Bottom and Plankton Fauna of the Akan Lake Group of Hokkaido*

By

Masuzo UÉNO

(上 野 益 三)

(With Plate VII and 6 text-figures)

Introduction

The nine lakes and lakelets in which the present study was conducted are all situated around the foot of the Volcano Oakan-dake, which stands in the center of the Akan Caldera of Eastern Hokkaido. The work was done in the first half of September, 1935. If these lakes and lakelets be separated on a basis of depth, Akan-ko, Panke-ko and Penke-ko are in one category and the other six in another. The largest lake, Akan-ko, is of the greatest interest from the ecological point of view not only in the bottom fauna but also in the plankton production. Panke-ko is the second largest, but is the deepest in the Akan lake group. Penke-ko is much smaller than the preceding two lakes although it is deeper than Akan-ko. These three lakes lie within a drainage basin extending from Penke-ko through Panke-ko and into Akan-ko, which is the most advanced eutrophic condition among them. The remaining small lakes or lakelets vary greatly from one another in morphometric, physical-chemical and biological conditions. A full account of these lakes will be published by Mr. S. YOSHIMURA shortly.

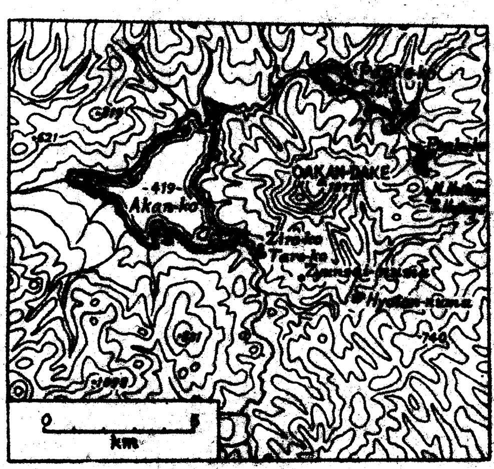

Fig. 1. Sketch map of Akan district.

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I. Bottom Fauna

A. Composition and Depth Distribution

a. Large and deep lakes

1. *Akan-ko* (*Lake Akan*)

This lake has an area of 11.86 square kilometer and a maximum depth of 36.6 m. Except for its steep, rocky eastern shore, the slope of the floor is gradual, the aquatic plants (chiefly *Vallisneria* and *Potamogeton*) extending down to a depth of about 5 m. The littoral zone seems to extend from the shoreline to a depth of about 8 m, the sub-littoral from 8 to 15 m, while the profundal consisting of soft black mud includes all the bottom from 15 to 36 m. One of the most striking features of the littoral zone is the presence of *Aegagropila sauteri* on the shallow sandy bottom in some of the wetsern and northern parts.

The bottom organisms were taken up with a small EKMAN-BIRGE dredge which collects a sample of 225 cm^2 surface area. Eight courses were taken by boat straight across different parts of the lake (Fig. 2). At 38 different stations on these courses samples were secured.

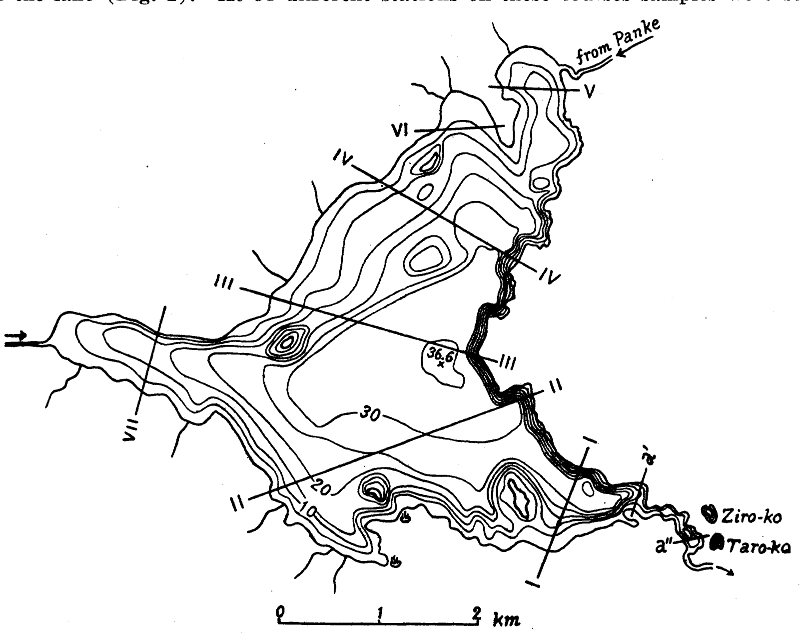

Fig. 2. Bathymetric map of Akan-ko, showing the courses of boat.

The results obtained are summarized in Table I.

Table I. Depth distribution of bottom fauna of Lake Akan (Number per m^2)

Depth in meters	Number of samples	*Chaoborus*	Orthocladiariae	*Ch. plumosus*	*Procladius*	*Sergentia*	*Endochironomus*	*Sialis*	*Ephemera*	*Baëtis*	*Ephemerella*	*Cambaroides*	*Pisidium*	*Viviparus*	*Lymnaea*	*Valvata*	*Planorbis*	Oligochaeta miscel.	Total number per m^2
0–1	1	—	1056	—	—	—	—	—	—	—	44	—	—	—	—	—	—	44	1144
1–2	4	44	264	176	—	440	—	—	88	132	—	—	—	176	176	—	264	352	2112
2–4	5	—	308	—	572	396	—	44	44	—	—	—	—	220	—	88	—	264	1936
4–6	4	—	—	308	—	176	—	44	—	—	—	88	—	—	—	88	88	—	792
6–8	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
8–10	3	—	—	440	—	—	—	—	—	—	—	—	—	—	—	—	—	—	440
10–15	6	132	44	572	—	220	220	—	—	—	—	—	—	—	—	88	—	352	1628
15–20	1	—	220	—	—	—	—	—	—	—	—	—	—	—	—	—	—	44	264
20–25	4	88	132	—	—	—	—	—	—	—	—	—	—	—	—	—	—	44	264
25–30	2	—	176	—	44	44	—	—	—	—	—	—	—	—	—	—	—	88	352
30–34	7	—	264	44	528	1628	—	—	—	—	—	—	572	—	—	—	—	572	3608

The bottom fauna of Akan-ko is composed of five major groups:

(i) Chironomid larvae.—At least five species of the Chironomidae make up more than 69% of the total bottom population by numbers, *Sergentia* larva being the most abundant (35% of the total chironomid fauna). With regard to the depth distribution of the chironomids as a whole, three distinct maxima in numbers are observed, the first in the upper littoral, the second in the lower sublittoral shallower than 15 m and the remaining one in the profundal deeper than 30 m. A great numerical abundacne occurring in the shallow littoral region is chiefly due to the predominance of the Orthocladiariae in the *Aegagropila*-association.

(ii) Chaoborus.—MIYADI (1932) who first studied the bottom fauna of this lake called attention to the predominance of *Chaoborus,* but in my study its larva and pupa make up a very small proportion of the total bottom population, being only 0.7% by numbers. It is not yet clear whether it emigrated out during the mid-summer or a pronounced succession has occurred since MIYADI's exploration.

(iii) Oligochæta.—The oligochæte fauna is composed of at least five species belonging to the genera,[1] *Nais, Stylaria, Limnodrilus, Tubifex* and *Lumbriculus,* forming about 15% of the total number of bottom population.

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1) Determined by Mr. HIDEJI YAMAGUCHI of the Hokkaido Imperial University.

They are distributed almost uniformly, except for the two slight masses occurring in both the littoral and sublittoral zones.

(iv) Mollusca.[2]—The molluscs consist of five species of gastropods and two species of pelecypods, namely, *Lymnaea* (*Radix*) *aulicularia* var., *Viviparus malleatus, Planorbis* (*Gyraulus*) *japonicus, Valvata piscinalis japonica, V. p. simusyuensis, V. cristata hokkaidoensis, V. pulchella saghalinensis, Pisidium* (*Eupisidium*) *cinereum* and *P.* (*E.*) *subtruncatum*. All of the gastropods are confined to the bottom of the upper 10 m, its maximum numbers being found in the water shallower than 2 m, while the bivalves occur only in the deeper bottom. The molluscs as a whole occupy only 10.3% of the total bottom population. Among them *Planorbis* is the most abundant (28.8% of the total molluscan fauna) and *Pisidium* the most scarce (13.9%).

The so-called "shell-zone" is not distinct, the living molluscs and empty shells being found in the following numbers:

Table II. Depth distribution of Mollusca in Lake Akan (Number per m^2)

Depth in meters	*Viviparus*		*Lymnaea*		*Valvata*		*Planorbis*		Total number per m^2		Weight g per m^2
0.5	0	0	0	0	0	0	0	0	0	0	0
1.5	88	(110)	88	(110)	0	(88)	264	(88)	440	(396)	2.9
2.0	88	0	0	(132)	0	0	0	(264)	88	(396)	—
2.5	44	0	0	(176)	0	0	0	(88)	44	(264)	—
3.0	44	0	0	(66)	88	0	0	0	176	(66)	4.2
4.5	0	(66)	0	(44)	88	0	66	0	154	(110)	3.9
5.0	0	(88)	0	0	0	0	0	(44)	0	(132)	—
6.5	0	0	0	(44)	0	(44)	0	0	0	(88)	—
10.0	0	0	0	0	0	(44)	0	0	0	(44)	6.2
10.5	0	0	0	0	88	0	0	0	88	0	—

Bracketted figures denote the empty shells.

The shells of both *Planorbis* and *Lymnaea* form the first abundance in the upper littoral zone shallower than 3 m, and the larger shells of *Viviparus* seem to make the second mass in the zone between 4.5–6.5 m.

(v) Insect larvæ other than chironomids and *Chaoborus*.—*Sialis*-larva and the burrowing nymph of the mayfly genus *Ephemera* occur most abundantly in the zone shallower than 5 m. All of these insect larvæ, including a crayfish *Combaroides japonicus*, form only 5% of the total number of the bottom population.

* * *

[2] *Valvata* and *Pisidium* were determined by Mr. SYUITI MORI of the Kyoto Imperial University. (cf. also MIYADI 1935).

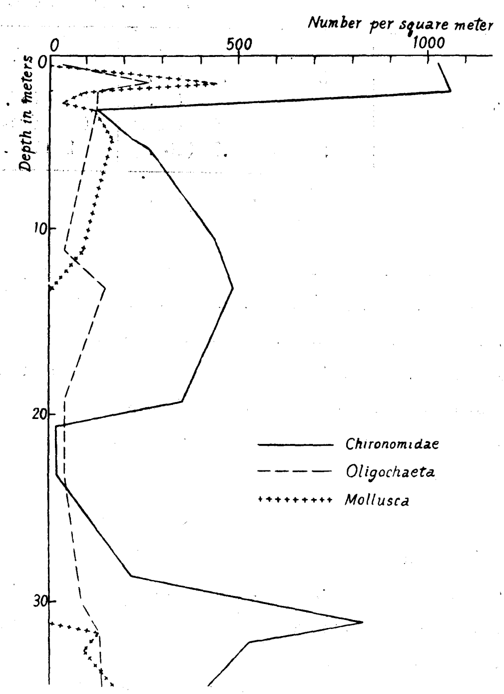


Fig. 3. Depth distribution of bottom fauna of Akan-ko in September, 1935.

Generally speaking, the bottom population below 10 m is composed of chironomids, *Chaoborus*, oligochætes and *Pisidium*, the gastropod molluscs and insect larvæ other than the above being practically absent. It has been well known that the bottom fauna is not uniformly distributed over the bottom from the shore to the deepest water. This is also true of Lake Akan. The present study, however, seems to show much more uniform distribution of the bottom population than MIYADI found in June (cf. MIYADI 1932), when different species were distributed very differently according to depth. In September there are seen three maxima or ''concentration zones'' (EGGLETON 1931, 1935) of the bottom population, viz. the first in the shallow littoral, the second in the lower sublittoral and the other in the middle profundal, and the population declines sharply above and below these zones. Iu the last zone the bottom population is very much more abundant than it is above that region.

Quantity of the bottom population. The quantitative results obtained in various ecological zones are summarized in Table III.

Table III. Quantity of bottom population of Lake Akan

A. Average number per m²

Zone	Number of samples	Chironomid larvæ	*Chaoborus* larva and pupa	Oligochæta	Molluska	Others
		%	%	%	%	%
Littoral	15	249 (37.4)	3 (12.0)	44 (32.1)	70 (57.8)	32 (100)
Sublittoral	9	181 (27.2)	15 (62.0)	39 (28.5)	10 (8.3)	0
Profundal	14	236 (35.4)	6 (26.0)	54 (39.4)	41 (40.8)	0
Total	38	666 (100.0)	24 (100.0)	137 (100.0)	121 (100.0)	32 (100)

B. Average wet-weight g per m^2

		%	%	%	* %	%
Littoral	15	0.57 (32.6)	— —	0.04 (36.4)	4.38 (84.5)	0.32 (100)
Sublittoral	9	0.73 (41.7)	0.005 (45.5)	0.02 (13.2)	0.69 (13.2)	—
Profundal	14	0.45 (25.7)	0.006 (54.5)	0.06 (50.4)	0.12 (2.2)	—
Total	38	1.75 (100.0)	0.011 (150.0)	0.12 (100.0)	5.19 (100.0)	0.32 (100)

* *Viviparus*-shell deducted.

The maximum population is found in the sublittoral, and the littoral population is a little larger than that of the profundal. The wet-weight of the bottom organisms is also the largest in the littoral, but that of the profundal is less than half of that of the sublittoral. RAWSON (1930) obtained corresponding results in Lake Simcoe in Canada, though he found the maxima in numbers and dry weight of the population in the lower profundal.

2. *Panke-ko* (*Lake Panke*)

Panke-ko is the deepest in the Akan lakes having a maximum depth of 49.9 m. Its area is 2.75 square kilometer. Owing to the steep rocky floor the mud deposit seems to be restricted to a small area deeper than 30 m. Even at a depth of 34 m the bottom mud contains fine sand and organic débris. This seems to make a rather large area of the bottom from 5 to 30 m uninhabitable by organisms. Accordingly, the bottom fauna as a whole is rather poor in both species and numbers, though this observation is drawn from fewer samplings than were taken at Akan-ko. The principal component is *Sergentia*-larva which makes up 72% of the total bottom population and attains its maximum number of 1940 per square meter at a depth of 43 m.

Table IV. Depth distribution of bottom fauna of Panke-ko (Number per m^2)

Depth in meters	Number of samples	Orthocladiariæ	*Sergentia*	Oligochæta	*Sialis*	*Ephemera*	Trichoptera	Zygoptera	Total number	Total wet-weight g/m^2
0–5	2	44	176	220	44	44	44	44	616	13.4
5–10	1	—	—	—	—	—	—	—	0	0
10–20	1	—	—	—	—	—	—	—	0	0
20–30	2	—	—	—	—	—	—	—	0	0
30–40	3	—	661	44	—	—	—	—	705	1.3
40–45	4	—	2992	—	—	—	—	—	2992	12.7

3. *Penke-ko* (*Lake Penke*)

The mud deposit in this lake seems to be much more restricted to a small deep area than in Panke-ko. In 12 samplings *Sergentia* and Tanypodinæ were taken up only from the bottom deeper than 30 m; the former numbered only 132 individuals per square meter at a depth of 38 m (maximum depth 39.4 m; cf. TAKAYASU and KONDO 1936 a).

b. Small and shallow lakes

4. *Taro-ko and Ziro-ko*

These two small lakes are situated close together but are greatly different in the components of their bottom faunæ. The species are richer in Taro-ko than in Ziro-ko. In the former *Chironomus plumosus* and *Sergentia* are widely distributed over the bottom, forming 73% of the total bottom population; *Valvata* occupies 15% and the remaining is represented by 6% each of oligochætes and *Sialis*-larva.

Table V. Depth distribution of bottom fauna of Taro-ko (Number per m^2)

Depth in meters	*Ch. plumosus*	*Sergentia*	*Valvata*	Oligochæta	*Sialis*	Total number
2	704	132	176	—	—	1012
3.5	—	—	—	—	44	44
4	264	176	—	44	—	484
4.5	572	88	—	44	—	704
7	88	132	44	—	44	308
8	352	176	—	44	—	572

Over almost the whole bottom of Ziro-ko (maximum depth 3 m) is a dirty yellow diatom-gyttja. The bottom fauna is very monotonous, consisting of only *Sergentia*, which numbers 352–1276 per square meter.

5. *Hyotan-numa*

This shallow lake is bounded by an overgrowth of cyperaceous and umbelliferaceous plants. The bottom deposits are blackish brown mud consisting of a very large amount of decaying vegetable matter. The bottom fauna of the main basin is represented by the molluscs which make up 55% of the total bottom population. The principal component of the chironomid fauna is *Sergentia*, forming only 18.2% of the total population. In the auxiliary basin neither molluscs nor chironomids are found, fauna being represented by larva of *Sialis* and the nymph of the mayfly genus *Ephemera* as seen in Table VI.

Table VI. Depth distribution of bottom fauna of Hyotan-numa (Number per m^2)

	Depth in meters	*Sergentia*	*Pisidium*	*Planorbis*		*Lymnaea*		Oligochæta	*Sialis*	*Ephemera*	Total number	
											Main basin	Auxiliary basin
main	1.5	—	—	—	(88)	44	(44)	132	—	—	176 (132)	—
	2	—	308	748	—	—	(132)	—	—	—	1056 (132)	—
	3	88	44	—	(44)	—	—	—	44	—	132 (44)	44
	4	—	132	—	—	—	—	—	—	—	132 —	—
	4.5	—	44	—	(132)	—	—	44	—	—	88 (132)	—
aux.	1.4	—	—	—	—	—	(88)	88	88	308	88 (88)	396
	3.7	—	—	—	—	—	—	44	—	—	44 —	—

B. General Discussion

The bottom faunæ of the three large and deep lakes are generally similar, but Akan-ko supports a much more varied and richer fauna, especially molluscs, than the other two lakes. However, the bottom population greatly vary quantitatively. It is the largest in Panke-ko in both numbers and weight; Akan-ko ranks second in numbers but is in weight inferior to Taro-ko, as data in Table VII will show.

Table VII. Average number (N) and weight (wet, W) of bottom fauna of the Akan Lake Group, calculated for 1 m^2

Group of Animals	Akan-ko		Panke-ko		Taro-ko		Ziro-ko		Hyotan-numa	
	N	W(*g*)	N	W(*g*)	N	W(*g*)	N	W(*g*)	N	W(*g*)
Chironomidæ....	666	1.75	775	2.90	537	3.03	616	4.25	88	—
Molluscs	121	5.19*	0	—	110	5.34	0	—	264	0.92
Oligochæta	137	0.12	132	0.44	44	—	0	—	88	1.26
Insect larvæ other than Chironomidæ..	32	0.32	176	12.54	44	2.86	0	—	44	—
Total	956	7.38	1083	25.88	735	11.23	616	4.25	484	2.18

* *Viviparus*-shell deducted.

In this table neither Penke-ko nor Zyunsai-numa are included, the former having an extremely poor population and the latter being entirely azoic over the bottom.

As discussed by EGGLETON (1935), it seems certain that the depth distribution of bottom population is not controlled by any one factor but may be determined by the combined effect of various physical and chemical as well as biological

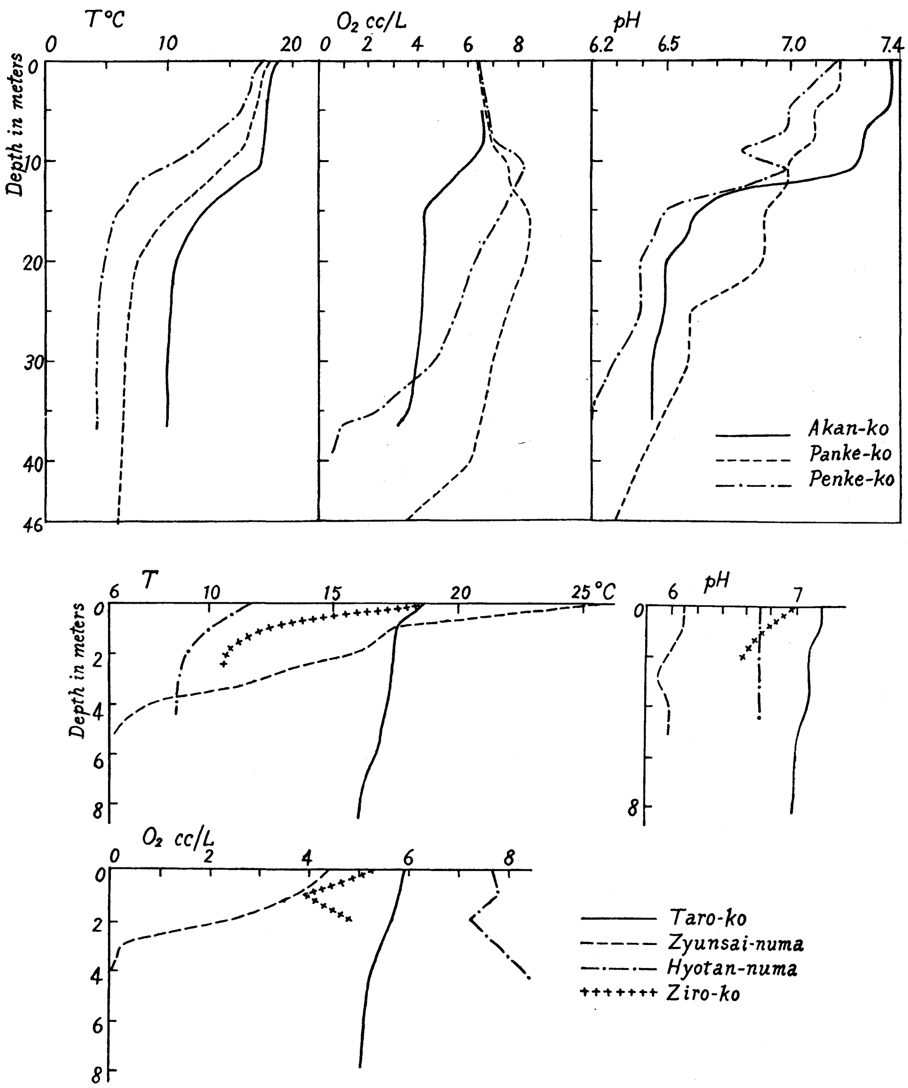


Fig. 4. Stratifications of temperature, pH and dissolved oxygen in the Akan lakes.

factors. It seems, however, that in certain instances any one of these factors may give the most powerful effect in causing migration of an organism. In Zyunsai-numa, for instance, all the *Chaoborus* larvæ migrated up as plankters from the bottom to the upper layer, apparently because of the great deficiency of dissolved oxygen in the deeper water. The accompanying figures will show the thermal and chemical stratifications in these lakes (Fig. 4).

It is a noticeable fact that one of the important factors found to be influencing the luxurience and the depth distribution of the bottom fauna in these larger lakes is the difference of the slope of the lake-floor. However, in the small and shallow lakes the nature of the bottom deposits is much more effective in the life of the bottom organisms. The abundant deposit of humic and decaying vegetable matter may cause a great diminution of dissolved oxygen (Zyunsai-numa) or may affect the food supply of the organisms (Hyotan-numa). The rather pure diatom-gyttja deposited in Ziro-ko appears also to limit the kinds of bottom animals inhabiting it. The writer is of the opinion that it is difficult to find any one of the general environmental factors controlling the distribution of the bottom fauna in the lakes studied.

It is worthy of notice that the occurrence of *Pisidium* and the anærobic larva of *Chaoborus* in association on the deeper bottom of Akan-ko, which has a good amount of dissolved oxygen in the deep water even in late summer (cf. also Miyadi 1932, p. 231). In both Panke-ko and Penke-ko, however, *Chaoborus* was found only as a plankter but not taken at all from the bottom mud. Since in these three lakes no more oxygen deficiency in deep water can be expected to occur after my observations, the occurrence of *Chaoborus* in these lakes especially in Akan-ko is to be regarded as quite an exceptional case.

II. Plankton

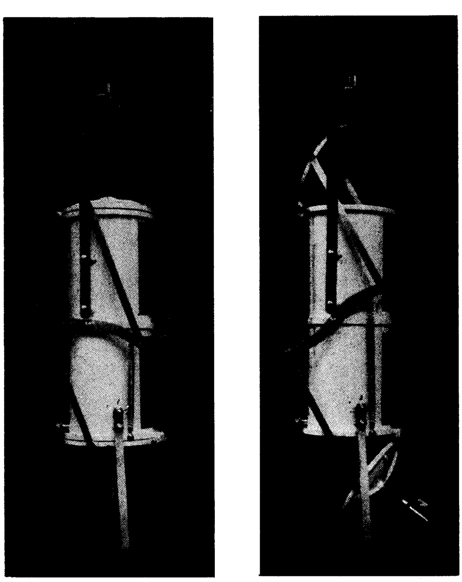


Fig. 5. An improved plankton-catcher of Münster Strøm's type.

The net-plankton was obtained by two kinds of nets, one being a small qualitative net of Apstein's type of 20 cm diameter for surface catches, and the other a small closing-net of Juday's type of 15 cm diameter of the upper cone for vertical hauls. To get the vertical series of plankton-samples from different depths, an improved plankton-catcher of Münster Strøm's type was used (Fig. 5). It has a volume of 10 liters (cf. Münster Strøm 1926). The rough volume of a plankton catch was determined by allowing the sample to settle in a graduated glass cylinder over a period of 24 hours, and then dried at a temperature of 50°C for hours to achieve a constant weight.

A. Composition of the Zooplankton

The percentage composition of the zooplankton is shown in Table VIII, from which will be seen the characteristics of the plankton-population of that season.

Table VIII. Percentage composition of the zooplankton of the Akan Lake Group (September, 1935)

	Akan-ko	Panke-ko	Penke-ko	N. Hutago-numa	S. Hutago-numa	Hyotan-numa	Zyunsai-numa	Taro-ko	Jiro-ko
Rotatoria	1	**49**	**54**	10	11	33	**95**	33	18
Cladocera	41	40	34	32	**67**	**35**	2	33	5
Copepoda	**58**	11	12	**58**	22	32	3	**34**	**77**

Table IX. Distribution of the zooplankters in the Akan Lake Group

Zooplankter \ Lake	Akan-ko	Panke-ko	Penke-ko	S. Hutago-numa	N. Hutago-numa	Zyunsai-numa	Hyotan-numa	Hyotan, auxiliary basin	Toro-ko	Ziro-ko	
Protozoa											
1. *Trintinnopsis lacustris* ENTZ	+	·	·	·	·	·	·	·	·	·	1
Rotatoria											
2. *Polyarthra trigla* (EHRENBERG)	+	+	·	·	·	·	·	·	·	+	3
3. *Keratella quadrata* (O. F. MÜLLER) ..	+	·	·	·	·	·	·	·	+	+	3
4. *Keratella cochlearis* (GOSSE)	·	·	·	+	+	+	+	·	·	+	5
5. *Notholca longispina* (KELLICOT)	·	+	+	·	·	·	+	·	·	·	3
6. *Asplanchna herricki* DE GUERNE	+	+	·	·	·	·	+	·	·	·	3
7. *Conochilus unicornis* ROUSSELET	+	+	+	·	·	+	+	·	·	·	5
8. *Filinia longiseta* (EHRENBERG)	·	+	+	·	·	·	·	·	·	·	2
Cladocera											
9. *Daphnia longispina* (O. F. MÜLLER) .	+	+	+	+	+	+	+	·	+	·	8
10. *Daphnia cristata longiremis* (G. O. SARS)	+	+	+	·	·	·	·	·	·	·	3
11. *Scapholeberis mucronata* (MÜLLER) ..	·	·	·	·	+	·	·	·	·	·	1
12. *Bosmina coregoni* BAIRD	+	+	+	·	·	·	·	·	·	+	4
13. *Alona guttata* (G. O. SARS)	+	+	·	·	·	·	·	·	·	·	2
14. *Leydigia acanthocercoides* (FISCHER) .	+	·	·	·	·	·	·	·	·	·	1
15. *Chydorous spiæricus* (O. F. MÜLLER) ..	·	·	·	·	·	·	+	·	·	·	1
16. *Polyphemus pediculus* (LINNÉ)	·	+	+	·	·	·	·	·	·	·	2
Copepoda											
17. *Acanthodiaptomus pacificus yamanacensis* (BREHM)	+	+	+	+	+	+	+	·	·	·	7
18. *Mesocyclops hyalinus* (REHBERG)	+	+	+	·	·	·	·	·	·	+	4
19. *Mesocyclops oithonoides* (G. O. SARS)	·	·	·	·	+	·	·	·	·	·	1
20. Copepodid (Cyclopoida)	+	+	+	·	·	·	+	·	·	·	4
Insecta											
21. *Chaoborus*-larva	·	+	+	+	·	+	·	·	·	·	4
22. *Ceratium hirundinella* O. F. MÜLLER .	+	·	·	·	+	·	·	·	+	+	4
Total.........	14	14	11	4	6	5	8	0	3	6	

The predominance of rotifers is found in three lakes, namely, Panke-ko, Penke-ko and Zyunsai-numa. The plankton of both S. Hutago-numa and Hyotan-numa are composed chiefly of the Cladocera, especially of *Daphnia,* while in the remaining four lakes the copepods predominate.

Among the rotifers, *Conochilus unicornis* and *Keratella cochlearis* occur most widely, *Filinia longiseta* being found in only two lakes. *Acanthodiaptomus pacificus yamanacensis* is distributed in almost all lakes, appearing most abundantly in Panke-ko. Of the Cladocera, *Daphnia longispina* is present in all of the lakes except Ziro-ko. In some of the lakes it is the most important component of the zooplankton.

The populations of *Daphnia longispina* living in these lakes seem to belong to four different races. The races inhabiting S. Hutago-numa, Zyunsai-numa and Hyotan-numa have large and heavy bodies which are characteristic of the littoral forms of the species; the race of the former two lakes differs from that of the last by having a broad head and posteriorly elongated rostrum. On the contrary, the races occurring in Akan-ko, Panke-ko and Penke-ko have short heads and hyaline shells. Among them the race found in Panke-ko is of a peculiar large size. They should be considered the so-called "*primitiva*-type" of *longispina hyalina,* as already pointed out (UÉNO 1934). It is of the great interest that the size and shape of these different races of *Daphnia longispina* seem to be quite well adapted to the sizes and depths of the lake-basins as well as to the clearness and nutritive conditions of the water.

It is noted that the larva of *Chaoborus* was obtained by a plankton-net in several lakes (see Table IX), in the bottom samples of which none of this larva was present. Since the bottom organisms in Zyunsai-numa were entirely absent owing to the entire lack of bottom oxygen, the presence of *Chaoborus* in an upper layer recalls the composition of the bottom fauna in this lake in an earlier season in which rich bottom oxygen might have been present.

B. Stratification of the Zooplankters

Two vertical series of the net-plankton were obtained by a plankton-catcher already mentioned. The weight of the instrument (cir. 12 kg) it was necessary to limit the collections to Akan-ko, which is the only lake equipped with large motor-boat. All of the zooplankters in each sample were counted. The results are shown in Tables X and XI.

It is evident from these tables and the accompanying figures that the zooplankters are all confined to the upper layer shallower than 10 m. Among them *Conochilus unicornis* was found only in the upper 5 m; *Bosmina coregoni* and *Mesocyclops hyalinus* extend somewhat down to the lower limit of the

Table X. Vertical distribution of the zooplankters in Lake Akan

Station A; 5 IX 1935, 16^h; number per 10 L.

Depth in meters	0	1	3	5	8	10	12	15	17	20	25	30	Total
Tintinnopsis lacustris	0	0	5	1	0	0	0	1	0	1	0	2	10
Polyarthra trigla	1	5	3	0	1	2	0	1	0	0	0	2	15
Keratella quadrata	0	3	2	0	2	1	0	1	1	0	2	1	13
Asplanchna herricki	0	3	3	5	1	2	2	3	1	0	0	0	20
Conochilus unicornis	19	240	224	7	5	2	1	1	0	0	0	0	499
Daphnia longispina hyalina	21	73	363	238	204	56	20	3	1	4	4	22	1009
D. cristata longiremis	0	0	0	0	0	0	22	26	13	20	9	20	110
Bosmina coregoni	17	134	174	101	122	60	7	4	3	5	8	11	651
Leydigia acanthocercoides	0	0	0	0	0	0	0	0	0	0	1	0	1
Mesocyclops hyalinus	190	320	566	324	236	148	31	25	10	16	23	34	923
Nauplii and copepodids of Copopeda	27	68	103	74	14	7	4	0	0	4	1	14	316
Ceratium hirundinella	901	619	1113	119	1504	122	54	77	71	23	71	0	—
Volvox	0	0	0	10	25	4	1	0	0	0	1	1	—
													4567

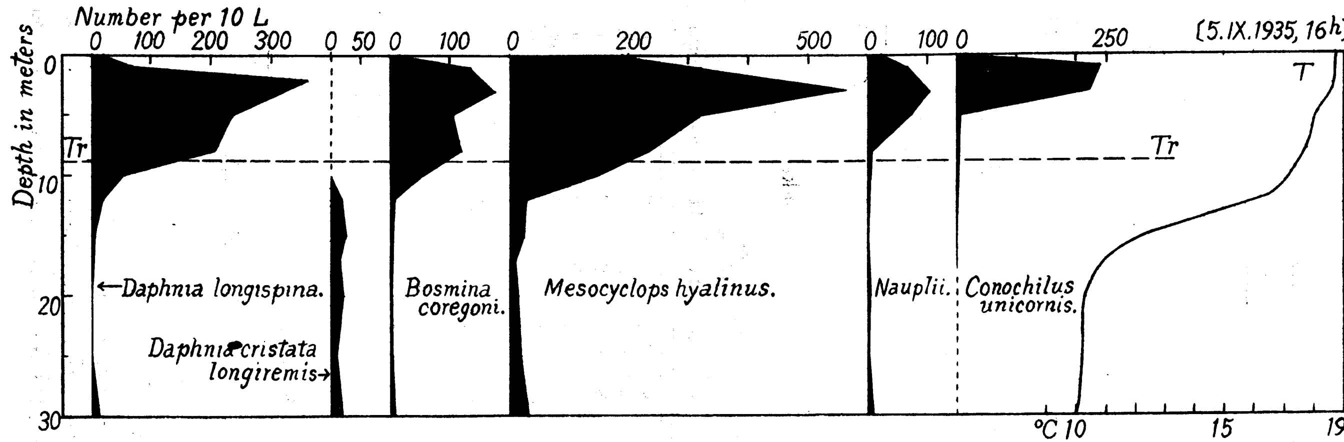
Table XI. Vertical distribution of the zooplankters in Lake Akan

Station B; 6 IX 1935, 14^h 30^m; number per 10 L.

Depth in meters	0	1	5	10	15*	20	25	30	Total
Tintinnopsis lacustris	0	0	0	0	—	0	0	1	1
Polyarthra trigla	4	12	3	2	—	2	1	3	27
Keratella cochlearis	0	0	1	3	—	0	0	0	4
Asplanchna herricki	0	0	4	3	—	0	2	0	9
Conochilus unicornis	1	25	19	0	—	0	2	0	47
Daphnia longispina hyalina	20	124	77	63	—	3	30	5	332
D. cristata longiremis	0	0	1	3	—	37	82	17	140
Bosmina coregoni	2	11	52	53	—	6	19	1	144
Leydigia acanthocercoides	0	0	0	0	—	0	1	1	2
Acanthodiaptomus pacificus yamanacensis	0	2	0	0	—	0	0	0	2
Mesocyclops hyalinus	20	123	321	160	—	15	50	52	741
Nauplii and copepodids of Copepoda	3	13	48	11	—	5	7	20	107
Volvox	0	0	16	23	—	1	0	0	—
									1546

* Vial destroyed.

epilimnion, but in the hypolimnion only a very few of them were secured. *Daphnia longispina*, which is always found living in the hypolimnion in some lakes in middle Japan during summer months (KIKUCHI 1930), occurs also in the water above the metalimnion. It seems probable that such a phenomenon



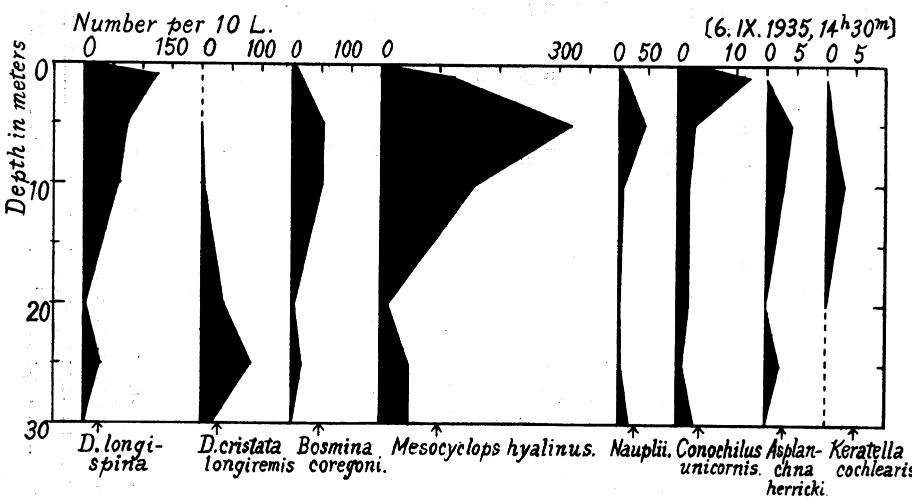


Fig. 6. Stratifications of zooplankters in Akan-ko.

Upper: Station A, Sept. 5th, 1935.
Lower: Station B, Sept. 6th, 1935.
T, water temperature (°C).
Tr, transparency in meters.

is chiefly due to the water-temperature of this lake which is so cold for these organisms as to cause them to migrate down to the hypolimnion.

On the other hand, there were found two species of the zooplankters occurring only in the hypolimnion. They are *Daphnia cristata longiremis* and *Leydigia acanthocercoides,* both of which are for the first time recorded in Japan. The former is a well-known cold-water animal which is distributed in the circum-boreal regions, and the latter was found only in the layer just above the lake-bottom.

Phytoplankton. The phytoplankton occurs most abundantly in Akan-ko, where *Ceratium hirundinella* predominates in the upper 5 m, forming a water-bloom together with the diatom *Asterionella formosa* and blue-green alga *Anabœna.* In both Panke-ko and Penke-ko the phytoplankton was hardly seen, while in Zyunsai-numa a rich production of *Peridinium* and *Dinobryon divergens* was found.

C. Productivity

a. Quantity

The rough volume and dry weight of the plankton which were secured from the samples obtained by the vertical hauls are shown in Table XII.

Table XII. Quantity of plankton of the Akan Lake Group

Lake	Depth of hauls (m)	Rough volume cc/m^3	Dry weight mg/L
Penke-ko	46–0	33.13	0.233
Akan-ko	33–0	21.00	0.341
Zyunsai-numa...	5–0	19.44	—
Panke-ko	30–0	15.74	0.140
Hyotan-numa ...	4.5–0	12.35	—

Panke-ko seems to yield the most profuse quantity of plankton per unit volume of water. This is chiefly due to the abundance of *Daphnia* which makes the total plankton catch voluminous. The same is also true of the plankton of Zyunsai-numa. However, the largest dry weight was secured in Akan-ko which is followed by Panke-ko; that of Penke-ko is much less than the preceding two lakes.

The amount of the plankton of the seven lakes studied may be rated in about the following order:

Panke > Akan > Zyunsai > Penke > Hyotan > Taro > Ziro.

b. Plankton Nitrogen

The total organic nitrogen content of the plankton was determined by digestion with sulphuric acid and perhydrol followed by the micro-Kjeldahl procedure after PARNAS and WAGNER (PREGEL 1930) on the dried materials mentioned already (cf. also COOPER 1934). The results are given in Table XIII.

Table XIII. Plankton-nitrogen of three lakes.

Lake	Depth of hauls m	Samples dry weight (mg)	Total organic nitrogen (mg)	Total organic nitrogen (%)	Crude protein* (%)
Akan-ko	33–0	40.6	1.97	4.9	30.3
"	Surface**	40.9	3.08	7.5	47.1
Panke-ko	46–0	38.7	2.31	6.0	37.4
Penke-ko	30–0	15.1	0.91	0.6	37.6

* N×6.25.

** Sample obtained from the surface where water-bloom appeared.

The quantity of crude protein in Panke-ko and in Penke-ko was nearly the same, but that of a surface sample from Akan-ko was larger than that of Panke-ko. The average quantity of the crude protein in the water of Lake Mendota is 44.5% (BIRGE and JUDAY 1934), and this value stands between the quantities obtained from Panke-ko and the surface of Akan-ko. According to BIRGE (BIRGE and JUDAY 1934), the crude protein is present 56.6% in the mixed Entomostraca, 51.2% in blue-green algæ and 44% in diatoms. It seems natural that 47% of the crude protein is present in the surface plankton of Akan-ko which consists of a rather large amount of mixed species of the Entomostraca, dinoflagellates, blue-green algæ and diatoms.

BIRGE and JUDAY (1926) called the nitrogen from the residues of the lake-water "dissolved", and noticed that the nitrogen of this form is from three to six times as great as that of the plankton, i.e. "plankton nitrogen". The dissolved nitrogen of the lakes studied was estimated by Mr. YOSHIMURA colorimetrically but not from the residues. According to his findings, its quantity is the largest in Akan-ko (aver. 0.332 mg/L) and that is followed by Penke-ko (aver. 0.16 mg/L). Panke-ko contained the smallest amount (aver. 0.077 mg/L).

III. Remarks on the Lake Type

It is of great interest that in the Akan lake group different types of water and of biocoenosis are seen. With regard to the plankton no marked differences are discernible, water-bloom appearing only in Akan-ko. The bottom fauna shows, however, some marked differences among the lakes. Panke-ko, Penke-ko and Ziro-ko belong to the *Sergentia* type, while Akan-ko and Taro-ko are *Sergentia* and mesotrophic *Plumosus* type (*sesu* MIYADI 1933). Akan-ko is characterized by the occurrence of both *Chaoborus* and *Pisidium* in the deeper bottom; in this lake and in Taro-ko the presence of *Valvata* is also noticed. Akan-ko belongs to an exceptional lake type, not referable to VALLE's mesotrophic *Pisidium-Corethra* or *Pisidium-Sergentia* types (VALLE 1927, p. 155).

LUNDBECK (1926) and DECKSBACH (1929) have shown that the succession of lake types from oligotrophic to eutrophic is well represented by chironomid species inhabiting them. According to this, Panke-ko, Penke-ko and Ziro-ko are in the oligotrophic or less advanced mesotrophic conditions, and Akan-ko and Taro-ko seem to belong to the somewhat advanced mesotrophic, of which the former is partly eutrophic and thus produces water-bloom. The chemical nature of the waters and the plankton-production coincide rather well with the above types.

Summary

1. The bottom and pelagic fauna of nine lakes and lakelets in the Akan district of Hokkaido were studied in the first half of September, 1935.

2. The largest lake, Akan-ko, is the richest in the species of the bottom animals, but ranks the second in the abundance of the bottom population. The most important component of the bottom faunæ of the lakes studied is the larva of the chironomid genus *Sergentia.*

3. The bottom faunæ of the large and deep lakes are markedly similar, particularly in deep water. They are somewhat different in each of the small and shallow lakes. None of the bottom fauna was found in a small lake, in the deep water of which the dissolved oxygen was entirely absent.

4. The depth distribution of the bottom population seems to be influenced not only by the complex effect of the physical and chemical factors but also by the condition of the mud deposits, which are largely affected by the slope of the lake-floor.

5. The net-plankton is composed chiefly of rotifers and cladocerans, among which *Conochilus, Keratella* and *Daphnia* are the important components of that season.

6. The data obtained in Akan-ko demonstrate the striking fact that all of the zooplankters occur chiefly in the epilimnion, below which they are found in very small numbers. This is the most important difference in the vertical distribution of the zooplankters between the lakes of Hokkaido and those of Middle Japan.

7. The rough volume of the plankton is the largest in the lake which produces luxuriant crustacean plankton especially large *Daphnia.* The largest dry weight is, however, obtained in the lake having various kinds of plankton

organisms especially of rich production of the algal plankton.

8. The plankton nitrogen was estimated by the mikro-Kjeldahl procedure for the first time in the Japanese lakes. The largest amount of crude protein of 47% was obtained in Akan-ko where an enormous water-bloom was present.

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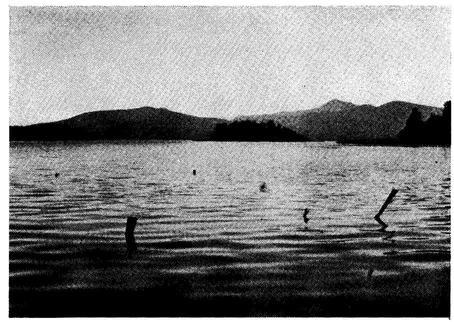

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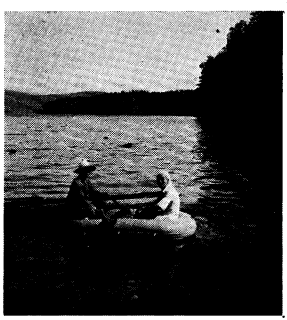

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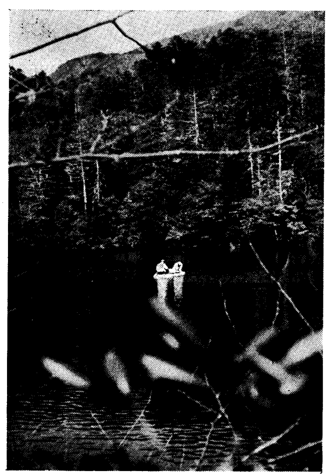

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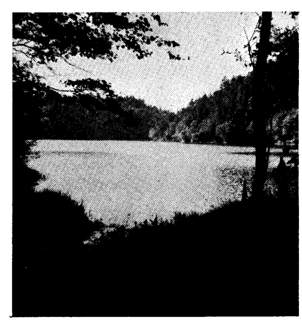

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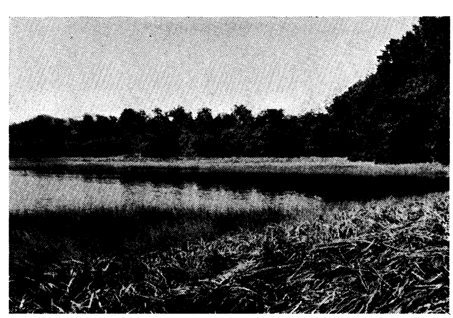

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Explanation of Plate VII

Fig. 1. Akan-ko. View from Senhoku-toge looking SE. The mountain at the left of the lake is Volcano Oakan-dake. (UÉNO photo).

Fig. 2. View over part of Akan-ko, from the north shore looking south. (UÉNO photo).

Fig. 3. Panke-ko, from the western end of the lake looking east. (Photo Prof. Yaichiro OKADA).

Fig. 4. Penke-ko. (Photo Prof. OKADA).

Fig. 5. Ziro-ko. (UÉNO photo).

Fig. 6. Taro-ko. (UÉNO photo).

Fig. 7. Hyotan-numa. From the north shore looking SW: cyperaceous plants cover the littoral region. (UÉNO photo).