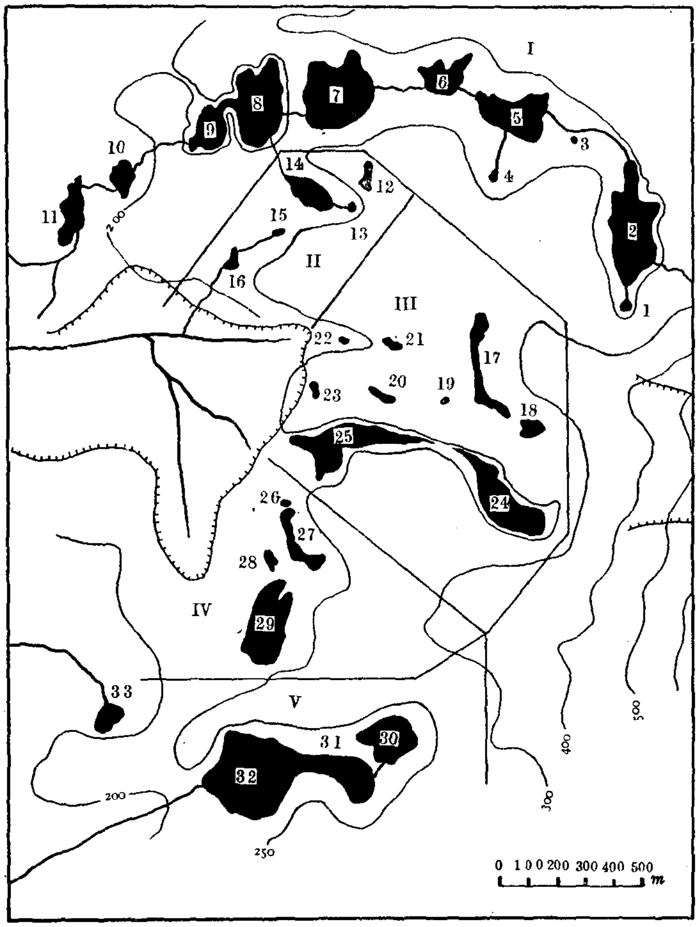

Fig. 1. Map showing location of thirty-three lakes and lakelets in Tsugarujuniko Lake Group, Nishitsugaru-gun, Aomori Prefecture

Five main sub-groups are shown by the symbols, I, II, III, IV and V.

I. Koikuchinoike lake group
1. Aoike, 2. Ketobanoike, 3. Hikiike, 4. Wakitsubonoike, 5. Ochikuchinoike, 6. Nakanoike, 7. Koikuchinoike, 8. Main lake basin of Ōike, 9. Sub lake basin of Ōike, 10. Futatsumenoike, 11. Hakkeinoike

II. Higurashinoike group
12. Nakamichinoike, 13. Hakkōnoike, 14. Higurashinoike, 15. Sayonuma, 16. Kagesakanoike

III. Itobatakenoike lake group
17. Nagaike, 18. Shigorōnoike, 19. Kodakaranoike, 20. Ikarigamanoike, 21. Michishibanoike, 22. Ishikokunoike, 23. Kayaharanoike, 24. Kanayamanoike, 25. Itobatakenoike

IV. Menkozakanoike lake group
26. Sanzōnoike, 27. Gobōnoike, 28. Chidorinoike, 29. Menkozakanoike

V. Nigoriike lake group
30. Nigoriike, 31. Sub-lake basin of Daiike, 32. Main lake basin of Daiike, 33. Yabureike

1. Geographical Situation of the Lake Group

The Tsugarujuniko Lake Group (Fig. 1), which consists of many small dammed lakelets, lies in Iwasaki-mura, Nishitsugaru-gun, Aomori Prefecture, Japan. The lake group is within an area of four by four kilometers, the altitude ranging from 150 to 250 meters above the sea level. Thirty-three lakelets in total, including several small ponds, compose the Tsugarujuniko Lake Group, and they may be subdivided into five smaller groups based on their situations (Yoshimura & Koba, 1933; Yoshimura, Koba & Osatu, 1934; Yoshimura, Koba, Obara & Osatu, 1934).

The first sub-group, the Koikuchinoike lake group, exists in the northern-most part of the area, consisting of ten lakelets; Aoike, Hikiike, Wakitsubonoike, Nakanoike, Ochikuchinoike, Ōike (main and sub-lake basins), Futatsumenoike and Hakkeinoike. This group extends approximately 2400 meters in length from east to west. Excepting Wakitsubonoike and Hikiike the other lakelets are linked together by a small brook running from east to west. One of the lakelets, Aoike, lies in the upper-most part of the area of this subdivision. There is no stream entering this lakelet, the lake water being supplied by spring water in the bottom. The outlet forms the brook which chains together the lakelets of this subdivision. There are, however, two other sources of lake water of this sub-group, one of which is the spring of Wakitsubonoike, and the other is a small brook flowing into Ketobanoike (Yoshimura & Koba, 1933; Yoshimura, 1934a; Yoshimura, Koba, Obara & Osatu, 1934; Ishida, Kokubo & Kawamura, 1944; Kokubo, Ishida & Kawamura, 1944; Kawamura & Kokubo, 1947).

The second subdivision is the Higurashinoike lake group which is situated to the south of Koikuchinoike and Ōike of the Koikuchinoike lake group; it comprises such small ponds as Nakamichinoike, Hakkōnoike, Sayonuma and Kagesakanoike. These lakelets have both their own inlets and outlets except certain small ponds; they are also connected by a stream.

The third group, the Itobatakenoike lake group occupies the central portion of the whole area. It includes nine lakelets, viz., Nagaike, Shigorōnoike, Kodakaranoike, Ikarigamanoike, Michishibanoike, Ishikokunoike, Kayaharanoike, Kanayamanoike and Itobatakenoike. These lakelets have neither inlet nor outlet, all being perfectly solitary bodies of water. This is probably one of the characteristics of this sub-group in respect to conditions of water supply.

The fourth sub-group, the Menkozakanoike, lies to the south of the former groups, and includes four lakelets, viz., Sanzōnoike, Gobōnoike, Chidorinoike and Menkozakanoike. Sanzōnonike is situated in the northern part and Menkozakanoike in the southern part. Although these lakelets are all situated within a comparatively small area, there is no channel connection between them. This is one of the points in which the fourth sub-group differs from the first and the second.

The fifth sub-group, the Nigoriike lake group, which lies in the southern-most part of the whole area, comprises three lakes, viz., Nigoriike, Daiike and Yabureike. Among them only Yabureike is isolated from other lakelets, the others being connected by a small brook extending from east to west. There is no brook of any importance entering Nigoriike. Daiike receives drainage from Nigoriike through a small stream on the northern shore and discharges the water by an outlet, flowing into the Japan Sea at a distance of about two kilometers.

The Tsugarujuniko Lake Group is surrounded by mountains. Therefore, all lake waters are not affected by wind from any direction, keeping usual calm.

2. Morphometry of Lakes

Of the lakes and lakelets mentioned above, the following ten were selected for the present observations. As to these lakes their morphometry will be described incorporating the results of previous investigators.

Nigoriike lake group	Nigoriike and Daiike
Menkozakanoike lake group	Menkozakanoike
Itobatakenoike lake group	Itobatakenoike
Higurashinoike lake group	Higurashinoike

Koikuchinoike lake group .... Ketobanoike, Ochikuchinoike, Koikuchinoike, Ōike and Hakkeinoike

(A) Nigoriike (Fig. 2–A)

The basin of this lake is rather shallow and dish-like. The diameter from east to west measures 230 meters, and the shoreline is 625 meters in approximate total length. The area and volume of water are 20900 square meters and 235460 cubic meters respecitively. The depth is 3.6 meters in mean, the maximum depth in the central part being 5.6 meters (Yoshimura, Koba, Obara & Osatu, 1934). In the present observation, however, the depth is 5.5 meters in maximum. According to the calculation of the present author from Yoshimura's data (Yoshimura, Koba, Obara & Osatu, 1934) the percentage volume of divided strata of the lake is given as follows : 0–2 meters 50.7%, 2–4 meters 37.4%, 4–5 meters 10.5% and 5–5.5 meters 1.4%.

There is no brook of any importance into the lake, but at the northern shore several springs are found. An outlet on the southern shore leads the outflow into Daiike.

(B) Daiike (Fig. 2–B)

Formerly the present lake was called Ōike (Yoshimura, Koba, Obara & Osatu, 1934), but this name should be abandoned because one may mistake it for Ōike of the northern Koikuchinoike lake group.

The lake is located in a distance of about 40 meters down the brook from Nigoriike. It is the largest and the deepest lake among all of the lakes in Tsugarujuniko. The greatest width of the lake extends from east to west, measuring approximately 600 meters. The lake basin is separated into two parts by morphological pattern, a main basin and an eastern sub-basin. The eastern sub-basin is shallow with the maximum depth of about 9 meters, while the main basin is trough-like in shape, of 310 meters in maximum width, its shoreline being 955 meters in length. The surface of water of the main basin has an area of 64150 square meters ; the volume of water filling the basin measures 958130 cubic meters. The deepest part of the basin exists in the central part, 14.9 meters in mean depth and 27.3 meters in maximum (Yoshimura, Koba, Obara & Osatu, 1934). However, the depth may be variously recorded with variable water level. For instance, it once showed about 25.3 meters in September, 1946 (Kawamura & Kokubo, 1947), while it is 28.5 meters in the present observation.

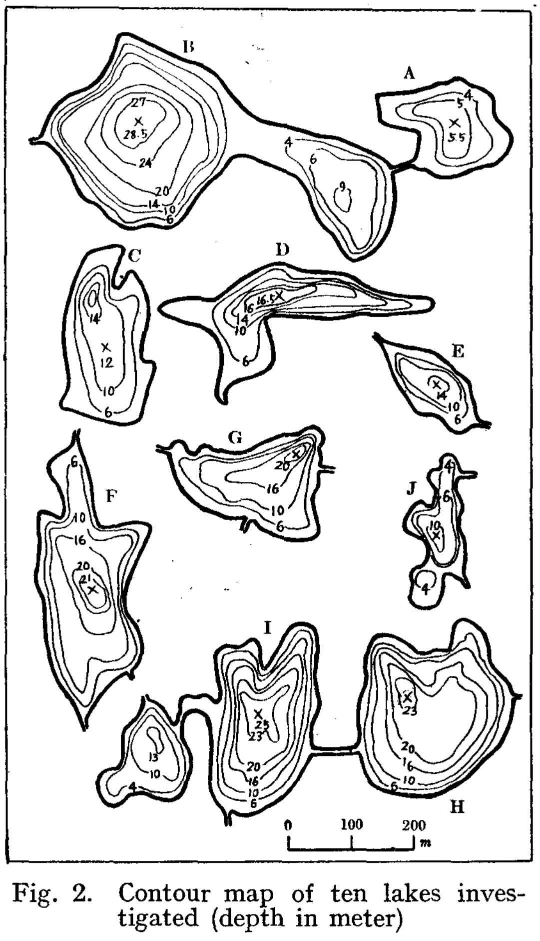

Fig. 2. Contour map of ten lakes investigated (depth in meter)

A. Nigoriike, B. Daiike, C. Menkozakanoike, E. Higurashinoike, F. Ketobanoike, G. Ochikuchinoike, H. Koikuchinoike, I. Ōike, J. Hakkeinoike. (Modified from Yoshimura, 1934)

The depth distribution of main lake basin is calculated by the present author on the basis of Yoshimura's data (Yoshimura, Koba, Obara & Osatu, 1934) as follows: 0–4 meters 25.0%, 4–8 meters 21.8%, 8–12 meters 18.4%, 12–16 meters 14.6%, 16–20 meters 11.0%, 20–24 meters 6.8%, 24–26 meters 1.9% and 26–27.3 meters 0.5%. The contour line in the map shows that the main basin has a considerable dimention of deep part as compared with other lakes in the present area.

The lake has both inlet and outlet brooks.

(C) Menkozakanoike (Fig. 2–C)

The present lake is the largest one in sub-group III. The lake has a shoreline of approximately 290 meters, with an area of 30500 square meters and volume of 235460 cubic meters. The depth of the lake measures 7.7 meters in mean and 15.5 meters in maximum near the north-west shore (Yoshimura, Koba, Obara & Osatu, 1934). However, in the central portion where the present observation was made, no such depth is found. It is just 12 meters.

The percentage volume of depth strata of the lake is calculated by the present author on Yoshimura's data (Yoshimura, Koba, Obara & Osatu, 1934), viz., 0–2 meters 25.1%, 2–4 meters 22.6%, 4–6 meters 18.5%, 6–8 meters 14.3%, 8–10 meters 10.4%, 10–12 meters 6.0%, 12–14 meters 2.2% and 14–15.5 meters 0.9%.

The present lake has neither inlet nor outlet on the shore.

(D) Itobatakenoike (Fig. 2–D)

In the lake group IV, Itobatakenoike and Kanayamanoike are remarkable for their large size and considerable depth.

Itobatakenoike is long and narrow, its shore stretches from east to west for a maximum length of 460 meters. Its area and volume are 29850 square meters and 232090 cubic meters respectively. The deepest part is in the intermediate portion of the long axis of the lake, with a depth of 7.8 meters and a maximum depth of 17.0 meters (Yoshimura, 1934a ; Yoshimura, Koba, Obara & Osatu, 1944), but this depth varies with the season, being about 16.0 meters in May 1943 (Kokubo, Ishida & Kawamura, 1944), while 16.5 meters in the present observation (May 18, 1952). The area above noted will be reduced in dry season.

The depth distribution of the lake is calculated on the basis of Yoshimura's data (Yoshimura, Koba, Obara & Osatu, 1934) : 0–2 meters 23.9%, 2–4 meters 19.6%, 4–6 meters 16.3%, 6–8 meters 13.2%, 8–10 meters 10.4%, 10–12 meters 7.8%, 12–14 merers 5.4%, 14–16 meters 3.1% and 16–17 meters 0.3%.

The lake is sometimes connected with Kanayamanoike through a small channel in the wet season. The lake has neither inlet nor outlet unless this connection is formed during rainy season.

(E) Higurashinoike (Fig. 2–E)

The present lake is the largest of sub-group II, with the moderate surface area of all the lakes of the Tsugarujuniko Lake Group. The largest diameter which extends from southeast to northwest measures 250 meters, the shoreline measuring 475 meters. The surface area and volume of water filling the basin are 11050 square meters and 76100 cubic meters respectively. The mean and maximum depths are 6.9 meters and 15.9 meters respectively, the deepest part existing in the central portion (Yoshimura, Koba, Obara & Osatu, 1934). The water level of this lake varies remarkably from season to season. A depth of 14.3 meters was observed in the present studies at the point, at which the maximum depth, 15.9 meters, was obtained by the previous investigators.

The depth distribution of the lake is calculated on the basis of Yoshimura's data (Yoshimura, Kaba, Obara & Osatu, 1934). The percentage volume of depth strata is as follows: 0–2 meters 26.7%, 2–4 meters 22.1%, 4–6 meters 17.7%, 6–8 meters 13.2%, 8–10 meters 9.6%, 10–12 meters 6.7%, 12–14 meters 3.5% and 14–15.9 meters 0.5%.

This lake has an inlet on the eastern shore and an outlet on the opposite side. The inlet receives the drainage from Hakkōnoike and the outlet flows into Ōike of the Koikuchinoike lake group at a distance of about 100 meters.

(F) Ketobanoike (Fig. 2–F)

This lake lies about 20 meters distant from Aoike, and about 400 meters from Ochikuchinoike. It is one of the comparatively large lakes of this group and ranks fourth in size of all lakes in this area. The basin of the lake is long and narrow. The largest diameter, about 430 meters, extends from south to north, the shoreline being 1100 meters. The lake has surface area of 41150 square meters and the volume of 425900 cubic meters. The maximum depth lies near the central portion. The depth is about 10.4 meters in mean and 21.9 meters in maximum (Yoshimura, Koba, Obara & Osatu, 1934).

The percentage volume of depth strata is calculated on the basis of Yoshimura's data (Yoshimura, Kaba, Obara & Osatu, 1934) : 0–4 meters 35.2%, 4–8 meters 27.7%, 8–12 meters 20.8%, 12–16 meters 11.3%, 16–20 meters 4.3% and 20–21.8 meters 0.7%.

This lake has two inlets and an outlet. One of the inlets is the short brook entering from Aoike at the southern-most point of the shoreline while the other is from the western slopes of Mt. Ōkuzure on the eastern shore. The former inlet is permanent, while the later is dried in certain periods of the year. The outlet exists at the northern-most end of the shore.

(G) Ochikuchinoke (Fig. 2–G)

The present lake lies between Ketobanoike and Nakanoike. Its shoreline is triangular in shape. The long axis extends about 260 meters from east to west. The shoreline measures 770 meters. The surface area is 27200 square meters and the volume of water measures 265100 cubic meters. The mean depth is about 9.8 meters and the deepest part, 20.3 meters in depth, is found at the northeastern corner (Yoshimura, Koba, Obara & Osatu, 1934). In the present observation, however, the depth is found to be slightly greater than the previous record, being 20.5 meters in maximum.

The percentage volume of depth strata in this lake is as follows : 0–4 meters 37.4%, 4–8 meters 29.2%, 8–12 meters 19.4%, 12–16 meters 10.4% and 16–20.3 meters 3.6%.

This lake has two inlets and an outlet. One of the inlets receives the drainage from Ketobanoike on the eastern shore and the other one, on the southern shore, contributes the water from Wakitsubonoike.

Wakitsubonoike has no inlet to receive water, but there is an ample supply of water from bottom springs. Such an invisible fountain seems to be one of the sources of the water in the course of the brook and in the lakes of area of sub-group I.

(H) Koikuchinoike (Fig. 2–H)

Koikuchinoike lies next to Nakanoike at a distance of about 350 meters from Ochikuchinoike ; it is situated close to Ōike, into which the water flows over a fall about ten meters high. This lake is one of the comparatively large bodies of water of sub-group I. The shape is almost round and the diameter measures 250 meters. The lake has an area of 47450 square meters and the volume of 675650 cubic meters, the shoreline measuring 900 meters. The mean depth measures 14.2 meters. The lake is comparatively deep in the central part, having been recorded as maximum depth 23.3 meters (Yoshimura, Koba, Obara & Osatu, 1934), but in the present study the maximum depth is observed to be 23.0 meters.

The percentage volume of depth strata of the lake is as follows : 0–4 meters 26.5%, 4–8 meters 23.4%, 8–12 meters 19.6%, 12–16 meters 15.3%, 16–20 meters 10.9%, 20–22 meters 3.4% and 22–23.3 meters 0.8%.

(I) Ōike (Fig. 2–I)

The present lake lies between Koikuchinoike and Futatsumenoike, consisting of main and sub-basins. The former plus the latter make 53500 square meters in area and 579040 cubic meters in volume. These figures show that this lake is second in size to Daiike which is the largest of all. The present study was only made on the main basin which extends about 320 meters in length from north to south, with an area of 39200 square meters. The volume is 472300 cubic meters. The shoreline totals 955 meters. The lake basin is deep in the central part, the mean depth being 12.1 meters and the maximum depth 24.0 meters (Yoshimura, Koba, Obara & Osatu, 1934). In the present study a depth of 25.0 meters is obtained as the maximum.

The percentage volume of depth strata of the basin is as follows : 0–4 meters 29.7%, 4–8 meters 23.2%, 8–12 meters 18.6%, 12–16 meters 14.7%, 16–20 meters 9.9%, 20–22 meters 3.2% and 22–23 meters 0.7%.

The main lake basin has two inlets on its shore ; one is led from Koikuchinoike on the easetrn shore and the other receives the drainage from Higurashinoike on the southern shore. The main lake basin is connected with smaller sub-basin through a furrow which is shallower than 13 meters in depth. It has two outlets on the shore ; one drains into the Hirasawa River from the northern shore and the other flows through a brook into Futatsumenoike.

(J) Hakkeinoike (Fig. 2–J)

Hakkeinoike is situated at the lowest level of all these lakes at a distance about 100 meters westward from Futatsumenoike. The largest width, from north to south, is 240 meters and the shoreline is 630 meters. The lake has an area of 11500 square meters and a volume of 46450 cubic meters. The mean depth is 4.0 meters (Yoshimura, Koba, Obara & Osatu, 1934). The maximum depth obtained in the present observation is 11.0 meters in May.

The percentage volume of depth strata in the lake is as follows : 0–2 meters 37.3%, 2–4 meters 24.0%, 4–6 meters 20.0%, 6–8 meters 11.8%, 8–10 meters 4.7%, 10–12 meters 2.0% and 12–12.8 meters 0.2%.

The outlet is present on the southeastern side of the lake, the water flowing into the River Sazanai through Kaikon village, and finally pouring into the Japan Sea.

With regard to the surface area the main basin of Daiike is largest of all lakes in the present lake group. The second is Koikuchinoike, and then Ketobanoike, Ōike, Menkozakanoike, and Itobatakenoike rank in order. In respect to the depth, the ranking is Daiike, Ōike, Koikuchinoike in order, though the differences are small.

It is of hydrological interest to note that while the lakes of the Nigoriike, the Higurashinoike and the Koikuchinoike groups have distinct inlets and outlets, the other lakes of the Menkozakanoike and the Itobatakenoike groups never have. In the latter lake groups the supply of water and the draining possibly occur through subterranean communications.

Most of the lakes freeze for the period from later December to mid-March, or a little longer. As Nigoriike has bottom springs and Ochikuchinoike receives the great mass of drainage from Wakitsubonoike, both bodies of water are usually free from the ice. It has been recorded that the cover is about 35 cm in thickness in Koikuchinoike and Ōike in early March (Kokubo & Kawamura, 1941a), while it is as thick as 70 cm approximately above deepest position in both lakes in mid-February according to the present study.

III. HYDROGRAPHIC OBSERVATIONS

FIELD observations were made on the representative lakes above described three or four times during the period from May, 1952, to February, 1953, so as to see the hydrographic conditions in different seasons and to ascertain their seasonal change

Lakes	Date	Hour	Weather	Surface conditions
Nigoriike	May 16, '52	11:40 a.m. -2:00 p.m.	Cloudy with upper clouds	Very smooth
	Aug. 27, 〃	9:25-9:50 a.m.	Cloudy with upper clouds	Very smooth
	Oct. 21, 〃	10:00-10:40 a.m.	Cloudy with upper clouds	Smooth
Daiike	May 16, '52	3:40-7:30 p.m.	Partly clouded	Very smooth
	Aug. 27, 〃	0:10-4:00 p.m.	Cloudy with upper clouds	Slight
	Oct. 21, 〃	0:15-2:00 p.m.	Partly clouded	Smooth
Menkozakanoike	May 17, '52	10:30 a.m. -12:00 m.	Blue sky	Dead calm
	Aug. 28, 〃	9:30-10:30 a.m.	Partly clouded	Smooth
	Oct. 21, 〃	3:30-4:30 p.m.	Cloudy with upper clouds	Very smooth
Itobatakenoike	May 18, '52	10:20 a.m. -12:00 m.	Blue sky	Very smooth
	Aug. 28, 〃	1:05-2:30 p.m.	Overcast with lower clouds	Slight
	Oct. 22, 〃	9:10-10:15 a.m.	Passing showers	Slight
Higurashinoike	May 18, '52	2:55-4:40 p.m.	Blue sky	Very smooth
	Aug. 29, 〃	11:10 a.m. -1:30 p.m.	Overcast with lower clouds	Smooth
	Oct. 22, 〃	11:30 a.m. -3:53 p.m.	Squalls	Moderate
	Feb. 21, '53	1:00-4:30 p.m.	Blue sky	—
Ketobanoike	May 19, '52	10:00 a.m. -0:40 p.m.	Drizzle	Smooth
	Aug. 29, 〃	3:30-5:30 p.m.	Overcast with lower clouds	Smooth
	Oct. 23, 〃	10:58 a.m. -0:15 p.m.	Drizzle	Smooth
Ochikuchinoike	May 21, '52	7:18-10:00 a.m.	Blue sky	Very smooth
	Aug. 30, 〃	9:10-11:50 a.m.	Rain	Smooth
	Oct. 23, 〃	2:17-3:55 p.m.	Overcast with lower clouds	Very smooth
Koikuchinoike	May 21, '52	11:12 a.m. -1:00 p.m.	Blue sky	Dead calm
	Aug. 30, 〃	1:30-4:00 p.m.	Overcast with lower clouds	Smooth
	Oct. 24, 〃	8:37-10:45 a.m.	Cloudy with upper clouds	Very smooth
	Feb. 20, '53	1:00-4:00 p.m.	Snow	—
Ōike	May 21, '52	2:10-5:00 p.m.	Blue sky	Very smooth
	Aug. 31, 〃	1:20-4:00 p.m.	Cloudy with upper clouds	Smooth
	Oct. 24, 〃	0:58-2:37 p.m.	Passing showers	Smooth
Hakkeinoike	May 22, '52	10:20-11:30 a.m.	Blue sky	Dead calm
	Sept. 1, 〃	11:30 a.m. -1:00 p.m.	Cloudy with upper clouds	Very smooth
	Oct. 24, 〃	4:00-4:38 p.m.	Overcast with lower clouds	Very smooth
	Feb. 21, '53	10:30 a.m. -0:30 p.m.	Blue sky	—

as completely as possible. During the winter when ice covers the lake surface, the sampling of water and measuring of temperature were performed by making a hole in the ice, but owing to the difficulty of the work in the cold season the observations were made only in the three lakes, Higurashinoike, Koikuchinoike and Hakkeinoike.

Usually the deepest part of the lakes was selected for the observation. For sampling the water a modified Ekman Reversing Bottle was used, and the temperature was measured by means of a reversing thermometer.

Dates of the observations on each lake with weather condition at these times are shown in the preceding page.

1. Results of Observations in Each Lake

(A) Nigoriike (Tables 1-3, Fig. 3)

Temperature of water:

The observations were made thrice, viz., on May 16, August 27 and October 21, 1952. The temperature ranged from 12.18°C at the surface to 10.63°C at the bottom on May 16, the time of observation must having been after the spring circulation. The difference of temperature between the surface and bottom was very small; of course, no thermocline was observed. By August 27 the surface temperature showed remarkable increase, having risen to 15.85°C, while the bottom temperature have shown 10.0°C. The thermocline with a decline of approximately 2.5°C per meter of depth appeared between the top and 2 meter depth. The temperature then decreased, on October 21, showing 11.37°C at the surface and 9.67°C at the bottom. The thermocline disappeared on account of partial circulation which had occurred with the decrease of surface temperature.

In the bottom-water temperature the difference between August and October was but little, while in May the temperature of bottom water was by far higher than in other months. Such high temperature of lower layers as observed in May was probably due to warming of bottom water by mixing with warm surface water during spring circulation. Comparatively low temperature below 2 meter depth in August and October was possibly caused by the effect of cold spring water on the shore which maintained nearly constant temperature as low as 9.5°C or less.

Color and transparency of water:

The reading of Forel's scale was very high, showing No. 9–10 at every time of observation, and the transparency as measured by disappearing depth of Secchi's disc was as low as 1.3–3.0 meters.

Dissolved oxygen:

In May the vertical distribution of the dissolved oxygen was almost uniform between the surface and the bottom, showing slight but abrupt decrease at 5 meter depth, near the bottom. In August and October the quantity of oxygen decreased toward the bottom, and the saturation percentage of the dissolved oxygen at the bottom was 9.8–1.2% (0.76–0.90 cc/l in dissolved content). The anaerobic bottom layer had greatly developed since summer, but indeed the trace of it, micro-stratification, had already been noted on May 16. The maximum value of the dissolved oxygen content through vertical range was found at the surface, showing 7.43–9.95 cc/l throughout the seasons and the saturation percentage ranged between 100 and 142%. Such high saturation of dissolved oxygen was common in this lake as was observed by Yoshimura (1937a) in July, 1934.

Hydrogen ion concentration:

The stratification of hydrogen ion concentration was almost parallel to that of the dissolved oxygen. On May 16 the pH value of the surface and bottom waters showed 7.4 and 7.0 respectively, but the water at 2 meter layer showed 7.6. This increase of pH value in the intermediate depth was possibly connected with the photosynthetic activity of diatoms in that layer. In contrast to this, on August 27 pH value showed no decrease in the intermediate layer. The values were continuously reduced from the surface to the deep, decreasing to 6.6 at the bottom layer. Exceptionally high value was observed in the surface water, as high as 8.8, undoubtedly because of diatom vegetation. This was also demonstrated by the large amount of dissolved oxygen at the corresponding layer. On October 21 the layer of high pH value had markedly sunk, and the vertical curve of pH value well agreed with the curve of temperature.

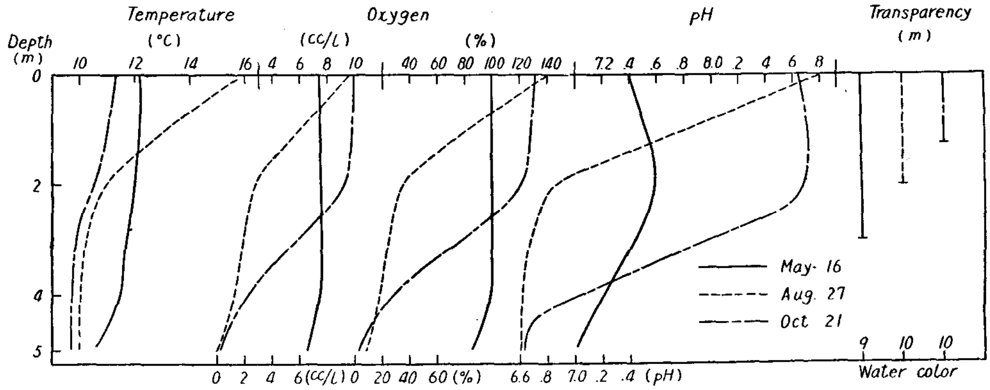

Fig. 3. Hydrographic conditions of Nigoriike

(B) Daiike (Tables 1–3, Fig. 4)

The deep main lake basin only was investigated.

Temperature of water:

In May the water above 4 meters was almost homothermous. The temperature was 14.30°C at the surface, but it decreased with depth, reaching to 6.54°C at 8 meters. The maximum decline of temperature per meter was about 2.8°C in the thermocline at 4–6 meters. The temperature of hypolimnion below 8 meter layer ranged from 6.54°C to 4.02°C, and an abnormal thermal stratification known as "poikilothermy" was observed in the vertical temperature range. In August, the temperature of water ranged from 23.24°C at the surface to 4.08°C at the bottom. The epilimnion was confined to the layers above 2 meters. The thermocline had the lowest limit at 8 meters, showing the maximum decline about 3.0°C per meter between 4 and 6 meters. When considered seasonally the temperature of hypolimnion showed almost no change since May. The circulation of water had no effect below 6 meters, that is, a "partial circulation" took place. The vertical distribution of water temperature in October was closely like to that in May, but with a little difference that the thermocline went down between 6 and 10 meters because the autumnal partial circulation had begun. The water temperature ranged from 15.01°C at the surface to 4.11°C at the bottom. The latter temperature was remarkably low as compared with that of other lakes in the present area in corresponding season. Yoshimura (1933, 1935a, 1938) observed the low temperature at the bottom in this lake as low as 4.0°C during summer and a still lower value, 3.88°C, in July, 1945. From these facts the bottom temperature of this lake may be noticed to be so low as to deserve special attention. The abnormal stratification found in the hypolimnion is also noteworthy (Fig. 4–B).

Color and transparency of water:

The reading of Forel's scale in this lake was very high like that in Nigoriike, and was especially high in May and August, i.e., No. 10 in Forel's scale and 4.0 meters in transparency. This value of Forel's scale was a little higher than that of Nigoriike.

Dissolved oxygen:

The stratification oi the dissolved oxygen was very distinct throughout the present observation. This was no prominent as to be incomparable to the values of any of the other lakes. In May the dissolved oxygen was almost uniform through the epilimnion because of the partial circulation, saturation percentage ranging from 98% at the surface to 101% at 4 meter layer (6.94–7.21 cc/l in content). The maximum quantity of 8.96 cc/l or saturation percentage of 110% was found at 6 meters in the metalimnion. Downwards from this the dissoved oxygen diminished rapidly, becoming zero at the middle layer of the hypolimnion, thus developing the anaerobic layer which had already attained a thickness of 6.5 meters by this time. In August the oxygen showed saturation of 106–107% or 6.30–6.41 cc/l in the surface layer. On the other hand, its maximum appeared also at 2 meter layer of the metalimnion as in the case of May, showing 137% of saturation or 9.12 cc/l in content. The rate of decrease of dissolved oxygen was most rapid below this depth, becoming zero at 14 meters. The anaerobic layer had progressively developed until this time, increasing its thickness up to 13 meters. In October the epilimnion showed an increase in thickness, the lower limit having sunk to 6 meters. The dichotomous stratification of dissolved oxygen which was found in May and August now disappeared. The anaerobic layer occupied the depth below 12 meters. As the thickness of anaerobic layer became as much as 15 meters, the hypolimnion was occupied by oxygenless water for the most part. Thus the anaerobic layer of this lake was by far thicker than that of any other lake of the present group.

Hydrogen ion concentration:

Remarkable stratification of hydorgen ion concentration was found at every time of observation. In May the vertical distribution of the hydrogen ion concentration was almost parallel to that of dissolved oxygen, and the value of pH ranged from 8.2 maximum at 6 meters to 6.5 minimum at the bottom. A distinct dichotomous stratification was found with the maximum at 6 meter depth. The pH value decreased rapidly downwards from this depth until the lower limit of the metalimnion. It was observed that at 26 meters in the hypolimnion the pH value slightly increased. Thus there was "reversal of pH value" in the hypolimnion. In August the hydrogen ion concentration ranged from 8.9 at 2 meters to 6.4 near the bottom. The maximum was found at 2 meters corresponding to the upper limit of the metalimnion, and slight increase was found at 12 meters corresponding to the upper part of the hypolimnion. The latter depth corresponded to the level just above the anaerobic layer. In October the pH value was 7.4 at the surface, with maximum values of 8.35 at 2 meters and 7.4 below 10 meters. A remarkable dichotomous stratification was observed with the two maxima at 6 meter and 20 meter depths. On the whole, the pH value of this lake ranged from 7.4 to 8.8 at the surface and 6.6 to 6.5 at the bottom. The maximum value of 8.2–8.9 was observed in the metalimnion. The dichotomous stratification developed in August and October. The above maximum values were slightly less than that obtained

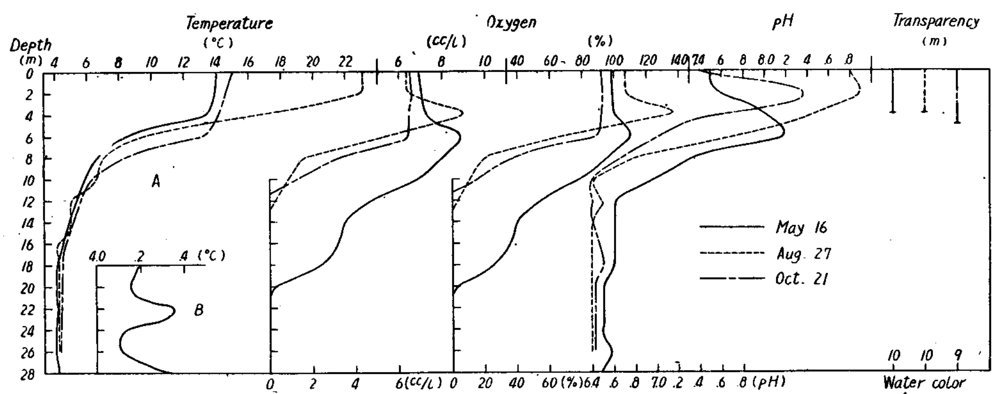

Fig. 4. Hydrographic conditions of Daiike

by Yoshimura (1937a) in this lake, but they weie more or less higher than that of Kawamura & Kokubo (1947).

(C) Menkozakanoike (Tables 1–3, Fig. 5)

Temperature of water:

The mode of thermal stratification and its seasonal change were not so prominent as those of other lakes. In May the surface temperature was 14.28°C and the bottom temperature was 6.84°C. The thermocline was found between 4 and 10 meters, ranging from 13.39°C to 7.20°C, but the upper limit of the hypolimnion was almost indistinguishable. In August the temperature ranged from 23.37°C at the surface to 8.68°C at the bottom. The position of the thermocline was approximately the same as in May, though its maximum decline reaching about 3.4°C per meter at 6–8 meters was more marked than in May. In October the water showed homothermal condition from the top to 8 meter depth, being 15°C or thereabouts. With the increase of the thickness of epilimnion the thermocline was depressed to 8–19 meter layers, but the position of the hypolimnion was almost similar to that in August. From above, the epilimnion of this lake is relatively thick throughout all seasons and the temperature of bottom water gradually increases with the progress of the seasons from May to October. These facts have been noticed by Yoshimura (1935a) in this lake.

Color and transparency of water:

The reading of Forel's scale showed moderate values, being No. 9 in May, No. 10 in August and No. 7 in October. The transparency was lower than that of any other lake, ranging from 5 to 6.5 meters.

Dissolved oxygen:

As described before, the present lake has an area of 30500 square meters and a depth of about 12 meters. As the ratio of the surface dimension to the water volume is very large, this lake naturally has relatively thick epilimnion through all seasons due to the turbulence caused by wind. By a glance at Fig. 5 one will note that the stratification of dissolved oxygen in the epilimnion is not very prominent. In May the dissolved oxygen was almost uniform above 6 meters, ranging from 92.9% or 6.54 cc/1 at the surface to 98.3% or 7.05 cc/1 at 4 meter depth in the epilimnion. Downwards from this depth it gradually decreased to 61% in saturation oı 5.10 cc/1 in content at the bottom. In August the dissolved oxygen showed 89.5–102.9% of saturation or 5.28–6.08 cc/1 of content in the epilimnion, the maximum of 102.9% of saturation being observed at 4 meters. The rate of decrease of dissolved oxygen was large below this depth, becoming zero near the bottom. In October the distribution of oxygen was nearly homogenous in the hypolimnion, showing the saturation of 94.3–98.4% or 6.24–6.74 cc/1. From 8 meter depth downwards the dissolved oxygen rapidly decreased, becoming zero near the bottom just as in August.

Hydrogen ion concentration :

The hydrogen ion concentration was found to be extremely high (low pH value) in all water layers throughout the observations. In May pH value was entirely equal through 0–6 meter layers, decreasing slightly with depth below 6 meter depth. It became 6.0 in the layers downward from 10 meters to the bottom. In August it ranged from 6.4 at the surface to 5.8 at the bottom, but the vertical gradient was parallel to that in May. In October pH value showed 6.35–6.2 above 8 meters and decreased to 5.9 at 10 meters, but it again increased to 6.0 at the bottom. Thus, a dichotomous stratification of pH value was present. Comparing with other lakes, the high hydrogen ion concentration (low pH value) is one of the characteristics of this lake as was stated by Yoshimura (1937a) and also by Kokubo & Kawamura (1948).

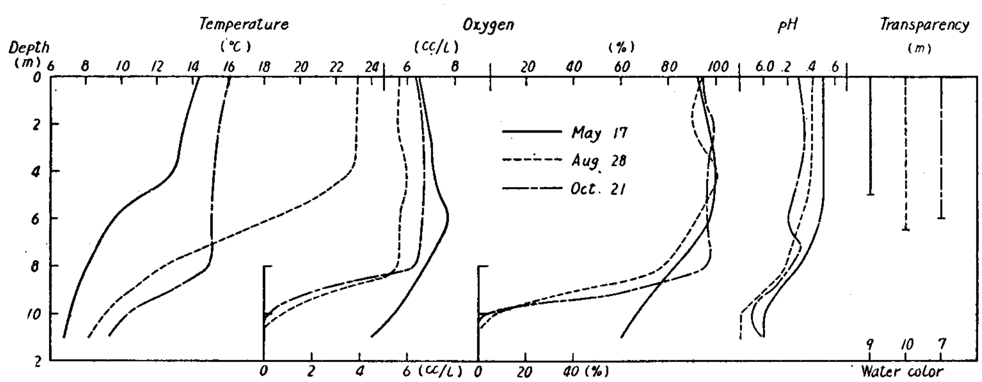

Fig. 5. Hydrographic conditions of Menkozakanoike

(D) Itobatakenoike (Tables 1–3, Fig. 6)

Temperature of water :

The present lake had a well-established thermal stratification throughout the seasons. In May the temperature was 15.47°C at the surface, 13.89°C at 4 meters, 4.97°C at 12 meters and 4.61°C at the bottom. The thermocline was found between 4 and 12 meter depths, the maximum decline being approximately 2.4°C per meter at 4–6 meter depth. In August the temperature was 23.90°C at the surface, 23.04°C at 2 meters, 5.35°C at 12 meters and 4.94°C at the bottom. The thermocline has remarkably developed, the lower limit coming up to 2 meter depth. The temperature at the bottom was almost similar to that in May. In October the water was entirely homothermous between the surface and 4 meters in the epilimnion due to the partial circulation in autumn. Accordingly, the thickness of thermocline was reduced to the layers from 6 to 12 meters, and its decline became about 2.3°C per meter in maximum. The bottom water temperature was 5.19°C, being slightly higher than that of the observation at the previous time, but it was not so high as that of Menkozakanoike. Looking through the above results, it will be noticed that the thermal conditions in the layers above the thermocline in this lake are almost similar to those of Daiike.

Color and transparency of water :

The reading of Forel's scale was slightly higher in this lake than in other lakes, ranging from No. 8 in May to No. 10 in October. The transparency was 3 meters in both May and August and 2.5 meters in October.

Dissolved oxygen :

A stratification of the dissolved oxygen was found throughout seasons observed. A slight excess of dissolved oxygen compared with normal solubility was found at the upper limit of the metalimnion, while the dissolved oxygen was reduced toward the bottom in summer. In May the dissolved oxygen ranged from 91.7% or 6.51 cc/1 at 4 meters to 106.3% or 8.40 cc/1 at 6 meters in the epilimnion above 8 meter depth, but it decreased downwards, becoming zero at 14 meter depth. The anaerobic layer was about 2.5 meters in thickness. In August the dissolved oxygen was rapidly reduced with depth, 90.0% or 5.21 cc/1 at the surface, 50.8% or 3.26 cc/1 at 4 meters and zero at 10 meters. The thickness of the anaerobic layer was 5.5 meters by this time. In October the saturation percentage at the surface was 103.7%, 85.2% at 2 meters and 95.7% at 4 meters, but it rapidly decreased below 4 meters, reaching zero at 10 meters. The thickness of the anaerobic layer became less than in August. The excess of dissolved oxygen over normal solubility has often been reported in this lake. According to the observation of Ishida, Kokubo & Kawamura (1944), the saturation percentage was as high as 150% in July, 1943. However, the depth and the thickness of the anaerobic layer in their cases were almost similar to those values in the present case.

Hydrogen ion concentration :

The pH value of this lake was not very high as compared with other lakes of the present group. In May the pH value was 7.4 at the surface, 7.5 at 2 meters, 7.4 at 4 meters and the maximum 7.7 at 6 meters, decreasing rapidly downwards from this depth. In the hypolimnion it ranged from 6.5 to 6.4. In August it was 7.6 at the surface, decreasing with depth to 6.4 or a little over below 4 meters. In October the pH values of the upper 4 meters were almost uniform, being 7.1 at the surface. Between 4 and 6 meters it rapidly decreased, being 6.4 at 6 meters and attaining the minimum of 6.3 at the bottom. So far as the present study is concerned, pH value of this lake ranged 7.1–7.6 at the surface, 6.4–7.7 at the metalimnion and 6.4–6.3 at the bottom. Thus, the lake water may be stated to have relatively high hydrogen ion concentration (low pH value) throughout the depths and seasons. But the pH value of this lake was reported to be such a high value as 9.2 in summer, 1943 (Ishida, Kokubo & Kawamura, 1944). Throughout the seasons no reversal of pH value was found in the anaerobic layer.

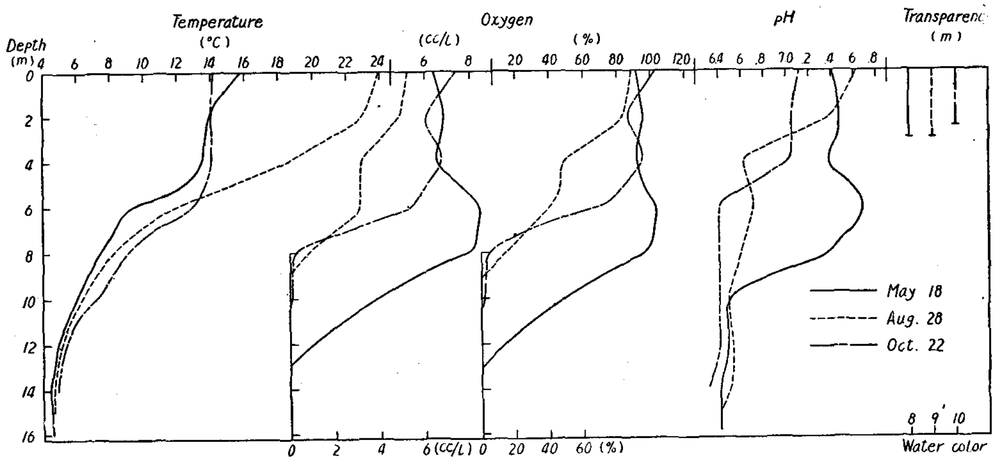

Fig. 6. Hydrographic conditions of Itobatakenoike

(E) Higurashinoike (Tables 1–3, Fig. 7)

Observations were made four times during the period from May, 1952, to February, 1953.

Temperature of water:

A unique feature of thermal stratification was observed in this lake during summer. In May gradual increase of temperature was observed between the surface (17.66°C) and 14 meter depth at the bottom (4.54°C). As the temperature at 10 meter layer showed 4.91°C, the upper 10 meters could be taken as the thermocline in this case. However, considering the matter in conjunction with the results of three other observations, the upper 2 meters must be considered to be the epilimnion, though a certain inhomogeneity in temperature was seen. In August the thermocline shifted to the layer between 2 meters and 8 meters due to a rise in the temperature of the hypolimnion. Above facts are not necessarily to be stressed as a peculiar condition, but the rapid sinking in thermocline from May to August is noteworthy. Such tendency of temperature change seems to be a common thing in this lake as it has also been observed by Yoshimura (1935a). In August a secondary thermocline, though less marked, appeared in deep layer. Entering October the thickness of epilimnion increased and two indistinct thermoclines, primary and secondary, were observed at 2–4 meters and 6–8 meters respectively. The development of a secondary thermocline is not always an uncommon thing in other lakes. It is ususally located in the upper stratum above the primary one, lasting only for a short period. Worthington & Beadle (1932) reported a secondary thermocline from 40 meter depth of Lake Edward (depth 117 meters). They, however, considered it not to be a true thermocline, but regarded it as one produced by the heavier water of volcanic origin which poured into the middle layer of this lake from one side of the basin. In the present case of Higurashinoike the sub-thermocline (secondary thermocline) mentioned above is known to be caused by the circulation of surface water. The water which is introduced from Hakkōnoike joining the surface layer of the lake results in a certain circulatory movement of surface water. In February the temperature was 0.79°C at the surface, 3.85°C at 2 meters and 4.05°C at the bottom. Thus the indirect stratification was formed.

Color and transparency of water :

The reading of Forel's scale was very high in this lake, especially in May, the values ranging from No. 10 to No. 11. The transparency was very low in all observations, showing 0.8–2.0 meters.

Dissolved oxygen :

The dissolved oxygen was moderately stratified in all months. In May the gradient of dissolved oxygen was almost parallel to the water temperature, the percentage saturation ranging from 1% (0.1 cc/l) at the bottom to 123% (8.8 cc/l) at 2 meters. The oversaturated oxygen was observed above 2 meters within the metalimnion, a microstratification of oxygen being formed close to the bottom. In August the saturation percentage ranged from the maximum of 103% at the surface to 0% at 8 meter depth. The microstratification showed in May has developed to the anaerobic layer with about 5.5 meter thickness by August. In October the stratification was like that of August, saturation percentage ranging from 90% (6.4 cc/l) at 2 meters to 0% at 10 meters. In February observation was made under the ice, when it was found that the layer of abrupt decrease in dissolved oxygen has descended to about 12 meter depth or lower. The saturation percentage was 94% (9.20 cc/l) at the surface under the ice, about 61% (5,48 cc/l) at 4 meters and 55% (5.22 cc/l) at 10 meters. The content decreased very rapidly below 12 meters, thus showing the minimum value of 18% (1.60 cc/l) at the bottom.

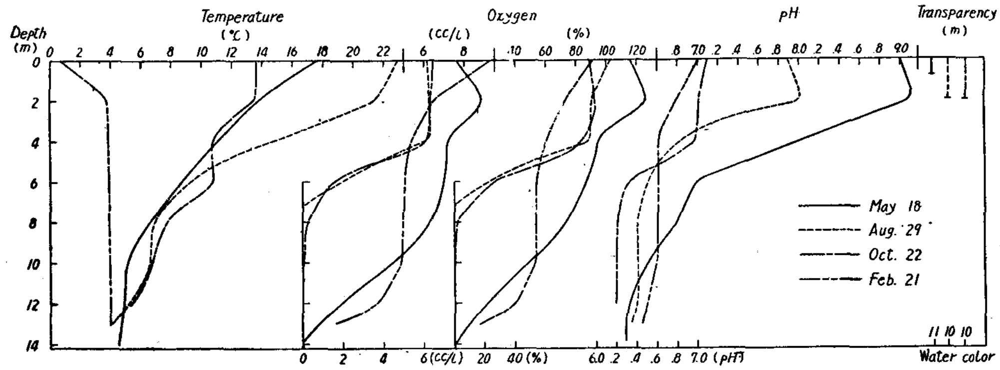

Fig. 7. Hydrographic conditions of Higurashinoike

Hydrogen ion concentration:

The hydrogen ion concentration was well stratified in all months except February. In general, the pH value was high at 2 meter depth. The pH value ranged from 7.0 to 9.0 at the surface, 6.3–7.0 at 6 meters and 6.2–6.45 near the bottom. In May, pH value ranged from the maximum of 9.1 at 2 meters to 6.3 near the bottom, and its stratification was parallel to that of the dissolved oxygen. In August the range was from 7.1 at the surface to 6.2 near the bottom. The value was almost uniform through the range of hypolimnion in both months. In February it ranged from 7.0 at the surface to 6.45 at the bottom. No reversal of the pH value was found near the bottom in any season.

(F) Ketobanoike (Tables 1–3, Fig. 8)

Temperature of water:

The temperature of the epilimnion in this lake was relatively low, but that near the bottom was a little higher than that of other lakes. Although the thermocline was comparatively thick, its decline was not always so marked as that of other lakes. In May the temperature was 17.3°C at the surface, 6.95°C at 8 meters in the lower limit of thermocline, and 4.95°C at the bottom. The thermocline was formed between the surface and 8 meters, its decline being 1.1°C per meter in 4–6 meters. At the end of August, the temperature ranged from 19.54°C at the surface to 5.00°C at the bottom. The thermocline existed between the surface and 10 meter layer at which 6.46°C was reached. The largest decline was found above 2 meter depth, approximately 2.9°C per meter. In October the temperature ranged 11.85°C–10.18°C in the epilimnion, and the water above 8 meter depth was homothermous. The thermocline was formed between 8 and 12 meters, because of the partial circulation in autumn, its maximum decline which occurred between 8 and 10 meters being 1.4°C per meter. The hypolimnion maintained the temperature of 5.69°C–5.12°C, the conditions being almost similar to those in August. Although this lake is one of the deep ones in this group of lakes, no abnormal thermal stratification has been found near the bottom. The water temperature in the epilimnion is by far lower than that of any other lake except the cases of Nigoriike and Ochikuchinoike. According to Yoshimura (1935a), the present lake was classified as a lakelet of low temperature due to the low surface temperature in summer stagnation period. Likewise, Kokubo & Kawamura (1941a) reported that the water temperature above the thermocline was essentially similar to that of Ochikuchinoike of which the lowness of the temperature was also characteristic. For this reason Kokubo & Kawamura (1941a) gave an explanation that the lake water was supplied by the large amount of cold spring water (9.0°C) from Aoike.

Color and transparency of water:

The color of lake surface as read by the Forel's scale ranged from No. 10 in May to No. 7 in August in this lake. The transparency was 1.0 meter in May, 5.0 meters in August and 3.0 meters in October.

Dissolved oxygen:

A remarkable stratification of the dissolved oxygen was formed in this lake, that is, the extreme excess in the epilimnion and scarcity in the hypolimnion occurred in both spring and summer seasons. In May the dissolved oxygen showed 108% (7.7 cc/l) at the surface, 141% (10.5 cc/l) at 2 meters, 115% (8.8 cc/l) at 3 meters and 145% (11.6 cc/l) at 4 meters. Below this level it decreased to about 8% (0.8 cc/l) at the bottom. An exceptionally large amount of dissolved oxygen appearing at 2 meters (8.8 cc/l) and 6 meters (11.6 cc/l) might be in response to the high concentration of phytoplankton in these layers as discussed later. In August the vertical distribution of the dissolved oxygen was entirely similar to that in May as far as the metalimnion above 10 meter level, but the anaerobic layer has developed to the thickness of about 6 meters by this time (below 12 meter depth). Saturation percentage was 104% (6.5 cc/l) at the surface, 137% (9.5 cc/l) at 2 meters, 111% (8.0 cc/l) at 4 meters and 136% (10.0 cc/l) at 6 meters, and then it was rapidly reduced to zero at 12 meters. In October it ranged from saturation of 106% (7.9 cc/l) at the surface to zero at 14 meters. The remarkable anaerobic layer had existed since August.

Hydrogen ion concentration:

The pH value ranged 7.7–8.8 at the surface, 7.1–9.0 at 6 meters and 6.4–6.8 at the bottom. The maximum value occurred at 6 meter depth in summer. The reversal of pH value in the hypolimnion was not observed in any season. In May the change of pH value was parallel to the vertical distribution of dissolved oxygen. The maximum of 9.0 appeared at 6 meters, below this the value decreasing rapidly to

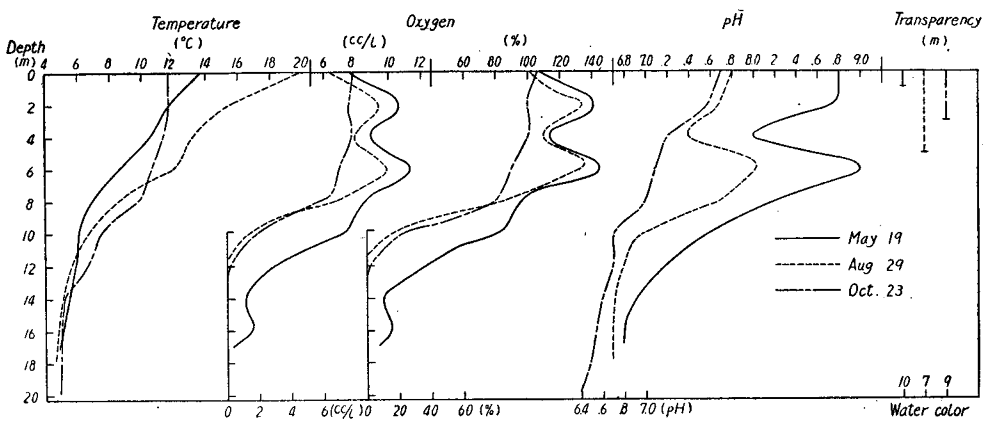

Fig. 8. Hydrographic conditions of Ketobanoike

the minimum of 6.8 near the bottom. In August the vertical distribution of pH value was, on the whole, similar to that in May. However, the values in all layers were lower than those in May, showing 7.8 at the surface, 8.0 at 6 meters and 6.7 at the bottom. In October it decreased gradually with depth from 7.6 at the surface to 6.4 at 20 meters, and the stratification of pH value was relatively simple as compared with that in August.

(G) Ochikuchinoike (Tables 1–3, Fig. 9)

Temperature of water:

In this lake the water temperature was fairly low in the epilimnion, and was rather high in the hypolimnion in general. In May the epilimnion existed above 6 meter level where the temperature ranged from 12.56°C at the surface to 11.32°C at 6 meters. The thermocline located in 6–10 meters and its thickness was comparatively small. Its decline reached rarely to 1.7°C per meter in maximum. In August, though the temperature rose to 16.06°C at the surface and 14.99°C at 6 meters of the lower limit of the epilimnion, the position of the epilimnion was quite the same as in May. The thermocline extended down to 12 meters with the maximum of decline reaching approximately 2.1°C per meter in 6–8 meters. In October the water became almost homothermous from the top to 10 meters on account of the autumn circulation. The temperature ranged from 12.00°C at the surface to 11.11°C at the lower limit of homothermous layer (epilimnion). Thus, in accordance with the increase of thickness of epilimnion, the thickness of thermocline was remarkably reduced, until it ranged between 10 and 12 meters. The temperature of the hypolimnion ranged from 6.35°C to 5.00°C in May, from 6.25°C to 5.38°C in August and from 6.69°C to 5.57°C in October. From the above, one will notice that the temperature in the epilimnion is fairly lower than that of other deep lakes, while the temperature of hypolimnion, especially near the bottom, is rather higher than that in other lakes. Yoshimura (1935a) first reported the low temperature of the surface water of this lake in 1934. Thereafter, it was also observed by Kawamura & Kokubo (1941, 1942), Kokubo & Kawamura (1941a, b) and Ishida, Kokubo & Kawamura (1944). They considered that this low surface temperature was due to the inflow of a large amount of cold spring water from Wakitsubonoike. The author has confirmed this by measuring the temperature of water introduced from Wakitsubonoike and finding that it was 9.2°C before pouring into Ochikuchinoike in summer. On the other hand, the comparatively high temperature of the bottom water of this lake, which has already been observed by Kokubo & Kawamura (1941a), depended probably upon the vertical turbulence due to the inflowing of the great mass of water from Wakitsubonoike.

Color and transparency of water:

Forel's scale showed relatively low values as compared with those of the former lake. The reading was No. 7 in May, No. 8 in August, and again No. 7 in October. The transparency was large comparing with other lakes, that is; 6 meters in May, 4.3 meters in August and 6 meters in October.

Dissolved oxygen :

The dissolved oxygen showed a remarkable stratification. However, the gradient of the vertical distribution was less than that of Koikuchinoike. No dichotomous stratification was found, while the anareobic layer was formed in the hypolimnion in all seasons. In May the dissolved oxygen was uniformly distributed above 6 meter depth, with the saturation percentage of 101–105% (7.3–7.9 cc/1), decreasing slowly from this depth downwards until the content became zero at 18 meter depth. In August the veritcal distribution of the dissolved oxygen above 6 meters was similar to that in May. It ranged from saturation of 106% (7.4 cc/1) at 6 meters to 109% (7.5 cc/1) at 2 meters. The anaerobic layer has developed in the bottom, attaining about 6 meters in thickness (below 14 meter level). In October the saturation ranged from 101% (7.5 cc/l) at the surface to 96% (7.2 cc/l) at 6 meters, being rapidly reduced from 98% (7.3 cc/1) at 8 meters to zero at 14 meter depth and finally reaching to the anaerobic condition of which the thickness was about 6 meters. The oxygen content in this lake is not always the same year by year. It was recorded by Kokubo & Kawamura (1941a) that the dissolved oxygen was 136% of saturation or 9.5 cc/l in content and the anaerobic layer in the hypolimnion reached about 10 meters in thickness.

Hydrogen ion concentration :

The curve of vertical distribution of pH value was not acute in all months, this probably being a characteristic feature of this lake. The pH value did not show any reversal in the lower part of the hypolimnion. It ranged from 8.0 in May to 7.5 in October at the surface, and from 6.65 in August to 6.45 in October at the

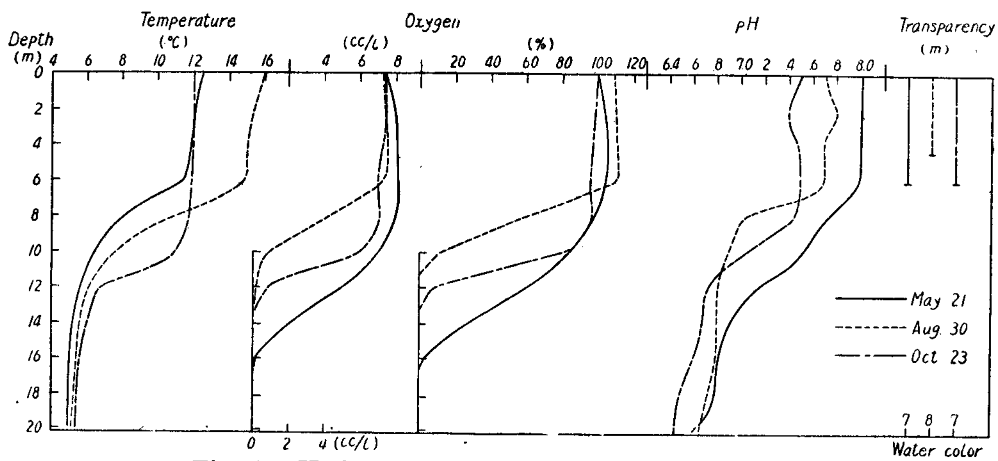

Fig. 9. Hydrographic conditions of Ochikuchinoike

bottom. In May the epilimnion above 5 meters was nearly equal to 8.0 in pH value. From this downwards it decreased slowly with depth to a value of 6.6 at the bottom. In August it ranged between 7.8 and 7.7 above 6 meters within the metalimnion, decreasing gradually below this until it reached 6.45 at the bottom. Through the present observation no reversal of pH value was observed.

(H) Koikuchinoike (Tables 1–3, Fig. 10)

Temperature of water:

Because of the deepness of this lake in relation to the surface area, thermal stratification was very marked during the summer stagnation period. Throughout the year the temperature was relatively high at the surface, but very low near the bottom. An abnormal thermal stratification always occurred in the hypolimnion. In May in the epilimnion within the part above 4 meter layer the water temperature ranged from 15.32°C at the surface to 13.79°C at the lower limit of the layer. The thermocline was formed between 4 and 8 meter layers, the largest decline showing approximately 2.5°C per meter in 4–6 meters. In the hypolimnion the temperature ranged from 5.62°C to 4.05°C. An abnormal thermal stratification, "mesothermy" came into existence. In August the temperature ranged from 20.76°C to 19.86°C at 4 meter level in the epilimnion. Though the position of the thermocline was entirely the same in May, the maximum decline of temperature per meter became 5.8°C. The temperature was 6.92°C–4.26°C in the hypolimnion, and "poikilothermy" developed within this layer. Thereafter, in October the layers above 7 meter depth showed a homothermal condition, the temperature being 13.0°C or slightly lower. Consequently, the layer of thermocline became thinner, shifting to the depths between 8 and 10 meters. The temperature ranged vertically from 5.89°C to 4.22°C in the hypolimnion (below 10 meter depth), and "poikilothermy" developed in this layer. In February an indirect stratification was obseved. The increase of temperature with depth was most prominent between 2 and 4 meter layers, being about 1.2°C per meter. Downwards from 4 meter depth the gradient was very gentle, and at last the temperature became 4.18°C at the bottom. According to Kokubo & Kawamura (1941a), the thermocline was formed in 10–15 meters in May after spring circulation period, but it came up 2–20 meters in July. They mentioned that this ascending of the thermocline was probably caused by a supply of cold spring water which poured into the middle layer of the lake basin. In the present observation the ascending tendency of the thermocline with progressing seasons was not observed, but a complex abnormal thermal stratification, which was probably caused by the cold water poured into the depth, was very notably observed in 11–16 meters (Fig. 10–B).

Color and transparency of water:

Forel's scale was No. 10 in May, No. 9 in August and No. 7 in October, the seasonal fluctuation being relatively large as compared with the other lakes. The transparency showed 2.0 meters in May, the same in August and 4.4 meters in October.

Dissolved oxygen :

The dissolved oxygen showed a remarkable stratification in this lake ; that is, the excess of dissolved oxygen appeared at the upper layer, while an oxygenless zone occurred in the hypolimnion through observations. In May the dissolved oxygen ranged from about 95% of saturation (6.5 cc/l) to 120% (9.5cc/l) between the surface layer and 6 meter depth, being reduced downwards to zero at 18 meters. The oxygenless zone was observed below 18 meters in the hypolimnion, and measured about 5 meters in thickness in May. In August the vertical stratification of dissolved oxygen became more pronounced than that in May, viz., the saturation percentage was 102% (6.3 cc/l) at the surface and 132% (8.7 cc/l) at 5 meters. The anaerobic layer had developed to 11 meters in thickness. In October the dissolved oxygen was uniformly distributed in the layers above 7 meter depth, showing the saturation of 92–95% (6.6–6.8 cc/l), while it decreased rapidly with depth, showing 2% (0.2 cc/l) at 10 meters. It became zero below 18 meter layer. In February a remarkable stratification was observed under the ice cover, a slight over-saturation occurring in 4 meter layer. The anaerobic condition was found below 20 meter depth. The over-saturation under the ice cover is of interest as it may probably be due to the vegetation of diatoms in that layer in such condition as under the ice.

Hydrogen ion concentration :

The stratification of hydrogen ion concentration occurred remarkably in this lake. The pH value of water ranged from 7.4 to 8.2 at the surface to 6.6–6.8

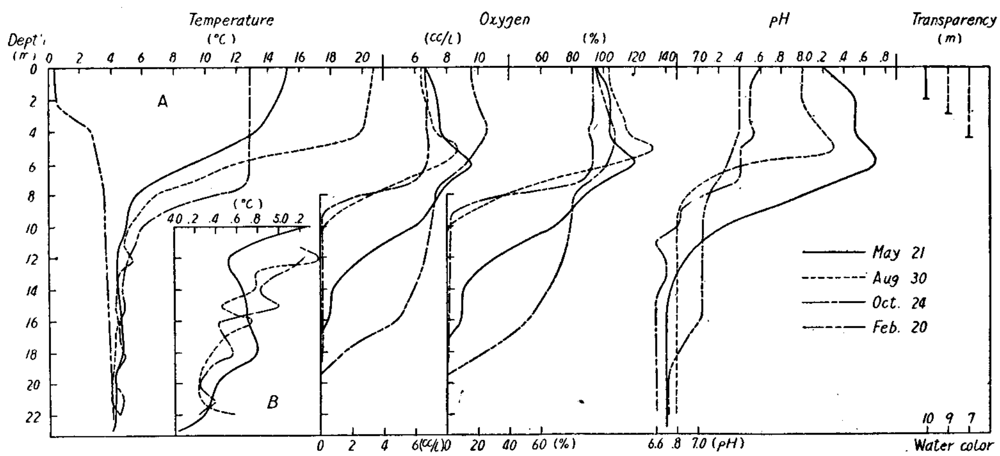

Fig. 10. Hydrographic conditions of Koikuchinoike

at the bottom throughout the seasons. In May the pH value was relatively high at the epilimnion, ranging from 8.2 at the surface to the maximum value of 8.7 at 6 meter depth. It declined rapidly downwards, showing 6.7 in the hypolimnion. In August the pH value showed 8.0 at the surface and maximum of 8.3 at 4 meters, rapidly decreasing downwards to 6.8 between 8 meters and the bottom. In October it ranged from 7.4 to 7.6 above the 7 meter level and from 6.8 to 6.6 below 8 meter layer. In February the stratification of pH value was relatively simple, ranging from 7.4 to 6.7 between the surface and the bottom. In the present observation no sign of reversal of pH value in anaerobic hypolimnion was observed.

Comparison of seasonal fluctuation of surface temperature between Ochikuchinoike and Koikuchinoike

More frequent observations on the surface temperature than called for by the regular program of observations were performed in the two lakes, Koikuchinoike and Ochikuchinoike, to learn the precise figure of seasonal fluctuation. Figure 11 is based on the calculation for monthly mean from the every day observation throughout the year 1952. The monthly mean of air temperature showed the minimum of –0.7°C in February and the maximum of 27.5°C in August. The temperature of surface water of Koikuchinoike showed the minimum of 4.1°C in February and the maximum of 19.4°C in August, the curve of seasonal fluctuation being in general like that of air temperature. On the other hand, seasonal

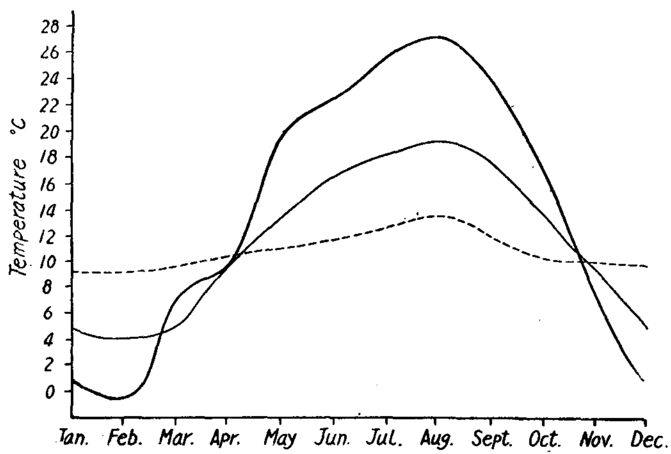

Fig. 11. Seasonal fluctuation of the air temperature and the temperature of surface water in Koikuchinoike and Ochikuchinoike

Thick line represents the air temperature. Thine line represents the water temperature of Koikuchinoike. Dashed line represents the water temperature of Ochikuchinoike.

fluctuation of the temperature of surface water of Ochikuchinoike scarcely followed the fluctuation of air temperature. The surface water of Ochikuchinoike was characterized by keeping comparatively constant temperature throughout the seasons.

It is commonly known that in most inland lakes, which are well sheltered from the wind, the surface temperature is largely governed by the air temperature, thus making the summer temperature extraordinarily high (Welch, 1935). However, the temperature relation may partly be caused by the influence of the drainage from the adjoining area. It is evident that in the case of Ochikuchinoike there is a certain factor which keeps the surface temperature low. This factor is nothing but the inflow of water from Wakitsubonoike, which is very cold, as low as 9.5°C in temperature. The range of seasonal fluctuation of surface temperature in Ochikuchinoike was approximately 5.0°C, much less as compared with the about 15°C fluctuation of Koikuchinoike. According to Yoshimura (1947c), the range of seasonal fluctuation of the surface temperature of lakes in northern Japan is generally 20°C–25°C.

(I) Ōike (Tables 1–3, Fig. 12)

Temperature of water:

Thermal stratification was observed through all seasons. The temperature was comparatively high at the surface and very low at the bottom. Abnormal thermal stratification occurred in the hypolimnion in May and August (Fig. 12–B). In May the temperature showed 18.16°C at the surface, 12.04°C at 4 meters and 5.54°C at 8 meters which depth corresponded to the lower limit of the thermocline. The thermocline was formed above 6 meters; the temperature gradient was approximately 2.7°C per meter at the middle part. There was no apparent epilimnion in this case. In August in the upper 2 meters the water was almost homothermous. Temperature was 22.00°C at the surface, 13.35°C at 4 meters, 6.93°C at 6 meters and 5.20°C at 8 meters. The decline of the thermocline reached the maximum of 3.2°C per meter in 2–4 meters. In October the epilimnion existed above 6 meter layer owing to the partical circulation of lake water, showing 13.62°C at the surface, so that the thermocline which had a decline of 3.1°C per meter of depth had sunk to the level of 6–10 meters. The hypolimnion was comparatively thick in all observations, the water temperature ranging vertically from 5.54°C at the upper limit of this layer to 4.25°C near the bottom. The temperature in the upper part of the hypolimnion varied seasonally to some extent, but that at the bottom was constantly kept low. Furthermore, abnormal thermal stratification occurred below 16 meter depth, thus bringing the whole stratification to the condition of "poikilothermy" in May and "katothermy" in August.

Color and transparency of water:

The Forel's scale was read to be No. 11 in May, No. 8 in August and No. 7

in October, thus the value decreased with progressing seasons. The transparency was 2 meters in May, 3 meters in August and 3.5 meters in October.

Dissolved oxygen:

Remarkable stratification of dissolved oxygen was found in all seasons, especially remarkably in August. The excess of dissolved oxygen appeared at the upper layer, and an anaerobic layer always existed in the hypolimnion. In May the dissolved oxygen showed 98% (6.4 cc/l) at the surface and the content gradually decreased from this to 0% at 20 meter depth. The anaerobic layer in the hypolimnion reached about 5 meters in thickness. In August the stratification had developed extremely in comparison with May observation. Saturation percentage ranged between about 100% (6.1 cc/l) and the maximum of 198% (14.2 cc/l) in the upper layer, but it decreased rapidly downwards to zero at 12 meter depth. The anaerobic layer was formed between 12 meter depth and the bottom, with a thickness of more than 10 meters. In October the oxygen distribution was uniform above 6 meter depth, with about 100% of saturation (7.9 cc/l) or a little lower at the surface, and rapid decrease was observed below this, becoming 5% (0.4 cc/l) at 10 meter depth. A little oxygen was found between 10 and 16 meters, but the layer below 20 meters was left entirely depleted of oxygen. From the above facts the present lake may be characterized by the extreme excess of dissolved oxygen in the metalimnion.

Hydrogen ion concentration:

The hydrogen ion concentration showed remarkable stratification, especially in August. The pH value ranged from 7.7 to 8.4 at the surface, from 7.56 to 9.1 at 4 meters and from 6.4 to 6.65 at the bottom. In May the pH value

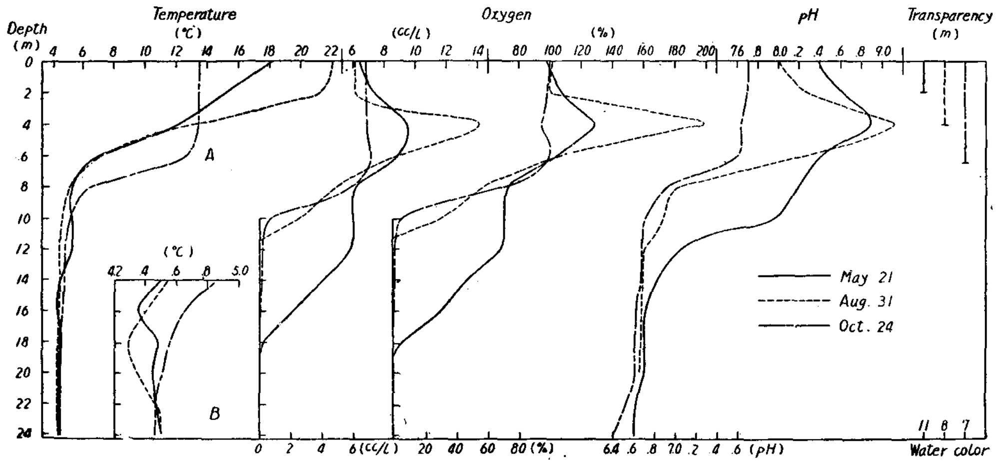

Fig. 12. Hydrographic conditions of Ōike

was relatively high above 4 meters (metalimnion), with range from 8.4 to 8.9 (maximum), but below this it decreased slowly, showing 6.8–6.6 in the hypolimnion. In August the pH value of the metalimnion was extremely high, ranging between 8.0 at the surface (the surface water was included in the metalimnion in this case) and 9.1 at 4 meters, while the water between this and 8 meter depth showed rapid decline of pH value, being 6.7–6.65 in the hypolimnion, i.e., nearly neutral. In October the distribution of pH value was uniform through the whole vertical range. The value was 7.7–7.65 above 6 meters (epilimnion) and 6.6–6.4 near the bottom. No reversal of pH value was observed in oxygenless layer.

(J) Hakkeinoike (Tables 1–3, Fig. 13)

Temperature of water :

The thermal stratification in this lake was closely like to that of Ōike except in the metalimnion of which in the latter lake the thickness was very great and the temperature was very low. The water of the present lake showed indirect stratification of temperature in winter, with distinct change between 4 and 6 meters. In May the thermocline was found above 8 meter layer with a maximum decline of approximately 3.0°C per meter in 4–6 meter depth. The temperature was 17.45°C at the surface, 5.72°C at the lower limit of the thermocline and 5.39°C near the bottom. This indicated that the thickness of the hypolimnion was very small in this season. In early September the epilimnion of which temperature ranged from 23.54°C to 22.29°C was formed above 4 meter depth. Though the thermocline was reduced in thickness, its decline showed the maximum of 5.7°C per meter as a result of the rising of temperature in the upper layers. The hypolimnion existed only near the bottom where the temperature was slightly higher than that of the preceding observations, showing 5.89°C. In October the temperature was entirly uniform above 6 meter depth, being 13.85°C at the surface. The thermocline existed below 8 meters. The temperature of bottom water showed 7.86°C higher than that of the previous measurement. In February the temperature was 0.85°C at the surface, 1.55°C at 4 meters, 3.61°C at 6 meters and 3.95°C at the bottom.

Color and transparency of water :

The color of lake surface as read by the Forel's scale was relatively high in this lake, No. 10 in May, No. 9 in August and No. 10 in October. The transparency was 1.0 meter in May, 2.5 meters in August and 2 meters in October.

Dissolved oxygen :

The water above 4 meter depth of this lake always showed homogenous distribution of oxygen irrespective of seasons (Fig. 13). In May no excess of dissolved oxygen existed above 4 meters probably because of want of phytoplankton in this season. On the other hand, the oxygenless zone had already developed below 10 meter depth. In early September the dissolved oxygen was uniformly distributed in the epilimnion, showing the saturation percentage of 89–94% (5.3–5.7 cc/l) but it decreased very rapidly with depth, the anaerobic layer occurring below 6 meter depth. In October the dissolved oxygen was almost uniformly distributed between the surface and 6 meter depth as the result of partial circulation in autumn, and oxygenless zone existed below 8 meters, being decreased in thickness as compared with that in September. In February the anaerobic condition disappeared, and a remarkable over-saturation of oxygen was found in the epilimnion, viz., 119% (11.5 cc/l) at 2 meters and 121% (11.6 cc/l) at 4 meters under the ice cover. Such marked excess of oxygen under the ice cover may probably be due to the low temperature as well as, possibly, the vegetation of diatom population.

Hydrogen ion concentration :

The pH value ranged from 7.6–8.0 at the surface, from 7.5 to 7.9 at 4 meters, and from 6.7 to 6.9 near the bottom. As found in May, the pH value ranged from 8.0 at the surface to 6.7 at the bottom. The uniform distribution of this value above 4 meter depth was perhaps related to the uniform distribution of oxygen in these layers.

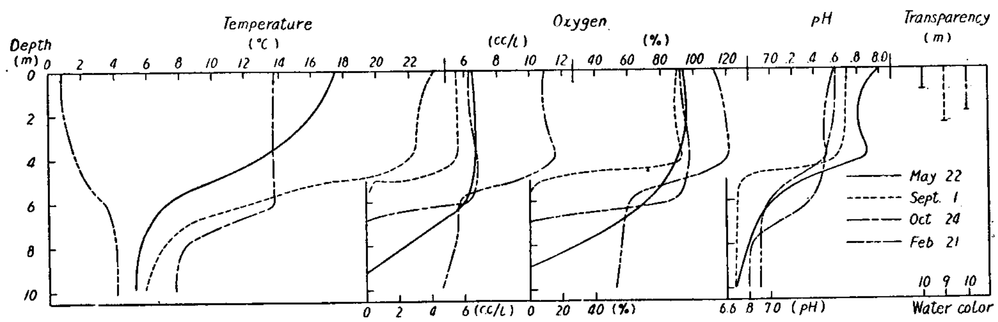

Fig. 13. Hydrographic conditions of Hakkeinoike

2. General Aspects of the Hydrography of the Lake Group

(a) *Temperature of Surface Water*

The temperature of the surface water of the lakes is correlated with the proper morphological conditions of the lakes. The surface temperature of Nigoriike, Ochikuchinoike and Ketobanoike is comparatively low, ranging from 11°C to 16°C in the former two and 13°C to 20°C in the last one, while that of Koikuchinoike, Ōike and Hakkeinoike is 13°C–21°C, 13°C–22°C and 13°C–24°C respectively, showing that these latter three lakes are an intermediate type in respect to surface temperature. The low temperature of the first type of lakes is suggested to be the effect of cold springs at the basin side or cold inflow on the shore from adjoining area. The second type of lakes having intermediate surface temperature has neither effective cold spring in the basin nor inflow on the shore. These lakes which are drainage lakes chained by a brook do not directly receive cold inflow of the springs of Aoike and Wakitsubonoike. The cold water from these springs enters the above lakes after passing through the comparatively long course of the brook and intermediate lakes, and therefore, the water is warmed up before the inflow. Although Higurashinoike directly receives the cold inflow from Hakkōnoike, the volume of cold inflow is very little, insufficient to lower the surface temperature of Higurashinoike. The third type, to which both Menkozakanoike and Itobatakenoike belong, lacks inlet and outlet, and Daiike (the main basin) also lacks any effective inflowing stream. The water is usually stagnant and hence the surface temperature in August is as high as 23.37°C in Menkozakanoike, 23.90°C in Itobatakenoike and 23.34°C in Daiike. When reference is made to the former studies on these lakes (Yoshimura, 1935a, b; Kokubo & Kawamura, 1941a; Ishida, Kokubo & Kawamura, 1944; Kawamura, 1947), it is learned that the surface temperature in the second and third types rises occasionally as high as 27°C, but is commonly between 22°C and 24°C.

(b) *Depth of the Thermocline* (Table 4)

A remarkable thermocline is formed in each lake of the present group within the period from May to October. The thermocline, on the whole, exists between the surface and 10 meter depth in May and August, and between 6 and 13 meter depth in October. In October the thickness of the thermocline is reduced by the partial circulation of upper epilimnion. The position of thermocline varies with lakes, being especially variable from lake to lake in August and October. In May the thermocline shifts to 0–8 meter depth in such drainage lakes as Higurashinoike, into which the volume of cold inflow is very little, and Ōike and Hakkeinoike which do not directly receive cold water of the springs of Aoike and Wakitsubonoike. On the other hand, in the drainage lakes such as Daiike, Koikuchinoike and Ochikuchinoike, the thermocline is formed in 4–10 meter depth in May. The tendence for the thermocline to be found lower in Daiike and Koikuchinoike is probably caused by the wind-raised turbulence of the upper water because of the large surface area of the lake. In Ochikuchinoike the cold inflow on the shore from Wakitsubonoike may have the affect of lowering the temperature of the epilimnion, thus naturally resulting in descending of thermocline. In such seepage lakes as Menkozakanoike and Itobatakenoike, the depth of the thermocline is nearly the same as that of Daiike or Ochikuchinoike. In this case the lakes are exposed to wind owing to their situation in an open area, and therefore the upper water is much disturbed. In August, though the position of the thermocline varies with the lakes, the difference of the depth of the thermocline between the former and the latter lake groups is generally maintained. According to the studies of Yoshimura (1935a, b), the position of the thermocline in the seepage lakes (third type) such as Menkozakanoike and Itobatakenoike is by far lower than that of the first type to which Nigoriike and Ochikuchinoike belong. In so far as the present investigation is concerned, however, no difference in the position of thermocline between the first and third types was found.

Table 4. Position of thermocline in ten lakes in different months

Lakes	Position of thermocline (depth in meters)		
	May	August	October
Nigoriike	None	0-2	None
Daiike	4-8	2-8	6-10
Menkozakanoike	4-10	4-10	8-10
Itobatakenoike	4-10	2-10	9-12
Higurashinoike	0-10	0-10	6-13
Ketobanoike	0-8	0-10	8-12
Ochikuchinoike	6-10	6-12	10-12
Koikuchinoike	4-8	4-8	7-10
Ōike	0-8	2-8	6-10
Hakkeinoike	0-8	4-8*	6-8

* Observed on Sept. 1

The maximum percentage volume of the metalimnion plus the epilimnion is estimated with the following result ; Nigoriike, Daiike, Koikuchinoike and Ōike about 50%, Ketobanoike 73%, Itobatakenoike and Ochikuchinoike about 85%, and Menkozakanoike, Higurashinoike and Hakkeinoike 90% or thereabouts. It is ascertained that these lakes generally have a well-developed hypolimnion.

(c) *Temperature of Bottom Water* (Table 5)

The temperature of bottom water is low in such deep lakes as Daiike, Koikuchinoike and Ōike. Former studies (Yoshimura, 1935a, b ; Kokubo & Kawamura, 1941a) have shown the low temperature to be below 4°C, but other studies (Ishida, Kokubo & Kawamura, 1944 ; Kawamura & Kokubo, 1947) have failed to obtain this low temperature. In the present observation the bottom temperature is about 4–5°C, but does not sink below 4°C. The low temperatures maintained in the deep parts are a consequence of "bradymixis" or "partial circulation" in spring in the present lakes. On the other hand, the temperature of bottom water is comparatively high in such shallow lakes as Nigoriike, Menkozakanoike and Hakkeinoike. In these shallow lakes, though the thermal stratification develops to some extent, the bottom water is easily subjected to some influence by upper warm water. Ochikuchinoike is one of the deep lakes, but the bottom water shows high temperature like shallow lakes. This may be due to the effect of the inflow (about 9°C) from Wakitsubonoike as mentioned before.

Table 5. Range of bottom-water temperature in the lakes in May-October, 1952

Lakes	Range of bottom-water temperature (°C)
Nigoriike	9.67-10.63
Daiike	4.08 - 4.36
Menkozakanoike	6.84 - 9.30
Itobatakenoike	4.61 - 5.19
Higurashinoike	4.05 - 5.16
Ketobanoike	4.95 - 5.12
Ochikuchinoike	5.00 - 5.57
Koikuchinoike	4.05 - 4.54
Ōike	4.46 - 4.59
Hakkeinoike	5.39 - 8.24

(d) *Thermal Conditions in the Hypolimnion*

An abnormal thermal stratification occurs in three lakes such as Daiike, Koikuchinoike and Ōike. The thermal stratification for the whole vertical range may be called "poikilothermy" in Daiike, "mesothermy" or "poikilothermy" in Koikuchinoike and "poikilothermy" or "katothermy" in Ōike.

The abnormal thermal stratification in Ōike was first found by Yoshimura (1935b) in July, 1934, and he stated that this was established by biochemical processes. Accordingly, this phenomenon has been found by the present author in Koikuchinoike and Ōike during the period from May to September, 1940, and in Daiike in May, 1946 (Kokubo & Kawamura, 1941a; Kawamura & Kokubo, 1947). According to their explanations, the abnormal thermal stratification in Koikuchinoike and Ōike was probably caused by the inflowing of underground water which contained different chemical compositions from those of other waters, while in the case of Daiike it was probably established by biochemical processes. Although the process of the development of the abnormal thermal stratification in these deep lakes is differently explained according to the authors, these lakes regularly have such stratification in every year.

(e) *Color and Transparency of Water* (Table 6)

Forel's scale reads rather high through all lakes, ranging No. 7–11. It is highest in Higurashinoike, and lowest in Menkozakanoike. The transparency is naturally low, the Secchi–disk readings being usually less than 6.5 meters. Taking the mean value of the readings of Secchi–disk, the rank of lakes according to the transparency is as follows: Higurashinoike, Hakkeinoike, Nigoriike, Itobatakenoike, Ketobanoike, Koikuchinoike, Daiike and Ōike, Ochikuchinoike, and Menkozanoike in order. The transparency varies seasonally from 5.0 to 1.8. The largest range within a year is obtained in Ketobanoike, Ōike, Higurashinoike and Hakkeinoike in order.

Table 6. Range of color and transparency of water in ten lakes

Lakes	Color of water	Transparency		
	Range (No.)	Range (meters)	Mean (meters)	Max./Min.
Nigoriike	9-10	1.3-3.0	2.2	2.3
Daiike	9-10	4.0-4.5	4.1	1.8
Menkozakanoike	7-10	5.C-6.5	5.8	1.8
Itobatakenoike	8-10	2.5-3.0	2.8	2.0
Higurashinoike	10-11	0.8-2.0	1.6	2.5
Ketobanoike	7-10	1.0-5.0	3.0	5.0
Ochikuchinoike	7-8	4.3-6.0	5.4	1.4
Koikuchinoike	7-10	2.C-4.4	3.1	2.2
Ōike	7-11	2.0-6.3	4.1	3.2
Hakkeinoike	9-10	1.C-2.5	1.8	2.5

According to Yoshimura (1935b), the transparency in these lakes ranged from 8.4 meters in Ōike to 1.1 meters in Itobatakenoike in June, 1934. He obtained high values in Ketobanoike, Koikuchinoike, Ōike, Hakkeinoike and Daiike, the low values in Ochikuchinoike, Itobatakenoike and Nigoriike, and intermediate values in Menkozakanoike and Higurashinoike.

Irregular discrepancy in transparency between the present observations and the previous records is found.

Transparency, of course, undergoes seasonal and irregular changes, on account of the suspension material, organic or inorganic. The plankton oraganisms, especially phytoplankton, are an important factor in decreasing the transparency of the water. In the present lakes the low transparency was dependent upon the growth of *Asterionella formosa* and *Anabaena* sp. in 1934 (Yoshimura, 1935a) and mainly upon the increase of *Asterionella formosa, Melosira granulata* and *Synedra acus* in 1940 (Kokubo & Kawamura, 1941b ; Kawamura & Kokubo, 1947).

(f) *Dissolved Oxygen* (Table 7)

The oxygen is dissolved in large amount in the present lakes throughout the observations. The maximum value in an individual lake ranged from 7.05 cc/l to 11.62 cc/l (98.3% to 145.1% saturation) in May, from 5.21 cc/l to 14.22 cc/l (90.8% to 198.3%) in August and from 6.42 cc/l to 8.96cc/l (90.2% to 119.5% saturation) in October. In winter Hakkeinoike the oxygen content is 11.59 cc/l (121.2% saturation) under the ice of 70 cm thickness. The high saturation percentage is observed in Ōike, Ketobanoike, Daiike and Nigoriike, especially in Ōike. The next rank of high saturation percentage is seen in Higurashinoike and Koikuchinoike. In Menkozakanoike, Ochikuchinoike and Hakkeinoike the satruation, about 100%, is not much higher than those of other lakes throughout the summer period. According to the results of the former studies (Yoshimura, 1937a, b ; Kokubo & Kawamura

1941a; Kawamura & Kokubo, 1947). the present lakes generally show a high saturation percentage of oxygen. Above all, in Ōike and Daiike the saturation is as high as above 160% in summer (Yoshimura, 1937a, b).

The position of maximum amount of dissolved oxygen approaches to the surface as the season progresses, but remains mainly within the metalimnion. As compared with the former studies (Yoshimura, 1935a, b; Kokubo & Kawamura, 1941a; Kawamura & Kokubo, 1947), the position of maximum amount of oxygen is found to exist generally to be shallower in the present observation.

Table 7. Maximum amount of dissolved oxygen through vertical range and the level of its occurrence in ten lakes in different months

Lakes	May			August			October		
	O_2cc/l	O_2%	Level (meters)	O_2cc/l	O_2%	Level (meters)	O_2cc/l	O_2%	Level (meters)
Nigoriike	7.43	100.8	0	9.67	142.7	0	8.96	110.5	6
Daiike	8.96	110.5	6	9.12	137.3	4	6.63	94.6	2
Menkozakanoike	7.05	98.3	4	6.08	102.9	4	6.74	98.0	4-6
Itobatakenoike	8.40	106.3	6	5.21	90.8	0	7.32	103.7	0
Higurashinoike	8.80	123.6	2	6.19	103.9	0	6.42	90.2	2
Ketobanoike	11.62	145.1	6	9.55	137.0	2	7.89	106.3	0
Ochikuchinoike	7.81	105.7	2	7.49	109.0	2	7.49	101.2	0
Koikuchinoike	9.56	120.3	6	8.69	132.5	5	6.85	94.6	3
Ōike	9.56	130.2	4	14.22	198.3	4	7.22	101.1	0
Hakkeinoike	6.63	97.6	0	5.67*	94.8*	4*	6.96	97.5	4

* Observed on Sept. 1

(g) *Anaerobic Layer* (Table 8)

The present lakes generally have an anaerobic layer or a microstratification of oxygen near the bottom.

The anaerobic layer occurs remarkably in deep lakes, viz., Daiike, Koikuchinoike and Ōike. Thickness of such a layer reaches to the maximum in the midsummer,

Table 8. Thickness of anaerobic layer developed in deep layer in ten lakes in different months

Lakes	Thickness of anaerobic layer (meters)			
	May	August	October	February
Nigoriike	0	0	0	
Daiike	6.5	13.0	15.5	
Menkozakanoike	0	1.0	1.0	
Itobatakenoike	2.5	5.5	2.5	
Higurashinoike	0	5.5	1.0	0
Ketobanoike	0	3.5	7.0	
Ochikuchinoike	2.0	6.3	6.25	
Koikuchinoike	5.0	11.5	4.0	2.0
Ōike	5.0	10.0	6.0	
Hakkeinoike	1.0	5.0*	3.0	0

* Observed on Sept. 1

though some exception exists. In the winter stagnation period, though the oxygenless layer does not develop in Hakkeinoike, a remarkable anaerobic lager (2 meters in thickness) develops in Koikuchinoike and a microstratification of oxygen appears in Higurashinoike.

The maximum percentage volume of anaerobic strata in ten lakes is as follows : Daiike 35%, Koikuchinoike and Ōike 30%, Hakkeinoike 15%, Higurashinoike and Ochikuchinoike 10%, Ketobanoike 5% and Menkozakenoike 1%.

(h) *Hydrogen ion concentration* (Table 9)

The pH value in the present lakes ranges from 9.1 to 6.5 in May, from 9.1 to 6.4 in August and from 8.7 to 6.35 in October. The high value occurs in Ōike and Higurashinoike, Ketobanoike and Daiike, while the low value is obtained in Menkozakanoike, Itobatakenoike and Ochikuchinoike through all seasons.

Table 9. Maximum value of hydrogen ion concentration as represented by pH value and its position of occurrence in ten lakes in different months

Lakes	May		August		October	
	Maximum	Position (meters)	Maximum	Position (meters)	Maximum	Position (meters)
Nigoriike	7.6	2	8.8	0	8.7	0
Daiike	8.2	6	8.9	2	8.35	2
Menkozakanoike	6.5	0-6	6.4	0-4	6.35	2
Itobatakenoike	7.7	6	7.6	0	7.1	0
Higurashinoike	9.1	2	8.0	2	7.1	0
Ketobanoike	9.0	6	8.0	6	7.7	0
Ochikuchinoike	8.0	0-6	7.8	2	7.5	0,4,6
Koikuchinoike	8.7	6	8.3	5	7.6	0
Ōike	8.9	4	9.1	4	7.7	0,2
Hakkeinoike	8.0	0	7.7*	0-3*	7.6	0,2

* Observed on Sept. 1

The reverse of pH value in oxygenless layer is recognized in Daiike and Menkozakanoike, but in the other lakes no such phenomenon is observed, in spite of the fact that the anaerobic layer develops in the hypolimnion. The above two lakes are peculiar in the point that they have the reverse of pH value in the layer just above the anaerobic layer.

It is natural that the high value of pH is accompanied by the abundant presence of oxygen (Tables 7 and 9).

3. Hydrographic Peculiarity of the Lake Group

The temperature of water near the bottom was very low in Daiike, Koikuchinoike and Ōike of the present lakes, showing 4.02–4.11°C in Daiike, 4.05–4.54°C in Koikuchinoike and 4.46–4.59°C in Ōike. Several previous reports (Yoshimura, 1933, 1035a, 1938; Kokubo & Kawamura, 1941a; Ishida, Kokubo & Kawamura, 1944 ; Kawamura & Kokubo, 1947) have ascertained that the temperature of bottom water in the present lake group fell below 4°C in some years. Yoshimura (1934b, 1936a, 1937d, 1938, 1944) mentioned that the temperature of deep water of such deep lakes in Japan as Lake Tazawa, Lake Shikotsu and Lake Tōya in summer period, in general, keeps 4°C at 100 meter depth or thereabouts, but it sinks as low as 3.8–3.6°C at levels deeper than 200 meters, which is the temperature of maximum density in fresh water at great pressure at that depth. It is noticed that, in spite of the moderate depth, the temperature of bottom water in the present lakes is almost the same as the temperature at 100 meter depth of deep lakes in Japan. Such a tnermal condition of the bottom water can be ascribed either to the presence of cold water springs in the lake basin or may be accounted for by the incomplete circulation of lake water during spring overturn probably due to some certain chemical stratification. In the case of Daiike, the presence of some spring of extremely cold water, below 4.0°C, is not ascertained. The temperature of the spring of Nigoriike in the neighborhood of Daiike is about 9.5°C, and therefore, the spring water flowing into Daiike, if there is any, may have similar temperature. It may be a more plausible explanation that there is a biochemical stratification in the deep layers in Daiike, keeping a continual stagnation of deep layer. As noted already, Daiike is the deepest lake among the present lake group and it well sheltered from the wind. The deepness of the lake as well as the biochemical stratification, if does occur in the deep layer, may result in the difficulty of complete mixing of lake water during the spring circulation, the low temperature near the bottom being probably due to the cold water which has remained since the previous autumnal overturn.

Furthermore, in such comparatively deep lakes as Daiike, Koikuchinoike and Ōike an abnormal thermal stratification comes into existence in the hypolimnion in the summer stagnation period. Such a condition has already been observed in these lakes by Yoshimura (1935b), Kawamura & Kokubo (1941a), Kawamura (1947) and Kawamura & Kokubo (1947).

Many examples of abnormal thermal stratification have been reported from various localities. Findeneg (1933, 1935) observed this in the lakes of Kurnten, Austria, and Ruttner (1933) also in certain Alpine lakes. According to the studies of the above authors, the abnormal thermal stratification of the above lakes is ascribable to the presence of a heavier water which was produced by biochemical processes during the summer stagnation period. On the other hand, Ohle (1934) observed a unique thermal stratification in Trammersee, Holstein. In his case the stratification was due to the large amount of chlorine content of lake water in the deep layer. Such thermal stratification has also been found in the investigation of some Japanese lakes (Tanakadate, 1925; Miyadi, 1931; Watanabe, 1931; Takayasu & Sawa (Kondo), 1933 ; Yoshimura, 1933 1934b, c, 1935b, 1937e ; Yoshimura &

Mashiko, 1935). Yoshimura (1937a, 1938) designated three kinds of stratification according to the process of their development on the basis of the results of the above several authors.

1) Biochemical stratification: This is the chemical stratification which is established by biochemical processes during the summer. Biochemical processes increase the density of water of the middle and deep layer of lakes and the heavier water is kept until the following spring or even until summer. Yoshimura included Lake Hangetsu, Lake Mashu, Lake Akan and Ōike of the Tsugarujuniko Lake Group in this type.

2) Non-biochemical stratification: This stratification is caused by the inflowing of underground water of different chemical composition from that of the lake water in the upper layer. Yoshimura mentioned that Cl, SO_4 and Na are best indicators for detecting the non-biochemical stratifications. According to him, Lake Towada, Lake Zaō-okama, Lake Yarokunuma and some others belong to this type.

3) Combined stratifications of biochemical and non-biochemical origins: According to Yoshimura, Lake Shikaribetsu, Lake Sumiyoshinuma and some others belong to this type.

As regards the dissolved oxygen in the upper layer, Yoshimura (1937b) observed the maximum of 12.5cc/l (175% saturation) in Ōike in August, 1933. Thereafter, Kokubo & Kawamura (1941a) also found a value of 9.62 cc/l (140% saturation) in Ochikuchinoike in August, 1940. On the other hand, an extremely high value of dissolved oxygen, 14.22 cc/l (198% saturation), was obtained in the present observation.

In comparison with other lakes, Ōike ranked second in order of the oxygen content among many lakes of Japan, followed by 15.65 cc/l of Lake Hangetsu. On the other hand, it ranked third in order of saturation percentage, next to 232% of Wakuike (Yoshimura, 1937b, c).

With regard to the position of the maximum layer of dissolved oxygen, Yoshimura (1936b, 1937b, 1939) considered it in connection with the compensation depth. According to him, the compensation depth is equal to a depth 1.5 times the maximum transparency in most Japanese lakes during spring and summer. He stated, furthermore, that the maximum of dissolved oxygen lies at a certain depth between the surface and the compensation depth, that is, it exists in the epilimnion or thermocline or in the upper part of the hypolimnion. In the present lakes the excess of dissolved oxygen occurred mainly in the metalimnion. This seems to follow the rule of most Japanese lakes.

An anaerobic layer or a microstratification of dissolved oxygen in the bottom layer was commonly found in the present lakes. The thickness of the anaerobic layer was 15.5 meters in Daiike, 11.5 meters in Koikuchinoike and 10.0 meters in Ȯike. The thickness of the anaerobic layer of Daiike was less than that of Lake Mary, Wisconsin (Juday & Birge, 1932), being by far greater than 10 meters of Yanagikubonoike, Japan (Yoshimura, 1937c). Therefore, Daiike probably ranks first in order of thickness of anaerobic layer among lakes of Japan.

Most Japanese lakes having anaerobic layer, in general, show the reverse of pH value in their hypolimnion (Miyadi, 1929 ; Yoshimura, 1932a, 1936c ; Hata & Kokubo, 1935). According to these authors, such a stratification is, in all probability, due to the increase of buffer action of sodium bicarbonate which is concentrated in the bottom layer.

In most of the present lakes, the pH value showed a simple direct stratification in the hypolimnion in contrast to many Japanese lakes having anaerobic layer, while the reverse of pH was recognized only in the hypolimnion of Daiike and Menkozakanoike. In Daiike the pH value in the layers below the metalimnion was generally lower than those of other lakes such as Koikuchinoike and Higurashinoike. This fact indicates that the lake water of Koikuchinoike and Higurashinoike contains a large amount of HCO_3-CO_2 than that of Daiike, though the analysis of this substances has not been made by the present author.

IV. PLANKTON

1. Methods of Collection

Plankton net was used so as to obtain as nearly as possible a complete sampling of all plankton species. In addition, specially designed quantitative sampler was also employed for obtaining the organisms from exactly known volume of water at various depths. In addition, one datum was obtained by means of the pump method so that the known volume of water was sampled from desired depth by pumping up.

The plankton net used is of ordinary type, having canvas cone at the mouth. The dimensions are 16 cm in diameter of ring of anterior opening at the top of the canvas cone, 32 cm in largest diameter of the ring connecting the canvas cone with the proper filtering portion, 20 cm in length alongside of the canvas cone, 1m in length along the side of the filtering bolting cloth, and 4 cm in diameter at the terminal tin. For the filtering cloth, bolting silk No. 13 having mesh aperture of 0.1 mm, made in Japan was used.

With this plankton net horizontal tow at the level of 3 meter depth was made for ten minutes. The materials collected by this method were studied for identification of the species involved. The relative abundance of each species composing the communities was recorded by the symbols, CC (abundant), C (very common), +(common), R (occasional), RR (rare) and RRR (very rare). Although this classification is only made subjectively, therefore, it is not valued as having quantitative exactness, the abundance of each species classified by this method is very useful in considering the general composition of the communities.

The quantitative plankton sampler (Motoda, 1949, 1950; Motoda & Ishida, 1950) is an apparatus composed of two parts, a canvas cylinder and inverteb cone of bolting cloth, just like a short plankton net (Fig. 14). The canvas cylinder which is supported by a slender brass tube on each side when stretched to its full length measures 22.5 cm in diameter and 51 cm in height. On the upper opening of the cylinder there is a lid consisting of two halves, each half being able to be raised up by the hinge at the central line. In operation the inverted cone is first lowered to a desired depth and then the cylinder is slid down along the rope. During the descending of the cylinder, water passes freely through the inside of the cylinder from the lower opening to the upper opening, plankton being not captured in the way. When the cylinder touches the eone, it is closely connected with the latter, because the frings of both cylinder and cone are made of quite the same size. The plates of lid on the upper opening of the cylinder are closed when the apparatus stops, and the plankton contained in the cylinder corresponding to 20 liters of water in capacity, is thus captured. The apparatus being taken above the surface of water, all plankton captured may be filtered by the bolting silk of the cone. The sample may be drained from the terminal tin into vials.

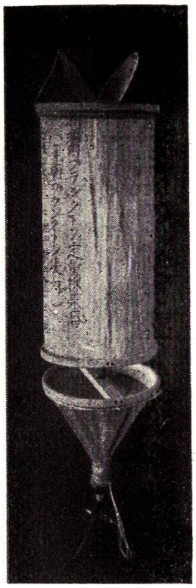

Fig. 14. Quantitative plankton sampler

On the material collected with the quantitative sampler, individual or cell number was calculated separately by species. The individual number of large plankton animals such as Copepoda and Cladocera was calculated under the binocular dissecting microscope without subsampling, but the small-sized organisms such as Rotifera, Tintinnoinea, Flagellata and plants were usually subsampled into a fraction from well-distributed original sample, and the countirg of number was made on the partial sample under ordinary microscope.

2. Plankton Species

From the materials by net collection the following seventy species of planktonic animals and plants were identified in total through the ten lakes and all the seasons (Table 10).

Copepoda

Cyclops vicinus ULJANIN (Pl. I, Fig. 1)

Mesocyclops oithonoides SARS	(Pl. I, Fig. 2)
Eucylops prasinus (FISHER)	(Pl. I, Fig. 3)
Cladocera	
Daphnia longispina O. F. MÜLLER	(Pl. I, Fig. 4)
Bosmina longirostris (O. F. MÜLLER)	(Pl. I, Fig. 5)
Alona rectangula G. O. SARS	
Infusoria	
Tintinnopsis rotundata JORGENSEN	(Pl. I, Fig. 6)
T. lacustris ENTZ	(Pl. II, Fig. 1)
Carchesium polypinum KENT ?	
Rotifera	
Synchaeta oblonga EHRENBERG	(Pl. II, Fig. 2)
Polyarthra trigla EHRENBERG	(Pl. II, Fig. 3)
Diurella sp.	(Pl. II, Fig. 4)
Rattulus longiseta (SCHRUNK)	(Pl. II, Fig. 5)
Brachionus angularis var. *bidens* PLATE	(Pl. II, Fig. 6)
B. pala f. *amphiceros* (EHRENBERG)	(Pl. II, Fig. 7)
Keratella cohchlearis (GOSSE)	(Pl. II, Fig. 8)
K. cochlearis var. *irregularis* LAUTERBON	(Pl. II, Fig. 9)
K. quadrata f. *quadrata* (O. F. MÜLLER)	(Pl. III, Fig. 1)
K. quadrata f. *divergens* (VOIGT)	
K. quadrata f. *brevispina* (GOSSE)	(Pl. II, Fig. 10)
Notholuca labis GOSSE	(Pl. III, Fig. 2)
Ploesoma truncatum (LEVANDER)	(Pl. III, Fig. 3)
Asplanchna priodonta GOSSE	(Pl. III, Fig. 4)
Conochilus unicornis ROUSSELET	(Pl. III, Fig. 5)
Filinia longiseta (EHRENBERG)	(Pl. III, Fig. 6)
Pedialion mirum HUDSON	(Pl. III, Fig. 7)
Pompholyx comlanata GOSSE	(Pl. III, Fig. 8)
Dinoflagellata	
Glenodinium foliaceum STAIN	(Pl. III, Fig. 9)
Peridinium willei HUITFELD-KAAS	(Pl. III, Fig. 10)
Ceratium hirundinella (O. F. MÜLLER)	(Pl. IV, Fig. 1)
Synura uvella EHRENBERG	
Dinobryon sertularia EHRENBERG	(Pl. IV, Fig. 2)
D. divergens IMHOF	(Pl. IV, Fig. 3)
Diatomaceae	
Melosira varians AGARPH	(Pl. IV, Fig. 4)
M. italica KÜTZING	(Pl. IV, Fig. 5)
Attheya Zachariasi J. BRUN	(Pl. IV, Fig. 6)

Tabellaria fenestrata (EHRENBERG) KÜTZING	(Pl. IV, Fig. 7)
Fragilaria crotonensis KITTON	(Pl. IV, Fig. 8)
F. construens (EHRENBERG) GRUNNOW	(Pl. IV, Fig. 9)
Asterionella formosa HASSALL	(Pl. V, Fig. 1)
Synedra acus KÜTZING	(Pl. V, Fig. 2)
S. ulna (NITZSCH) EHRENBERG	
Gyrosigma accuminatum (KÜTZING) RABENHORST	(Pl. V, Fig. 3)
Navicula spp.	
Pinnularia maior (KÜTZING) CLEVE	(Pl. V, Fig. 4)
Cymbella lanceolata (EHRENBERG) VAN HEURCK	(Pl. V, Fig. 5)
C. sp.	
Gomphonema constrictum EHERNBERG	(Pl. V, Fig. 6)
Epithema zebra (EHRENBERG) KÜTZING	
Rhopalodia gibba (EHRENBERG) O. F. MÜLLER	(Pl. V, Fig. 7)
Surirella Capronii BRÉBISSON	(Pl. VI, Fig. 1)
S. tenera GREGORY	(Pl. V, Fig. 8)
Cyanophyceae	
Gomphosphaeria lacustis CHODAT	(Pl. V, Fig. 9)
Anabaena planctonica BRUNNTHALAR	(Pl. VI, Fig. 2)
A. spiroides KLEBAHN	(Pl. VI, Fig. 3)
A. Lemmermanni P. RICHTER	(Pl. VI, Fig. 4)
A. catenula var. *intermedia* GRIFFITHS	(Pl. VI, Fig. 5)
A. sp.	(Pl. VI, Fig. 6)
Lyngbya sp.	
Conjugatae	
Genicularia spirotaenia BRÉBISSON	(Pl. VI, Fig. 7)
Clostrium moniliferum var. *concavum* EHRENBERG	(Pl. VI, Fig. 8)
Docidium baculum BRÉBISSON	(Pl. VI, Fig. 10)
Staurastrum paradoxum MEYEN	(Pl. VI, Fig. 9)
Mougeotia sp. ?	(Pl. VII, Fig. 2)
Chlorophyceae	
Volvox aureus EHRENBERG	(Pl. VII, Fig. 1)
Pandorina morum (O. F. MÜLLER) BORY	(Pl. VII, Fig. 3)
Eudorina elegans EHRENBERG	(Pl. VII, Fig. 4)
Trochiscia sp. ?	
Crucigenia rectangularis (NÄGELI) GAY	(Pl. VII, Fig. 5)
Characium longipes RABENHORST	

Cyclops vicinus listed here has not been recorded from the present lake group. This species is closely allied to *C. strenuus* but the two can be distinguished from each other by the number of spines on terminal segments of the exopodites of 1st–4th swimming feet, that is,

	1st s.f.	2nd s.f.	3rd s.f.	4th s.f.
Cyclops strenuus	3	4	3	3
C. vicinus	2	3	3	3

It may be possible that this species was misnamed as *C. strenuus* in the former studies (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941; Okitsu, 1954).

Mesocyclops oithonoides was found only in Daiike, Menkozakanoike and Itobatakenoike in the present observation just as in a former observation (Kokubo & Kawamura, 1948). It is an interesting fact that the distribution of this species is limited only to lakes other than the Koikuchinoike group. These lakes inhabited by this species are all very small bodies of water as compared with other lakes in Japan. In Norway the present species occurs in the pelagic region of large lakes (Sars, 1918) and in Japan it has also been found in such large as Lake Hibara (Yoshimura, 1932b, 1937f; Uéno, 1936) and Lake Biwa (Kikuchi, Enokida & Tateno, 1942). This species has been reported to prefer the warm-water (Naber, 1933; Rylov, 1935).

Eucyclops prasinus occurred only in the lakes of the Koikuchinoike lake group as was found in the former observations (Kokubo & Kawamura, 1940c, 1941c; Kokubo, 1941). The lakes of the Koikuchinoike group are characterized by the occurrence of *E. prasinus*. It has been known to inhabit the warm and eutrophic water. The presence of this species in Koikuchinoike group suggests that its preference for warm-water is of less degree than that of *Mesocyclops oithonoides*.

Daphnia longispina is the commonest species of all Cladocera occurring from small ponds to large lakes irrespective of the size of milieu in Japan (Uéno, 1927; Kokubo, 1941). This species was commonly found in all lakes of Koikuchinoike group in the former observations (Kokubo & Kawamura, 1940c. 1941c; Kokubo, 1941; Kokubo & Matsuya, 1942; Motoda, 1953). However, the presence of this species was limited to Ochikuchinoike and Koikuchinoike and the individual number was very small in the present observation. On the other hand, a phenomenon like that of *Daphnia longispina* described above was also found in the case of *Acanthodiaptomus pacificus* (*Diaptomus pacificus*), and this species, occurring abundantly in 1940–1943 (Kokubo & Kawamura, 1940c, 1941c; Kokubo, 1941; Kokubo & Matsuya, 1942b; Motoda, 1953), disappeared entirely in the present observation. As to *Daphnia longispina*, it has been reported by Yoshimura (1937f) that the production of this species remarkably declined during the years from 1928 to 1934 in Lake Haruna from some unknown reason. It is probable, in the case of Koikuchinoike group, that the daphnids have been grazed in abundance by pond smelts, *Hypomesus olidus* (PALLAS) which were transplanted to these lakes from Lake Kogawara in 1942 and from Lake Suwa in 1943.

Bosmina longirostris is also a common species of Cladocera which appears widely in ponds and lakes in Japan. In has been known that this species is abundantly distributed in or below the metalimnion in general, showing cold-water preference. In the present observation this species was also commonly found in all lakes of the Tsugarujuniko lake group as in the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941).

Alona rectangula was collected in small number only from two shallow lakes, Nigoriike and Hakkeinoike, as in the former observations (Kokubo & Kawamura, 1940c; Kokubo, 1941). In habit it prefers the shallow ponds or littoral waters of lakes (Uéno, 1927). Tamura (1936) has reported that this species appaered in Lake Osoresan in spite of the extremely low value of pH, as low as 3.0.

Tintinnopsis rotundata and *T. lacustris* occurred very rarely, especially the latter species, in the present lakes. However, *T. lacustris* appeared commonly in the lakes of the Koikuchinoike group in the former observations (Kokubo & Kawamura, 1940c, 1941; Kokubo, 1941). These species have been known generally to occur both in eutrophic and oligotrophic lakes in Europe.

Synchaeta oblonga was found in only Nigoriike, Koikuchinoike, Ōike and Hakkeinoike, occurring mainly in deep cold water. It was previously found only in the lakes of the Koikuchinoike group (Kokubo & Kawamura 1930c, 1941c; Kokubo, 1941). The present specimens showed 250–310 μ in length, being larger than these described by some authors (Collin *et al.*, 1912; Rylov, 1935).

The present specimens of *Brachionus angularis* var. *bidens*, 130–145μ in the length of lorica, are smaller than those described by Collin *et al.* (1912), but within the range of those described by Rylov (1935). This species was abundantly found only in Nigoriike. As the water of Nigoriike is comparatively cold, the present species seems to be a form of more or less cold-water nature.

B. pala f. *amphiceros*, about 240μ in body length together with spine in the present specimens, are smaller than those of Collin *et al.* (1912). In the present observation this species appeared in Menkozakanoike, though in a small number. In habit it is a warm-water form.

As a general thing *Keratella cochlearis* was found very rarely, but at times abundantly. It was especially rich in Higurashinoike. This species was less in quantity than *K. quadrata* in the former observations (Kokubo & Kawamura, 1940c, 1941; Kokubo, 1941) in the lakes of the Koikuchinoike group, but in the present observations the relative abundance was reversed. In habit this species is widely distributed from small ponds in plain areas to oligotrophic mountain lakes (Kokubo & Kawamura, 1940c). It is well known that this species exhibits as seasonal variation in body form, becoming larger in summer and smaller in winter, thus showing adaptations to enable it to keep floating in spite of variations in temperature which really means density of water.

K. quadrata f. *quadrata* was found in most of the present lakes. The former observation (Kokubo, 1941) has also proved the remarkable occurrence of this species. It has been reported that the occurrence of this species has relation to the altitude of habitat from the sea-level, being found in summer in the lakes of high level, but in winter in the lakes of low level (Rylov, 1935). So far as the present lakes are concerned, this species is considered to be a cold-water form.

K. quadrata f. *divergens* appeared in warm-water and intermediate temperature lakes as Daiike, Menkozakanoike, Koikuchinoike and Hakkeinoike corresponding to Rylov's observation (1935). The species is colsely like to *K. quadrata* f. *quadrata*, except in respect to the length of posterior spines. According to Yamamoto (1952), an intermediate type between these two varieties was found in the lake of Kyoto city in Japan. This species may have more or less elongated body with well developed anterior and posterior spines in summer, while in winter the size of the body is reduced and spines are much shortened.

Notholuca labis occurred only in Hakkeinoike and Higurashinoike. In the present specimens the body length measured 125μ, being less than Rylov's description (1935).

Ploesoma truncatum occurred in such warm-water as Menkozakanoike and Hakkeinoike. In the former observation (Kokubo & Kawamura, 1938) this species was found only in Menkozakanoike.

Asplanchna priodonta has been reported to be widely distributed from small ponds to large oligotrophic lakes, and to show a seasonal change of body size (Rylov, 1935; Yamamoto, 1951). In the present observation this speices occurred in every lake and the seasonal change of body-size was also observed.

Conochilus unicornis: The present specimens, though they are tentatively identified as *C. unicornis*, differ from the description of Rylov (1935) in body length. This species occurred only in two warm-water lakes, Menkozakanoike and Itobatakenoike.

Filinia longiseta occurred in all the present lakes, especially abundantly in such cold-water lakes as Nigoriike, Ketobanoike and Ochikuchinoike. This species is one which is widely distributed from eutrophic to oligotrophic lakes.

Pedialion mirum occurred in considerable number in the warm-water lakes such as Itobatakenoike and Hakkeinoike. In the former observation, however, it was found very rarely in these lakes (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941).

Pompholyx complanata was found in all lakes. In habit this species occurs seldom in large lakes, preferring pond water.

Glenodinium foliaceum occurred in all lakes except Ketobanoike. In the former studies this species was reported only from Daiike (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941).

Peridinium willei appeared in all lakes except Nigoriike and Hakkeinoike. In the former observations (Kokubo & Kawamura, 1940c; Kokubo, 1941) this species was commonly obtained from the lakes of the Koikuchinoike group.

Ceratium hirundinella: In the former studies by Kokubo & Kawamura (1940c, 1941c) and Kokubo (1941), the distribution of *Ceratium hirundinella* was limited to the lakes other than the lakes of the Koikuchinoike group, but in the present observation, which was made about ten years after those former ones, a remarkable occurrence of this dinoflagellate was found in the lakes of the Koikuchinoike group as well as other lake groups (sub-groups). *Ceratium hirundinella* found in the present observation included two types, viz., two- and three-horned types. The abnormality of this species has been reported by Okada (1933) from Lake Mashu and by Fuji (1949) from the pond of Goryokaku Park, but such form were not found in the present lakes. In Europe and America the abnormal specimens of this species are rather uncommon in general lakes, while common in limetrophic lakes (Huber-Pestalozzi, 1927; Wimmer, 1929). The size change of this species has been thoroughly studied by Schilling (1913); he reported range from 92μ to 707μ in the extreme case. The present specimens were moderate in size, measuring 220–240μ.

Dinobryon sertularia occurred in all lakes in the present obervation, but in the former observations (Kokubo & Kawamura, 1940c, 1941c; Kokubo, 1941) it was scarcely in these lakes.

D. divergens was found only in Higurashinoike and Koikuchinoike, but in the former observations (Kokubo & Kawamura, 1941c, 1948) it was more widely distributed.

Melosira varians was found in the six lakes other than Itobatakenoike, Ketobanoike, Ochikuchinoike and Hakkeinoike in the present observation. In the former observations (Kokubo & Kawamura, 1940c, 1941c. 1948; Kokubo,

1941) the occurrence of this species was recorded as very rare or common. In habit it is widely distributed in eutrophic lakes and also in distrophic lakes more commonly than in eutrophic.

M. italica has perivalver rows and cross rows, and many spines on end. In the present observation this species was found to occur in warm-water lakes such as Menkozakanoike, Itobatakenoike and Koikuchinoike, but in the former observation (Kokubo & Kawamura, 1948) it occurred only in Menkozakanoike. In habit this species appears also in the inorganic acidtrophic lake, Lake Osoresan, Aomri Prefecture (Tamura, 1936).

Attheya Zachariasi was found in Daiike and Menkozakanoike in the present observation as in the former observation (Kokubo & Kawamura, 1948). In Japan the present species has been found only in a few lakes (Marukawa & Azuma, 1914; Kikuchi *et al.*, 1942; Kokubo & Kawamura, 1948). In habit this species occurs mainly in a limetrophic lake like *Rhizosolenia longiseta.*

Tabellaria fenestrata occurred in all lakes except Daiike, but the quantity was very low in the present observation as it was in the former observations (Kokubo, 1941; Kawamura, 1947). In the present specimens the change of shell-length was observed, the length ranging from 40μ to 100μ. In habit this species occurs usually in eutrophic lakes, showing littoral and also pelagic preference.

Fragillaria crotonensis occurred in all the lakes except Menkozakanoike and Itobatakenoike, but very low in quantity in the present observation just as in the former observations (Kokubo, 1941; Kawamura, 1947; Kokubo & Kawamura, 1948).

Asterionella formosa was found in all lakes in the present observation. This species was also found throughout the lakes in the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941). The colony is cross-shaped in spring and star-shaped in summer.

Synedra ulna and *S. acus* occurred in all lakes in the present observation. The former species is larger than the latter. These species are the dominant one in the present lakes together with *Asterionella formosa.* In the former observations (Kokubo & Kawamura, 1940c, 1948c; Kokubo, 1941) the latter species was found abundantly throughout the present lakes.

Gyrosigma accuminatum occurred in the warm-water lakes such as Daiike, Menkozakanoike and Hakkeinoike in the present observation. In the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941) this species did not occur at all in the present lakes.

Pinnularia mair appeared only in Menkozakanoike in the present observation.

In the former observations (Kokubo & Kawamura, 1940c, 1041c, 1948; Kokubo, 1941) very few specimens were collected from these lakes.

Cymbella lanceolata was found only in Menkozakanoike. Besides this, *C.* sp. was collected from Itobatakenoike. Both species were seldom found in these lakes in the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo 1941).

Gomphonema constrictum was collected only in Daiike and Menkozakanoike in the present observation. In habit it is widely distributed from the lakes in the plain to mountain lakes (Schônfeldt, 1913; Hustedt, 1930).

Epithemia zebra occurred mainly in the lakes of Nigoriike and Koikuchinoike groups in the present observation. This species has several varieties. In habit it is widely distributed in various types of lake (Schônfeldt, 1913; Hustedt, 1930).

Rhopalodia gibba occurred mainly in the cold-water lakes such as Nigoriike, Ketobanoike and Ochikuchinoike. In the former observations (Kobubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941) this species did not occur in any of the present lakes.

Surirella Capronii was occurred in Daiike, Menkozakanoike and Hakkeinoike in the present observation. At the time of former study (Kokubo, 1940) this species seldom occurred in the Koikuchinoike group. In habit it is found in all plain land lakes as well as in mountain lakes.

S. tenera occurred in Nigoriike, Daiike, Menkozakanoike, Ochikuchinoike and Hakkeinoike. In the former studies (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo 1941) this species was not found in any of the present lakes.

Gomphosphaeria lacustris was found in Nigoriike and Daiike. Colonies take the form of an indistinct gelatinous mass, cells being developed on dichotomously or trichotomously branched gelatinous stalks. In the former observations (Kokubo & Kawamura, 1940c, 1948; Kokubo, 1941) this species did not occur at all in the present lakes.

Anabaena planctonica occurred in seven lakes except Itobatakenoike, Ketobanoike and Hakkeinoike, sometimes resulting in water bloom in Nigoriike. Trichomes are straight. Diameter of cell measured 9-13μ.

A. spiroides occurred in Higurashinoike, Koikuchinoike, Ōike and Hakeinoike, and sometimes the water bloom in Daiike. In the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941) this species seldom occurred in the present lakes. There are several varieties (Huber-Pestalozzi, 1938).

A. Lemmermanni occurred in Nigoriike, Itobatakenoike, Higurashinoike and

Ochikuchinoike. In Higurashinoike it produced water bloom. Trichomes are long and coiled.

A. catenula var. *intermedia* occurred only in Higurashinoike. In the former investigations (Kokubo & Kawamura, 1940c, 1941c, 1948 ; Kokubo, 1941) this species was not found in these lakes.

A. sp.: Species could not be identified. Cells are smaller than that of the former species. This species occurred mainly in such warm-water lakes as Higurashinoike, Koikuchinoike, Ōike and Hakkeinoike.

Lyngbya sp.: The species, although the exact name was not determined, closely resembles *L. Bergei* G. M. SMITH. This species occurred only in Hakkeinoike in the present observation. In the former studies (Kokubo & Kawamura, 1940c, 1941c, 1948 ; Kokubo, 1941) it was entirely absent from all lakes.

Genicularia spirotaenia was found in several lakes, Nigoriike, Menkozakanoike, Ochikuchinoike and Hakkeinoike, especially common in Hakkeinoike. This species was also found in the former observations (Kokubo & Kawamura, 1940c, 1941c 1948; Kokubo, 1941).

Clostrium moniliferm was found only in Hakkeinoike in the present observation. In the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941) it did not appear in these lakes.

Docidium baculum occurred in Itobatakenoike in the present observation. Cells taper more or laess toward the ends, membranes either smooth or with minute protuberances. In the former observation in these lakes it was rarely collected.

Staurastrum paradoxum appeared in Daiike, Ochikuchinoike and Ōike, but in the former observations it did not occur in these lakes (Kokubo & Kawamura, 1940c, 1941c, 1948 ; Kokubo, 1941). Length of cells 30–100μ. This species varies greatly in shape.

Mougeotia sp.: The exact name was not determined. This species occurred only in Hakkeinoike in the present observation. In the former observations the same species was also found in these lakes (Kokubo & Kawamura, 1940c, 1941c, 1948 ; Kokubo, 1941).

Volvox aureus occurred in the warm-water lakes, Daiike, Ōike and Hakkeinoike. Diameter of cells about 270μ, smaller than was stated by Kokubo (1941). The previous reports proved that this species appeared in cértain years (Kokubo, 1941).

Pandorina morum occurred in all lakes except Nigoriike and Menkozakanoike.

In the previous studies this species seldom occurred (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941).

Eudorina elegans was found in all lakes. It was also found in the previous observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941). In habit this species appears commonly in eutrophic lakes.

Trochiscia sp. ?: The exact name was not determined. The species was mainly found in warm-water of intermediate temperature lakes such as Itobatakenoike, Higurashinoike, Koikuchinoike, Ōike and Hakkeinoike.

Crucigenia rectangularis occurred only in Higurashinoike in the present observation. It has rarely appeared in these lakes in the former observations (Kokubo, 1941; Kokubo & Kawamura, 1941c).

Characium longipes was found only in Koikuchinoike in the present observation as also in the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941).

3. Plankton Communities in Each Lake

(A) Nigoriike (Tables 10–13, Fig. 15)

The number of species of plankton collected from the present lake through all observations was 31 in total (Table 10). Among them the dominant species were *Filinia longiseta*, *Fragilaria construens*, *Asterionella formosa* and *Anabaena planctonica*.

Filinia longiseta was very rare in May, very common in August and rare in October. *Asterionella formosa* was found in all seasons, occurring very commonly in May, occasionally in August and rarely in October. *Anabaena planctonica*, though absent in May, appeared very commonly in August and October. *Fragilaria construens* was relatively important in quantity.

The majority of *Filinia longiseta* crowded below the middle layer in every

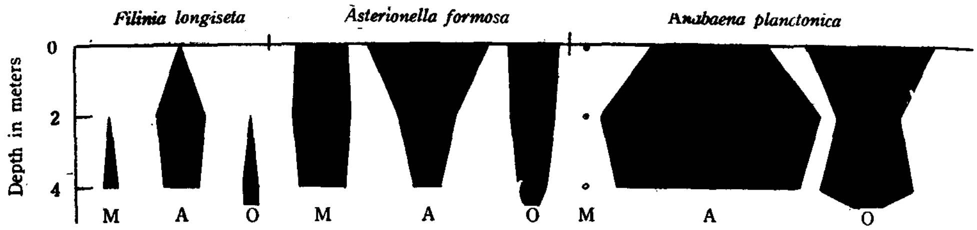

Fig. 15. Vertical distribution of three dominant species of plankton in Nigoriike
M, May 16, 1952, 11:40 a.m. -2:00 p.m.
A, Aug. 27, 1952, 9:25 a.m. -9:50 a.m.
O, Oct. 21, 1952, 10:00 a.m. -10:40 a.m.
(from Tables 11–13)

month. As to the phytoplankton, *Asterionella formosa* was abundantly distributed in all layers, especially in the upper layer, through all seasons. *Anabaena planctonica* showed the maximum abundance at 2 meter depth in August, while in October it was at the surface.

(B) Daiike (Tables 10, 14–16, Fig. 16)

Thirty-eight species were found from this lake through all observations. Of these species, *Asterionella formosa* occurred dominantly. Besides this species, *Ceratium hirundinella*, *Synedra acus* and *Anabaena planctonica* were important in quantity.

Ceratium hirundinella inhabited all layers, its maximum occurrence being found in 4–6 meter depth in all months. *Asterionella formosa* and *Synedra acus* were rich in spring and autumn, but poor in summer. In manner of vertical distributions of these two species were similar to each other through all seasons. These species were found in all depths in May and October, their maximum positions generally occurring within the metalimnion. In August either of the species appeared in maximum below the lower limit of the metalimnion or within the hypolimnion, especially near the bottom. *Anabaena planctonica* appeared in abundance through all layers in May, its maximum existing in 4 meter depth.

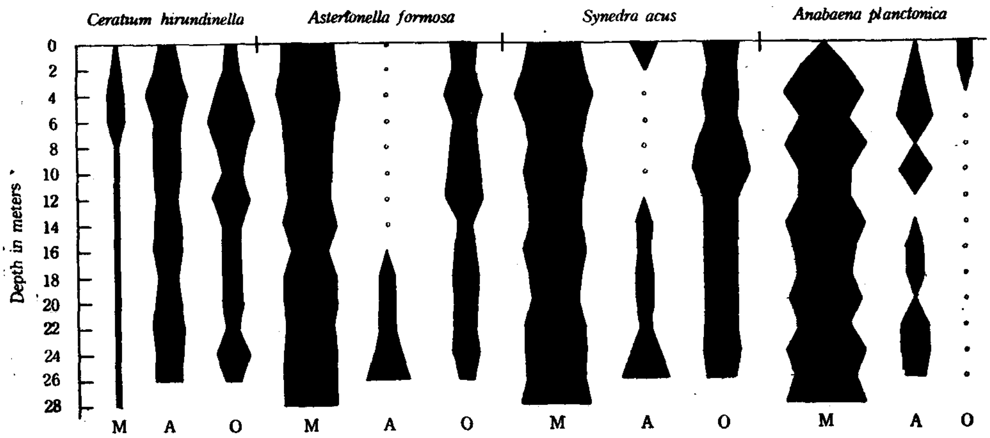

Fig. 16. Vertical distribution of four dominant species of plankton in Daiike
M, May 16, 1952, 3 : 40 p.m. -7 : 30 p.m.
A, Aug. 27, 1952, 0 : 10 p.m. -4 : 00 p.m.
O, Oct. 21, 1952, 0 : 15 p.m.-2 : 00 p.m.
(from Tables 14–16)

(C) Menkozakanoike (Tables 10, 17–19, Fig. 17)

The number of species collected from the present lake was 38 in total. The dominant species were *Bosmina longirostris*, *Ceratium hirundinella*, *Asterionella formosa* and *Synedra acus.*

Bosmina longirostris occurred very rarely in May, commonly in August and rarely in October. This species was widely distributed in all depths.

Asterionella formosa and *Synedra acus* occurred temporarily. The former species was commonly found in May and very rarely in other months, while the latter species appeared commonly in May and October, and very rarely in August. *Asterionella formosa* was widely distributed in all depths in May and August, and below 6 meters in October. *Synedra acus* appeared in all layers through all observations, nearly uniformly through vertical range as in *Asterionella formosa.* The above two species appeared usually in maximum near the bottom.

Ceratium hirundinella appeared commonly in October and very rarely in other months. The vertical distribution of this species was irregular with seasons. In May it was found only above 4 meter layer, in August it was absent between 6 meters and 8 meters, and in October it was found in 2–11 meter layer. The maximum occurrence of this species was usually found in the epilimnion. This species crowded near the upper part of anaerobic layer in August.

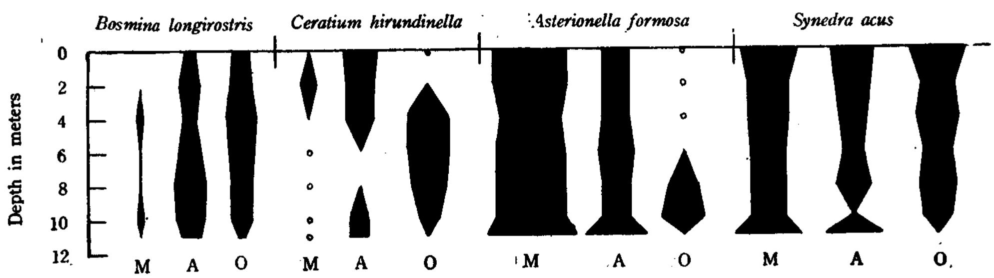

Fig. 17. Vertical distribution of four dominant species of plankton in Menkozakanoike

M, May 17, 1952, 10 : 30 a.m. -12 : 00 m.
A, Aug. 28, 1952, 9 : 30 a.m. -10 : 30 a.m.
O, Oct. 21, 1952, 3 : 30 p.m. -4 : 30 p.m.
(from Tables 17–19)

(D) Itobatakenoike (Tables 10, 20–22, Fig. 18)

Thirty-seven species were found in this lake in all collections. The leading species were *Ceratium hirundinella, Asterionella formosa* and *Synedra acus. Ceratium hirundinella* was commonly found in August and October but very rarely in May. *Asterionella formosa* decreased in quantity as the seasons progressed ; it occurred commonly in May, rarely in August and very rarely in October. *Synedra acus* appeared more or less abundantly than the former ; it was commonly found in May, rarely in August and occasionally in October.

Ceratium hirundinella was widely distributed in all layers in August and October. The maximum occurrence of this species was at the 10 meter depth in

August and in 2 meters and 6 meters in October. This species was even abundantly distributed in the anaerobic layer.

Asterionella formosa was found in all layers in May, between 2 and 12 meters in August and scarcely in all layers in October. The maximum occurrence appeared at 14 meter depth in May and at 2 meter in August. *Synedra acus* occurred in all layers throughout the seasons, especially in May. The maximum layer of this species appeared at 10 meter depth in May, at the bottom in August and 2 meter layer in October.

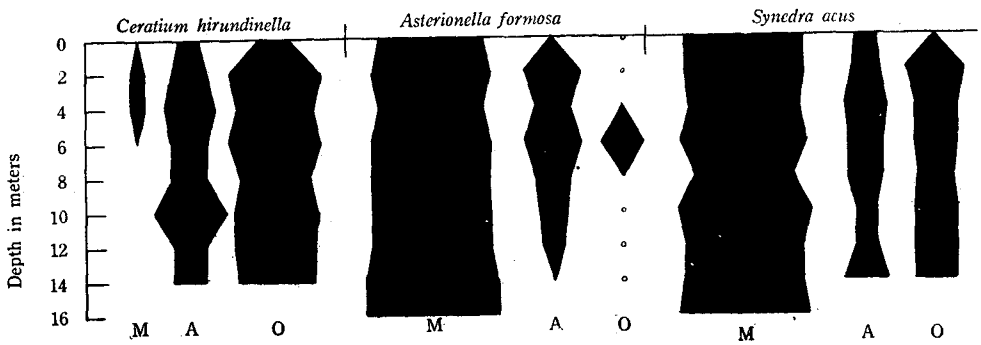

Fig. 18. Vertical distribution of three dominant species of plankton in Itobatakenoike

M, May 18, 1952, 10 : 20 a.m. -12 : 00 m.
A, Aug. 28, 1952, 1 : 0.5 p.m. -2 : 30 p.m.
O, Oct. 22, 1952, 9 : 10 a.m. -10 : 15 a.m.
(from Tables 20–22)

(E) Higurashinoike (Tables 10, 23–26. Fig. 19)

The number of species collected from Higurashinoike was 24 in total. Among them, *Keratella cochlearis*, *Ceratium hirundinella*, *Din bryon sertularia*, *Anabaena Lemmermanni*, *A. catenula* var. *intermedia* and *A.* sp. occurred dominantly.

Keratella cochlearis appeared abundantly in May, very rarely in August, rarely in October and commonly in February.

Ceratium hirundinella appeared abundantly in August, very commonly in October and rarely or very rarely in other months. *Dinobryon sertul..ria* was not found in May, occurring in August and February and commonly in October. *Anabaena Lemmermanni* occurred abundantly only in May and it was not found in other months. *A. catenula* var. *intermedia* did not occur in May, but very rarely appeared in August, commonly in October and February. *A.* sp., though it was not found in May and August, appeared abundantly in October and very commonly in February.

Keratella cochlearis was widely distributed in all layers in May and October, with its maximum distribution appearing at 2 meter depth. In August it was found below the 2 meter layer and its maximum occurrence existed at 4 meter depth. In February this species occurred at the surface and below 6 meter layer. The distribution of *Ceratium hirundinella* was similar to that of *Keratella cochlearis*. The maximum of this species existed at 2 meter depth in May and October, and at 4 meter depth in August. However, in February this species crowded round the surface. *Dinobryon sertularia* was distributed below 4 meter layer in August and in all layers in October. The maximum occurrence existed at 4 meters in August and in 2 meter layer in October. *Anabaena Lemmermanni*, *A. catenula* var. *intermedia* and *A.* sp. occurred temporarily. As to all of these species, the maximum abundance was observed mainly in 2–4 meter layer in the summer period. In February *Anabaena* sp. crowded near the surface under the ice cover.

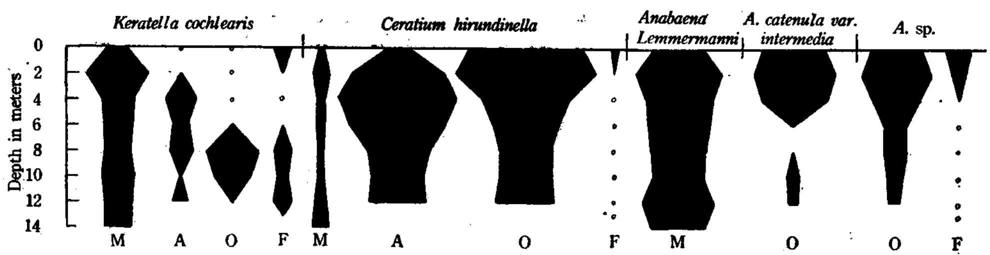

Fig. 19. Vertical distribution of five dominant species of plankton in Higurashinoike

M, May 18, 1952, 2 : 55 p.m. -4 : 40 p.m.
A, Aug. 29, 1952, 11 : 10 a.m. -1 : 30 p.m.
O, Oct. 22, 1952, 11 : 30 a.m. -3 : 53 p.m.
F, Feb. 21, 1953, 1 : 00 p.m. -4 : 30 p.m.
(from Tables 23–26)

(F) Ketobanoike (Tables 10, 27–29, Fig. 20)

The number of species collected from the present lake was 24 in total for the entire period. Among them, *Ceratium hirundinella*, *Asterionella formosa*, *Synedra ulna* and *S. acus* were dominant species. Besides these, *Keratella cochlearis*, *Dinobryon sertularia* and *Fragilaria crotonensis* occurred commonly at certain times.

Ceratium hirundinella appeared very rarely in May, abundantly in August and commonly in October. *Keratella cochlearis* was found rarely in May and October, and commonly in August. In this lake *Mesocyclops oithonoides* did not occur, but instead of this species, *Eucyclops prasinus* appeared in May, although the number was very scant.

Dinobryon sertularia occurred scarcely in May and August but appeared commonly in October. *Asterionella formosa* was found commonly in May, rarely in August and abundantly in October. *Synedra ulna* occurred abundantly in May and very rarely in August and October. *S. acus* decreased gradually as the seasons progressed from May to February : it was very common in May, rare in August and very rare in October.

Ceratium hirundinella was found in 2–4 meter layer in May, but it was found in all layers in August and October. The maximum abundance was in 2 meters in May and August and in 4 meter depth in October. *Asterionella formosa* was found in all layers and every month except August. It occurred in 2 meter depth in maximum. *Synedra ulna* and *S. acus* were also found from the surface to the bottom, but they appeared above 2 meter layer in maximum.

Keratella cochlearis was also found from the surface to the bottom, occurring at 6 meter layer in maximum in May and October. But some individuals crowded at 10 meters where dissolved oxygen was scanty. Again this species showed high abundance in 10 meters just above the anaerobic layer in August.

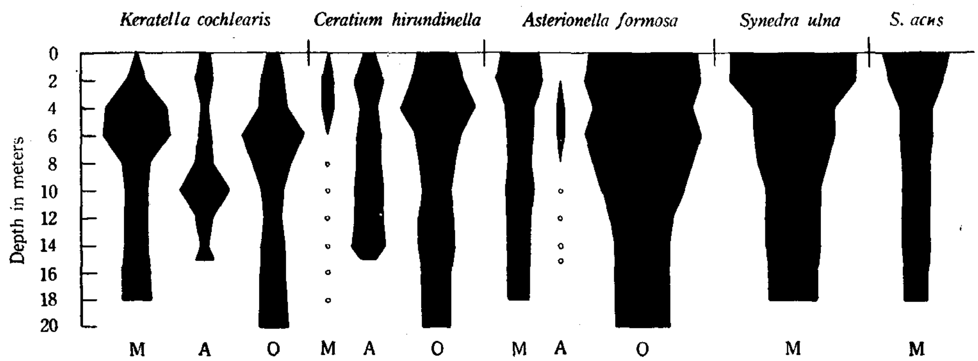

Fig. 20. Vertical distribution of five dominant species of plankton in Ketobanoike

M, May 19, 1952, 10 : 00 a.m. -0 : 40 p.m.
A, Aug. 29, 1952, 3 : 30 p.m. -5 : 30 p.m.
O, Oct. 23, 1952, 10 : 58 a.m. -0 : 15 p.m.
(from Tables 27-29)

(G) Ochikuchinoike (Tables 10, 30–32, Fig. 21)

Species of plankton collected from the present lake totaled 32. Among them, *Asterionella formosa* and *Synedra ulna* were dominant in all seasons. Besides these, *Ceratium hirundinella, Dinobryon sertularia, Fragilaria crotonensis* and *Synedra acus* were abundant temporarily. *Eucyclops prasinus* occurred also in this lake, though the number was very small, similarly to Ketobanoike.

Asterionella formosa was abundant in quantity through all months. *Synedra ulna* was abundantly present in May and very rarely in summer. *Dinobryon sertularia* appeared only in May and October ; in the former month it was very rarely present and in the latter month it occurred commonly. *Fragilaria crotonensis* was commonly present in May, occasionally in August and very rarely in October. *Synedra acus* was found commonly in May, rarely in August and very rarely in October.

Asterionella formosa and *Synedra ulna* found as dominant species were widely distributed in all layers in most of the months. The maximum occurrence of the former species existed in the layer above 2 meters in May and August, and at 8 meter depth in October. The maximum distribution of the latter species appeared in the surface in May and at 4 meter depth in August. In October a slight occurrence of this species was found only near the bottom. *Fragilaria crotonensis* and *Synedra acus* were similar to *Synerda ulna* in vertical distribution. These species were widely distributed in all layers in May and August. The maximum abundance appeared above 2 meter layer in May and in 4 meter depth in August. Again, this species appeared in small number only near the bottom in October. On the contrary, *Dinobryon sertularia* occurred only below 12 meters in May, but in October it was widely distributed in all layers. The maximum occurrence appeared in 12 meter depth in May and in 2 meter depth in October.

Ceratium hirundinella occurred commonly after summer, though it had very rarely been present in spring. This species occurred in the maximum between 4 and 6 meters.

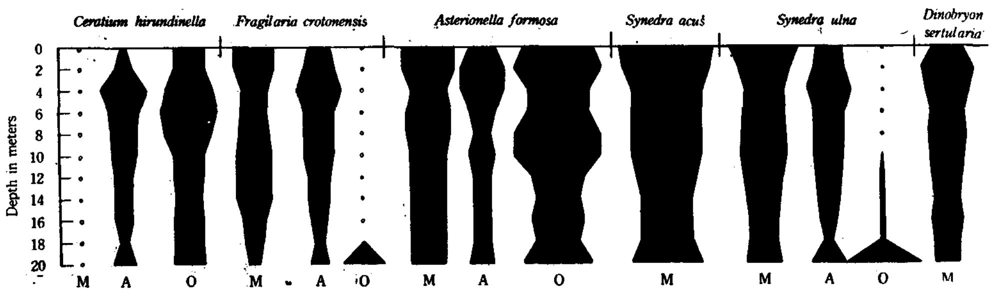

Fig. 21. Vertical distribution of six dominant species of plankton in Ochikuchinoike

M, May 21, 1952, 7 : 18 a.m. -10 : 00 a.m.
A, Aug. 30, 1952, 9 : 10 a.m. -11 : 50 a.m.
O, Oct. 23, 1952, 2 : 17 p.m. -3 : 55 p.m.
(from Tables 30–32)

(H) Koikuchinoike (Tables 10, 33–36, Fig. 22)

Thirty-nine species of plankton were collected from the present lake. Of these, *Ceratium hirundinella*, *Asterionella formosa* and *Synedra ulna* were dominant in certain months. Besides them, *Keratella cocdlearis* and *Anabaena* sp., though they were not the dominant species, occurred in quantities in this lake.

Ceratium hirundinella was rich in summer and autumn, and more exactly it occurred rarely in May and February, commonly in August and abundantly in October. This species occurred between 4 and 18 meters in May, but in all layers in August and October. In February the distribution was limited between 2 and 8 meter layers. The maximum occurrence appeared in 10 meter depth in May, at 5 meter depth in August, at the surface in October and at 2 meter depth under the ice in February.

Asterionella formosa was plentiful during the months from May to October, but disappeared entirely in February. This species which dominated in all seasons was found in all layers. Its maximum appeared at 2 meters in May, at 9 meters in August, at the surface in October and 2 meter depth under the ice in February.

Synedra ulna occurred in abundance in May, but very rarely in other months. It was widely distributed in all layers, the maximum occurrence being at 3 meter depth in May.

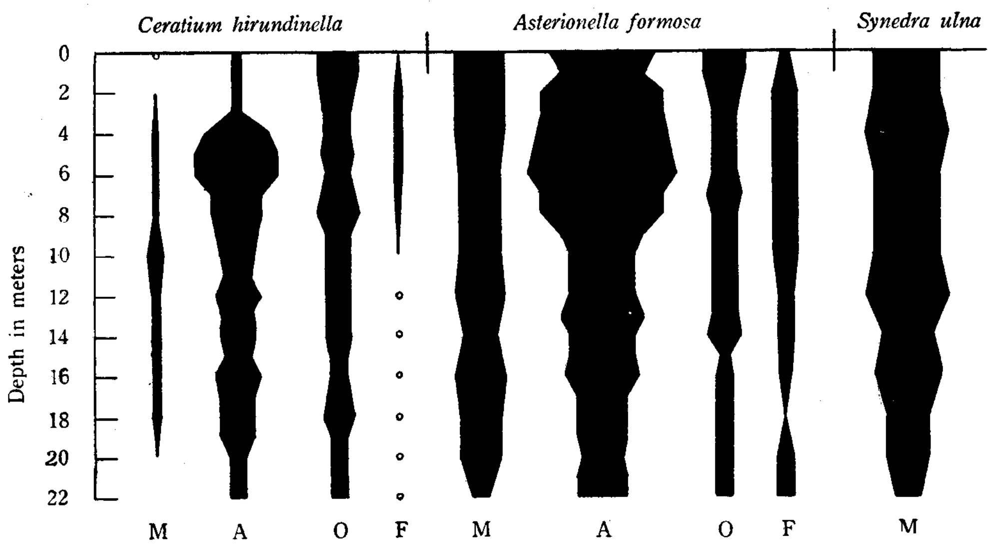

Fig. 22. Vertical distridution of three dominant species of plankton in Koikuchinoike

M, May 21, 1952, 11 : 12 a.m. -1 : 00 p.m.
A, Aug. 30, 1952, 1 : 30 p.m. -4 : 00 p.m.
O, Oct. 24, 1952, 8 : 37 a.m. -10 : 45 a.m.
F, Feb. 20, 1953, 1 : 00 p.m. -4 : 00 p.m.
(from Tables 30-32)

(I) Ōike (Tables 10, 37-39, Fig. 23)

From the present lake 37 species were collected. Among them, the dominant species were *Bosmina longirostris*, *Ceratium hirundinella*, *Tabellaria fenestrata*, *Asterionella formosa*, *Synedra ulna* and *Anabaena* sp.

Bosmina longirostris was rich in summer; this species was found very rarely in May, very commonly in August and rarely in October. *Ceratium hirundinella* occurred in quantities after summer, though it occurred rarely in May. *Tabellaria fenestrata* was never found before summer, but in autunm occurred in abundance. *Asterionella formosa* was commonly found in May, and abundantly in August and October. *Synedra ulna* appeared commonly in May and was occasionally present in August and October. *Anabaena* sp. occurred in quantities in spring, though in small number in summer and fall. This species showed abundant presence in May, very rare in August and occasional in October.

The occurrence of *Bosmina longirostris* was limited to above 8 meters in May, covering, however, all layers from the surface to the bottom in other months. The maximum of this species appeared at 2–8 meters throughout the seasons. *Ceratium hirundinella* was found in all layers in other months except May. It occurred in maximum at 4 meters in August and at 8 meter depth in October. A slight concentration of this species was observed at 20 meter depth, i. e., in the upper limit of oxygenless layer, in May.

Tabellaria fenestrata, *Asterionella formosa*, *Synedra ulna* and *Anabaena* sp. were widely distributed from the surface to the bottom. *Tabellaria fenestrata*, coming into occurrence only in October, was found at 6 meter depth in the maximum in this month. *Asterionella formosa* occurred in quantities at the upper layer,

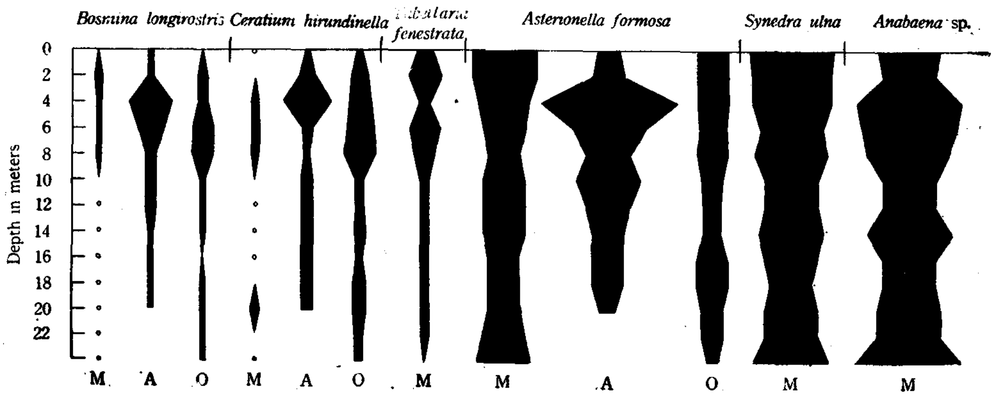

Fig. 23. Vertical distribution of six dominant species of plankton in Ōike

M, May 21, 1952, 2 : 10 p.m. -5 : 00 p.m.
A, Aug. 31, 1952, 1 : 20 p.m. -4 : 00 p.m.
O, Oct. 24, 1952, 0 : 58 p.m. -2 : 37 p.m.
(from Tables 37–39)

its maximum distribution occurring at the surface in May, at 4 meters in August and at 8 meter depth in October. The maximum occurrence in every month corresponded to the depth of the metalimnion. The veritcal distribution of *Synedra ulna* was similar to that of *Asterionella formosa*, i. e., the position of the maximum occurrence gradually descended as the season progressed. This species showed the maximum occurrence at the surface in May, at 6 meters in August and at 18 meter depth in October. The distribution of *Anabaena* sp. extended from the surface to the bottom in May, but it was limited between 2 and 14 meter layers in August and between the surface and 8 meter layer in October. The maximum of this species was found at the surface in May, at 6–8 meters in August and at 4 meters in October.

(J) Hakkeinoike (Tables 10, 40–43, Fig. 24)

A total of forty-three species were taken from the present lake. Of these, dominant species were as follows: *Asterionella formosa*, *Synedra ulna* and *Anabaena* sp. Besides these primary dominant species, the common species were *Keratella cochlearis*, *Ceratium hirundinella*, *Dinobryon sertularia*, *Synedra acus*, *Genicularia spirotaenia* and *Mougeotia* sp.

Keratella cochlearis was found in small number during the months from May to October, but commonly in February. *Creatium hirundinella* was also found in small number in September and October, but commonly in May and February.

Dinobryon sertularia occurred commonly in May and September, but it disappeared entirely in February. *Asterionella formosa* was rich during the period from May to October, but it was found in small number in February. *Synedra ulna* occurred abundantly in May, very rarely in September and rarely in October and February. *S. acus* was occasionally present in May and February, commonly in September and very rarely in October. *Anabaena* sp. occurred only in May, very abundantly. *Genicularia spirotaenia* and *Mougeotia* sp. appeared commonly in October.

Keratella cochlearis was widely distributed in all layers in May and between 2 meters and the bottom in October and February. But the distribution of this species was limited between 5 and 7 meter layers in September. The maximum of this species existed at 6 meter depth from May to October and at the bottom in February.

Ceratium hirundinella occurred in abundance in all layers and in all months except May. This species occurred in large quantity at 4 meters in May, at 5 meters in September, and at 8 meters in October. In February it appeared at the bottom like the case of *Keratella cochlearis*. *Dinobryon sertularia* was distributed in all layers in May, between the surface and 6 meter depth in September, while the population was separated to above 6 meter layer and at the bottom in October. In February this species was entirely absent. *Asterionella formosa* and *Synedra acus* were found in all layers throughout the seasons. The former species occurred in maximum at the surface in May and October, at 5 meters in September and 4 meter layer in February. The latter species appeared in quantities at 6 meters in May, at 8 meters in September, and near the bottom in October and February. *S. ulna* occurred in all layers in May, October and February, but in September a small number of this species appeared only in 1 and 3 mefer layers and 10 meter depth near the bottom. The maximum occurrence was found at 6 meters in May, at the bottom in September and in 4 meter depth in February. *Anabaena* sp. was found in all layers in May, in small number at bottom and in the layer above 8 meter depth. In February this species disappeared entirely in all layers.

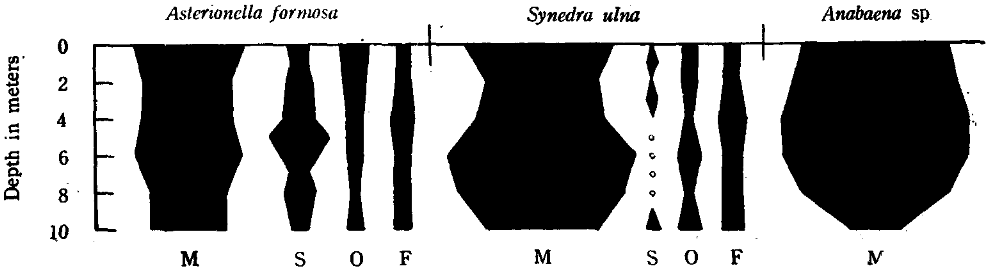

Fig. 24. Vertical distribution of three dominant species of plankton in Hakkeinoike

M, May 22, 1952, 10 : 20 a.m. -11 : 30 a.m.
S, Sept. 1, 1952, 11 : 30 a.m. -1 : 00 p.m.
O, Oct. 24, 1952, 4 : 00 p.m. -4 : 38 p.m.
F, Feb. 21, 1953, 10 : 30 a.m. -0 : 30 p.m.
(from Tables 40-43)

4. Difference of Communities by Sub-groups of the Lakes

The number of plankton species showed a remarkable difference according to the lakes. The present sampling have listed 43 species in Hakkeinoike, 39 species in Koikuchinoike, 38 in Daiike and Menkozakanoike, 37 in Itobatakenoike and Ōike, 34 in Higurashinoike, 32 in Ochikuchinoike, 31 in Nigoriike and 24 species in Ketobanoike. It may be noticed from these results that a large number of species is, in general, found in the lakes with warm-water and intermediate temperature conditions such as those observed in Daiike, Menkozakanoike, Itobatakenoike, Koikuchinoike and Hakkeinoike. However, in the cold-water lakes such as Ketobanoike, Nigoriike and Ochikuchinoike the number of species is comparatively small.

On the other hand, in respect to the quantity of plankton, i. e., the individual number, the lakes differ from each other to certain extent. The quantity of plankton is very large in the lakes barring the cold-water condition, while it is very poor in the warm-water lakes. The intermediate temperature lakes such as Higurashinoike and

Koikuchinoike yield a comparatively large population of plankton, indicating that these lakes are of the intermediate type.

In short, the lakes of the Menkozakanoike and Itobatakenoike groups are remarkably characterized by the large number of species and the small quantity of plankton as compared with the lakes of the other groups.

As for each species, by the occurrences of *Mesocyclops oithonoides*, *Eucyclops prasinus* and *Attheya Zachariasi* certain sub-groups of lakes are differentiated. The distribution of *Mesocyclops oithonoides* is limited to the lakes of the Nigoriike, Menkozakanoike and Itobatakenoike groups, which are the lakes having warm-water conditions. On the other hand, *Eucyclops prasinus* appears only in the lakes of the Koikuchinoike group. *Attheya Zachariasi* is observed only in the lakes of the Nigoriike and Menkozakanoike groups. *Daphnia longispina*, *Alona rectangula* and *Ploesoma truncatum* occur in certain lakes. The occurrence of *Daphnia longispina* is limited to Ochikuchinoike and Koikuchinoike. *Alona rectangula* appears only in shallow lakes such as Nigoriike and Hakkeinoike. *Ploesoma truncatum* is distributed in Menkozakanoike, Koikuchinoike and Hakkeinoike, which are the lakes possessing warm-water or intermediate temperature conditions.

The reason for the large number of plankton species found in Menkozakanoike and Itobatakenoike may be related to these lakes being comparatively warmer than the other lakes in the present groups.

The small amount of volume of plankton in the seepage lakes, Menkozakanoike and Itobatakenoike is probably caused by the lack of necessary nutrient substances for the growth of phytoplankton in the lake water. In these two lakes having no inflow, the supply of nutrient substances from outside is very small as compared with that in the drainage lakes. Moreover, as the water in these lakes stagnates during the summer period, necessary nutrient substances which are accumulated in the bottom do not come up to the surface layer. Accordingly, after spring increase of phytoplankton, the growth of phytoplankton may be controlled by lack of small amount of nutrient substances.

The hydrogen ion concentration in the aquatic environment also has direct bearing upon the production of plankton. Prescott (1951) has pointed out that a luxuriant desmid flora was typical for soft-water lakes in Michigan and Wisconsin, whereas hard-water lakes in those states were characterized by cyanophycean-diatom flora. He has mentioned that *Anabaena flos-aque* was consistently related to hard-water lakes, while *Nitella* was almost always confined to soft-waters which were rich in humic acids ; he stated that these might be used as indicator organisms for high pH. Maciolek (1954) has stated that productive waters generally have an alkaline reaction (pH 7.0–8.5). On the hardness of water in the present lake group some considerations may be entered into here. According to Miyadi (1929) and Yoshimura (1932a, 1936c, 1937b, 1939), the soft-water lakes of Japan always showed reversal of pH in their hypolimnion, where the anaerobic layer was formed near the bottom. Yoshimura (1937a, b) observed that the lake water of the Tsugarujuniko Lake Group, which contained a large amount of half-bound carbon dioxide, was more hard than that of most lakes of Japan. He stated that the lakes of this group showed no indication of a reversal of pH value in anaerobic layer owing to the high buffer action of water. He (1937a, b) has also found that the amount of half-bound carbon dioxide differed greatly with sub-groups of the lakes, ranking them in the order: Koikuchinoike group (30mg/l), Itobatakenoike and Nigoriike groups (20mg/l), Higurashinoike group (15mg/l) and Menkozakanoike group (9mg/l). Thereafter, Kawamura & Kokubo (1941), Kokubo & Kawamura (1941a, b), Ishida, Kokubo & Kawamura (1944) and Kawamura (1947) have also observed no reverse of pH value in the hypolimnion of the Koikuchinoike group. On the other hand, Kawamura & Kokubo (1947) ascertained the existence of reverse sign of pH value within the hypolimnion in Daiike and Menkozakanoike just as in the present study. The author measured the buffer value (cot. α) of water in the present observation in mid-summer, finding the following results. The buffer effect was probably due to the high content of HCO_3–CO_2 in the bottom water.

Lakes	Nigori-ike	Daiike	Menkoza-kanoike	Itobata-kenoike	Higura-shinoike	Ketoba-noike	Ochiku-chinoike	Koikuchi-noike	Ōike	Hakkei-noike
Buffer value (cot. α)	1.17	1.50	0.50	2.00	2.00	4.17	4.17	3.50	4.00	2.17

The above data prove that the buffer value of bottom water varies greatly with lakes, i. e., that the buffer value is generally high in the Koikuchinoike sub-group and low in the Menkozakanoike and Nigoriike sub-groups. As compared with the former studies (Kokubo & Kawamura, 1940a, b) the buffer value of Koikuchinoike group is found to be more or less high in the present observation. Generally the plankton production is high in the hard water, i. e., in the water having high buffer value, but there is the exception that Nigoriike yields a large amount of plankton in spite of the comparatively low buffer value of the lake water.

The most potent of the factors controlling the inhabitation of plankton speceies may be the temperature of the lake water. The difference in plankton species between lakes in the present observation will be discussed in respect of temperature difference. As described already, *Mesocyclops oithonoides* and *Eucyclops prasinus* occur in different sub-groups of the lakes. The former species, known to be a warm-water species, indeed occurs only in such warm-water lakes as Daiike, Menkozakanoike and Itobatakenoike. The distributon of *Eucylcops prasinus* does not likely have connection with the water temperature, but it is an interesting fact that this species is limited to the lakes of the

Koikuchinoike group. These facts on the distribution of these two species have been already observed by Kokubo (1941), though no explanation of this phenomenon was given by him. The presence of this species in the Koikuchinoike group may suggest that warm-water preference of this species is in a less degree as compared with that of *Mesocyclops oithonoides*. The distribution of *Ploesoma truncatum*, a warm-water form, occurs only in the lakes with the warm-water condition, such as Menkozakanoike, Koikuchinoike and Hakkeinoike. This distribution undoubtedly results from the warm-water preference of this species.

On the other hand, the distribution of *Alona rectangula* seems to be related to the shallowness of the lakes for certain reasons, probably because of the necessity of closeness to the bottom for completing the whole life cycle. It has been known that in habit this species prefers shallow ponds (Ward & Whipple, 1918 ; Uéno, 1927). *Daphnia longispina* has been widely distributed in all lakes of the Koikuchinoike group in the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948 ; Kokubo, 1941), but its occurrence is limited to Ochikuchinoike and Koikuchinoike in the present observation. On this disappearance of this species in the lakes other than the above two, the author is of opinion that the implantation of pond smelts in 1942–1943 may have resulted in depletion of daphnids by the subsisting of fish upon them.

The dominant species differs between the lakes. Most of the present lakes are occupied by *Ceratium hirundinella*. However, Nigoriike with a small number of the above species is characterized by the occurrence of a cold-water rotifer, *Filinia longiseta*. In Daiike, Ochikuchinoike and Hakkeinoike no dominant zooplankton species is observed, various species occurring without particular dominance.

By phytoplankton flora, Nigoriike and Higurashinoike are clearly distinguished from other lakes. The former lake is characterized by *Fragilaria construens*, *Asterionella formosa* and *Anabaena planctonica*, and the latter lake by the appearances of warm-water flora, such as *Dinobryon sertularia*, *Anabaena Lemmermanni*, *A. catenula* var. *intermedia* and *A.* sp. On the other hand, Daiike, Menkozakanoike and Itobatakenoike are occupied by *Asterionella formosa* and *Synedra acus*, and the lakes of the Koikuchinoike group by *Asterionella formosa* and *Synedra ulna*. It seems that *Asterionella* and *Synedra* are able to acclimate to a wide range of temperature, since they occur dominantly at times in various lakes. Damann (1943) has determined the temperature relation of certain plankton from Lake Michigan in laboratory observation. According to him, the optimum range of water temperature of phytoplankton was as follows : *Tabellaria*, *Asterionella*, *Fragilaria* and *Synedra*, 10 to 13°C ; green algae and some blue-green algae, 17 to 22°C ; and blue-green algae, 30 to 32°C. Rodhe (1948) has obtained the following result on phytoplankton from the Algonquin Park Lakes and Lake Michigan. A temperature above 15°C is not suitable for the cultures of *Asterionella formosa* and *Fragilaria crotonensis*, while *Scenedesmus*, *Pediastrum* and *Coelastrum* grew best at 20–25°C. McCombie (1953), thereafter, obtained the temperature range of growth of phytoplankton in the Algonquin Park Lakes. For *Tabellaria* and *Asterionella* the optimum temperature may range from 14 to 21°C. *Dinobryon* from 11 to 19°C, *Synedra* and *Chrysosphaerella* from 15 to 18°C, and *Anabaena* from 17 to ?°C.

The above experiments show that the optimum temperature of phytoplankton species widely varies according to the cases. However, the temperature range obtained by the experiments may be useful as a rough indication of whether one species is of warm-water nature and another of cold-water nature.

5. Seasonal Fluctuation in Occurrence of Each Species

Cyclops vicinus occurred generally in all seasons, though in small number. The adult female carrying eggs appeared commonly under the ice cover in February, and again in May.

Mesocyclops oithonoides occurred from spring to autumn but did not in winter. The adult female carrying eggs occurred in autumn as in the former observations (Kokubo & Kawamura, 1948). This species has been known to be a warm-water species (Naber, 1933 ; Rylov, 1935).

Eucyclops prasinus occurred throughout the seasons, especially in spring and summer in a large number. The adult female carrying eggs was commonly found in late summer.

Daphnia longispina occurred in summer and also in winter, though in small number. In habit, this species belongs to a cold water form.

Bosmina longirostris predominated from summer to autumn, disappearing entirely in winter. Thus, this species occurred in abundance in the warm water season in the present lakes, though it has generally been known to be a cold water form.

Synchaeta oblonga occurred during the period from spring to autumn, being entirely absent in winter. However, this species has generally been known as a cold-water form in certain lakes of Hokkaido, Japan (Hada, 1937 ; Motoda & Ishida, 1948, 1949).

Polyarthra trigla occurred the year round without remarkable seasonal change of occurrence. Rylov (1935) has also stated that this species occurs the year round in Europe. However, it has been said that this species is abundant in the warmer months in Wisconsin and also in Hokkaido, Japan (Scheffer & Robinson, 1939 ; Motoda & Ishida, 1948).

Keratella cochlearis occurred in all seasons, especially abundantly in winter. According to several authors (Collin *et al.*, 1912 ; Scheffer & Robinson, 1939 ; Rylov, 1935), this species occurs very commonly in May-June, and eggs are found from April to August, especially commonly in May in North America. However, in the present observation this species was found to be the commonest one in winter in agreement with results of the study by Kikuchi (1931) in Lake Suigetsu, hinting that it is probably a winter form so far as Japan is concerned.

K. quadrata f. *quadrata* was found very rarely in summer but commonly under the ice cover. A former observation (Kokubo, 1941) has also proved the similar seasonal fluctuation of occurrence of this species to certain extent. As far as the present lakes are concerned, this species is considered to be a cold water form.

K. quadrata f. *divergens* occurred only in summer, disappearing entirely in winter. The similar seasonal change of occurrence of this species has been noted by Rylov (1935) in Europe. The species is probably a summer form.

Ploesoma truncatum occurred only in summer and autumn. This species has been generally known to be a mid-summer form in Japan (Yamaguchi, 1938).

Asplanchna priodonta predominated in spring and autumn.

Conochilus unicornis occurred from spring to autumn, disappearing in winter. It has been said that this species belongs to a warm-water form in European lakes (Rylov, 1935) and also in Japanese lakes (Hada, 1937).

Filinia longiseta occurred the year round, but the seasonal change of occurrence differed greatly with lakes. This species usually shows two maxima of occurrence, in summer and autumn, in most of the Japanese lakes. However, so far as the present lakes are concerned, such tendency was not observed.

Peaialion mirum occurred only in summer and autumn, the occurrence being limited to the warm season. It has been reported that this species is a stenothermal warm-water form, showing propagation in summer and autumn (Rylov, 1935).

Pompholyx complanata was found during the period from spring to autumn, disappearing in winter. It has been said that in occurrence this species predominates during the summer.

Ceratium hirundinella occurred in all seasons, in summer and autumn resulting in a water-bloom.

Dinobryon sertularia predominated in summer and autumn, though a certain number were present the year round.

D. divergens occurred only in summer. Though it has occurred in the cold-water of a mountain lake (Yoshimura, 1937f), in the present lakes it was not found in the cold season even in the comparatively warm lakes and was entirely absent in the comparatively cold lakes.

Melosira varians occurred in all seasons.

M. italica occurred in spring and autumn, disappearing entirely in summer and winter. It is said that in occurrence this species is dominant in autumn and winter in Europe (Hustedt, 1930), but it is not found in winter in the present lakes.

Attheya Zachariasi occurred only in autumn in the present observation. It is said that this species occurs mainly from winter to spring in other lakes of Japan (Kikuchi *et al.*, 1942).

Fragilaria crotonensis predominated in spring and in autumn. It is said that in habit this species appears at times in such quantites as to make a water bloom on the surface of a lake in America and certain European lakes (Ward & Whipple, 1918; Hustedt, 1930).

Asterionella formosa predominated from spring to autumn, though a certain number occurred the year round. So far as the present lakes are concernd, it has been stated that this species is a warm-water species (Kokubo, 1941).

Synedra ulna occurred in abundance in spring and autumn, though it appeared in all seasons in certain quantities.

S. acus showed a similar seasonal fluctuation of occurrence to that of *S. ulna* predominating in spring and in autumn.

Anabaena planctonica predominated generally in summer, but was absent in winter. Sometimes this species formed a water bloom on the surface of lake.

A. spiroides occurred only in spring and in autumn, disappearing in other seasons. This species sometimes also formed a water bloom as *A. planctonica* did.

A. Lemmermanni occurred only in spring and in summer. It has been reported that this species grows in early summer and again in autumn in the lakes of Wisconsin (Smith, 1920).

A. sp. predominated in the warm seasons, and also occurred commonly in winter.

Staurastum paradoxum occurred mainly in summer and in autumn but was not found in winter.

Pandorina morum was found in spring, autumn and winter, but was entirely absent in summer.

Eudorina elegans occurred mainy in spring and in autumn. In the former observations (Kokubo & Kawamura, 1940c, 1948) this species predominated from May to August, and in the lakes of Wisconsin (Smith, 1920) it occurred in abundance in April-June and October-November. From the above findings, this species may be said probably to be of somewhat warm-water nature.

Bosmina longirostris, Polyarthra trigla, Keratella cochlearis, K. cochlearis var. *irregularis, K. quadrata* f. *quadrata, K. quadrata* f. *divergens, Ploesoma truncatum* and *Pedialion mirum* showed seasonal fluctuations of occurrence to a certain extent. Among them, *Bosmina longirostris, Keratella cochlcaris* var. *irregularis, K. quadrata* f. *divergens, Ploesoma truncatum* and *Pedialion mirum* preferred warm season. On the other hand, *K. quadrata* f. *quadrata* and *Polyarthra trigla* preferred cold water.

While each species of phytoplankton above mentioned has its own pulse in reproduction at certain seasons of a year, the major constituents of phytoplankton population in the spring and autumnal maxima mainly comprised several species, viz., *Asterionella formosa, Synedra ulna, S. acus* and several species of *Anabaena*. Particularly *Asterionella* and *Anabaena* are the most important as had been indicated in the former observations (Kokubo & Kawamura, 1940c, 1941c, 1948; Kokubo, 1941).

6. Vertical Distribution of plankton in Relation to the Environmental Conditions

Cyclops vicinus, Mesocyclops oithonoides, Eucyclops prasinus and *Bosmina longirostris* appeared in maximum occurrence within the metalimnion from spring to autumn, though there were some exceptions. In detail, their maximum positions diffiered more or less with each other (Fig. 25). The maximum number of *Cyclops vicinus* was,

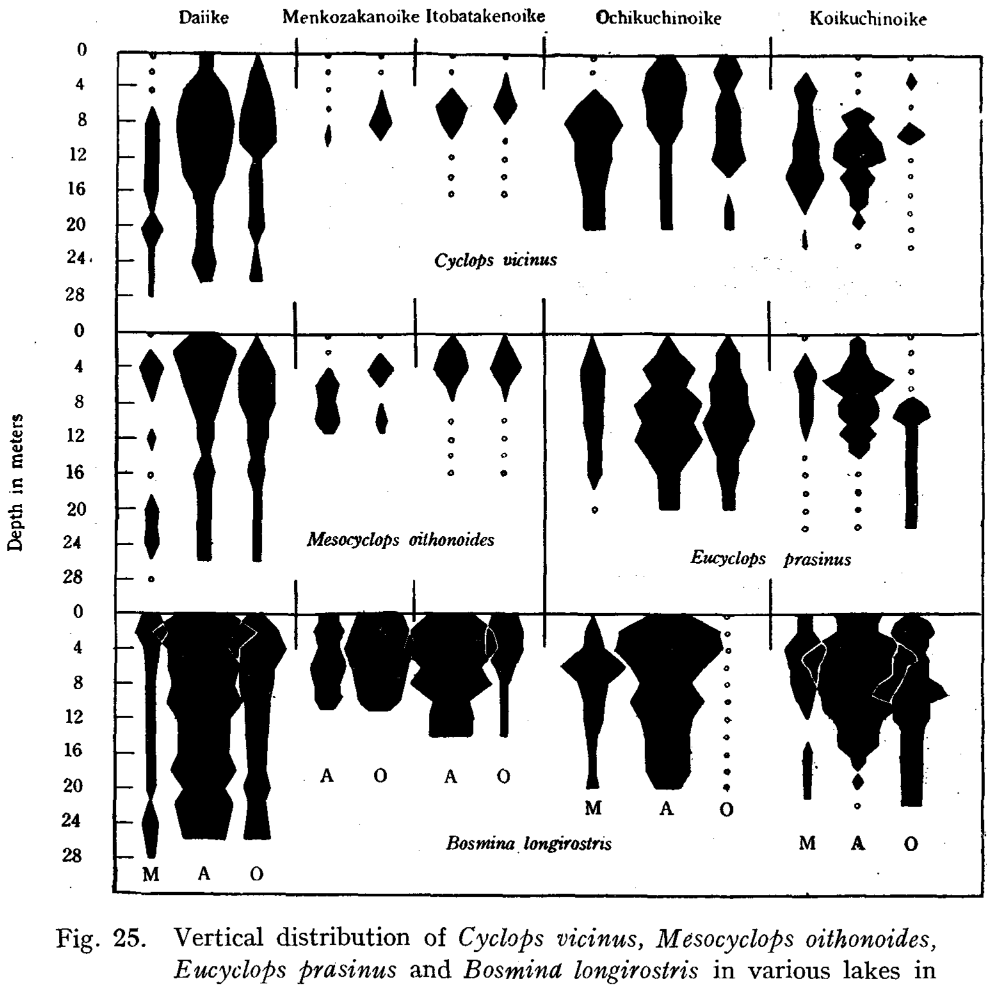

Fig. 25. Vertical distribution of *Cyclops vicinus, Mesocyclops oithonoides, Eucyclops prasinus* and *Bosmina longirostris* in various lakes in different months

M: May, A: August, O: October

on the whole, found between 4 and 10 meter depths (metalimnion), but appeared also sometimes below the metalimnion. *Mesocyclops oithonoides* appeared in 2–8 meters. *Eucyclops prasinus* maintained its maximum position in 4–12 meters. The maximum number of *Bosmina longirostris* was usually found in 2–9 meter depth. *Bosmina longirostris* and *Mesocyclops oithonoides* inhabited a more shallow layer than *Cyclops vicinus* and *Eucyclops prasinus* did. The similar results to the above have been obtained by Motoda (1953) in Koikuchinoike. Most of *Bosmina longirostris* migrated actively within the warm epilimnion (21–24°C), not descending below 5 meter depth owing to the existence of cold water. On the other hand, *Cyclops strenuus* migrated passing through the thermocline to be found in maximum below 12–5 meters in daytime. *Cyclops vicinus* and *Eucyclops prasinus* often crowded remarkably in the layer just above the anaerobic layer in the hypolimnion.

The species of Rotifera were, on the whole, distributed in maximum occurrence within the metalimnion during the period from May to October. However, certain species irregularly maintained their maximum positions at various depth other than in the metalimnion (Fig. 26). *Keratella cochlearis* and *K. quadrata* appeared mainly between 2 and 10 meter layers, corresponding to the metalimnion, through all lakes with some exceptions. On the other hand, the maximum position of *Polyarthra trigla* was commonly found between 2 and 8 meter layers in general, but appeared in the various depths of the epilimnion in Daiike, Menkozakanoike and Itobatakenoike, in which a thick epilimnion developed in spring and autumn. According to the study of Yamamoto (1948), in Lake Aoki, Nagano Pref., Japan, *Keratella cochlearis* and *Polyarthra trigla* occurred in maximum above the metalimnion while *Conochilus unicornis* maintained its maximum position in the upper part of hypolimnion. However, so far as the present lakes are concerned, the distribution of the latter species was entirely limited in the upper layer, differing from the observations of Yamamoto (1948). In contrast to the above species, *Filinia longiseta* usually occurred in maximum in the lower part of the metalimnion or in the hypolimnion (Fig. 26). That is to say, it crowded in cold-water layers, often in the deep layers just above the anaerobic layer or thereabouts. According to Harada (1935), in Lake Jitsugetsutan the pH value of lake water in the hypolimnion is an important limiting factor for the vertical distribution of this species, i.e., the neutrality or acidity of lake water hinders distribution of this species. In the present observation, however, such has not always been the case, for example, numerous individuals of this species were found in the neutral as well as in the acidic (pH 6.8–6.6) water in Nigoriike, Ketobanoike and Ochikuchinoike.

The phytoplankton was almost always distributed in all layers ; the maximum distribution was found in the epilimnion but also at times in the metalimnion. The maximum number of *Tabellaria fenestrata* was found between 4 and 6 meters, within the metalimnion. *Fragilaria crotonensis, Asterionella formosa, Synedra ulna* and *S. acus* appeared mainly in maximum occurrence between 2 and 6 meter layers, the vertical range covering the strata of the epilimnion and metalimnion. In *Anabaena* : *A. planctonica, A. spiroides, A. Lemmermanni, A. catenula* var. *intermedia* and *A.* sp., the distribution was commonly maintained in the epilimnion and the metalimnion. In contrast to these species, *Ceratium hirundinella* and *Dinobryon sertularia* usually had their maximum concentration at higher levels than those of the diatoms. It was observed that *Fragilaria construens, Asterionella formosa, Synedra ulna* and *S. acus* often had their maximum occurrence in the bottom layers. This phenomenon was a common thing in Daiike (Fig. 16) (p. 52), Menkozakanoike (Fig. 17) (p. 53) and Itobatakenoike (Fig. 18) (p. 54) from spring to summer. It is probable that a countless number of these species flourishing in the upper layer in the spring season might have sunk down near the bottom in summer. Particularly, in Menkozakanoike and Itobatakenoike in which the epilimnion is very thick and the thermocline lies near the bottom in summer, they are possibly accustomed to sink quickly down to the bottom. However, no morphological difference between the specimens collected from the bottom and those obtained from the upper layer of water was found in the present observation.

In winter Crustacea appeared in very small number or was entirely non-existent. On the other hand, several species of Rotifera and phytoplankton occurred commonly in winter and therefore, the vertical distribution of plankton in the winter season can be mentioned in respect to Rotifera and phytoplankton. *Polyarthra trigla, Keratella cochlearis* and *K. quadrata* f. *quadrata* maintained their position in various depths, within 2 and 12 meters. *Tabellaria fenestrata, Asterionella formosa, Synedra ulna* and *S. acus* showed their maximum number between 4 and 8 meter layers in which water temperature ranged from 1.5 to 4.0°C. *Ceratium hirundinella* and *Dinobryon sertularia* maintained their maximum position at 2 meter layer under the ice cover (water temperature 0.4–3.8°C). In winter the depth of effective light penetration was restricted under the ice cover. Accordingly, *Ceratium* and *Dinobryon* might be expected to occupy a somewhat higher position than in other seasons.

In lakes exhibiting physicochemical stratification, findings as to the vertical distribution of the plankton may profoundly be effected by various events which may occur near the time of the observation. It has been reported from various lakes that in the summer stagnation period the progression of the formation of stratification is accompanied by a gradual decrease and sometimes a diappearance of plankton from a part or all of the hypolimnion, as proved in Lake Suigetsu (Kikuchi, 1931). On the other hand, a concentration of plankton population in the thermocline in the summer season has been known to occur in some lakes (Kikuchi, 1931; Naber, 1933; Tamura & Fuji, 1949). The present observations also proved the concentration of plankton organisms in the metalimnion in summer. The sinking plankton from upper layer may be kept in the thermocline due to discontinuity in density of lake water. Moreover, it

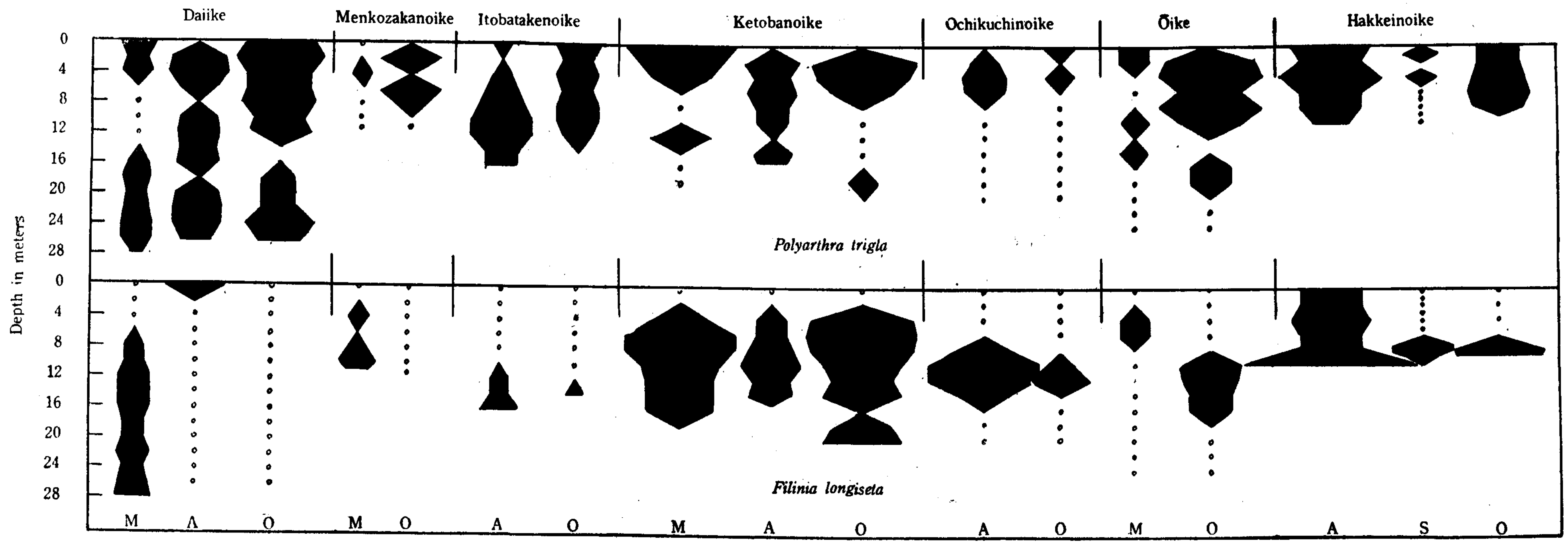

Fig. 26. Vertical distribution of *Polyarthra trigla* and *Filinia longiseta* in various lakes in different months

M : May, A : August, O : October

has been said that certain zooplankton crowd sometimes in the layer just above the anaerobic layer (Birge & Juday, 1914 : Utermöhl, 1925 ; Kikuchi, 1931 ; Naber, 1933). According to Utermöhl (1925) and Naber (1933), the congregation of zooplankton is governed by the presence of their food. Accumulation of such food substances as bacteria etc. causes the assemblege of protozoa etc. in this layer and then, in turn the Crustacea and Rotifera crowd there to feed upon the protozoa. On the other hand, Welch (1935) has mentioned that some zooplankton do not always crowd in the layer just above the anaerobic layer. In the present observation, the crowding of such zooplankton as rotifers above the anaerobic layer in summer season was clearly recognized (Figs. 19, 20 and 26; *Keratella cochlearis* and *Filinia longiseta*). The distribution of rotifer plankton of these lakes was probably determined by the food relation. Hada (1937) and Hada & Kusuki (1938) have stated that a remarkable decrease in number of Rotifera at a certain layer is usually accompanied by the crowding of Crustacea which subsist on Rotifera, but this was not perceived in the present observation. Kikuchi (1931) observed that *Diaptomus*, *Daphnia* and *Limnocalanus* (*Sinocalanus*) in Lake Suigetsu were not found in the anaerobic layer just above the bottom, but Hada & Kusuki (1938) found that the living Crustacea, *Acanthodiaptomus* (*Diaptomus*), *Mesocyclops* and *Daphnia*, occurred in the anaerobic bottom. In the present lakes *Cyclops*, *Mesocyclops* and *Bosmina* were also actually distributed within the anaerobic layer. According to Hada & Kusuki (1938), these species migrated actually for short time in seeking out their food in the oxygenless layer. The present author made a tentative experiment to ascertain the survival time of certain species in anaerobic water of Koikuchinoike with the following results :

Acanthodiaptomus pacificus	survived for about	20 min.
Cyclops strenuus	〃	45 min.
Daphnia longispina	〃	8 min.
Bosmina longirostris	〃	10 min.

Above results show that the anaerobic water of lakes exerts a fatal influence even within a very short time. Though this is no novelty in physiological sense, the exclusion of Crustacea in anaerobic layer undoubtedly does take place. Yet, it is of interest that in fact *Cyclops*, *Mesocyclops* and *Bosmina* were found in the lower part of well-developed anaerobic layer in the present field observation.

As already mentioned, excess of dissolved oxygen and high pH value existed in 2–4 meter depth from spring to autumn, and in winter the presence of over-saturation of oxygen was found in 4 meter depth under the ice cover. These levels corresponded to the levels in which the large population of phytoplankton were present. It is natural to conclude that high oxygen contents and high pH value resulted from the photosynthetic activity of phytoplankton.

V. PRODUCTIVITY OF LAKES AS EVALUATED BY THE QUANTITY OF PLANKTON

As will be supposed from the above descriptions of morphometry, hydrography and biotic communities, it is expected that the lakes composing the Tsugarujuniko Lake Group are comparatively independent of each other in their milieu, every lake having characteristic nature to a certain extent in the type of production. This is not only a matter of scientific interest but also of a practical importance from the view point of fisheries. In this chapter the productivity of these lakes will be discussed on the basis of the data of quantitative estimation of plankton with considerations of topographic and hydrographic environments. Here, the computation of plankton number from quantitative sampling is tentatively employed for the basis of determination of productivity. Table 44 shows the maximum and minimum values of plankton number in each lake for all depths and for all seasons. The number of plankton denoted here is the individual number for zooplankton and the cell number for phytoplankton.

Table 44. The maximum and minimum values of plankton number in each lake group for various depths and for different seasons (except February)

Lakes	Maximum	Minimum
Nigoriike	7413855	13730
Daiike	311135	3965
Menkozakanoike	34690	310
Itobatakenoike	101134	634
Higurashinoike	12597583	62611
Ketobanoike	51697505	1805
Ochikuchinoike	6613701	29124
Koikuchinoike	28666444	110618
Ōike	9341999	31807
Hakkeinoike	9891958	17204

Table 45. Mean of plankton numbers for epilimnion, metalimnion and (Numbers denote individuals or cells

Lakes		Nigoriike	Daiike	Menkozaka-noike
Epilimnion	Zooplankton	2514	4471	1066
	Phytoplankton	119627	81023	5536
	Total	122141	85494	6602
Metalimnion	Zooplankton	11636	12268	840
	Phytoplankton	4922750	48606	3644
	Total	4934386	60874	4484
Hypolimnion	Zooplankton	8885	4056	555
	Phytoplankton	6032900	64934	25085
	Total	6041785	68990	25640
Mean of epilimnion, metalimnion and hypolimnion		3699437	71786	12242

The average number for the number in epilimnion, metalimnion and hypolimnion is shown in Table 45.

It will be noticed that the plankton production is more rich in the drainage lakes such as Nigoriike, Higurashinoike and in the lakes of the Koikuchinoike lake group than in the seepage lakes such as Menkozakanoike and Itobatakenoike. Another

Table 46. The composition of average number of plankton between draingae and seepage lakes as investigated by pump method (numbers denote individuals or cells per 20 liters of water)

Drainage lake		Seepage lake	
Koikuchinoike Aug. 17, 1943 4:30 p.m.	Ōike Aug. 17, 1943 9:40 a.m.	Menkozakanoike Aug. 19, 1943 1:00 p.m.	Itobatakenoike Aug. 20, 1943 10:00 a.m.
18612720	6010540	29990	82560

Table 47. Average dry weight of plankton in ten lakes in May-October, 1952

Lakes	Dry weight of plankton (mg/m^3)	Total dry weight of plankton of lake (kg)	Dry weight of plankton (kg/ha)	Weight of organic matter (kg/ha)
Nigoriike	210	49.4	23.5	12.9
Daiike	57	54.6	8.5	4.7
Menkozakanoike	20	4.7	1.5	0.8
Itobatakenoike	22	5.1	1.7	0.9
Higurashinoike	230	17.5	15.9	8.7
Ketobanoike	345	146.9	35.9	19.7
Ochikuchinoike	192	50.9	18.8	10.3
Koikuchinoike	881	595.3	125.4	69.0
Ōike	138	79.9	15.0	8.2
Hakkeinoike	27.6	12.8	11.6	6.3

hypolimnion in ten lakes during period from May to October, 1952
per 20 liters of water)

Itobatake-noike	Higurashi-noike	Ketoba-noike	Ochikuchi-noike	Koikuchi-noike	Ōike	Hakkei-noike
3327	1967480	167594	64418	253286	23727	9871
29151	7878100	31842900	2714042	4980152	209850	63389
32478	9845580	32010494	2778460	5233438	233577	73260
3882	288761	36792	20025	1032236	214004	82166
21684	1244142	13104714	1415433	8898511	3215500	3187840
25566	1532903	13141506	1435458	9930747	3429504	3270006
12456	73130	18215	12538	140490	6968	26746
25258	1525850	7188183	796600	1589598	1098252	310450
37714	1598980	7206398	809138	1730088	1105220	337196
31919	4325821	17452799	1674352	5631424	1589434	1226821

experiment, in which 20 liters of water were sampled by means of wing pump from various depths, showed also that the plankton number in seepage lakes was much less than that in drainage lakes (Table 46).

Next, the standing crops of net plankton assembled plants and animals of these lakes were determined by measuring their dry weight in the materials obtained by vertical haul with plankton net described above (p. 40) (Table 47).

As shown in Table 47, the dry weight of net plankton per cubic meter differed remarkably from lake to lake. The results were, on the whole, similar to those obtained from the computation of individual (or cell) number on the quantitative samples. The dry weight plankton ranged from 881 mg per cubic meter of Koikuchinoike to 20 mg per cubic meter of Menkozakanoike ; it was clearly larger in the drainage lakes than in the seepage lakes.

From the value by cubic meter, the dry weight of plankton per hectare was calculated. The lakes will be ranked on the production in order as follows : Koikuchinoike (125kg/ha), Ketobanoike (36kg/ha), Nigoriike (24kg/ha), Ochikuchinoike (19kg/ha), Hakkeinoike (12kg/ha), Daiike (9kg/ha), Itobatakenoike (2kg/ha) and Menkozakanoike (2kg/ha).

The data show that the plankton productivity of these lakes differs in wide range. Although it is difficult accurately and scientifically to estimate the eutrophy and oligotrophy of the lakes, the production of a lake can be conveniently expressed in terms of the standing crops and the annual crops. "Standing crops" means the amount of plankton present in the water at a selected time, and "annual crops" means the total quantity of plankton produced during the entire year.

Birge & Juday (1922) estimated standing crops of plankton in Lake Mendota for several seasons. As a result, they obtained as annual average of 177kg of plankton in dry weight per hectare in this lake. Thereafter, they (1934) obtained the annual crops 94 kg in dry weight of plankton per hectare in Lake Trout. Recently, Rawson (1953) estimated standing crops by using a net of No. 20 silk bolting cloth in the lakes of western Canada, and, taking into account other's data (Birge & Juday, 1922, 1934), he concluded that the morphometric factor is importnant, governing the production ot plankton crops. He stated that the mean depth of lakes will provide a crude index determining the trophic type of the lakes. According to him, the lowest value of standing crops of plankton ranged from 10 to 20kg in dry weight per hectare among the lakes that be investigated. This was found in some Alpine lakes of the Canadian Rockies and in the extremely deep bays of Great Slave Lake, and so they were considered to be oligotrophic in type. Several other lakes of oligotrophic type ranged from 20kg to 40kg in dry weight per hectare. In moderate eutrophic lakes it ranged from 50 kg to 100kg per hectare, and in very eutrophic lakes it was about 150kg per hectare.

As compared with the results above noted (Birge & Juday, 1922, 1934 ; Rawson, 1953), Koikuchinoike which yields a crop of 125kg is undoubtedly a eutrophic lake.

Contrasted with this, other lakes showed below 50kg of dry plankton per hectare, suggesting each to be oligotrophic in type. However, in making comparison in such cases the mesh of plankton net must also be considered. In Rawson's case (1935) the silk cloth of net used was No. 20, while in the present case it was No. 13, a much coarser mesh. Therefore it follows that if the minute plankton which passed through the meshes of net are taken into account the plankton crops in the present lakes must be by far greater than the estimation described above.

Recently, Hogetsu *et al.* (1952) studied the biological production and the metabolism of Lake Suwa, Nagano Pref., Japan, which is known as one of remarkable eutrophic lakes in Japan. According to them, the average dry weight of seston in this lake changed greatly from season to season, within a range from the maximum of 11500 mg per cubic meter of water in November to the minimum of 2500 mg per cubic meter of water in February. The average dry weight of organic matter contained in seston ranged from 7200 mg to 700 mg per cubic meter of water. That is, the weight of seston of the whole area of the lake was calculated to be 750–180 tons, and the organic matter 0.336–0.024 tons per hectare.

It is notable that the average dry weight of plankton in Koikuchinoike (881mg) is but one-third of that in Lake Suwa (2500mg) in winter. However, standing crops of plankton in lakes decrease during the winter season in general, hence, it can be said that Koikuchinoike and other lakes in the present lake group are much inferior to Lake Suwa in plankton productivity. The organic matter was measured by the ash in the plankton ; the value indicated 69kg per hectare in Koikuchinoike and 20kg in Ochikuchinoike respectively. As compared with Lake Suwa (336–24kg/ha), the amount of organic matter of Koikuchinoike is moderate and that of Ketobanoike is closely similar to the limit of range of Lake Suwa.

Ichimura (1956) observed the seasonal change of dry weight of plankton calculated from chlorophyll content of water in Lake Nakanuma, Ibaragi, Pref., a eutrophic lake, in 1950–1951. The dry weight of phytoplankton ranged from 2.50 mg to 0.04 mg per liter of lake water in this lake through the seasons. The average value of dry weight is calculated 1330 mg per cubic meter in summer and 840 mg throughout seasons respectively. Accordingly, it follows that the dry weight of phytoplankton in Koikuchinoike in summer is superior to the limit of range of Lake Nakanuma.

Kokubo & Kawamura (1951) and Kawamura & Kokubo (1953) estimated the standing crops of plankton of Lake Towada, an oligotrophic lake, finding that this lake produced 236–200 tons (wet weight) in its whole area, count showing 4.5–3.4kg in dry weight per hectare. Compraing with this Menkozakanoike and Itobatakenoike are far lower in productivity.

In Lake Oshima-Ōnuma, eutrophic lake in southern Hokkaido, Takayasu, Igarashi & Kuroda (1936) measured the number of plankton per 100 liters of water to be 1000240 in May, 11634749 in September and 3345903 in October. The average value of above three is calculated 5326964 which corresponds to 1065393 individuals per 20 liters of water. Thereafter, Mori (unpublished) counted 373530 individuals of plankton per 20 liters of water in this lake. From the above, it follows that Ketobanoike, Koikuchinoike and Nigoriike are superior to Lake Oshima-Ōnuma in plankton number, Ochikuchinoike, Ōike and Hakkeinoike being almost in similar condition, while Daiike, Menkozakanoike and Itobatakenoike are inferior to the Lake Oshima-Ōnuma in plankton number.

Judging from the above estimations, it is obvious that Koikuchinoike is a highly eutrophic lake, Ketobanoike and Nigoriike are moderately eutrophic in type, Ochikuchinoike, Higurashinoike, Ōike and Hakkeinoike are mesotrophic in type, while Daiike, Itobatakenoike and Menkozakanoike are of oligotrophic type.

As mentioned above, Rawson (1953) stated that in lakes of western Canada the mean depth of lakes will provide a crude index in determining the trophic type of the lakes. However, so far as the present lakes are concerned, the mean depth is not always important as a scale in determining the trophic type of the lakes.

VI. FISH IMPLANTED

1. History of Implantation

At present three species of fish inhabit these lakes. All of them have been implanted from other lakes.

It is said that the carp, *Cyprinus carpio* LINNÉ, which now pleases many anglers, was first implanted by Mr. S. Shibata in 1917 ; at present it is found in all lakes of the Tsugarujuniko Lake Group.

The rainbow trout, *Salmo irideus* (GIBBON), which was implanted by Mr. Ōya during 1916–1919, is now the most important fish in the Koikuchinoike group. They have been baited and artificially propagated by the hatchery on the shore of Koikuchinoike.

The pond smelt, *Hypomesus olidus* (PALLAS), was first introduced into Ochikuchinoike and Koikuchinoike from Lake Kogawara of Aomori Pref. by Dr. S. Kokubo and the present author in 1942 and again in 1943, from Lake Suwa, Nagano Pref. by Dr. S. Kokubo. Recently the pond smelts were proved to propagate successfully in this lake as their large shoals have often been seen around the shore.

Since 1940 Kokubo & Kawamura have studied the hydrographic conditions and the plankton of these lakes. Concerning the rainbow trout, they have become aware of the fact that the yield of trout in this lakes was not only becoming very poor but also that the body size of individuals was being greatly reduced, resulting in distaste. They were of opinion that the trout could not have got satisfactory food. *Diaptomus* and *Daphnia* and other plankton Crustacea abundantly inhabit the lake, but these are so small in size that the adult trout may not be able to retain them by their coarse gill rakers. There may be an ecological gap in the food chain between rainbow trout and food plankton. The gap must be bridged by some moderate-sized organisms which feed on smaller plankton and are themselves available food for trout. Dr. S. Kokubo and the present author have attemped to implant the pond smelt into this lake for the above reason. In the present observation it is proved that by the successful implantation of pond smelts the nutrition of the trout has gradually been improved.

2. Feeding Habit of Fish

The feeding habits of rainbow trout and pond smelt have been observed in Koikuchinoike in various seasons.

Rainbow trout: Fifty fish were collected during spawning season, i.e., April-May, and their stomach contents were examined. It was found that the stomachs were always nearly quite empty, only a few insects being contained in some stomachs. However, in the stomachs of 50 fish (body length 18~30 cm) collected during July

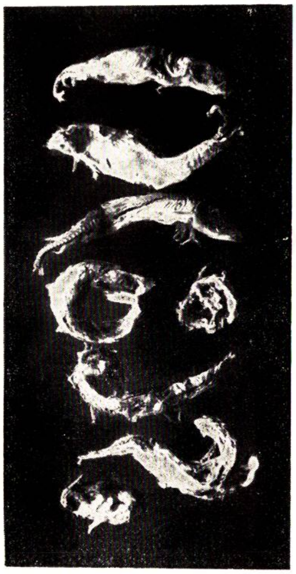

Fig. 27.

Fig. 28.

Fig. 27. Bodies of pond smelts, *Hypomesus olidus*, found in the stomachs of rainbow trouts, *Salmo irideus*, caught from Koikuchinoike in July-August, 1952

Fig. 28. Stomach content of pond smelts, *Hypomesus olidus*, caught from Koikuchinoike on Aug. 15, 1952, comprising principally by a daphnid, *Bosmina longirostris*

to August, ample food was found, of which 80% was mysids, "Isaza" in Japanese, *Neomysis* sp., which had been thrown to the lake for their feeding. The remaining 5% were plankton and insects, the remainder being uncertain materials. The stomach samples of rainbow trout contained 32 individuals of pond smelt in all, that is to say, 0.6 pond smelts per one rainbow trout on an average (Fig. 27).

Pond smelt: The stomach content of 200 individuals of pond smelts caught on April 15 was composed of 20% of their own eggs with, in addition, a little quantity of some insects and 80% of uncertain materials. Zooplankton was scarcely found in their stomachs at that time. On May 15, the stomach content of pond smelts was composed of 25% bait mysids, 10% plankton (*Synchaeta*) and 65% uncertain materials. On June 15, it was composed of 40% bait mysids, 30% plankton (*Synchaeta, Polyarthra* and *Bosmina*) and 30% uncertain materials. On July 15, 55% zooplankton (*Bosmina* and *Cyclops*), 40% bait mysids and 5% uncertain materials were found. On August 15, the food was composed of 65% zoolpankton (*Bosimina* and *Cyclops*), 30% bait mysids and 5% uncertain materials. (Fig. 28).

Generally speaking, the principal plankton which serve as food of the pond smelts are *Bosmina longirostris*, *Cyclops vicinus*, *Synchaeta oblonga* and *Polyarthra trigla*. Although the composition of food varies with season, *Bosmina longirostris* is the most important food throughout the seasons.

Concerning the food of pond smelt, many studies have been made. Sakurai & Sakai (1943) observed that pond smelts caught from Lake Chimikeppu contained many adult *Chironomus* and *Bosmina longirostris* in their stomachs during the summer period. Kitazawa & Ito (1948) also found that the same fish taken from Lake Suwa under ice cover in January-March mainly has many *Chironomus* larvae and other small benthic animals in their stomachs. Miyauchi (1934) observed that the stomachs of pond smelts from Lake Kasumigaura contained mainly larval fishes. On the other hand, Tomita (unpublished) reported that the pond smelts caught from Lake Akan in August were separable into two groups according to their stomach contents. One group of this fish mainly fed on zooplankton (*Daphnia* and *Bosmina*), while the other fed exclusively on phytoplankton (diatoms and cyanophyceae). Moreover, Ishida (1949) investigated the feeding habit of pond smelt in Lake Abashiri, and reported that *Neomysis, Cyclops, Bosmina, Diaphanosoma, Pseudodiaptomus, Sinocalanus*, larvae of fish and some forms of benthos were caught by the pond smelts as the principal food, but the Rotifera and phytoplankton abundantly inhabited this lake were entirely absent in the stomachs of pond smelts. An investigation on a favorite food for young larvae of pond smelt was made by Sato in 1950 in Lake Kogawaranuma. He stated that the food organisms of larval fish, *Brachionus* (a small Rotifera), was replaced by larger plankton, e.g., *Bosmina, Moina* and *Cyclops*, as the fish grew. On the other hand, he maintained that the adult fish of pond smelt took any zooplankton whenever they were abundantly present within reach (private communication).

As mentioned above, different authors have reported different findings concerning the feeding habit of the pond smelt, but it is no wonder that the feeding habit of the fish may change under different circumstances.

Ishida (1949) stated in the observation at Lake Abashiri that the inhomogeneous distribution of food plankton of pond smelts might be reflected in the different composition of the stomach contents of the fish caught in the same fishing net. However, in Koikuchinoike no difference in the stomach contents of the pond smelts which were caught at one time was found, *Bosmina longirostris* always composing the main part of contents.

Of the plankton of Koikuchinoike group, two important species as the food of pond smelt, viz., *Acanthodiaptomus pacificus* and *Daphnia longispina* have occurred in the earlier observations (Kokubo & Kawamura, 1940c, 1941c; Kokubo, 1941). However, these two species have nearly disappeared after the implantation of pond smelt as described elsewhere. It has been stated that some of plankton Crustacea, which had grown abundantly, suddenly diminish in number for a year, finally nearly entirely disappearing form the lakes, as proved on the *Acanthodiaptomus pacificus* (*A. yamanacensis*) in Lake Yamanaka and Lake Shikotsu (Motoda, 1953). It is well known that in certain lakes the amount of certain species of plankton almost disappeared over a long period, often lasting more than several years, for unknown reasons though probably because of some chemical, physical or biological causes. The change of the plankton population of the present lakes is supposed to provide such an example. As a biological cause it is believed in all probability that the pond smelt implanted since the time of earlier studies must have devoured these plankton throughly, thus, giving rise to the complete extinction of the above two species, *A. pacificus* and *D. longispina.*

In a preceding page it was stated that in Koikuchinoike the pond smelt is being eaten by the rainbow trout. As to the pond smelt serving as the food of other fishes, Hata & Takeda (1941) observed that in Lake Ashinoko also the pond smelt is being eaten by black bass (*Micropterus salmoides* LACÉPÉDE). A like case that in many rivers of Hokkaiko the rainbow trout was feeding on young salmon (*Oncorhynchus keta* (WALBAUM)) was reported by Kubo (1946). Some authors noted that benthos such as insect larvae serve as the food of the rainbow trout. In the present study, however, no benthos was found in the stomachs of either the rainbow trout or the pond smelt. This is probably due to the existence of anaerobic layer in the bottom of the lake which must have checked the migration of the fish. From above results, it is evident that the pond smelt is now an important food for the rainbow trout, and that *Bosmina longirostris* is a splendid source of food for a plankton feeder such as the pond smelt.

VII. GENERAL CONCLUSION

ON THE basis of the temperature of surface water during the months from May to

October, these lakes can be divided into three groups, viz., the low temperature lakes (11–20°C) the intermediate temperature lakes (13–23°C) and the high temperature lakes (14–24°C). The first group includes three lakes, Nigoriike, Ketobanoike and Ochikuchinoike. The second group includes Higurashinoike, Koikuchinoike, Oike and Hakkeinoike; the third group, Daiike, Menkozakanoike and Itobatakenoike.

The thermocline comes into existence probably in early spring. It is clearly formed in all lakes (except Nigoriike) by May, and in October it is reduced by the circulation of water. In August the position of the thermocline is generally between the surface and 10 meter layers, its thickness ranging from 2 meters to 10 meters. The position of thermocline varies with lakes, having a tendency to descend in lakes such as Daiike, Menkozakanoike, Itobatakenoike and Ochikuchinoike owing to the influence of wind or of cold spring water which pours from the side of basin or shore. In August the hypolimnion is isolated from the epilimnion by the developed thermocline. The volume of water in the hypolimnion measuers from 90% to 50% of the whole volume, occupying a large percentage in the deep lakes.

Under such conditions, a remarkable low temperature (about 4°C), which is equal to that of 100 meter depth in the ordinary deep lakes in Japan, is maintained in the bottom layer (22–28 meter depth) of the deep lakes of this group. On the other hand, the abnormal thermal stratification, i. e., "poikilothermy" or "mesothermy" or "katothermy" comes into existence in such deep lakes as Daiike, Koikuchinoike and Ōike. The low temperature and the abnormal stratification in the deep layer result from the continued presence of cold water which has remained since the previous autumnal overturn owing to difficulty of complete mixing of lake water during the spring circulation.

Color of lake water as expressed by Forel's scale is rather high in all the present group of lakes, and the transparency of water is naturally rather low in general. These attributes depend upon the high concentration of plankton organisms. The mean value of transparency ranks in the order Higurashinoike, Hakkeinoike, Nigoriike, Itobatakenoike, Ketobanoike, Koikuchinoike, Daiike, Ōike, Ochikuchinoike and Menkozakanoike. It follows that the trophogenous zone measures from 40% to 85% of the whole volume, the large value being in the deep lakes such as Daiike, Higurashinoike, Koikuchinoike, Ōike and Menkozakanoike.

The stratification of dissolved oxygen is distinctly formed in the summer period. A large amount of dissolved oxygen due to the photosynthesis of phytoplankton population occurs mainly within the metalimnion. A remarkable super-saturation of oxygen appears generally in Nigoriike, Daiike, Ketobanoike, Koikuchinoike and Ōike. Above all, 198% saturation or 14.22cc/1 content of dissolved oxygen is the largest. From this downwards the dissolved oxygen decrease rapidly with depth. Thus, an anaerobic layer developed due to the decomposition of remains of plankton organisms is formed in the bottom layer in all lakes. The anaerobic layer develops particularly well in the deep lakes. Daiike probably ranks first in order to thickness of anaerobic layer among all lakes in Japan. In the winter period super-saturation of dissolved oxygen is seen in the layer just below the ice cover, and the micro-stratification of dissolved oxygen comes into existence in the bottom layer. Judging from the above fact, it is maintained that the microstratification of dissolved oxygen is already formed at the bottom in winter in these deep lakes.

The stratification of hydrogen ion concentration is remarkably formed. The high pH value occurs generally within the metalimnion, its position corresponding to the layer of large amount of dissolved oxygen.

According to the average pH value through all depths, the lakes may be divided into hard-water and soft-water groups. In the former group are included Higurashi-noike, Ketobanoike, Ochikuchinoike, Koikuchinoike, Ōike and Hakkeinoike, and in the latter group Nigoriike, Daiike, Menkozakanoike and Itobatakenoike. In some of the soft-water lakes (Daiike and Menkozakanoike) a reversal of pH value is observed in the hypolimnion.

The number of plankton species collected from these lakes is 70 in total through all seasons. This number is not far different from that of the previous record. The number of plankton species differs greatly with lakes, ranging from 43 species in Hakkeinoike to 24 species in Ketobanoike. Generally, the number is large in warm-water lakes and small in cold-water lakes.

The occurrence of some zooplankton species in the lakes shows apparent correlations between the degree of water temperature and temperature preference of plankton species. *Mesocyclops oithonoides*, *Keratella cochlearis* var *irregularis*, *K. quadrata* f. *divergens*, *Ploesoma truncatum* and *Pedialion mirum* indicate the warm-water condition of the lakes, while, *Keratella cochlearis*, *K. quadrata* f. *quadrata* and *Polyarthra trigla* the cold-water condition of the lakes.

The maximum concentration of plankton is generally found within the metalimnion in the summer stagnation period. The phytoplankton remains in the metalimnion probably owing to the presence of effective light and to the high stability of lake water. A majority of individuals of *Mesocycolps oithonoides* and *Bosmina longirostris* appear in the warm water of the upper layer, whlie *Cyclops vicinus* and *Eucyclops prasinus* often occur abundantly in the cold water below the metalimnion.

A certain zooplankton, for instance Rotifera, crowds in the layer just above the anaerobic layer. This is supposed to have relation to the availability of food.

The high plankton productivity of the Tsugarujuniko Lake Group leads to the conclusion that this lake group is of eutrophic type. This is, of course, true when all lakes of this lake group are considered altogether. However, in detail, the ten lakes studied in the present work differ greatly in respect to the presence of plankton. The difference is correlated with their hydrological and morphological conditions. While the number of plankton species is large in the high temperature lakes and small in low temperature or in intermediate lakes, the quantity of plankton is more abundant in the cold-water lakes than in the warm-water lakes, especially than that in the seepage lakes, Menkozakanoike and Itobatakenoike. In other words, the plankton productivity is high in drainage lakes, to which the low temperature and intermediate temperature lakes belong, while it is low in the seepage lakes such as Menkozakanoike and Itobatakenoike owing to the lack of necessary nutrient substances for the growth of phytoplankton. The present ten lakes rank in trophic order as follows : Koikuchinoike, Ketobanoike, Nigoriike, Ochikuchinoike, Higurashinoike, Ōike, Hakkeinoike, Daiike, Itobatakenoike and Menkozakanoike.

On the basis of productivity of plankton, these lakes can be separated into three groups, eutrophic, oligotrophic and mesotrophic. To the first group belong Koikuchinoike, Ketobanoike and Nigoriike. The second group includes Menkozakanoike, Itobatakenoike and Daiike, while Higurashinoike, Ochikuchinoike, Ōike and Hakkeinoike belong to the third group.

From the above trophic order, it follows that in the present lakes the large volume of trophogenous zone does not always mean the high productivity of plankton. This is true because of the lack of necessary nutrients for the growth of phytoplankton.

In Koikuchinoike the important food organism for the pond smelt is, at present, *Bosmina longirostris* which is found in great abundance throughout the seasons, and the pond smelt is in turn important as the principal food for the rainbow trout. The culture of rainlow trout was carried out in Koikuchinoike lake group, but the result was far from being successful because of the gap in the food chain between plankton and rainbow trout. It is proved that this gap was bridged by transplanting the pond smelt, which feeds exclusively on plankton and falls prey, in turn, to rainbow trout. Since the implantation of pond smelts was done the culture of trout in these lakes has been greatly improved.

Except Menkozakanoike and Itobatakenoike which are oligotrophic in type, the lakes in the present group, are considered to have potential utility for the culture of rainbow trout, with implantation of some intermediate animal such as the pond smelt. Otherwise it will be better to implant "Himemasu", *Oncorhynchus nerka*, which feeds directly on plankton. This fish can retain such tiny plankton as *Bosmina longirostris* by its very fine gill rakers. As "Himemasu" is an inhabitant of cold water, the culture in the present lakes may promise success.

VIII. SUMMARY

(1) Limnological and biological studies on the principal ten lakes of the Tsugarujuniko Lake Group, Aomori Prefecture, Japan, (Nigoriike, Daiike, Menkozakanoike, Itobatakenoike, Higurashinoike, Ketobanoike, Ochikuchinoike, Koikuchinoike, Ōike and Hakkeinoike) were carried out in spring, summer, autumn and winter during the

period from May, 1952 to February, 1953.

(2) The relationship between the hydrographic conditions and the morphological patterns of each lake was discussed.

(3) The seepage lakes, such as Menkozakanoike and Itobatakenoike, showed high surface temperature, ranging from 14°C to 24°C in May-October. On the other hand, the drainage lakes, such as Nigoriike and Higurashinoike, and the lakes of the Koikuchinoike sub-group showed intermediate or low surface temperature, ranging from 13°C to 23°C and from 11°C to 20°C in May-October respectively.

Remarkable thermal stratification was commonly formed in all lakes. In May and August, it generally occurred between surface and 10 meter depth and in October between 6 and 13 meter depths.

Bottom temperatures ranged from the maximum of 10.63°C to the minimum of 4.05°C throughout the lakes from May to October. The very low temperature was obtained in the deep layer of the deep lakes as Daiike, Koikuchinoike and Ōike, where the temperature was almost the same as that observed at about 100 meter depth in deep lakes of Japan.

Abnormal thermal stratification, "poikilothermy", "mesothermy" or "katothermy", came into existence due to chemical stratification in the hypolimnion in Daiike and probably in Koikuchinoike and Ōike.

In winter the surface temperature under the ice cover showed below 1°C, but the bottom temperature was almost similar to that in the summer period.

(4) The reading of Forel's scale was rather high throughout the lakes, ranging from No. 7 to No. 11. It was highest in Higurashinoike, and lowest in Menkozakanoike. The transparency of water was rather low, the Secchi-disk reading ranged from 0.8 meters to 6.5 meters through all lakes. High value was obtained in Ketobanoike, Koikuchinoike, Ōike, Hakkeinoike and Daiike, and low value was seen in Ochikuchinoike, Menkozakanoike and Itobatakenoike.

(5) A remarkable stratificatin of dissolved oxygen was observed. The maximum amount of dissolved oxygen (per liter) throughout the lakes, ranged from 7.05cc to 11.62cc (98.3 to 145.1% saturation) in May, from 5.21cc to 14.22cc (90.8 to 198.3% saturation) in August, and from 6.42cc to 8.96cc (90.2 to 119.5% saturation) in October. Over-saturation of dissolved oxygen was observed at the metalimnion in Ōike, Ketobanoike and Nigoriike, while in Menkozakanoike, Ochikuchinoike and Hakkeinoike the saturation percentage was a little smaller, showing 100% or thereabouts.

The anaerobic layer occurred in all lakes, especially remarkably in such deep lakes as Daiike, Koikuchinoike and Ōike. The percentage volume of water of the anaerobic layer to the total amount of lake water was 35% in Daiike, 30% in Koikuchinoike and Ōike, 15% in Hakkeinoike, 10% in Itobatakenioke, Higurashinoike and Ochikuchinoike, 5% in Ketobanoike and less than 1% in Menkozakanoike and Nigoriike.

(6) A remarkable stratification of pH value occurred in the present lakes. The maximum position of pH value appeared above 6 meter layer coinciding to the growth layer of such phytoplankton as *Asterionella formosa*, *Synedra ulna*, *S. acus*, *Anabaena* sp. and *Ceratium hirundinella*. Generally, the pH value was high in Ōike, Higurashinoike and Ketobanoike, while it is lowest in Daiike, Menkozakanoike and Itobatakenoike.

A reversal of pH value in the anaerobic layer was observed in Daiike and Menkozakanoike, but in other lakes no reversal was observed. It is supposed that the water of Daiike, Menkozakanoike and Itobatakenoike is more or less softer than that of other lakes, so that the buffer activity of water is possibly more reduced, and thence the pH value is reversed in the anaerobic layer in which oxidation no longer takes place.

(7) A total of seventy species of plankton in plant and animal forms were identified from the present lakes. The dominant species of zooplankton were *Bosmina longirostris* and *Keratella cochlearis*. The majority of phytoplankton was comprised of diatoms, of which *Asterionella formosa*, *Synedra acus* and *S. ulna* were dominant. Besides these, *Ceratium hirundinella* and a few species of *Anabaena* occurred in abundance in certain lakes.

The number of species of plankton differed greatly with lakes ; the difference was generally correlated to the temperature of water. In Hakkeinoike 43 species occurred, in Koikuchinoike 39 species, in Daiike and Menkozakanoike 38 species, in Itobatakenoike and Ōike 37 species, in Higurashinoike 34 species, in Ochikuchinoike 32 species, in Nigoriike 31 species and in Ketobanoike 24 species. Thus, number of species was, on the whole, large in warm-water lakes and small in cold-water lakes.

(8) In Contrast with the number of species, the amount of plankton volume as estimated by quantitative sampling was large in the drainage lakes, possessing water under cold or intermediate temperature conditions. The water of these lakes was assumed to be hard because of its comparatively high buffer value.

(9) The occurrence of animal plankton in relation to the temperature of water was discussed. The presence of *Mesocyclops oithonoides*, *Keratella cochlearis* var. *irregularis*, *K. quadrata* f. *divergens*, *Ploesoma trunctum* and *Pedialion mirum* indicated the warm-water condition of lake, while the cold-water condition of lake was characterized by the existence of *Keratella cochlearis*, *K. quadrata* f. *quadratà* and *Polyarthra trigla*.

(10) The maximum population of plankton, both phyto- and zooplankton, occurred mainly within the thermocline at times. In certain cases, most of *Mesocyclops oithonoides* and *Bosmina longirostris* were distributed in the warm upper layer, whilst *Cyclops vicinus* and *Eucyclops prasinus* often showed their maximum occurrence in the cold water layer below the metalimnion. The zooplankton, especially the Rotifera, crowded in the depth just above the anaerobic layer probably for seeking out their food.

(11) The amount of the net plankton was estimated. It was found that these

lakes differed greatly in that respect. The dry weight of plankton per hectare of surface area ranged from 125.4 kg in Koikuchinoike to 1.5 kg in Menkozakanoike. The trophic degree of these lakes as calculated from the amount of net plankton ranked them in order as follows: Koikuchinoike, Ketobanoike, Nigoriike, Ochikuchinoike, Higurashinoike, Ōike, Hakkeinoike, Daiike, Itobatakenoike and Menkozakanoike. Three main groups may be classified: i.e., the eutrophic type included Koikuchinoike, Ketobanoike and Nigoriike, the mesotrophic type Higurashinoike, Ochikuchinoike, Ōike and Hakkeinoike, the oligotrophic type Daiike, Itobatakenoike and Menkozakanoike.

(12) The ecological gap in the food cycle between plankton, mainly *Bosmina*, and the rainbow trout of Koikuchinoike has been bridged since 1942 by implanting there the pond smelt. Since then the nutrious environment of rainbow trout has been proved to be greatly improved.

(13) At present, in Koikuchinoike the pond smelt subsist on *Bosmina longirostris*, while the pond smelt in turn fall prey to the rainbow trout. Thus the main food chain is established between these three major groups.

(14) The lakes of Nigoriike and Hakkeinoike can be also utilized for the purpose of rainbow trout culture if the above ecological gap is bridged, or else other fishes having even more delicate gill rakers, such as "Himemasu", *Oncorhynchus nerka*, are expected to be successfully cultured.

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(* Inaccessible)

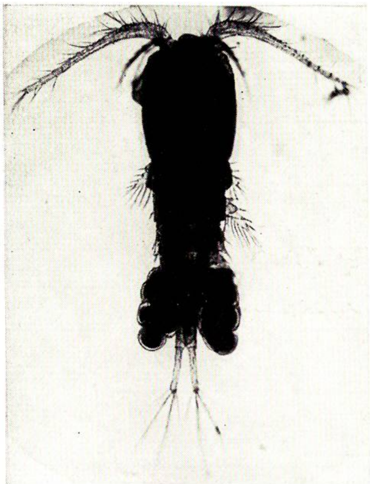
Plate I

Fig. 1.	*Cyclops vicinus* ULJANIN		♀, dorsal ×25
Fig. 2.	*Mesocyclops oithonoides* SARS	a.	♀, dorsal ×55
		b.	♀, posterior portion
		c.	♀, 5th foot
Fig. 3.	*Eucyclops prasinus* (FISHER)	a.	♀, dorsal ×65
		b.	♀, connecting band of 5th swimming feet
		c.	♀, 5th foot

Fig. 4. *Daphnia longispina* O. F. MÜLLER ×50

Fig. 5. *Bosmina longirostris* (O. F. MÜLLER) ×100

Fig. 6. *Tintinnopsis rotundata* JORGENSEN ×600



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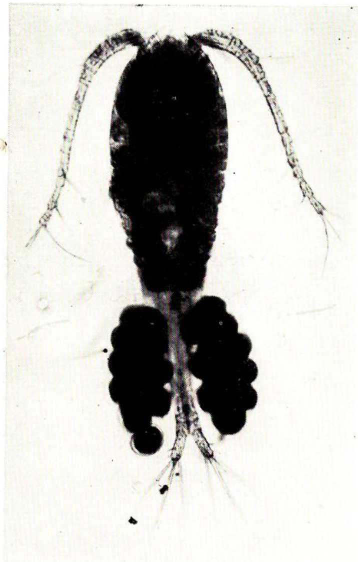

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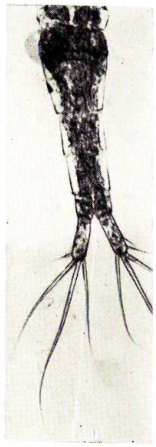

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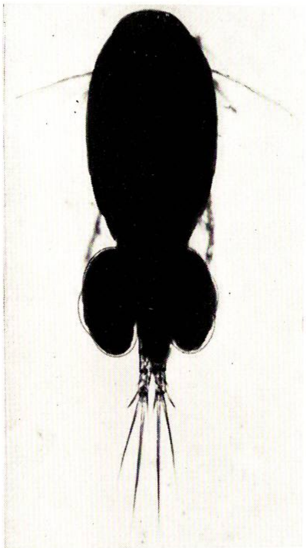

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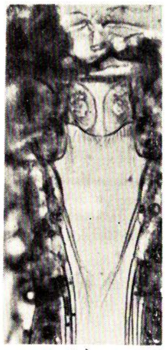

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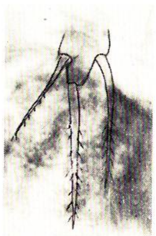

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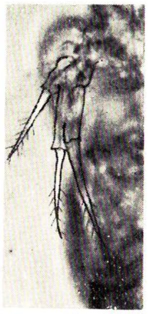

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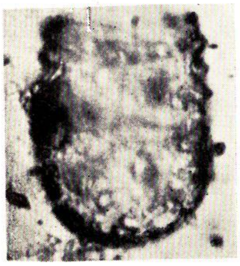

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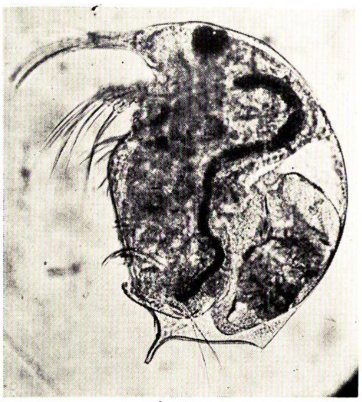

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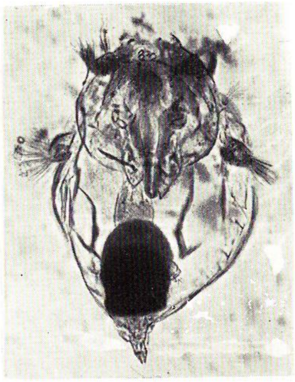
Plate II

Fig.	1.	*Tintinnopsis lacustris* ENTZ	×665
Fig.	2.	*Synchaeta oblonga* EHRENBERG	×145
Fig.	3.	*Polyarthra trigla* EHRENBERG	×220
Fig.	4.	*Diurella* sp.	×365
Fig.	5.	*Rattulus longiseta* (SCHRUNK)	×130
Fig.	6.	*Brachionus angularis* var. *bidens* PLATE	×285
Fig.	7.	*B. pala* f. *amphiceros* (EHRENBERG)	×190
Fig.	8.	*Keratella cochlearis* (GOSSE)	×390
Fig.	9.	*K. cochlearis* var. *irregularis* LAUTERBON	×400
Fig.	10.	*K. quadrata* f. *brevispina* (GOSSE)	×330

Plate II

1



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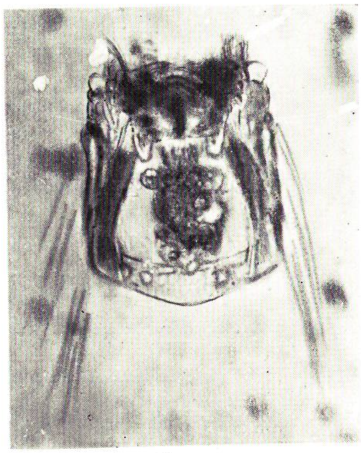

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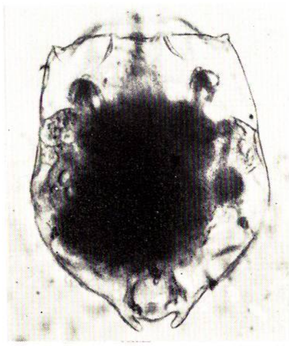

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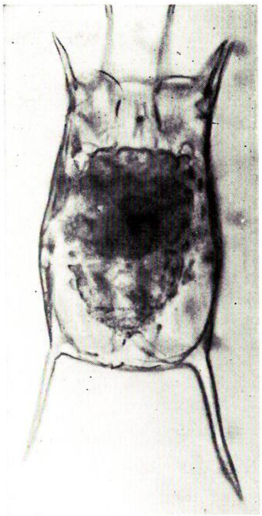
Plate III

Fig. 1.	*Keratella quadrata* f. *quadrata* (O. F. MÜLLER)	×470
Fig. 2.	*Notholca labis* GOSSE	×425
Fig. 3.	*Ploesoma truncatum* (LEVANDER)	×145
Fig. 4.	*Asplanchna priodonta* GOSSE	×95
Fig. 5.	*Conochilus unicornis* ROUSSELET	×310
Fig. 6.	*Filinia longiseta* (EHRENBERG)	×200
Fig. 7.	*Pedialion mirum* HUDSON	×165
Fig. 8.	*Pompholyx complanata* GOSSE	×330
Fig. 9.	*Glenodinium foliaceum* STAIN	×665
Fig. 10.	*Peridinium willei* HUITFELD-KAAS	×400

Plate III



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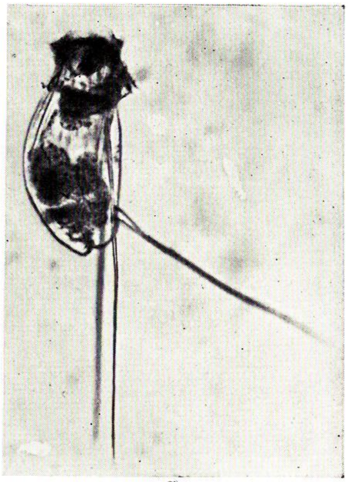

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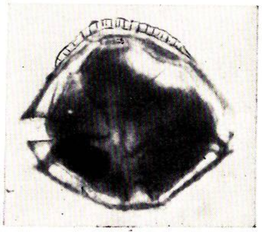

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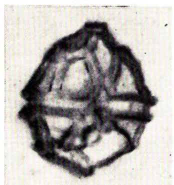

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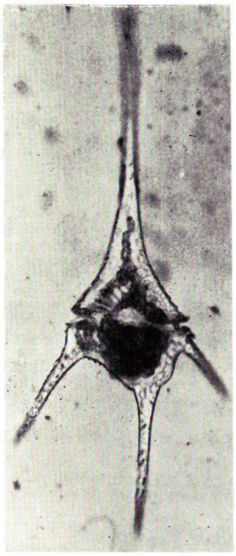
Plate IV

Fig. 1.	*Ceratium hirundinella* (O. F. MÜLLER)	
	a. three-horned type	×330
	b. two-horned type	×330
	c. resting spore	×470
Fig. 2.	*Dinobryon sertularia* EHRENBERG	×330
Fig. 3.	*D. divergens* IMHF	×450
Fig. 4.	*Melosira varians* AGARPH	×530
Fig. 5.	*M. italica* KÜZING	×470
Fig. 6.	*Attheya Zachariasi* J. BRUN	×470
Fig. 7.	*Tabellaria fenestrata* (EHRENBERG) KÜTZING	×365
Fig. 8.	*Fragilaria crotonensis* KITTON	×440
Fig. 9.	*F. construens* (EHRENBERG) GRUNNOW	×470

Plate IV



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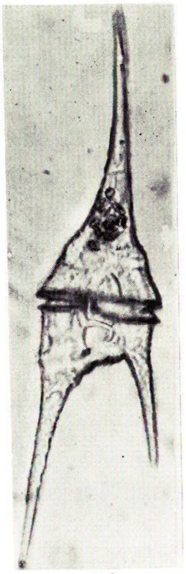

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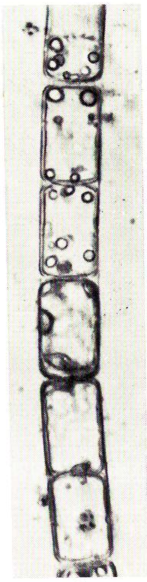

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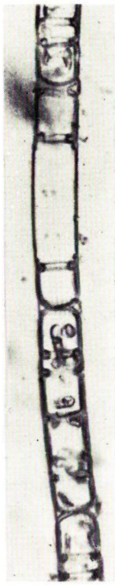

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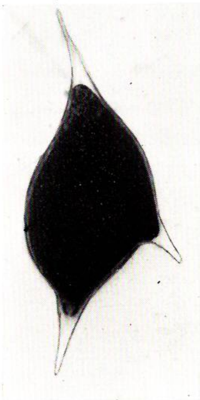

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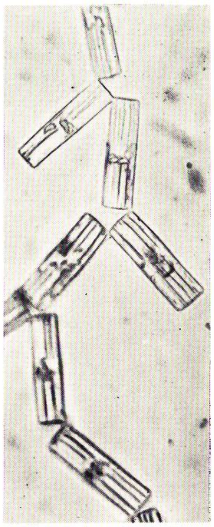

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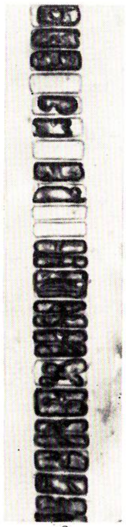

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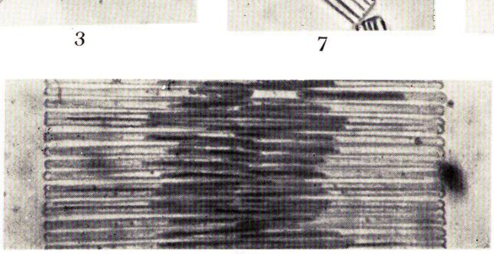

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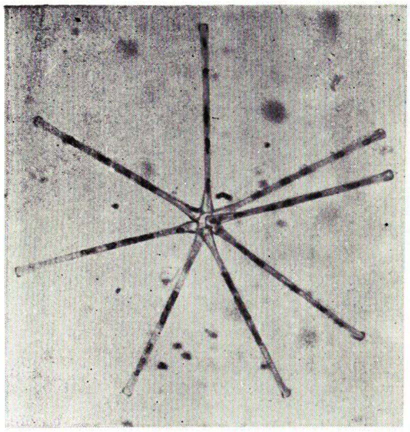
Plate V

Fig. 1.	*Asterionella formosa* HASSALL	a. star-shaped	×400
		b. cross-shaped	×530
Fig. 2.	*Synedra acus* KÜTZING		×340
Fig. 3.	*Gyrosigma accuminatum* (KÜTZING) RABENHORST		×360
Fig. 4.	*Pinnularia maior* (KÜTZING) CLEVE	a. valve	×365
		b. girdle	×365
Fig. 5.	*Cymbella lanceolata* (EHRENBERG) VAN HEURCK		×470
Fig. 6.	*Gomphonema constrictum* EHRENBERG		×570
Fig. 7.	*Rhopalodia gibba* (EHRENBERG) O. F. MÜLLER		
		a. valve	×400
		b. girdle	×400
Fig. 8.	*Surirella tenera* GREGORY	a. valve	×365
		b. girdle	×365
Fig. 9.	*Gomphosphaeria lacustris* CHODAT		×260

Plate V



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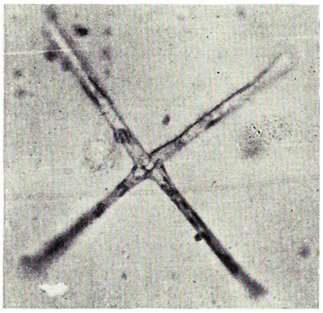

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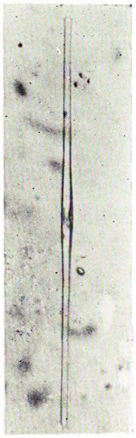

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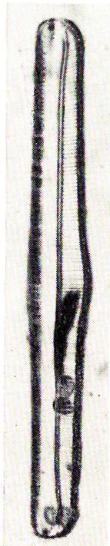

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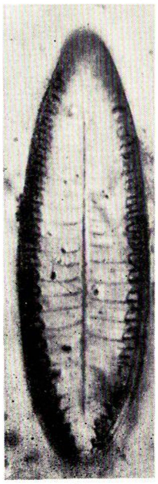

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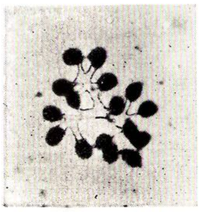

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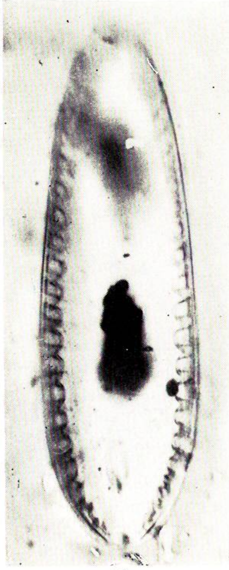
Plate VI

Fig. 1.	*Surirella Capronii* Brébisson	a. valve	×365
		b. girdle	×365
Fig. 2.	*Anabaena planctonica* Brunnthalar		×330
Fig. 3.	*A. spiroides* Klebahn		×400
Fig. 4.	*A. Lemmermanni* P. Richter		×330
Fig. 5.	*A. catenula* var. *intermedia* Griffiths		×440
Fig. 6.	*A.* sp.		×500
Fig. 7.	*Genicularia spirotaenia* Brébisson		×330
Fig. 8.	*Clostruim moniliferum* var. *concavum* Ehrenberg		×120
Fg. 9.	*Staurastrum paradoxum* Meyen		×580
Fig. 10.	*Docidium baculum* Brébisson		×70



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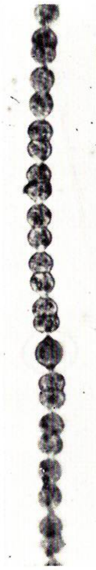

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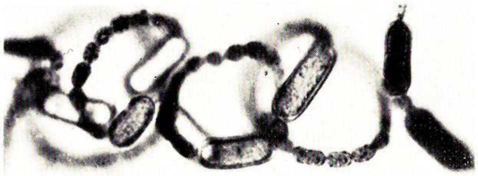

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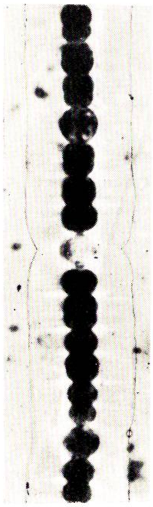

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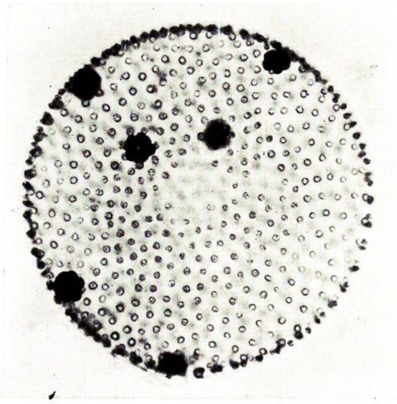
Plate VII

Fig. 1.	*Volvox aureus* EHRENBERG	$\times 170$
Fig. 2.	*Mougeotia* sp.	$\times 360$
Fig. 3.	*Pandorina morum* (O. F. MÜLLER) BORY	$\times 340$
Fig. 4.	*Eudorina elegans* EHRENBERG	$\times 210$
Fig. 5.	*Crucigenia rectangularis* (NÄGELI) GAY	$\times 330$
Fig. 6.	Statoblast of Bryozoa ?	$\times 210$

Plate VII



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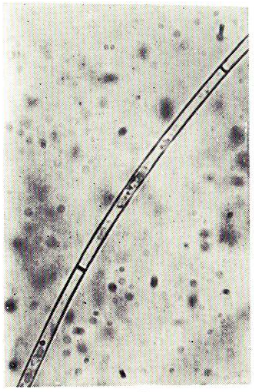

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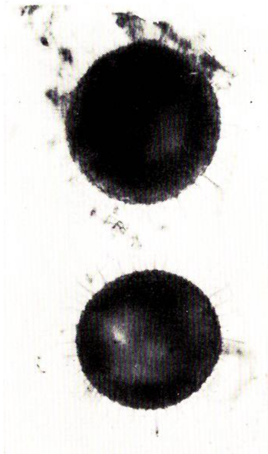

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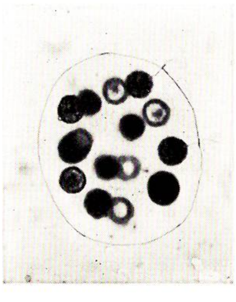

4

Table 1. Water temperature, transparency and water color in ten lakes of Tsugarujuniko Lake Group in 1952–1953

Depth (m)	Nigoriike Lake Group: Nigoriike V.16	VIII.27	X.21	Daiike V.16	VIII.27	X.21	Menkozakanoike Lake Group: Menkozakanoike V.17	VIII.28	X.21	Itobatakenoike Lake Group: Itobatakenoike V.18	VIII.28	X.22	Higurashinoike Lake Group: Higurashinoike V.18	VIII.29	X.22	II.21
0	12.18	15.85	11.37	14.30	23.24	15.01	14.28	23.37	15.89	15.47	23.90	14.23	17.66	22.70	13.79	0.79
2	11.96	10.80	10.55	14.09	22.87	14.51	13.60	23.27	15.55	14.24	23.04	14.25	13.75	21.44	13.69	3.85
4	11.45	9.94	9.79	13.65	17.08	14.39	13.39	23.16	15.40	13.89	18.59	14.25	11.39	15.06	10.79	3.92
6	10.63 (5m)	10.03 (4.5m)	9.67 (4.5m)	8.03	9.08	13.38	9.52	19.70	15.32	9.14	11.94	13.28	9.22	9.22	10.74	3.85
8				6.54	6.85	8.08	8.24	12.43	15.35	7.52	8.24	8.77	6.62	6.82	7.75	3.92
10				6.14	6.54	6.27	7.20	9.09	10.22	6.19	6.32	7.36	4.91	6.60	6.76	3.98
12				5.48	5.24	5.64	6.84 (11m)	8.68 (11m)	9.30 (11m)	4.97	5.33	5.67	4.91	5.04	5.16	3.98
14				5.02	5.00	4.95				4.84	4.97	5.19	4.54	4.05 (13m)		4.05 (13m)
16				4.56	4.42	4.57				4.61	4.94 (15m)					
18				4.18	4.31	4.35										
20				4.15	4.31	4.33										
22				4.36	4.22	4.16										
24				4.11	4.17	4.11										
26				4.02	4.08	4.11										
28				4.36												
Bottom (m)	5.5	5.0	4.7	28.5	27.0	27.5	12.0	12.0	12.0	16.5	15.5	14.5	14.3	13.6	13.0	13.0
Transparency (m)	3.0	2.0	1.3	4.0	4.0	5.0	5.0	6.5	6.0	3.0	3.0	2.5	0.8	2.0	2.0	-
Color of water (No.)	9	10	10	10	10	9	9	10	7	8	9	10	11	10	10	-

Depth (m)	Koikuchinoike Lake Group: Ketobanoike V.19	VIII.29	X.23	Ochikuchinoike V.21	VIII.30	X.23	Koikuchinoike V.21	VIII.30	X.24	II.20	Ōike V.21	VIII.31	X.24	Hakkeinoike V.22	IX.1	X.24	II.21
0	13.79	19.54	11.85	12.56	16.06	12.00	15.32	20.76 20.64	13.00 12.98	0.40	18.16	22.00	13.62	17.45	23.54 22.75	13.85	0.85
2	11.67	14.81	11.73	12.10	15.45	11.92	14.47	20.40 20.16	12.98 12.98	0.40	15.32	21.50	13.55	15.97	22.65 22.55	13.72	1.25
4	10.67	13.27	11.44	11.88	15.19	11.90	13.79	19.86 17.66	12.95 12.95	2.74	12.04	13.35	13.47	13.04	22.29 16.60	13.64	1.55
6	8.52	12.24	10.68	11.32	14.99	11.85	8.75	11.78 9.71	12.95 12.95	2.98	6.71	6.93	13.07	7.13	11.16 8.11	13.50	3.61
8	6.95	8.64	10.18	7.86	10.87	11.74	5.62	6.92 6.41	10.68 7.86	3.51	5.54	5.20	6.68	5.72	6.94 5.92	8.24	3.93
10	6.09	6.46	7.37	6.53	7.60	11.11	5.34	5.64 5.19	5.89 5.69	3.58	5.52	4.79	5.28	5.39	5.89	7.86	3.95
12	6.06	5.52	5.69	5.65	6.25	6.69	4.53	5.47 4.79	5.24 5.09	3.71	5.52	4.52	4.98				
14	5.60	5.14	5.39	5.25	5.78	5.97	4.66	4.79 4.45	4.81 5.05	3.82	4.49	4.52	4.85				
16	5.25	5.04	5.28	5.15	5.40	5.68	4.72	4.72 4.49	4.42 4.48	3.92	4.35	4.42	4.67				
18	4.95 (17m)	5.00	5.27	5.00	5.38	5.87	4.83	4.35 4.26	4.58 4.37	3.95	4.63	4.25	4.54				
20			5.12	5.00	5.38	5.57	4.41	4.26 4.26	4.22 4.40	4.10	4.44	4.37	4.51				
22							4.32	4.54	4.23	4.18	4.54	4.47	4.47				
24							4.05 (23m)				4.59	4.50	4.46				
26																	
28																	
Bottom (m)	18.5	18.5	21.0	20.5	20.3	20.2	23.0	22.5	23.0	23.0	25.0	24.0	24.0	11.0	11.0	11.0	11.0
Transparency (m)	1.0	5.0	3.0	6.0	4.3	6.0	2.0	3.0	4.4	-	2.0	4.0	6.3	1.0	2.5	2.0	-
Color of water (No.)	1.0	7	9	7	8	7	10	9	7	-	11	8	7	1.0	9	10	-

Table 3. Hydrogen ion concentration as represented by pH value in ten lakes of Tsugarujuniko Lake Group

Depth (m)	Nigoriike Lake Group: Nigoriike V.16	VIII.27	X.21	Daiike V.16	VIII.27	X.21	Menkozakanoike Lake Group: Menkozakanoike V.17	VIII.28	X.21	Itobatakenoike Lake Group: Itobatakenoike V.18	VIII.28	X.22	Higurashinoike Lake Group: Higurashinoike V.18	VIII.29	X.22	II.21
0	7.4	8.8	8.65	7.45	8.8	7.4	6.5	6.4	6.3	7.4	7.6	7.1	9.0	7.9	7.1	7.0
2	7.6	6.8	8.7	7.6	8.9	8.35	6.5	6.4	6.35	7.5	7.4	7.05	9.1	8.0	7.0	6.8
4	7.2	6.6	6.65	8.0	8.4	7.4	6.5	6.4	6.3	7.4	6.6	7.05	8.0	6.8	7.0	6.6
6	7.0 (5m)	6.6 (4.5m)	6.65 (4.5m)	8.2	7.8	7.0	6.5	6.3	6.2	7.7	6.7	6.4	7.0	6.5	6.3	6.6
8				7.3	6.8	6.5	6.3	6.2	6.25	7.4	6.6	6.4	6.8	6.4	6.2	6.6
10				7.0	6.4	6.4	6.0	5.8	5.9	6.5	6.5	6.4	6.5	6.4	6.2	6.6
12				6.6	6.5	6.4	6.0 (11m)	5.8 (11m)	6.0 (11m)	6.5	6.5	6.4	6.3	6.4	6.2	6.5
14				6.6	6.4	6.4				6.4	6.5	6.3	6.3	6.35 (13m)		6.45 (13m)
16				6.6	6.4	6.45				6.4	6.4 (15m)					
18				6.6	6.4	6.5										
20				6.5	6.4	6.4										
22				6.5	6.4	6.4										
24				6.5	6.4	6.4										
26				6.6	6.4	6.4										
28				6.5												

Depth (m)	Koikuchinoike Lake Group: Ketobanoike V.19	VIII.29	X.23	Ochikuchinoike V.21	VIII.30	X.23	Koikuchinoike V.21	VIII.30	X.24	II.20	Ōike V.21	VIII.31	X.24	Hakkeinoike V.22	IX.1	X.24	II.21
0	8.8	7.8	7.7	8.0	7.7	7.5	8.2	8.0 8.0	7.6 7.5	7.4	8.4	8.0	7.7	8.0	7.7 7.7	7.6	7.6
2	8.8	7.7	7.6	8.0	7.8	7.4	8.5	8.0 8.1	7.5 7.5	7.4	8.6	8.2	7.7	7.8	7.7 7.7	7.6	7.8
4	8.0	7.4	7.2	8.0	7.7	7.5	8.5	8.2 8.3	7.55 7.4	7.4	8.9	9.1	7.65	7.9	7.6	7.5	7.5
6	9.0	8.0	7.1	8.0	7.7	7.5	8.7	7.4 7.0	7.4 7.4	7.3	8.4	8.2	7.65	7.0	6.7 6.7	7.4	7.0
8	8.2	7.7	7.0	7.7	7.0	7.45	8.0	6.8 6.8	6.8 6.8	7.1	8.2	7.0	6.9	6.8	6.7 6.7	6.8	6.9
10	7.7	6.9	6.7	7.5	6.9	7.0	7.2	6.8 6.8	6.6 6.7	7.05	8.0	6.9	6.7	6.7	6.7	6.8	6.9
12	7.2	6.8	6.7	7.1	6.8	6.7	6.9	6.8 6.8	6.7 6.65	7.05	7.0	6.7	6.7				
14	6.9	6.7	6.6	6.9	6.8	6.7	6.7	6.8 6.8	6.6 6.6	7.05	6.8	6.7	6.7				
16	6.8	6.7	6.55	6.8	6.8	6.6	6.7	6.8 6.8	6.6 6.6	7.05	6.7	6.7	6.65				
18	6.8 (17m)	6.7	6.5	6.8	6.7	6.5	6.7	6.8 6.8	6.6 6.6	6.8	6.7	6.7	6.65				
20			6.4	6.6	6.65	6.45	6.7	6.8 6.8	6.6 6.6	6.7	6.7	6.65	6.65				
22							6.7	6.8	6.6	6.7	6.6		6.5				
24							6.7 (23m)				6.6		6.4				
26																	
28																	

Table 2. Content of dissolved oxygen and saturation percentage of oxygen in ten lakes of Tsugarujuniko Lake Group

Depth (m)	Nigoriike Lake Group: Nigoriike (cc/L) V.16	VIII.27	X.21	Nigoriike (%) V.16	VIII.27	X.21	Daiike (cc/L) V.16	VIII.27	X.21	Daiike (%) V.16	VIII.27	X.21	Menkozakanoike Lake Group: Menkozakanoike (cc/L) V.17	VIII.28	X.21	Menkozakanoike (%) V.17	VIII.28	X.21
0	7.43	9.67	9.95	100.8	142.0	132.7	6.94	6.30	6.42	98.6	106.8	92.5	6.54	5.21	6.42	92.9	93.4	94.3
2	7.39	2.67	9.42	99.9	35.2	123.3	7.16	6.41	6.63	101.3	107.9	94.6	6.83	5.28	6.74	95.7	89.5	98.4
4	7.39	1.41	2.03	98.7	18.2	26.7	7.21	9.12	6.53	101.3	137.3	92.7	7.05	6.08	6.74	98.3	102.9	98.0
6	6.51 (5m)	0.76 (4.5m)	0.90 (4.5m)	85.2	9.8	1.2	8.96	5.15	6.53	110.5	65.3	91.1	7.63	5.75	6.74	97.4	91.3	97.4
8							8.15	1.52	2.96	96.8	19.2	36.7	6.88	5.71	6.74	84.6	78.0	98.0
10							6.94	1.09	1.18	81.6	13.0	13.9	5.57	0.54	0.13	67.4	6.8	1.7
12							4.77	0.32	0	55.2	3.7	0	5.10 (11m)	0 (11m)	0 (11m)	61.1	0	0
14							3.47	0	0	39.7	0	0						
16							3.38	0	0	38.3	0	0						
18							2.49	0	0	27.9	0	0						
20							0.34	0	0	3.8	0	0						
22							0	0	0	0	0	0						
24							0	0	0	0	0	0						
26							0	0	0	0	0	0						
28							0			0								

Depth (m)	Itobatakenoike Lake Group: Itobatakenoike (cc/L) V.18	VIII.28	X.22	Itobatakenoike (%) V.18	VIII.28	X.22	Higurashinoike Lake Group: Higurashinoike (cc/L) V.18	VIII.29	X.22	II.21	Higurashinoike (%) V.18	VIII.29	X.22	II.21
0	6.40	5.21	7.32	93.3	90.8	103.7	7.59	6.19	6.42	9.19	115.7	103.9	82.5	94.1
2	6.83	4.99	6.00	96.7	84.1	85.2	8.80	6.30	6.42	6.47	123.6	90.8	90.2	72.0
4	6.51	3.26	6.74	91.7	50.8	95.7	7.16	6.30	6.31	5.48	95.5	90.8	86.2	61.0
6	8.40	3.36	5.29	106.3	41.4	73.6	7.05	1.85	1.54	5.00	89.4	23.5	20.2	55.6
8	8.08	0.87	0.11	98.4	10.8	1.4	6.40	0	0.27	5.00	76.2	0	3.3	55.6
10	3.92	0	0.11	46.2	0	1.3	4.57	0	0.05	4.94	52.2	0	0.6	55.1
12	1.07	0	0	12.2	0	0	1.75	0	0	3.83	20.2	0	0	42.7
14	0	0	0	0	0	0	0.11	0 (13m)		1.60 (13m)	1.2	0		17.9
16	0	0 (15m)		0	0									

Depth (m)	Koikuchinoike Lake Group: Ketobanoike (cc/L) V.19	VIII.29	X.23	Ketobanoike (%) V.19	VIII.29	X.23	Ochikuchinoike (cc/L) V.21	VIII.30	X.23	Ochikuchinoike (%) V.21	VIII.30	X.23
0	7.70	6.51	7.89	108.1	104.8	106.3	7.39	7.38	7.49	101.2	108.7	101.2
2	10.52	9.55	7.49	141.0	137.0	100.4	7.81	7.49	7.32	105.7	109.2	98.7
4	8.78	8.03	7.81	115.2	111.7	104.1	7.81	7.49	7.28	105.3	108.4	98.1
6	11.62	10.00	6.85	145.1	136.1	89.9	7.93	7.38	7.17	105.5	106.3	96.6
8	8.15	6.73	6.31	98.0	84.4	81.8	7.93	4.34	7.32	97.5	57.3	98.1
10	7.52	1.09	1.61	88.5	12.9	19.6	7.28	0.98	6.03	86.5	12.0	79.9
12	3.16	0	0.02	37.2	0	0.2	5.10	0.22	0.54	59.4	2.6	6.5
14	1.05	0	0	12.2	0	0	2.33	0	0	26.8	0	0
16	1.52	0	0	17.5	0	0	0.11	0	0	1.3	0	0
18	0.76 (17m)	0	0	8.7	0	0	0	0	0	0	0	0
20			0			0	0	0	0	0	0	0

Depth (m)	Koikuchinoike (cc/L) V.21	VIII.30	X.24	II.20	Koikuchinoike (%) V.21	VIII.30	X.24	II.20
0	6.51	6.30 6.41	6.74 6.74	9.46	94.9	102.6 103.6	93.1 93.1	94.9
2	7.39	6.73 7.16	6.81 6.85	10.00	105.4	108.2 114.6	94.1 94.6	100.3
4	7.39	7.28 8.69	6.68 6.81	9.89	103.8	115.7 132.5	92.3 94.1	106.6
6	9.56	7.81 5.43	6.81 6.63	9.15	120.3	105.3 68.5	94.1 91.6	100.3
8	7.61	2.93 1.52	2.46 0.17	7.44	88.3	35.2 18.1	32.3 2.1	81.3
10	6.29	0.21 0	0.17 0.15	6.91	72.5	0.02 0	2.0 1.7	76.3
12	2.63	0 0	0.13 0.11	6.74	28.6	0 0	1.5 1.3	74.6
14	1.01	0 0	0.11 0.11	5.85	11.5	0 0	1.3 1.3	64.9
16	0.85	0 0	0.11 0.06	4.79	9.7	0 0	1.2 0.7	53.3
18	0	0 0	0.06 0	1.66	0	0 0	0.7 0	18.5
20	0	0 0	0 0	0	0	0 0	0 0	0
22	0	0	0	0	0	0	0	0
24	0 (23m)				0			

Depth (m)	Ōike (cc/L) V.21	VIII.31	X.24	Ōike (%) V.21	VIII.31	X.24	Hakkeinoike (cc/L) V.22	IX.1	X.24	II.21	Hakkeinoike (%) V.22	IX.1	X.24	II.21
0	6.40	6.19	7.22	98.6	102.7	101.1	6.29	5.32 5.32	6.49	10.95	95.4	90.6 89.4	91.4	112.3
2	7.39	6.12	6.91	107.3	100.5	100.0	6.63	5.47 5.43	6.74	11.49	97.6	91.8 91.0	94.7	119.6
4	9.56	14.22	6.85	130.2	198.3	95.7	6.63	5.69 0.34	6.96	11.59	91.6	94.8 8.1	97.5	121.2
6	9.16	9.01	7.21	109.4	108.3	99.9	6.18	0 0	6.50	5.58	74.5	0 0	91.0	61.6
8	6.18	4.89	6.14	71.5	55.7	73.4	2.17	0 0	0	5.32	25.3	0 0	0	59.2
10	6.18	2.61	0.43	71.5	29.6	5.0	0	0	0	4.79	0	0	0	53.3
12	6.18	0	0.11	71.5	0	1.3								
14	4.01	0	0.06	45.3	0	0.7								
16	2.40	0	0.06	27.0	0	0.7								
18	0.18	0	0	2.0	0	0								
20	0	0	0	0	0	0								
22	0		0	0		0								
24	0		0	0		0								

Table 10. Relative abundance of plankton occurring in ten lakes of Tsugarujuniko Lake Group in various months

No.	Species	Nigoriike Lake Group						Menkozakanoike Lake Group			Itobatakenoike Lake Group			Higurashinoike Lake Group				Koikuchinoike Lake Group																
		Nigoriike			Daiike			Menkozakanoike			Itobatakenoike			Higurashinoike				Ketobanoike			Ochikuchinoike			Koikuchinoike				Ōike			Hakkeinoike			
		V.16	VII.27	X.20	V.16	VII.27	X.20	V.17	VII.28	X.20	V.18	VII.28	X.21	V.18	VII.29	X.21	I.21	V.19	VII.29	X.21	V.19	VII.29	X.22	V.21	VII.30	X.24	I.20	V.21	VII.31	X.24	V.22	IX.1	X.24	I.21
	Copepoda																																	
1	*Cyclops vicinus*	RRR	RRR	RRR	RRR	RRR	RRR	RRR	RRR			RRR			RRR			RRR	RRR	RRR	RR	RRR	RRR	RRR	RRR	RRR	RRR	RRR	RRR	RRR	RRR			
2	*Mesocyclops oithonoides*				RR	RRR	RRR			RRR			RRR																					
3	*Eucyclops prasinus*																	RRR			RR	RR	RRR	RRR	RRR	RRR	RRR	RRR	RRR		RRR	RRR		
	Copepodid of *Cyclops*	RR	RRR	RRR	RRR	RR	RRR	RRR	RRR	RRR	RRR	RRR	RR	RRR				RRR	RRR	RR	R	RRR	RRR	RRR	RR	RRR	RR	RRR	RR	RRR	RRR	RRR	RRR	
	Nauplius of *Cyclops*	RR	RRR	RRR	RRR	RR	RR	RRR	RRR	RRR	RRR	RRR	RRR	RRR				RRR	RRR	RRR	R	RRR	R	RRR	RR	RRR	RRR	RRR	RRR	RRR	RRR	RRR	RRR	RRR
	Phyllopoda																																	
4	*Daphnia longispina*																					RRR	RRR		RRR									
5	*Bosmina longirostris*	RRR	RR	RR	RR	R	R	RRR	+	R	RRR	R	R	RRR	RRR	R		RRR	R	R	RR	R		RR	R	R		RRR	C	RR	RRR	R	RRR	
6	*Alona rectangula*	RRR																														RRR	RRR	RRR
	Infusoria																																	
7	*Tintinnopsis rotundata*						RRR			RRR	RRR					RRR		RRR			RRR	RRR			RRR			RR		RRR			RRR	
8	*T. lacustris*						RRR									RRR																		
9	*Carchesium polypinum* ?	RRR																																
	Rotifera																																	
10	*Synchaeta oblonga*		RRR	RR																				RRR	RRR			RRR	RRR				R	
11	*Polyarthra trigla*	RRR	R	RRR	RRR	RR	RR	RRR	RRR	RRR	RR	RR	R	RR	RRR	R	R	RR	RRR	RRR	RRR	RRR	RRR	RRR	RR	RR	RRR	RRR	R	RRR	RR		RRR	R
12	*Diurella* sp.				RRR		RRR					RRR			RRR	RRR						RRR	RRR		RRR				RRR	RRR			RRR	RRR
13	*Rattulus longiseta*																																RRR	
14	*Brachionus angularis* var. *bidens*	R	RR	+	R	RRR		RRR			RR	RRR		RR																		RRR		
15	*B. pala* f. *amphiceros*												RRR																					
16	*Keratella cochlearis*		RRR	RRR	R	R	R	R	RRR	RRR	R	R	RRR	CC	RRR	RR	+	RR	+	RR	R	RR	RR	R	RRR	RR	+	RR	R	RR	R	RRR	RR	+
17	*K. cochlearis* var. *irregularis*											RRR							RRR										RRR					
18	*K. quadrata* f. *quadrata*				RRR			RRR			RRR	RRR		RRR			R		RRR	RRR	RRR	RRR		RRR	RRR	RRR	R	RRR			RRR	RRR	RRR	R
19	*K. quadrata* f. *divergens*					RRR			RRR			RRR																	RRR			RRR		
20	*K. quadrata* f. *brevispina*																							RRR			RRR							RRR
21	*Notholca labis*																RRR																	RRR
22	*Ploesoma truncatum*									RRR															RRR								RRR	
23	*Asplanchna priodonta*		RRR	R	RRR			RR			RRR			+	RRR	RRR		RRR	RRR	RRR	RRR		RRR	RRR			RRR	RRR	RRR		RR		RRR	
24	*Conochilus unicornis*							RRR	RRR	RRR		RRR	RRR																					
25	*Filinia longiseta*	RRR	C	RR	R	RRR		RRR			RRR	RRR		RRR	RRR		RRR	RR	RR	RR	R	R	RR	RRR		RRR	RRR			RRR		RRR		RRR
26	*Pedialion mirum*											RRR																				R	RRR	
27	*Pompholyx complanata*		RRR	RRR		RRR	RRR			RRR	RRR	RRR	RRR		RRR					RRR		RR		RRR	RR	RRR			RR	RR	R	RRR	RRR	
	Dinoflagellata																																	
28	*Glenodinium foliaceum*	RRR		RRR			RRR			RRR		RR	RRR		RRR							RRR		RRR					RRR	RRR		RRR		
29	*Peridinium willei*				RRR	RRR		RRR	RRR			RRR	RRR						RRR	RRR	RRR		RR		RRR	RR	RR	RRR		RRR		RRR		
30	*Ceratium hirundinella*		RRR	RRR	RRR	+	R	RRR	RRR	+	RRR	+	+	RR	CC	C	RRR	RRR	CC	+	RRR	+	+	RR	+	CC	RR	RR	C	+	R	+	R	RRR
31	*Synura uvella*										RRR																							
32	*Dinobryon sertularia*		RRR		RRR		RR	R		RRR	R		RRR		RRR	C	RRR			+	RRR		+	RRR		R		R	RRR	R	+	+	R	
33	*D. divergens*															+										R								
	Diatoms																																	
34	*Melosira varians*	RRR		RRR	RRR		RRR	RRR	RRR	RRR					RRR										RRR	RRR	RRR			RRR				
35	*M. italica*							R		RRR	RRR		RRR													RRR								
36	*Attheya Zachariasi*						RRR			RRR																								
37	*Tabellaria fenestrata*	RRR	RRR					R	RRR	RRR	RR		RRR	RRR			RRR						R		RRR	R	RR			C			RRR	R
38	*Fragilaria crotonensis*			RRR		RRR											RRR	+		RR	+	R	RRR	R	RRR		RRR	RR		RRR	RR			R
39	*F. construens*	C		RRR	R		RRR	RRR		RR	RRR	RRR	RRR	RRR						RRR	R	RRR	RR						RRR	RRR				
40	*Asterionella formosa*	C	R	RR	C	RRR	+	+	RRR	RRR	+	RR	RRR	R	RR		RR	C	RR	CC	+	C	C	+	CC	C		+	CC	CC	+	C	+	R
41	*Synedra ulna*	RRR	+	RRR	R	RRR	RR	RRR	RRR	RRR	RR	RRR		RR				CC	RRR	RRR	CC	RRR	RRR	CC	RRR	RR	RR	CC	R	+	CC	RRR	RR	RR
42	*S. acus*	R	R	+	+	RRR	+	+	RRR	+	C	RR	R	R	RRR	RRR	RRR	C	RR	RRR	+	RR	RRR	+	RRR	RR	R	RR	+	+	R	+	RRR	R
43	*Gyrosigma acuminatum*				RRR			RRR																							RRR		RRR	
44	*Navicula* spp.	R		RRR			RRR	RRR			RRR			RRR													RRR							
45	*Pinnularia maior*							RRR																										
46	*Cymbella lanceolata*							RRR	RRR																									
47	*C.* sp.										RRR																							
48	*Gomphonema constrictum*				RRR			RRR																										
49	*Epithemia zebra*	RRR		RRR			RRR													RRR	RRR	RRR			RRR	RRR				RRR				
50	*Rhopalodia gibba*			RRR			RRR	RRR														RRR	RRR	RRR		RRR	RRR			RRR				
51	*Surirella Capronii*				RRR			RRR																									RRR	
52	*S. tenera*	RRR		RRR	RRR			RRR		RRR												RRR										RRR	RRR	
	Cyanophyceae																																	
53	*Gomphosphaeria lacustris*		RRR	+	RRR	RRR	RRR																											
54	*Anabaena planctonica*		C	C	+	RRR	RRR	RRR							RR							RRR			RRR				RR		RRR			
55	*A. spiroides*													+										RRR	RRR			RR			R			
56	*A. Lemmermanni*		RRR								RRR			CC							R													
57	*A. catenula* var. *intermedia*														RRR	C	RRR	RRR																
58	*A.* sp.		RR						RR			RRR				CC	C							+	RRR			CC	RRR	R	CC	RRR	RRR	
59	*Lyngbya* sp.																																RRR	
	Conjugatae																																	
60	*Genicularia spirotaenia*			RRR						RRR											RRR	RRR	RRR							RRR			+	
61	*Clostrium moniliferum* var. *concavum*																																RRR	
62	*Docidium baculum*											RRR																						
63	*Staurastrum paradoxum*					RRR	RRR																RRR			RR	RRR			RRR				
64	*Mougeotia* sp.										RRR								RRR	RRR			RRR			RR			R	R		RRR	+	
	Chlorophyceae																																	
65	*Volvox aureus*				RRR																									RRR			RRR	
66	*Pandorina morum*				RRR		RRR				RRR						RRR	RRR		RRR			RRR	RRR		RR				RRR			RRR	RRR
67	*Eudorina elegans*	RR	RRR	RRR	RRR			RRR			RRR	RRR		RRR			RRR	RRR	RRR		RRR	RRR	RR	RRR	RRR	RRR	RRR	RRR		RRR			RRR	RRR
68	*Trochiscia* sp. ?										RRR			RRR												RRR				RRR	RRR			
69	*Crucigenia rectangularis*													RRR																				
70	*Characium longipes*																									RRR								
	Number of species	31			38			38			37			34				24			32			39				37			43			

Table 11. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Nigoriike on May 16, 1952

Number of individuals (or cells) per 20 liters of water

Plankton / Depth (m)	0	2	4
Cyclops vicinus	0	0	3
Copepodid of Cyclops	2	3	2
Nauplius of Cyclops	1	2	15
Bosmina longirostris	2	13	0
Alona rectangula	2	2	0
Filinia longiseta	0	0	100
Brachionus angularis var. bidens	410	700	410
Melosira varians	0	1400	0
Tabellaria fenestrata	230	380	200
Asterionella formosa	10800	12200	9300
Fragilaria construens	3400	3300	300
Synedra ulna	500	350	300
S. acus	14000	3400	1600
Surirella tenera	0	130	0
Eudorina elegans	500	1700	1500
Total of zooplankton	417	719	530
Total of phytoplankton	29430	19890	13200
Total of both	29847	20609	13730

Table 12. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Nigoriike on Aug. 27, 1952

Number of individuals (or cells) per 20 liters of water

Plankton / Depth (m)	0	2	4
Cyclops vicinus	0	0	4
Copepodid of Cyclops	1	5	11
Nauplius of Cyclops	0	0	3
Bosmina longirostris	1	53	67
Asplanchna priodonta	0	1000	0
Filinia longiseta	0	11600	6300
Polyarthra trigla	0	6200	2500
Brachionus angularis var. bidens	0	1200	0
Keratella cochlearis	0	1000	0
Pompholyx complanata	0	1000	0
Glenodinium foliaceum	0	1200	0
Fragilaria crotonensis	5300	0	0
Asterionella formosa	137500	18300	2200
Synedra ulna	690300	21000	4300
S. acus	74300	87500	56400
Anabaena planctonica	142300	7239000	5968700
A. Lemmermanni	5200	0	0
A. sp	1381500	10200	0
Dinobryon sertularia	18300	5300	0
Gomphosphaeria lacustris	0	9300	1300
Total of zooplankton	2	23258	8885
Total of phytoplankton	2454900	7390600	6032900
Total of both	2454902	7413858	6041785

Table 13. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Nigoriike on Oct. 21, 1952

Number of individuals (or cells) per 20 liters of water

Plankton / Depth (m)	0	2	4	4.5
Cyclops vicinus	0	0	5	6
Copepodid of Cyclops	1	1	17	23
Nauplius of Cyclops	0	0	4	5
Bosmina longirostris	0	5	11	7
Synchaeta oblonga	0	200	0	0
Brachionus angularis var. bidens	0	1600	2200	0
Polyarthra trigla	100	3000	3800	350
Asplanchna priodonta	0	150	0	0
Filinia longiseta	0	0	200	200
Pompholyx complanata	0	200	200	190
Glenodinium foliaceum	400	1100	1600	170
Ceratium hirundinella	0	200	0	0
Fragilaria crotonensis	520	0	0	0
F. construens	0	0	0	15000
Asterionella formosa	13000	7200	3500	1600
Synedra ulna	650	800	600	300
S. acus	13200	14800	12500	124100
Rhopalodia gibba	0	0	0	200
Anabaena planctonica	181800	23800	84400	16000
Gomphosphaeria lacustris	101500	78000	63400	18000
Total of zooplankton	501	6456	8037	950
Total of phytoplankton	310670	124600	164400	175200
Total of both	311171	131056	172437	176150

Table 14. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Daiike on May 16, 1952

Number of individuals (or cells) per 20 liters of water

Plankton / Depth (m)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28
Cyclops vicinus	0	0	0	0	3	3	2	2	2	1	4	1	1	1	1
Mesocyclops oithonoides	0	0	8	2	0	0	0	0	0	0	4	2	3	0	1
Copepodid of Cyclops	0	0	0	1	1	3	1	0	0	1	1	1	2	0	2
Nauplius of Cyclops	1	4	0	0	0	0	2	0	0	0	1	0	0	0	1
Bosmina longirostris	8	18	8	2	3	1	1	1	1	2	2	0	12	13	3
Polyarthra trigla	250	50	155	0	0	0	0	0	60	100	60	100	230	160	30
Dinochalis sp.	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachionus angularis var. bidens	1000	500	500	500	350	1400	400	600	60	160	330	100	400	260	760
Keratella cochlearis	500	750	1150	900	550	500	420	510	410	630	960	760	1130	260	500
K. quadrata	0	0	0	0	0	50	0	0	0	0	30	30	30	0	0
Asplanchna priodonta	50	100	50	50	0	0	0	0	0	0	0	0	0	0	30
Filinia longiseta	0	0	0	0	50	50	100	150	130	60	60	230	60	100	230
Peridinium willei	0	0	0	50	20	0	0	0	0	0	0	0	0	0	0
Ceratium hirundinella	20	100	500	650	70	45	30	25	30	40	30	20	20	20	20
Melosira varians	0	0	630	350	0	0	0	0	0	0	0	0	0	0	0
Fragilaria construens	1300	1000	2400	600	250	500	350	750	550	260	1000	460	760	460	630
Asterionella formosa	33900	43400	60100	37700	27000	24700	19000	28300	14400	29500	34600	28000	34500	35000	32000
Synedra ulna	·400	1200	1200	850	350	150	200	350	80	130	160	130	60	60	160
S. acus	33400	56300	105000	59500	34900	64100	39200	39300	63200	43900	33100	48600	45600	54400	73200
Surirella robusta	0	150	0	0	0	100	0	0	0	0	0	0	0	0	0
Eudorina elegans	350	500	150	250	100	50	100	0	20	0	30	0	60	100	30
Anabaena planctonica	0	31000	138700	31100	90000	53400	39700	90100	74000	51200	82700	33100	120800	62800	130300
Dinobryon sertularia	0	0	0	0	0	0	0	0	110	700	460	100	200	1900	2200
Gomphosphaeria lacustris	0	400	600	150	150	150	230	150	0	0	0	0	0	60	100
Total of zooplankton	1829	1622	2355	2155	1047	2042	956	1288	693	994	1482	1244	1899	814	978
Total of phytoplankton	69350	133950	308780	120500	152750	143150	98980	158850	152360	125690	152050	10390	201980	154720	238620
Total of both	71179	135572	311135	122655	153797	145192	99936	160238	153053	126684	153532	11634	203879	155534	239598

Table 15. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Daiike on Aug. 27, 1952

Number of individuals (or cells) per 20 liters of water

Plankton / Depth (m)	0	2	4	6	8	10	12	14	16	18	20	22	24	26
Cyclops vicinus	2	2	73	105	134	132	74	56	9	3	4	5	9	2
Mesocyclops oithonoides	10	165	87	50	27	9	9	2	12	7	5	4	3	3
Copepodid of Cyclops	5	120	66	333	122	284	64	34	17	13	9	16	6	25
Nauplius of Cyclops	2	29	2	12	366	349	30	37	43	27	4	21	13	15
Bosmina longirostris	90	1012	318	333	227	433	138	111	196	210	68	151	93	78
Polyarthra trigla	0	630	1200	200	0	200	400	200	400	0	400	600	600	100
Brachionus angularis var. bidens	0	430	800	0	0	0	0	0	0	0	0	0	0	0
Keratella cochlearis	0	0	2200	2200	2200	1400	800	2400	2400	1200	2200	1200	1600	1800
Filinia longiseta	1100	0	0	0	0	0	0	0	0	0	0	0	0	0
Pompholyx complanata	0	0	1400	0	0	0	100	0	100	0	0	100	0	0
Glenodinium foliaceum	0	0	400	200	0	0	0	400	400	400	400	100	1100	400
Ceratium hirundinella	1100	4200	23200	5600	4400	5200	2200	4800	6300	1800	3000	6600	4200	3600
Fragilaria crotonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	3800
Asterionella formosa	0	0	0	0	0	0	0	0	0	800	800	800	4200	12200
Synedra ulna	0	430	0	200	200	150	150	6600	600	11400	600	400	850	200
S. acus	4300	0	0	0	0	0	0	1200	450	1400	1000	400	4400	22800
Staurastrum paradoxum	0	0	0	0	0	0	0	0	0	0	0	0	0	250
Anabaena planctonica	0	450	6000	8500	0	7300	0	0	1100	1400	0	2800	3000	1400
Gomphosphaeria lacustris	0	820	400	400	0	0	0	0	0	0	0	0	0	0
Total of zooplankton	2309	6588	29768	9053	7976	8027	3815	8040	9877	3660	6090	8797	7625	6023
Total of phytoplankton	4300	1700	6400	9100	200	7450	150	7800	2150	15000	2400	4400	12450	40650
Total of both	6609	8288	36168	18153	8176	15477	3965	15840	12027	18660	8490	13197	20074	46673

Table 16. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Daiike on Oct. 21, 1952

Number of individuals (or cells) per 20 liters of water

Plankton / Depth (m)	0	2	4	6	8	10	12	14	16	18	20	22	24	26
Cyclops vicinus	0	3	8	13	22	28	1	4	4	4	5	0	1	4
Mesocyclops oithonoides	0	3	18	15	19	9	6	8	7	2	2	2	2	1
Copepodid of Cyclops	5	44	64	66	162	42	12	30	17	3	28	9	9	27
Nauplius of Cyclops	12	71	123	41	43	42	12	23	18	16	9	7	9	11
Bosmina longirostris	9	87	163	46	38	30	14	20	11	8	27	5	10	20
Tintinnopsis rotundata	0	0	0	0	0	0	0	0	0	0	400	0	0	0
Polyarthra trigla	1600	3200	1200	1200	1600	600	1200	0	0	200	200	200	1600	400
Keratella cochlearis	200	1000	3450	800	7200	2300	400	1600	840	400	400	600	1400	400
Pompholyx complanata	0	0	0	400	400	400	400	0	0	0	0	0	200	200
Glenodinium foliaceum	640	0	450	0	200	0	0	200	0	0	0	0	0	0
Ceratium hirundinella	200	1250	7300	17800	12200	2450	9600	2200	1650	1600	2800	1000	5600	1000
Melosira varians	0	0	0	0	0	0	0	0	0	0	0	0	0	6200
Attheya Zachariasi	200	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria crotonensis	0	0	0	0	5100	0	0	0	0	2200	0	0	0	0
F. construens	7000	0	0	0	0	0	0	0	0	0	0	0	0	0
Asterionella formosa	5800	4600	12200	2800	5800	7400	9000	1000	1800	2800	2400	2400	4200	1200
Synedra ulna	1400	800	800	200	200	0	0	0	180	0	0	400	200	200
S. acus	10000	8000	13400	7000	21600	27400	10800	7400	6200	7400	7400	10400	14600	7200
Anabaena planctonica	500	1000	0	0	0	0	0	0	0	0	0	0	0	0
Dinobryon sertularia	13600	44600	1400	13200	5600	1600	7200	0	3400	600	1200	0	0	2800
Gomphosphaeria lacustris	1200	1200	2400	200	600	1200	400	200	200	400	600	0	200	200
Total of zooplankton	2664	5658	12776	20381	21884	5901	11645	4081	2547	2233	3871	1823	8831	2063
Total of phytoplankton	39700	60200	30200	23400	38900	37600	27400	8600	11780	13400	11600	13200	19200	17800
Total of both	42364	65858	42976	43781	60784	43501	39045	12681	14327	15633	15471	15023	28031	19863

Table 17. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Menkozakanoike on May 17, 1952

Number of individuals (or cells) per 20 liters of water

Plankton / Depth (m)	0	2	4	6	8	10	11
Cyclops vicinus	0	1	10	1	0	0	0
Copepodid of Cyclops	0	1	0	0	2	1	0
Nauplius of Cyclops	1	0	0	0	1	3	0
Bosmina longirostris	0	1	3	1	1	2	0
Polyarthra trigla	0	0	20	0	0	0	0
Brachionus angularis var. bidens	360	200	60	160	130	160	0
Keratella cochlearis	70	130	100	60	30	200	130
K. quadrata	0	0	0	0	0	30	360
Asplanchna priodonta	0	0	0	0	0	100	200
Conochilus unicornis	0	130	0	0	0	0	0
Filinia longiseta	0	0	30	0	30	200	130
Peridinium willei	70	67	0	0	0	0	0
Ceratium hirundinella	0	30	0	0	0	0	0
Melosira varians	70	0	0	0	0	0	0
M. italica	160	0	100	0	660	0	12900
Tabellaria fenestrata	1000	360	1400	100	100	0	0
Fragilaria construens	0	0	0	0	0	0	2600
Asterionella formosa	5400	5900	3500	4200	4600	4200	12800
Synedra ulna	70	70	60	30	0	60	200
S. acus	20600	800	1000	800	600	800	3600
Gyrosigma acuminatum	0	0	0	0	0	30	0
Pinnularia maior	0	0	0	30	0	0	570
Surirella Capronii	0	0	0	0	0	0	1200
Anabaena planctonica	900	0	0	0	0	0	0
Eudorina elegans	0	30	0	0	0	0	0
Total of zooplankton	501	560	223	222	194	696	820
Total of phytoplankton	28200	7160	6060	5160	5960	5090	33870
Total of both	28701	7730	6283	5382	6154	5786	34690

Table 18. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Menkozakanoike on Aug. 28, 1952

Number of individuals (or cells) per 20 liters of water

Plankton / Depth (m)	0	2	4	6	8	10	11
Cyclops vicinus	0	0	0	0	0	1	0
Mesocyclops oithonoides	0	0	0	21	4	9	2
Copepodid of cyclops	2	9	9	34	27	15	4
Nauplius of cyclops	0	2	8	2	2	2	1
Bosmina longirostris	10	96	44	164	340	205	84
Conochilus unicornis	0	100	0	0	0	0	0
Polyarthra trigla	0	0	0	100	100	0	0
Peridinium willei	0	0	120	0	0	100	100
Ceratium hirundinella	550	320	200	0	0	100	100
Melosira varians	0	0	0	0	0	0	1100
Tabellaria fenestrata	0	100	600	100	0	0	0
Asterionella formosa	200	200	200	500	200	200	3100
Synedra ulna	0	0	0	0	700	300	10300
S. acus	750	550	300	100	500	0	1800
Anabaena sp.	0	0	0	6500	2100	0	0
Total of zooplankton	562	527	381	321	473	432	291
Total of phytoplankton	950	850	1100	7200	3500	500	16300
Total of both	1512	1377	1481	7521	3973	932	16591

Table 20. Full data on the indvidual (or cell) number of plankton organisms occurring at each depth in Itobatakenoike on May 18, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14	16
Copepodid of Cyclops	0	0	0	0	0	0	4	0	0
Nauplius of Cyclops	1	2	3	1	0	3	1	1	0
Bosmina longirostris	1	2	3	4	0	1	0	0	0
Synura uvella	0	0	0	0	0	0	600	17500	30700
Tintinnopsis lacustris	0	0	0	0	30	130	60	30	30
Synchaeta oblonga	0	0	0	0	0	60	330	0	0
Polyarthra trigla	30	0	30	130	360	860	1200	300	300
Keratella cochlearis	130	0	300	160	1460	1670	1300	1100	1400
K. quadrata	0	0	30	30	0	0	67	0	0
Asplanchna priodonta	0	0	0	0	30	30	160	0	0
Filinia longiseta	0	0	0	0	0	0	30	30	230
Pompholyx complanata	0	0	0	0	0	30	160	30	0
Ceratium hirundinella	0	30	0	0	0	0	0	0	0
Melosira italica	0	0	600	0	0	0	0	0	0
Tabellaria fenestrata	0	0	0	400	600	300	200	400	0
Fragilaria construens	400	400	200	60	4700	1400	200	100	0
Asterionella formosa	16500	21500	15100	22400	20600	20500	17000	28400	25500
Synedra ulna	200	300	800	300	700	500	900	1160	1000
S. acus	18700	19600	16500	23300	13500	28200	17300	21500	25500
Anabaena Lemmermanni	2500	3500	3600	0	2000	2500	2000	800	900
Dinobryon sertularia	36700	53800	38700	13900	12300	9200	12900	12100	1330
Mougeotia sp.	2300	2000	0	0	0	0	0	0	0
Trochiscia sp. ?	0	0	30	0	0	0	0	0	0
Total of zooplankton	162	34	368	325	1880	2784	3912	18991	32660
Total of phytoplankton	77300	101100	75530	62360	54400	62600	50500	64460	54230
Total of both	77462	101134	75898	62685	56280	65384	54412	83451	86890

Table 22. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Itobatakenoike on Oct. 22, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14
Cyclops vicinus	0	0	3	10	1	0	0	0
Mesocyclops oithonoides	0	5	41	1	0	0	0	0
Copepodid of Cyclops	3	11	10	4	0	1	0	0
Nauplius of Cyclops	7	4	4	4	0	2	0	0
Bosmina longirostris	24	37	36	10	3	1	1	1
Polyarthra trigla	0	2600	2200	1400	100	650	400	0
Keratella cochlearis	200	0	0	0	0	250	0	0
Pompholyx complanata	100	0	0	0	0	0	0	0
Glenodinium foliaceum	0	0	0	200	200	0	0	0
Peridinium willei	0	0	0	0	100	0	0	0
Ceratium hirundinella	300	1000	7400	10800	4800	8000	7000	6400
Asterionella formosa	0	0	0	830	0	0	0	0
Synedra acus	0	1900	800	1000	600	1000	1200	1000
Dinobryon sertularia	0	0	0	1200	0	0	0	0
Total of zooplankton	634	3657	9664	12429	5204	8904	7401	6401
Total of phytoplankton	0	1900	800	3030	600	1000	1200	1000
Total of both	634	5557	10464	15459	5804	9904	8601	7401

Table 21. Full data on the indivdual (or cell) number of plankton organisms occurring at each depth in Itobatakenoike on Aug. 28, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14
Cyclops vicinus	0	0	0	17	5	0	0	0
Mesocyclops oithonoides	0	10	15	1	0	0	0	0
Copepodid of Cyclops	18	19	41	39	19	6	5	1
Nauplius of Cyclops	6	11	34	23	24	5	5	1
Bosmina longirostris	70	463	588	275	387	36	57	58
Synchaeta oblonga	0	0	100	0	100	0	0	0
Polyarthra trigla	400	100	300	90	300	300	100	0
Brachionus angularis var. bidens	0	0	0	0	100	0	0	0
Keratella cochlearis	500	800	700	800	1000	400	600	300
K. quadrata	0	0	0	0	0	0	0	200
Filinia longiseta	0	0	0	0	0	0	0	100
Pompholyx complanata	0	100	100	0	0	0	0	0
Glenodinium foliaceum	0	0	100	200	1100	100	300	200
Peridinium willei	0	0	100	0	0	0	0	0
Ceratium hirundinella	100	400	1400	800	400	3900	400	400
Asterionella formosa	0	1700	400	1400	800	400	200	0
Synedra ulna	0	0	300	0	0	0	0	0
S. acus	300	400	700	600	600	100	100	800
Anabaena sp.	0	0	0	900	0	0	5500	0
Eudorina elegans	0	300	0	0	100	100	0	0
Total of zooplankton	1094	1903	3378	2245	3435	4747	1467	1260
Total of phytoplankton	300	2400	1400	2900	1500	600	5800	800
Total of both	1394	4303	4778	5145	4935	5347	7267	2060

Table 23. Full data on the individual (or cell) number of plankton organisms occurring at each in Higurashinoike on May 18, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14
Nauplius of Cyclops	0	0	1	1	0	0	0	0
Bosmina longirostris	0	17	2	1	1	0	0	0
Polyarthra trigla	250	550	350	200	120	200	200	300
Brachionus angularis var. bidens	300	150	1000	50	50	0	100	50
Keratella cochlearis	2200	58200	13900	6200	4300	7700	3700	5000
Asplanchna priodonta	0	2300	1800	850	350	100	750	50
Filinia longiseta	0	0	460	100	50	0	0	250
Ceratium hirundinella	150	1800	360	200	150	130	300	400
Tabellaria fenestrata	600	500	1100	100	300	200	2900	0
Fragilaria construens	100	400	0	0	300	0	0	0
Synedra ulna	500	100	370	50	360	100	200	100
S. acus	1600	700	1600	900	850	700	1500	700
Anabaena spiroides	59800	87500	9000	5500	7000	3000	3500	4500
A. Lemmermanni	1188000	3725000	2972000	2712000	2474000	2280000	3286000	2712000
Eudorina elegans	0	50	0	0	0	0	0	0
Trochiscia sp.?	0	50	0	0	0	0	0	0
Crucigenia rectangularis	0	50	0	0	0	0	0	0
Total of zooplankton	2900	63017	17873	7602	5021	8130	5050	6050
Total of phytoplankton	1250600	3814350	2984070	2718550	2482810	2284000	3294100	2717300
Total of both	1253500	3877367	3001943	2726152	2487831	2292130	3299150	2723350

Table 24. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Higurashinoike on Aug 28, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12
Bosmina longirostris	11	39	27	195	39	9	11
Polyarthra trigla	300	2200	1200	2000	0	0	1100
Keratella cochlearis	0	0	9100	1300	2400	0	1100
Pompholyx complanata	0	600	6800	3100	1200	0	0
Ceratium hirundinella	7100	592400	1572000	684500	208900	118700	160500
Asterionella formosa	2100	58000	22000	18000	4400	0	0
Synedra acus	3100	2200	3000	2800	3200	2000	3000
Anabaena planctonica	50000	24000	110000	0	0	0	0
Dinobryon sertularia	0	0	658500	427000	39200	66000	21000
Total of zooplankton	7411	595239	1588827	691095	212459	118709	162711
Total of phytoplankton	55200	78200	793500	447000	47000	68000	24000
Total of both	62611	673439	2382327	1138095	259459	186709	186711

Table 25. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Higurashinoike on Oct. 22, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12
Bosmina longirostris	277	683	312	1195	27	38	15
Keratella cochlearis	0	0	0	0	36000	13000	0
Tintinnopsis lacustris	0	0	0	1000	0	0	0
Ceratium hirundinella	1592000	2342000	563000	407000	100000	0	138000
Synedra acus	6300	900	0	0	0	10000	5800
Anabaena catenula var. intermedia	1335000	1792000	151000	0	0	10000	9200
A. sp.	1342000	3580000	1285000	55000	60000	21000	17000
Dinobryon sertularia	2123000	3888000	786000	25000	186000	7000	155000
D. divergens	495000	994000	148000	0	25000	0	34000
Total of zooplankton	1592277	2342683	563312	409195	136027	113038	138015
Total of phytoplankton	5501300	10254900	2371000	80000	271000	48000	181000
Total of both	7093577	12597583	2934312	489195	407027	161038	319015

Table 26. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Higurashinoike on Feb. 21, 1953

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	13
Polyarthra trigla	1800	2000	600	600	400	0	0	400
Keratella cochlearis	400	0	0	0	400	200	800	0
K. quadrata	0	0	200	0	0	0	0	0
Asplanchna priodonta	0	200	200	0	0	0	0	0
Filinia longiseta	0	0	100	0	0	0	0	0
Ceratium hirundinella	200	0	0	0	0	0	0	0
Tabellaria fenestrata	0	2000	1600	8200	4400	6000	6400	7000
Fragilaria crotonensis	0	100	0	0	0	0	0	0
Asterionella formosa	1400	2600	7200	13000	16400	12000	13600	600
Synedra ulna	0	0	0	100	0	0	0	0
S. acus	200	0	400	1400	800	600	800	600
Anabaena sp.	60000	10000	0	0	0	0	0	0
Dinobryon sertularia	0	2600	0	0	0	0	0	0
Total of zooplankton	2400	4800	1100	600	800	200	800	400
Total of phytoplankton	61600	14700	9200	22700	21600	18600	20800	8200
Total of both	64000	19500	10300	23300	22400	18800	21600	8600

Table 27. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ketobanoike on May 19, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14	16	18
Cyclops vicinus	0	0	0	0	0	1	1	0	1	0
Copepodid of Cyclops	0	0	0	0	0	1	0	0	0	0
Nauplius of Cyclops	1	4	4	2	2	2	0	8	4	0
Bosmina longirostris	4	9	21	12	9	4	3	2	1	3
Tintinnopsis lacustris	0	500	0	0	0	0	0	0	0	0
Polyarthra trigla	6500	3500	1000	0	0	0	900	0	0	0
Keratella cochlearis	0	3300	137700	173000	16300	11200	6200	6000	8000	8000
Filinia longiseta	0	0	500	6300	4300	2000	1500	1500	1500	0
Ceratium hirundinella	0	1200	1000	0	0	0	0	0	0	0
Fragilaria crotonensis	124800	179500	169000	317000	147000	75500	126800	79800	107800	7700
Asterionella formosa	1337000	1834000	470000	434000	245000	637000	324000	239000	289000	191000
Synedra ulna	44265000	44736000	15504000	16157000	11009000	34056000	57130000	44371000	34100000	33619000
S. acus	5716000	3506000	9120000	4092000	6344000	399000	477000	433000	396000	252000
Anabaena sp.	0	0	25400	0	0	50000	65000	0	68500	80000
Dinobryon sertularia	0	0	0	0	3400	13200	66800	0	0	0
Eudorina elegans	48500	105200	7300	2300	2000	6300	5300	2000	0	1200
Total of zooplankton	6505	8513	140225	177314	20611	13208	8604	7510	9506	8003
Total of phytoplankton	51691000	50348700	17087700	18022300	12033400	66606000	6764500	5123500	4242500	4100700
Total of both	51697505	50357213	17227925	18199614	12054011	66619208	6773104	5131010	4252006	4108703

Table 19. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Menkozakanoike on Oct, 21. 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	11
Cyclops vicinus	0	0	0	3	14	1	0
Mesocyclops oithonoides	0	0	31	0	0	3	0
Copepodid of Cyclops	2	4	0	1	2	0	0
Nauplius of Cyclops	1	1	3	1	2	5	0
Bosmina longirostris	68	149	293	158	132	58	10
Tintinnopsis rotundata	0	0	0	0	0	100	0
Polyarthra trigla	0	1200	0	900	100	0	0
Keratella cochlearis	0	0	0	50	0	0	0
Ploesoma truncatum	0	0	20	10	0	0	0
Pompholyx complanata	0	300	0	0	0	0	0
Glenodinium foliaceum	380	350	0	0	100	100	0
Ceratium hirundinella	0	0	950	950	500	100	0
Melosira italica	0	100	300	50	0	0	0
Tabellaria fenestrata	0	0	1300	500	0	400	0
Fragilaria construens	0	0	9300	0	0	0	0
Asterionella formosa	0	0	0	0	300	850	0
Synedra ulna	0	0	0	0	0	0	200
S. acus	1600	600	900	300	500	200	0
Surirella tenera	0	0	0	0	0	0	100
Dinobryon sertularia	0	0	30	0	0	0	0
Genicularia spirotaenia	0	0	100	0	0	0	0
Total of zooplankton	451	2004	1297	2073	850	367	10
Total of phytoplankton	1600	700	11930	850	800	1450	300
Total of both	2051	2704	13227	2923	1650	1817	310

Table 28. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ketobanoike on Aug. 29, 1952

	Plankton / Depth (m)	0	2	4	6	8	10	12	14	16
Number of individuals per 20 liters of water (or cells)	Cyclops vicinus	0	7	27	29	56	145	8	1	3
	Copepodid of Cyclops	0	10	40	119	156	195	8	3	9
	Nauplius of Cyclops	0	37	106	55	11	3	5	2	5
	Bosmina longirostris	5	142	523	184	16	7	30	11	10
	Polyarthra trigla	0	600	200	400	100	100	0	200	100
	Keratella cochlearis	800	2600	400	1400	4500	48700	2700	500	1900
	K. quadrata	0	0	0	0	100	0	0	0	0
	Filinia longiseta	0	0	100	100	400	800	200	400	0
	Peridinium willei	0	0	100	0	0	0	0	0	0
	Ceratium hirundinella	900	25300	5200	9300	6200	8400	5700	11200	4600
	Asterionella formosa	0	0	1500	1700	700	0	0	0	0
	Synedra ulna	0	0	0	0	0	0	0	200	1400
	S. acus	100	300	0	1100	15100	29900	9300	11000	24000
	Dinobryon sertularia	0	0	0	0	0	1900	0	300	0
	Mougeotia sp.	0	520	200	100	0		0		0
	Eudorina elegans	0	0	100	0	0	200	0	0	100
	Total of zooplankton	1705	28696	6696	11587	11534	58350	8651	2317	6627
	Total of phytoplankton	100	820	1800	2900	15800	31800	9300	11500	25500
	Total of both	1805	29516	8496	14487	27334	90150	17951	13817	32127

Table 29. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ketobanoike on Oct. 23, 1952

	Plankton / Depth (m)	0	2	4	6	8	10	12	14	16	18	20
Number of individuals per 20 liters of water (or cells)	Cyclops vicinus	0	2	1	8	4	88	4	0	1	0	2
	Copepodid of Cyclops	2	4	22	11	1	118	3	0	2	3	3
	Nauplius of Cyclops	38	18	13	4	2	0	0	0	1	1	2
	Bosmina longirostris	19	931	734	221	122	3	52	36	11	35	48
	Polyarthra trigla	0	6100	3200	1000	0	0	0	0	0	1000	0
	Keratella cochlearis	900	6100	66000	18300	46000	10000	5000	11000	8000	10000	13000
	K. quadrata	0	0	0	0	0	2200	0	0	0	0	0
	Asplanchna priodonta	117	49	41	5	2	0	0	1	1	0	7
	Filinia longiseta	0	0	4500	5100	4900	2100	1200	2000	0	1000	2000
	Peridinium willei	950	4000	5000	3500	1000	3000	0	1000	0	1000	1000
	Ceratium hirundinella	34200	84500	311100	39000	30000	13000	20000	21000	20000	18000	14000
	Fragilaria crotonensis	0	0	0	0	0	0	0	0	0	1300	0
	F. construens	0	0	26000	8400	29000	29000	62000	0	0	0	0
	Asterionella formosa	36874000	41622000	22063000	37692000	18255000	14511000	6541000	4462000	3883000	5271000	5437000
	Synedra ulna	0	0	0	0	0	0	0	1000	0	0	0
	S. acus	0	0	0	0	0	0	0	1000	1000	1000	2000
	Dinobryon sertularia	1128000	658000	361000	320000	111000	0	0	51000	12000	33000	8000
	Mougeotia sp.	19000	23000	39000	0	0	0	0	0	6600	0	0
	Total of zooplankton	36266	101724	390611	224349	87042	30506	26059	35037	28016	31039	30062
	Total of phytoplankton	38021000	42303000	22488000	38020500	18395000	14540000	6683000	4715000	3904000	5307500	5449000
	Total of both	38057266	42404724	22878611	38244849	18482042	14570506	6709059	4750037	3932016	5338539	5479062

Table 30. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ochikuchinoike on May 21, 1952

	Plankton / Depth (m)	0	2	4	6	8	10	12	14	16	18	20
Number of individuals per 20 liters of water (or cells)	Cyclops vicinus	0	0	32	124	48	46	18	13	9	10	7
	Eucyclops prasinus	0	1	12	13	6	9	3	2	4	0	0
	Copepodid of Cyclops	0	0	12	368	76	68	19	21	15	11	7
	Nauplius of Cyclops	1	21	38	44	42	79	53	107	185	54	41
	Bosmina longirostris	0	4	13	168	21	11	9	5	1	1	8
	Keratella cochlearis	0	0	0	5300	3200	3200	2100	1200	0	3000	2500
	K. quadrata	0	0	0	0	0	0	1000	0	0	0	0
	Asplanchna priodonta	0	550	0	0	0	0	0	0	0	0	0
	Filinia longiseta	0	0	0	0	0	0	0	1200	2200	0	0
	Peridinium willei	0	0	0	0	0	1000	0	0	0	0	0
	Fragilaria crotonensis	185200	102000	22800	19200	50500	54300	42200	58000	25300	9500	34000
	F. construens	35500	110000	105000	105200	265500	220300	160500	140000	110000	120000	40500
	Asterionella formosa	1102000	1105000	345000	457000	429000	335000	271000	232000	212000	235000	283000
	Synedra ulna	4966000	3768000	1872000	2764000	2641000	2721000	1654000	1309000	1005000	1338000	1754000
	S. acus	405000	223000	85000	102000	121000	153000	78500	65000	49000	41000	60000
	Epithemia zebra	0	0	0	1100	0	0	0	0	0	0	0
	Anabaena sp.	0	0	0	3300	0	0	0	3000	0	0	0
	Dinobryon sertularia	0	0	0	0	0	0	21700	15500	11100	6000	17000
	Eudorina elegans	0	1000	1000	0	0	3300	0	0	1100	0	1200
	Total of zooplankton	1	576	107	6017	3393	4413	2302	2548	2414	3076	2543
	Total of phytoplankton	6613700	5309000	2430300	3451800	3507000	3486900	2227900	1822500	1413500	1749500	2188500
	Total of both	6613701	5309576	2430407	3457817	3510393	3491313	2230202	1825048	1415914	1752576	2191043

Table 31. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ochikuchinoike on Aug. 30, 1952

	Plankton / Depth (m)	0	2	4	6	8	10	12	14	16	18	20
Number of individuals per 20 liters of water (or cells)	Cyclops vicinus	3	43	65	37	38	4	5	5	8	7	5
	Eucyclops prasinus	0	17	107	40	206	86	229	56	5	6	4
	Copepodid of Cyclops	13	92	131	75	337	189	592	245	38	13	25
	Nauplius of Cyclops	4	3	0	1	4	4	5	3	3	2	4
	Daphnia longispina	1	3	6	18	31	85	42	13	6	2	4
	Bosmina longirostris	12	921	1019	495	100	307	90	68	92	94	12
	Tintinnopsis lacustris	0	0	0	0	0	0	0	0	0	0	600
	Polyarthra trigla	0	100	400	200	0	0	0	0	0	0	0
	Keratella cochlearis	200	400	1600	1800	4500	4400	1400	100	400	200	0
	K. quadrata	0	100	0	0	0	0	0	0	0	0	0
	Filinia longiseta	0	0	0	0	1000	5500	5500	500	0	0	0
	Pompholyx complanata	100	200	1800	600	2800	3200	600	100	600	0	0
	Glenodinium foliaceum	0	100	0	0	0	0	0	0	0	0	0
	Ceratium hirundinella	100	8400	142400	46600	21400	17800	8800	10400	9800	600	14600
	Fragilaria crotonensis	15500	37900	107600	50600	51600	54600	24400	21000	7400	1800	69000
	F. construens	0	0	0	9300	0	0	4000	6500	0	0	14100
	Asterionella formosa	82000	174000	287000	147000	61000	68000	31000	41000	31000	26000	92000
	Synedra ulna	0	0	0	0	0	0	0	0	0	0	800
	S. acus	1900	1900	400	400	800	600	200	200	200	400	2400
	Epithemia zebra	0	0	0	0	0	0	0	0	0	0	200
	Surirella ovalis	0	0	0	0	0	200	0	0	0	0	0
	Genicularia spirotaenia	0	0	0	0	0	600	0	800	0	0	0
	Eudorina elegans	0	0	0	0	0	0	0	0	0	0	200
	Total of zooplankton	433	10379	147528	49866	30416	31575	17263	11490	10952	924	15254
	Total of phytoplankton	99400	213800	395000	207300	113400	124000	59600	69500	38600	28200	178700
	Total of both	99833	224179	542528	257166	143816	155575	76863	80990	49552	29124	193954

Table 34. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Koikuchinoike on Aug. 30, 1952

	Plankton / Depth (m)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Number of individuals per 20 liters of water (or cells)	Cyclops vicinus	0	0	0	0	0	0	0	24	16	40	80	127	8	16	6	6	5	5	0	6	0	0	0
	Eucyclops prasinus	0	4	4	15	32	231	88	24	48	48	8	25	7	7	0	0	0	0	0	0	8	0	0
	Copepodid of Cyclops	5	50	16	104	102	384	200	248	296	296	184	504	33	80	47	24	65	8	39	36	40	35	41
	Nauplius of Cyclops	2	44	12	104	66	93	72	70	32	71	124	312	41	32	32	15	13	8	7	27	0	0	0
	Daphnia longispina	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bosmina longirostris	151	46	88	478	1328	2076	1384	824	512	328	304	345	128	97	95	94	112	49	48	24	96	122	104
	Tintinnopsis rotundata	0	1200	1200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Synchaeta oblonga	400	0	0	0	0	0	3300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Polyarthra trigla	850	2300	5800	6500	2000	1000	1000	0	1000	0	1000	0	0	1000	0	0	0	0	0	0	0	0	0
	Diurella sp.	0	0	0	1000	1000	2000	3400	1100	0	0	0	0	0	1000	0	0	0	0	0	0	0	0	0
	Keratella cochlearis	0	0	0	0	0	0	19300	14900	18900	13300	12000	14000	59000	1000	2000	1000	5500	3200	1000	1500	2100	2900	0
	K. quadrata	0	0	0	0	0	0	1000	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ploesoma truncatum	0	0	1000	2200	1000	0	2200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Pompholyx complanata	0	0	0	6200	15400	28400	12300	8200	4800	4800	2300	3500	2200	0	0	0	0	1000	0	2200	2700	1000	0
	Peridinium willei	0	0	0	0	0	0	0	6200	4900	2500	1000	0	0	0	0	0	0	0	0	0	0	0	0
	Ceratium hirundinella	8300	8300	9100	81000	1611000	3006000	2862000	1242000	1278000	508000	216000	187500	542000	275000	193500	166000	186300	180000	216000	252000	90000	48000	38000
	Melosira varians	0	0	0	0	0	0	0	0	0	0	0	7700	0	0	0	0	0	0	0	0	0	0	0
	Tabellaria fenestrata	0	0	8500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fragilaria crotonensis	0	0	0	0	3300	0	9200	0	0	0	5500	1100	0	0	0	0	0	0	0	0	0	0	0
	Asterionella formosa	11438000	5643000	12006000	7054000	8138000	19875000	25749000	13050000	12222000	4986000	1836000	2610000	2274000	2672000	1417000	2187000	2826000	1348000	2178000	1602000	666000	1160000	1098000
	Synedra ulna	0	0	0	0	0	0	0	0	2700	1900	2100	3300	2500	2500	2000	1000	2000	1800	1000	0	0	0	0
	S. acus	0	0	1100	0	0	0	0	2300	24300	24500	15600	12200	8900	7000	6300	5000	8000	2800	3000	2200	2000	3000	2000
	Epithemia zebra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0
	Anabaena planctonica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2500	0	0	0	0	0	0
	A. sp.	0	0	0	0	0	0	0	0	0	75500	0	20300	0	0	0	0	0	0	0	0	0	0	0
	Eudorina elegans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1000	0	0	0	0	0
	Total of zooplankton	9709	11945	16420	97601	1629928	3040184	2908244	1274590	1308504	529383	233000	206313	603417	278232	198680	167139	191997	184270	217096	255793	94936	52057	38145
	Total of phytoplankton	11438000	5643000	12015600	7054000	8141300	19875000	25758200	13052300	12249000	5087900	1859200	2619100	2285400	2681500	1419310	2193000	2838500	1352000	2182000	1604200	668000	1163500	1100000
	Total of both	11447709	5654945	12032020	7151601	9771228	22915184	28666444	14326890	13557504	5617283	2092200	2825413	2888817	2959732	1617990	2360139	3030497	1536270	2399096	1859993	762936	1215557	1138145

Table 33. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Koikuchinoike on May 21, 1952

	Plankton / Depth (m)	0	2	4	6	8	10	12	14	16	18	20	22
Number of individuals per 20 liters of water (or cells)	Cyclops vicinus	0	0	7	3	4	10	10	21	9	2	0	1
	Eucyclops prasinus	0	0	5	3	1	2	0	0	0	0	0	0
	Copepodid of Cyclops	0	1	38	15	1	1	1	2	3	1	0	0
	Nauplius of Cyclops	1	2	5	2	1	0	0	1	0	1	1	0
	Bosmina longirostris	5	3	74	42	13	8	0	1	6	5	4	2
	Tintinnopsis rotundata	0	0	0	0	0	0	0	1000	0	0	0	0
	Synchaeta oblonga	0	0	0	0	3000	1000	2000	3000	1000	1000	0	0
	Polyarthra trigla	0	0	0	1000	500	0	1000	1000	0	0	0	0
	Keratella cochlearis	0	1000	6000	13500	19200	8500	9300	8300	12000	6000	6000	3200
	Asplanchna priodonta	0	0	0	0	0	0	1000	1000	2000	0	2000	0
	Filinia longiseta	0	0	0	0	1000	1000	1000	0	0	0	0	0
	Pompholyx complanata	0	0	0	1000	1000	0	0	0	0	2000	1000	0
	Peridinium willei	0	0	0	0	0	0	0	0	1000	0	0	0
	Ceratium hirundinella	0	1000	7000	2000	40500	2300	2300	4000	2200	0	0	0
	Fragilaria crotonensis	7300	45000	17300	17300	9300	24000	48500	13300	34600	12000	13000	0
	Asterionella formosa	881000	1205000	1108000	934000	654000	641000	1073000	369000	1087000	491000	576000	48000
	Synedra ulna	2081000	1964000	3245000	1586000	2236000	1727000	1781000	1265000	2258000	2135000	2346000	235000
	S. acus	127000	57000	81000	37000	56000	77000	74000	36000	37000	31000	45000	4000
	Anabaena spiroides	0	0	0	170000	40000	20000	155000	45000	0	0	0	0
	A. Lemmermanni	0	0	0	0	0	0	0	0	0	0	5000	0
	A. sp.	30000	940000	1200000	340000	2150000	165000	1295000	925000	500000	370000	1025000	110000
	Dinobryon sertularia	0	0	0	1000	12000	240000	534000	18300	18300	12000	9000	5000
	Pandorina morum	0	0	0	1000	0	0	1000	1000	0	0	0	1000
	Eudorina elegans	0	0	1000	0	0	0	1000	0	0	1000	0	0
	Total of zooplankton	6	2006	13129	17565	65220	13821	16611	20325	16218	11009	7005	3203
	Total of phytoplankton	3126300	4211000	5651300	3386300	5157300	2834000	6382500	2652600	3934900	2130000	3019000	423000
	Total of both	3126306	4213006	5664429	3403865	5222520	2847821	6399111	2672925	3951118	2141009	3026005	426203

Table 32. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ochikuchinoike on Oct. 23, 1952

	Plankton / Depth (m)	0	2	4	6	8	10	12	14	16	18	20
Number of individuals per 20 liters of water (or cells)	Cyclops vicinus	1	14	4	6	8	16	2	0	0	1	1
	Eucyclops prasinus	0	14	13	35	36	116	35	6	5	2	2
	Copepodid of Cyclops	5	17	11	50	47	158	32	9	5	8	2
	Nauplius of Cyclops	17	34	8	8	8	10	4	0	0	0	0
	Daphnia longispina	38	43	174	111	238	64	14	9	14	14	2
	Polyarthra trigla	1000	0	1000	0	0	0	0	0	0	0	0
	Keratella cochlearis	0	0	1000	1000	2200	4500	1000	1000	0	0	0
	Asplanchna priodonta	1000	0	0	0	0	0	0	0	0	0	0
	Filinia longiseta	0	0	0	0	0	150	1000	0	0	0	0
	Peridinium willei	0	0	1000	2300	1000	0	0	0	0	0	0
	Ceratium hirundinella	48000	41500	149500	239000	158000	40500	31000	21000	27500	22500	40000
	Tabellaria fenestrata	108000	64500	121500	121500	72000	100000	154000	10000	25000	19000	16000
	Fragilaria crotonensis	0	0	0	0	0	0	0	0	0	0	99000
	F. construens	0	35000	2000	0	0	0	0	0	0	0	250000
	Asterionella formosa	2121000	3255000	1869000	1982000	4641000	3673000	840000	388000	1092000	86000	2226000
	Synedra ulna	0	0	0	0	0	0	1000	1000	1000	1000	777000
	S. acus	0	0	0	0	0	0	0	0	0	0	315500
	Dinobryon sertularia	48000	179000	134000	65000	97000	61000	50000	3000	53000	3200	3200
	Genicularia spirotaenia	1000	64500	121500	121500	72000	100000	154500	10000	25000	19000	16000
	Staurastrum paradoxum	0	0	0	0	0	4300	0	0	2000	0	0
	Mougeotia sp.	3000	0	0	3000	26500	14500	0	0	0	0	0
	Volvox aureus	0	1000	0	0	0	0	2200	0	0	0	0
	Eudorina elegans	0	2000	1000	0	0	0	0	0	0	0	0
	Total of zooplankton	45052	41622	152710	242510	161537	45514	33087	22024	27524	22525	40007
	Total of phytoplankton	2270000	3601000	2293000	2293800	4908500	3934800	1201700	612000	1198000	126200	3702700
	Total of both	2315052	3642622	2401710	2535810	5070037	4000314	1234787	634024	1225524	148725	3742707

Table 35. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Koikuchinoike on Oct. 24, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Cyclops vicinus	0	0	0	2	0	0	0	0	3	31	50	0	0	0	0	0	0	0	0	0	0	0	0
Eucyclops prasinus	0	0	0	0	0	0	0	0	14	52	3	3	3	2	4	2	2	4	2	2	1	4	2
Copepodid of *Cyclops*	1	3	5	7	1	4	4	3	149	321	2	0	4	6	8	3	4	5	3	3	3	1	5
Nauplius of *Cyclops*	1	1	2	2	3	0	4	6	18	19	5	10	2	2	0	0	0	0	1	1	0	0	0
Bosmina longirostris	1	55	83	26	29	47	67	78	247	355	36	35	35	15	20	13	15	19	12	22	13	13	19
Tintinnopsis lacustris	0	0	0	1000	0	0	0	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polyarthra trigla	3500	0	0	0	3100	4200	1000	2000	4000	0	0	2100	0	0	0	0	0	0	0	0	400	0	400
Keratella cochlearis	2000	2000	5500	2000	1000	2000	1000	0	2400	1000	1000	0	2000	3200	1500	800	1600	3000	1600	0	400	400	1600
K. quadrata	0	0	0	0	0	0	0	0	0	400	600	400	400	0	0	700	0	0	0	0	0	0	0
Filinia longiseta	0	0	0	1000	0	0	0	1000	0	0	0	0	0	0	1000	0	0	0	0	0	0	0	0
Pompholyx complanata	0	0	0	0	1000	1000	1000	3100	3100	0	0	0	1000	0	0	0	0	0	400	400	400	0	0
Peridinium willei	0	0	0	1000	0	0	1000	0	1000	1000	1000	0	0	0	0	0	0	0	0	0	0	0	400
Ceratium hirundinella	354000	429000	368000	220000	131000	214000	126000	184000	411000	153000	89000	75000	89000	119000	130000	59000	52000	75000	84400	68000	72000	68000	81000
Tabellaria fenestrata	93000	53400	62000	3000	17000	23000	18400	21500	17000	35000	56000	69000	19300	25000	7000	11000	10400	11000	18000	16400	18000	17200	6400
Asterionella formosa	574000	368000	216000	134000	111000	120000	97000	186000	129000	133000	146000	130000	99000	135000	164000	33000	43000	56000	69500	54800	77000	83000	60800
Synedra ulna	1000	1000	0	0	1000	1000	1000	0	2000	1000	0	0	1000	0	0	400	0	800	400	400	3600	400	2400
S. acus	0	2000	2000	1000	1000	0	0	2000	2000	1000	0	1000	2000	2000	0	0	1600	400	400	0	1200	800	400
Dinobryon sertularia	4600	21000	20000	0	7300	8400	8000	8000	1000	23500	0	0	0	0	7400	6000	4800	3200	0	0	0	0	0
D. divergens	8200	0	0	0	0	0	0	0	22000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum paradoxum	0	4000	2000	2000	0	0	0	0	4000	2000	0	2000	0	0	0	0	0	0	0	1200	0	0	0
Mougeotia sp.	85500	46000	29000	24000	12000	8500	0	0	5000	16000	13000	18500	6000	9000	0	0	0	4000	4000	2000	9500	9500	4400
Pandorina morum	0	2000	1000	1000	0	1000	0	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eudorina elegans	0	0	0	0	0	0	0	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total of zooplankton	539503	431059	373590	225037	136133	221251	130075	191187	427931	156178	91696	77548	92444	122225	132532	60218	53621	83028	86418	68427	73217	68418	83426
Total of phytoplankton	786300	497400	332000	185000	149300	161900	124400	219500	182000	211500	215000	221500	127300	171000	178400	50400	59800	75400	92300	94800	109300	110900	74400
Total of both	1325803	928459	705590	410037	285433	383151	254475	410687	609931	367678	306696	299048	219744	293225	310932	110618	113421	158428	178718	163227	182517	179318	157826

Table 38 Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ōike on Aug. 31, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14	16	18	20
Cyclops vicinus	0	1	3	3	23	149	110	5	16	5	3
Eucyclops prasinus	1	1	1	3	1	0	0	0	0	0	0
Copepodid of *Cyclops*	0	3	5	12	20	38	53	9	8	2	3
Nauplius of *Cyclops*	1	4	1	3	20	6	9	8	1	7	2
Bosmina longirostris	15	11	2189	402	75	49	28	11	10	14	12
Polyarthra trigla	200	200	7300	0	0	0	0	0	0	0	0
Keratella cochlearis	100	200	6000	27000	2000	1000	4000	1000	1000	2000	1000
Asplanchna priodonta	30	0	0	0	0	0	0	0	0	0	0
Pompholyx complanata	0	0	2500	1200	1200	1200	0	0	0	0	0
Glenodinium foliaceum	0	100	0	0	0	0	0	0	0	1000	0
Ceratium hirundinella	300	3500	642000	8000	1000	32500	9000	10000	14000	8000	5000
Asterionella formosa	74000	165000	8568000	1725000	283000	1072000	198000	68000	149000	193000	52000
Synedra ulna	300	200	9000	4000	1200	3000	1000	1000	1000	1000	1000
S. acus	1800	2700	58000	117000	23000	71000	18000	11000	11000	19000	11000
Anabaena planctonica	0	0	4500	0	0	0	0	0	0	0	0
A. sp.	0	1500	3000	110500	110500	90000	0	50000	0	0	0
Dinobryon sertularia	0	1000	0	0	1100	0	0	0	0	0	0
Mougeotia sp.	400	600	39500	2000	0	0	0	0	0	0	0
Total of zooplankton	647	4020	659999	36623	4339	34942	13200	11025	15035	11028	6020
Total of phytoplankton	76500	171000	8682000	1958500	418800	1236000	217000	130000	161000	213000	64000
Total of both	77147	175020	9341999	1995123	423139	1270942	230200	141025	176035	224028	70020

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Table 36. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Koikuchinoike on Feb. 20, 1953

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14	16	18	20	22
Cyclops vicinus	12	16	13	4	4	4	3	1	4	0	2	0
Eucyclops prasinus	0	0	4	6	9	4	4	6	1	0	13	2
Copepodid of *Cyclops*	23	15	33	25	10	9	4	7	2	0	5	5
Nauplius of *Cyclops*	6	3	4	11	8	11	4	8	1	0	0	0
Polyarthra trigla	600	1000	700	300	300	800	200	100	100	100	400	100
Keratella cochlearis	100	3100	3100	4800	800	2800	1700	1100	1000	100	500	800
K. quadrata	100	200	0	0	0	0	0	0	0	0	0	0
Asplanchna priodonta	0	300	200	400	200	100	200	100	100	0	0	0
Filinia longiseta	0	0	0	200	400	500	300	300	100	0	0	0
Peridinium willei	100	100	100	0	0	0	0	100	0	0	0	0
Ceratium hirundinella	0	800	200	100	200	0	0	0	0	0	0	0
Melosira varians	0	100	0	0	0	0	0	0	0	0	0	0
Tabellaria fenestrata	1700	22900	13200	16300	10000	20600	5500	4000	7900	7700	7700	9300
Asterionella formosa	14000	169000	97000	129700	87000	158000	49000	39000	25000	4000	58700	66000
Synedra ulna	200	900	800	1500	900	500	400	300	500	1500	2900	20900
S. acus	1300	21000	11700	23000	12600	4800	4700	4500	5000	5500	8800	67700
Staurastrum paradoxum	0	0	200	0	0	0	0	0	0	0	100	0
Eudorina elegans	0	100	0	100	0	0	0	0	0	0	0	0
Total of zooplankton	941	7334	4334	5846	1931	4225	2415	1722	1308	200	920	907
Total of phytoplankton	17200	214000	122900	370800	110500	183900	59800	47800	38400	18700	78200	163900
Total of both	18141	221534	127234	376646	112431	188128	62215	49522	39708	18900	79120	164807

Table 39. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ōike on Oct. 24, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14	16	18	20	22	24
Cyclops vicinus	0	0	1	0	0	48	2	1	1	1	0	0	1
Eucyclops prasinus	0	0	0	0	15	1	0	0	0	0	0	0	0
Copepodid of *Cyclops*	0	0	0	4	15	285	8	4	3	1	6	2	4
Nauplius of *Cyclops*	0	1	2	3	10	4	2	3	0	1	0	0	0
Bosmina longirostris	1	18	28	135	146	11	10	7	1	9	6	5	2
Tintinnopsis lacustris	0	0	0	400	0	0	400	0	0	0	0	0	0
Polyarthra trigla	0	2700	3800	1200	5000	800	0	0	400	400	0	0	0
Keratella cochlearis	0	800	1800	1800	1212000	12000	3000	30000	2000	2000	1000	800	800
Filinia longiseta	0	0	0	0	0	1200	800	400	400	0	0	0	0
Pompholyx complanata	0	200	400	400	2200	0	0	400	0	0	400	400	0
Peridinium willei	100	0	0	400	800	800	400	0	800	0	0	0	400
Ceratium hirundinella	4500	24000	19000	76000	126500	12000	10000	16000	8000	19000	20000	13500	7000
Melosira varians	0	0	500	0	0	0	0	0	0	0	0	0	0
Tabellaria fenestrata	27900	104500	10600	136800	56000	13000	11600	11000	16400	10800	6000	8800	2000
Fragilaria crotonensis	0	0	0	0	0	0	0	0	2000	0	0	0	0
F. construens	0	0	0	0	0	0	0	0	22000	0	0	0	0
Asterionella formosa	91000	104000	153600	95000	218000	43000	46000	34000	71000	58500	24000	26400	14000
Synedra ulna	700	1500	1600	800	2000	800	2800	1000	11000	6400	3600	400	1200
S. acus	1300	700	1800	2000	3200	10000	9600	2800	110000	18800	11600	8000	6400
Epithemia zebra	0	0	0	0	0	0	0	0	0	800	0	0	0
Rhopalodia gibba	0	0	0	400	400	0	0	0	0	0	0	0	0
Anabaena sp.	4300	8000	10000	4000	20000	0	0	0	0	0	0	0	0
Dinobryon sertularia	2400	4500	600	6400	2400	1600	0	0	0	0	0	0	0
Staurastrum paradoxum	0	200	800	0	0	800	0	0	0	0	0	0	0
Mougeotia sp.	78200	47600	79200	30000	21200	3300	5600	11200	5000	5000	1600	19200	0
Pandorina morum	0	100	200	400	0	0	0	0	0	0	0	0	0
Total of zooplankton	4601	27719	25031	80342	1346686	27149	14622	46815	11605	21412	21412	14707	8207
Total of phytoplankton	205800	271100	258900	275800	323200	71800	75600	60000	385000	100300	46800	62800	23600
Total of both	210401	298819	283931	356142	1669886	98949	90222	106815	396605	121712	68212	77607	31807

Table 37. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Ōike on May 21, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10	12	14	16	18	20	22	24
Cyclops vicinus	0	0	0	0	3	0	1	0	1	0	0	0	1
Eucyclops prasinus	0	0	0	1	1	0	0	0	0	0	0	0	0
Copepodid of *Cyclops*	0	0	0	3	0	0	0	0	0	0	0	0	0
Nauplius of *Cyclops*	0	1	1	1	0	0	0	0	0	0	0	0	0
Bosmina longirostris	0	12	4	3	2	0	0	0	0	0	3	0	0
Synchaeta oblonga	0	0	0	0	2300	1000	0	0	0	0	0	0	0
Polyarthra trigla	1000	1000	0	0	0	0	0	1000	0	0	0	0	0
Keratella cochlearis	0	0	14000	21000	18000	2000	6000	11600	2000	1000	4000	3000	4000
K. quadrata	0	0	0	1000	1000	0	0	0	0	0	0	0	0
Asplanchna priodonta	0	0	0	0	0	3300	0	0	0	1300	0	0	0
Filinia longiseta	0	0	1000	1000	0	0	0	0	0	0	0	0	0
Ceratium hirundinella	0	0	1300	1300	1300	0	0	0	0	0	0	0	0
Fragilaria crotonensis	13300	13300	6500	14200	12500	9300	6800	4300	2000	1300	6500	10000	14000
Asterionella formosa	980000	860000	416500	246000	211000	324000	274000	351000	98000	103000	174000	229000	389000
Synedra ulna	2047000	1686000	1427000	860800	1254300	1181000	921000	1278500	498500	338000	2540000	707000	1480000
S. acus	66000	45000	38000	24300	48300	34000	42500	47600	6000	10000	18700	38800	65000
Anabaena spiroides	0	40000	50500	40000	0	0	0	0	0	0	0	0	0
A. Lemmermanni	0	0	0	0	0	60000	60000	25500	0	0	0	0	60000
A. sp.	1050000	655500	3635000	3123500	1666000	1293000	293000	1785000	450000	315000	825500	885000	3775700
Dinobryon sertularia	0	22000	0	18500	112000	45000	98000	51000	6000	66500	42000	44000	113500
Eudorina elegans	1000	0	0	0	0	0	0	0	0	0	0	0	0
Total of zooplankton	1000	1013	16302	24308	22605	7300	6001	12600	2001	2300	4003	3000	4001
Total of phytoplankton	4157300	3281800	5583000	4334500	3344100	2856300	2693000	3377400	1086000	833800	1818700	1863800	5907200
Total of both	4158300	3282813	5599302	4358808	3366705	2863600	2701001	3389000	1088001	836100	1822703	1866800	5911201

Table 40. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Hakkeinoike on May 22, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10
Cyclops vicinus	0	0	3	13	90	42
Eucyclops prasinus	0	4	1	2	3	5
Copepodid of *Cyclops*	2	1	5	20	67	18
Nauplius of *Cyclops*	1	1	11	21	18	2
Bosmina longirostris	0	3	9	2	0	0
Polyarthra trigla	2000	1000	4300	1000	1000	3000
Keratella cochlearis	21000	3000	45500	49000	26000	18000
Asplanchna priodonta	0	0	0	1300	0	0
Filinia longiseta	1000	1000	2000	1000	1000	47000
Pompholyx complanata	0	0	1000	1000	0	0
Ceratium hirundinella	2000	3300	19300	12000	9300	3200
Fragilaria crotonensis	24500	8200	4500	15300	6000	7000
Asterionella formosa	870000	516800	481000	702000	252500	280000
Synedra ulna	2051000	1087000	1390000	4046000	1376700	783000
S. acus	56000	8200	23000	98300	27000	20000
Gyrosigma acuminatum	1000	0	0	0	0	0
Anabaena spiroides	0	40500	75000	35000	0	20000
A. sp.	1875000	3060000	5363000	4725000	2623000	57000
Dinobryon sertularia	55500	123000	124000	205000	65000	24000
Trochiscia sp. ?	1000	0	0	0	0	0
Total of zooplankton	26003	8309	72129	65358	37478	73267
Total of phytoplankton	4935000	4843700	7460500	9826600	4250200	1191000
Total of both	4961003	4852009	7532629	9891958	4287678	1264267

Table 41. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Hakkeinoike on Sept 1, 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	1	2	3	4	5	6	7	8	9	10
Eucyclops prasinus	0	0	0	1	1	1	2	0	0	0	0
Copepodid of *Cyclops*	0	0	0	0	0	3	10	3	2	1	0
Nauplius of *Cyclops*	0	0	1	0	0	0	0	0	0	0	0
Bosmina longirostris	0	0	25	74	56	104	45	5	3	12	4
Alona rectangla	0	1	1	0	0	2	0	0	0	0	0
Polyarthra trigla	0	200	0	0	400	0	0	0	0	0	0
Brachionus angularis var. *bidens*	0	0	0	0	400	3100	0	0	0	0	0
Keratella cochlearis	0	0	0	0	0	1000	1000	1000	0	0	0
K. quadrata	0	0	0	0	0	0	0	0	0	200	0
Filinia longiseta	0	0	0	0	0	0	0	900	900	200	0
Pedialion mirum	0	0	0	200	200	3100	2200	1000	0	0	0
Pompholyx complanata	0	0	0	0	0	0	200	0	0	0	0
Ceratium hirundinella	250	800	600	1800	14500	316000	191000	14000	15000	8800	6400
Asterionella formosa	14400	98000	18100	24000	32400	98000	58700	1000	18000	10000	4800
Synedra ulna	0	200	200	0	0	0	0	0	0	0	1000
S. acus	8400	16400	11800	10000	7600	23000	7300	11000	4000	7000	4800
Anabaena sp.	0	0	0	0	0	0	0	0	0	0	200
Dinobryon sertularia	3800	14700	5600	26000	10000	205000	109000	0	0	0	0
Mougeotia sp.	0	73500	5600	5400	3000	2500	0	0	0	2400	0
Total of zooplankton	250	1001	627	2075	15557	323310	194457	16907	15905	9713	6404
Total of phytoplankton	26600	202800	41300	65400	53000	328500	167000	12000	22000	19400	10800
Total of both	26850	203801	41927	67475	68557	651810	361457	28907	37905	29113	17204

Table 42. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Hakkeinoike on Oct 24 1952

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	9
Copepodid of *Cyclops*	0	1	0	0	2	0
Nauplius of *Cyclops*	0	0	1	0	0	0
Bosmina longirostris	2	4	0	16	3	0
Alona rectangula	0	0	5	0	0	0
Synchaeta oblonga	0	200	0	0	600	0
Polyarthra trigla	400	400	600	1000	600	0
Keratella cochlearis	0	400	1000	4200	1000	1000
K. quadrata	0	200	200	200	7600	0
Ploesoma truncatum	0	0	100	0	0	0
Asplanchna priodonta	0	0	0	200	0	0
Filinia longiseta	0	0	0	0	31800	600
Pedialion mirum	0	0	100	0	0	0
Pompholyx complanata	0	0	100	0	0	0
Peridinium willei	0	200	0	0	200	0
Ceratium hirundinella	9600	1800	4000	42400	120000	16000
Tabellaria fenestrata	9000	3400	0	800	0	800
Asterionella formosa	16800	10000	1600	3200	800	3000
Synedra ulna	2000	1800	800	3400	1200	4000
S. acus	3600	2000	400	1400	1000	8800
Anabaena sp.	7200	33200	6000	23001	27300	0
Dinobryon sertularia	11600	5400	13000	3000	0	4000
Mougeotia sp.	2000	10600	2400	3800	2600	0
Total of zooplankton	10002	3205	6106	48016	161805	17600
Total of phytoplankton	52200	66400	24200	38600	32900	20600
Total of both	62202	69605	30306	86616	194705	38200

Table 43. Full data on the individual (or cell) number of plankton organisms occurring at each depth in Hakkeinoike on Feb. 21, 1953

Number of individuals per 20 liters of water (or cells)

Plankton \ Depth (m)	0	2	4	6	8	10
Nauplius of *Cyclops*	1	0	1	0	2	0
Alona rectangula	0	0	0	2	1	0
Polyarthra trigla	500	400	400	1000	100	500
Keratella cochlearis	0	1600	8700	8500	4400	9300
Asplanchna priodonta	0	0	0	100	0	0
Filinia longiseta	0	0	100	400	400	0
Ceratium hirundinella	0	200	0	0	100	0
Tabellaria fenestrata	0	0	1300	1000	900	800
Fragilaria crotonensis	400	1500	500	2300	1300	1900
Asterionella formosa	2100	1800	8100	3900	5500	7700
Synedra ulna	0	100	300	100	3300	400
S. acus	300	1200	1500	400	9800	12200
Cymbella lanceolata	0	0	0	0	200	0
Pandorina morum	0	0	0	0	0	100
Total of zooplankton	501	2200	9200	10002	5003	9800
Total of phytoplankton	2800	4600	11700	7700	21000	23000
Total of both	3301	6800	20900	17702	26003	32800