Bottom Fauna of Lake Abasiri and the Neighbouring Waters in Hokkaido[1]

By

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With 8 text-figures

Introduction

A number of lakes of various sizes and depths lie on the north-eastern Ochotsk sea coast of Hokkaido. The majority of these lakes are lagoons, and some of the larger ones are connected directly with the sea. Of the freshwater lakes, Abasiri-ko is the largest and is one of the most productive of piscivorous fishes among the lakes of Hokkaido. It was once investigated by the officials of the staff of the Hokkaido Fisheries Experiment Station (cf. TAKAYASU et al. 1930), but its bottom fauna was left unexplored. The present contribution deals with the bottom fauna not only of Abasiri-ko, but also of the Abasiri river, the effluent of the lake, and Mokoto-numa, a small lake lying some 8 km south-east of Abasiri-ko. These inland waters were studied from the end of August to the beginning of September, 1936. The bottom animals were collected in each case by using an EKMAN-BIRGE bottom-sampler which takes up the bottom mud over a surface area of 225 cm^2. The physical and chemical results obtained will be discussed in detail by Dr. YOSHIMURA in a separate paper.

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1. Abasiri-ko (Lake Abasiri)

a) General Features of the Lake

Abasiri-ko occupies a large flat depression some 5 km south-west of the

1) Contribution from the Ōtsu Hydrobiological Station, Kyoto Imperial University.

Abasiri harbour, which in turn lies close to the coast of the Ochotsk Sea. The lake lies at 43°54′–44°N, 144°7′–144°13′E and at an altitude of about 0.6 m. The entire depression in which the lake lies is surrounded by a series of terraces not higher than 200 m above the sea. The principal influent of the lake is the Abasiri-gawa (Abasiri river) which runs from the northern side of the Akan caldera (UÉNO 1936) at the southern end of the lake. The effluent which flows out at the north-east end and empties into the Ochotsk Sea is also called Abasiri-gawa.

Abasiri-ko is rather irregular in form, the shore-line being 40 km, the greatest length being about 11 km in the NE-SW direction. The area is 34.04 km². The maximum depth is 17.6 m at about the centre of the lake. At both ends of the main basin there is a bay, Yobito-wan in the north and

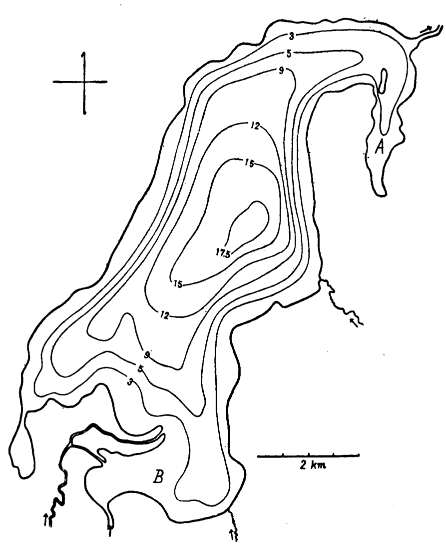

Fig. 1. Bathymetric map of Abasiri-ko. A, Yobito-wan; B, Memanbetu-wan Isobath in metres.

Memanbetu-wan in the south. These two gulfs and the main basin are somewhat different ecologically. The margin of the main basin is formed by sandy shores, but at several headlands especially in the north and west the water washes against a shore of rocky fragments. In the southern bay, south of the delta of the influent, there is an abundant growth of aquatic phanerogamic plants.

The littoral region may be said to extend from 0 to 6 m in depth, the sublittoral from 5–9 m to 12 m, and the profundal in those areas deeper than 12 m. The littoral region is well-developed, occupying nearly 50 % of the total surface area of the lake. Both bays in the north and south may be regarded as littoral.

The mean monthly temperature at Abasiri harbour varies from -7.0°C in January to 16.7°C in July. The mean annual rainfall at the same place is about 800 to 1100 mm. Abasiri-ko is usually frozen over in the middle of December and loses its ice about the middle of April.

Bottom deposits. The bottom of the north bay, Yobito-wan, is covered with blackish brown mud, containg a rather large amount of allochthonous detritus, while in the south bay, Memanbetu-wan, the bottom mud is brown ochre and contains a large amount of fine sand. The bottom deposit of the main basin where the water is deeper than 4-5 m is blackish grey mud containing still fine sand to a depth of 10 m. The total nitrogen content of such a mud, estimated by the micro-Kjeldahl procedure, is 1.2%, which is about one-sixth of the "plankton nitrogen" (*sensu* BIRGE and JUDAY 1926) of the lake-water at that season. On the bottom of the central part of the lake deeper than 13-14 m there was found black cream-like soft mud which gave off an odor of hydrogen sulphide and contained no organic detritus. This kind of black mud is usually found in the coastal lakes, in which the water of higher salinity is stagnant in the deeper layer (cf. YOSHIMURA and MIYADI 1936). The origin and constitution of such peculiar deposits were fully discussed by MÜNSTER STRÖM (1936) in connection with a number of Norwegian lakes.

b) Physical and Chemical Results

The series of observations made by YOSHIMURA parallel to the writer's work is presented in Table I.

Hypolimnion was hardly recognized just above the bottom. Dissolved oxygen decreased rapidly below depths of 10 m, at 12 m being about ⅓ of that of the surface, and in water deeper than 14 m entirely absent. The dichotomous stratification of pH, well-known in certain Japanese lakes, was also observed in this lake. The salinity of deep water is about half that of sea water and it is of interest that it corresponds to the area of black mud deposit described above. The water of the Ochotsk Sea may have flowed up the effluent into the lake during a heavy storm, the water of high salinity then stagnating on the deeper bottom. This is substantiated by the fact that certain bleached marine shells were taken from the deep bottom. On the basis of the chemical analysis of the water, Abasiri-ko is regarded as eutrophic, the water-bloom consisting chiefly of *Aphanizomenon flos-aquae* occurring in mid-summer.

TABLE I

Lake Abasiri. 29. VIII. 1936.

Depth in metres	Temp. °C	pH	O_2 cc/l	O_2 %	Chlorine g/l
0	23.70	7.7	6.16	103	0.198
1	23.30	—	—	—	—
2	22.67	7.6	—	—	—
3	22.36	7.5	5.59	91	—
4	22.30	7.3	—	—	—
5	22 26	7.1	5.33	87	0.185
6	22.00	7.1	—	—	—
7	21.61	7.0	—	—	—
8	21.58	7.0	5.50	88	—
9	21.04	6.8	—	—	—
10	20.14	6.6	3.87	60	0.137
11	18.98	6.6	—	—	—
12	18.41	6.5	2.23	34	2.6
13	14.19	7.0	0.08	1	—
14	9.78	7.3	0	0	—
15	7.06	7.5	0		9.9
16	6.32	7.5	0		10.5

Transparency: 2.9 m.

c) Bottom Fauna

i) *Composition of the bottom fauna.* The bottom fauna is composed of the following five groups of animals:

	%
Chironomidae (larvae and pupae)	47.0
Insect larvae other than Chironomidae	0.3
Crustacea	16.4
Mollusca	32.9
Oligochaeta	3.4
	100.0

The number of species is about 20, corresponding with those of the lakes of Honsyu and of the Southern Kuriles especially in the Island of Etorohu. The percentage composition of the mollusks is much higher than in any lakes south of Hokkaido, but they resemble those of the shallower lakes of Etorohu and Hokkaido. The composition of the bottom fauna of the two lakes of Etorohu is cited below (cf. MIYADI 1933).

	Tosimoé-ko	Kimon-numa
	%	%
Chironomidae	54.1	45.1
Crustacea	—	—
Mollusca	33.4	38.5
Oligochaeta	12.5	16.4
	100.0	100.0

1. *Chironomidae larvae.* At least 6 species of chironomid larvae were found in the bottom mud. Of these, the larvae belonging to the Orthocladiariae were most widely distributed down to a depth of 7 m, their number per unit area (squre metre) being estimated at more than 2100. The blood-red larva and pupa of *Chironomus plumosus* were also widely distributed, but much fewer in number (less than 300 per m^2) than the precending forms. The finding of this larva at a depth of 14.6 m is noteworthy because the bottom water close to the mud at such a depth is greatly contaminated by the presence of chlorine and hydrogen sulphide, as stated already. Besides those mentioned above, the larvae of Tanypodinae, *Tanytarsus*, *Sergentia* and *Glyptotendipes* were also found in small numbers.

2. *Crustacea.* Three species of malacostracan Crustacea inhabit the lake:

Amphipoda—*Anisogammarus* (*Eogammarus*) *kygi* (DERSHAVIN)
Isopoda —*Exosphaeroma oregonensis* DANA
Mysidacea —*Neomysis intermedia* CZERNIAVSKY

Of these species, *Neomysis* is the most widely distributed over the bottom down to a depth of 10 m, at which the chlorine content of water is less than 1 g per litre. The numerical estimate generally shows less than 50 per m^2, but often as many as 264 per m^2. The other two crustaceans inhabit bottoms shallower than 2 m; *Anisogammarus* is usually fewer than 300 per m^2, while *Exosphaeroma* often exceeds 1600 per m^2. The latter species is readily adaptable to freshwater, it being found in certain habitats in the Abasiri river (see later chapter).

3. *Mollusca.* 12 species (determined by MORI) were found inhabiting the lake, most of them being bivalves.

1. *Pisidium* (*Eupisidium*) *cinereum nikkoense* MORI
2. *P.* (*E*) *subtruncatum* MORI
3. *P.* (*E.*) *subtruncatum altus* ?
4. *P.* (*E.*) *pulchellum* JENYNS

5. *Anodonta arcaeformis* (HEUDE) (determined by KURODA)
6. *Amnicola* sp.
7. *Valvata piscinalis japonica* VON MARTENS
8. *V. cristata hokkaidoensis* MIYADI
9. *Anisus* (*Gyraulus*) *albus spirillus* (GOULD)
10. *Stenothyra* n. sp. (KURODA *MS*)
11. *Viviparus malleatus* (REEVE)
12. *Lymnaea* (*Radix*) *auricularia* ?

Most of these mollusks are found in the littoral region shallower than 4 m (usually 2 m). The only genus living on a deeper bottom is the *Pisidium* which is found down to a depth of 9 m. This genus is also the richest in individual numbers, often exceeding 800 per m^2 in the shallow bottom of 2 m. *Anisus* is found also in shallow regions especially among luxurious growths of aquatic phanerogams, it being estimated as 100-300 per m^2. *Valvata* is restricted to the bottoms shallower than 3 m, and reaches 700 or more individuals per m^2. The variety of Mollusca rich both in species and individual numbers is one of the outstanding characteristics of the bottom fauna of the lake.

4. Oligochaeta. *Limnodrilus* was found sporadic down to a depth of 9 m,

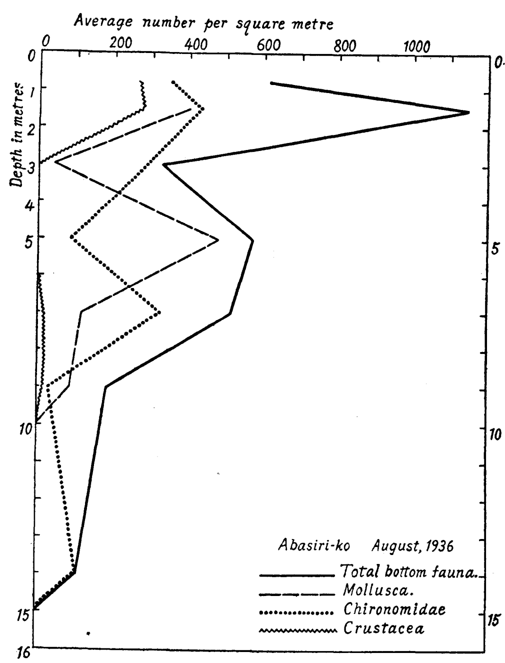

Fig. 2. Depth distribution of the bottom fauna of Abasiri ko.

its number being usually less than 150 per m^2.

ii) *Depth distribution.* The distribution of the bottom inhabitants with depth is summarized in fig. 2. Among the Chironomidae there are two concentrated zones, the one larger in the littoral and the other smaller in the sublittoral, then decreasing in number with increase of depth. The occurrence of *Chironomus plumosus* at a depth of 14.6 m is unusual. The distribution of the Mollusca is similar to that of the Chironomidae, but its concentrated zones are somewhat shallower than those of the Chironomidae. The Crustacea is quite confined to the shallow littoral region, showing no marked distribution with depth. The depth distribution as a whole also shows two concentrated zones, the one larger in the littoral and the other smaller in the sublittoral. About 87 % of the total bottom population obtained is confined to the littoral region. Such a type of depth distribution was obtained by LUNDBECK (1926) in many eutrophic lakes in North Germany. In those German lakes, however, the second concentrated zone is a little smaller and lying some what deeper than in Abasiri-ko.

iii) *Density.* The abundance of the bottom inhabitants per unit area are summarized in Table II.

TABLE II

Average number of bottom inhabitants per square metre in Abasiri-ko.[1] 27-29. VIII. 1936.

Depth in metres	Mollusca	Crustacea	Oligochaeta	Chironomidae	Insect larvae other than Chironomidae	Total number	Total weight[2] g/m²	Mollusca	Others
0 - 1	0	264	0	352	0	616	2.4	0	2.4
1— 2	410	275	15	434	11	1145	5.3	2.3	3.0
2— 4	39	0	0	290	0	329	3.4	0.9	2.5
4— 6	484	0	0	88	0	572	1.1	1.1	-[3]
6— 8	117	15	59	325	0	515	2.7	0.9	1.8
8—10	88	15	44	29	0	176	2.4	0.7	1.7
10—15	0	0	0	110	0	110	0.3	0	0.3
15—16	0	0	0	0	0	0	0	0	0
Total:	1138	569	118	1628	11	3463			

Note. — 1) Total number of samples: 40.
2) So called "formalin weight".
3) Too small a quantity as to be weighed.

The population density of the bottom fauna in Abasiri-ko is not very large, the average being 500 per m^2, the maximum number of 1145 per m^2 being found at a depth of 1–2 m. The greatest average weight was also obtained at the same depth: 5.3 g per m^2, of which 2.3 g was mollusks. On the deeper bottom the biomass does not correspond to the numerical abundance of the inhabitants. The average number of individuals at a depth of 6-8 m attains 570 per m^2, while their average weight is only 1.1 g per m^2 due to the minuteness of *Pisidium* inhabiting there.

iv) *The difference of the bottom fauna according to the nature of the bottom.* The differences between the species and the variation of their abundance according to the nature of the bottom is noteworthy ecologically. This data is shown in the Table III.

Of the six classes, nos. 1, 2, 4 and 5 belong to the littoral, comprising about 87 % of the total bottom population. The sandy bottom with aquatic vegetation is abundantly inhabited and accounts for 29% of the total bottom population. The mud bottom covered with weeds is inferior serving as a habitat for only 25.5%. This evidence suggests that aquatic vegetation is one of the important factors determining the nature of the bottom inhabitants. The sublittoral zone of sandy mud is the most void of bottom animals, accounting for only 10 % of the total population. LUNDBECK (1935) reports a similar condition among the bottom fauna of two shallow inland seas in North Germany. In the "Kurischen Haff" the bottom population is the largest where there is a sand bottom with vegetation, the total average number reaching 8721 per m^2; that of the dark mud bottom ranks second (6024 per m^2) which is about twice that of the sandy mud (3249 per m^2). The inhabitants of the sand bottom numbered only 1077 per m^2.

The south bay, Memanbetu-wan, is richer per unit area both in species and individual numbers than the north bay, Yobito-wan (Table IV). The former is regarded as a part of the littoral region of the main basin, the surface exposed to strong wind, while the latter is a narrow bay which is protected from wind. The deep soft mud deposits in the latter bay accumulate a large amount of allochthonous detritus. Owing to such an environmental difference the bottom fauna of the south bay is richer than that of the north. In the Memanbetu-wan the mollusks comprise as much as 66.8% of the total bottom fauna and are rich in the number of species, while in Yobito-wan the Chironomidae larvae are dominant, exceeding even the mollusks. Crustaceans are entirely absent from the latter. This difference is apparently due to the nature of the bottom deposits. The blackish grey mud in Yobito-wan contains a large

TABLE III

Difference of the Bottom Fauna (average number per spuare metre) according to the nature of the bottom.

Bottom	1 Sand	2 Sand with vegetation	3 Sandy mud	4 Mud with vegetation	5 Mud	6 Black mud
Depth in metres	1.2–3.5	0.8–3.0	7–10	1–1.5	1.3–4	14–16
Lymnaea auricularia	—	11	—	97	—	—
Anisus albus spirillus	—	33	—	18	—	—
Valvata spp.	6	11	—	273	6	—
Stenothyra sp.	39	—	—	26	12	—
Viviparus malleatus...	—	—	—	9	—	—
Pisidium spp.	22	22	74	77	226	—
Anodonta arcaeformis	—	—	—	(9)	—	—
Anisogommarus kygi	—	22	—	70	—	—
Exosphaeroma oregonensis ...	10	518	—	77	—	—
Neomysis intermedia	6	11	29	53	—	—
Limnodrilus sp.	—	—	—	35	—	—
Orthocladiariae	507	396	250	70	176	—
Tanypodinae	11	—	—	53	—	—
Glyptotendipes	—	—	—	18	—	—
Sergentia	—	—	—	9	—	—
Chironomus plumosus	11	—	15	—	57	—
Tanytarsus	—	—	—	—	6	132
Molanna	—	—	—	9	—	—
Brachycentrinae	—	—	—	9	—	—
Total:	622	1024	368	903	483	132
%:	17.6	29.1	10.4	25.5	13.7	3.7

amount of organic substance which is favourable to the Chironomidae larvae, but not to crustaceans which prefer sandy mud. The abundance of aquatic plants in Memanbetu-wan also favours apuatic life especially débris-eating mollusks. The percentage composition of the bottom fauna of Yobito-wan to that of the main basin as a whole is about as follows:

	%
Chironomidae	46.6
Insect larvae other than Chironomidae	0.6
Crustacea	19.0
Mollusca	31.4
Oligochaeta	2.4
	100.0

TABLE VI

Difference of the Bottom Fauna (average number per square metre) between the Two Bays.

Bottom inhabitant	Memanbetu-wan		Yobito-wan	
	Number	%	Number	%
Lymnaea auricularia	60	8.3	—	—
Anisus albus sprillus	110	15.1	—	—
Valvata spp.	171	23.5	73	12.4
Stenothyra sp.	22	3.1	22	3.8
Viviparus malleatus	6	0.8	—	—
Pisidium spp.	116	15.9	198	33.8
Anisogammarus kygi	44	6.1	—	—
Exosphaeroma oregonensis	50	6.9	—	—
Neomysis intermedia	33	4.5	—	—
Limnodrilus sp.	22	3.1	—	—
Orthocladiariae	39	5.4	212	36.2
Tanypodinae	22	3.1	15	2.6
Glyptotendipes	11	1.5	—	—
Sergentia	7	0.9	—	—
Chironomus plumosus	—	—	59	10.0
Tanytarsus	—	—	7	1.2
Molanna	7	0.9	—	—
Brachycentrinae	7	0.9	—	—
Total:	729	100.0	586	100.0

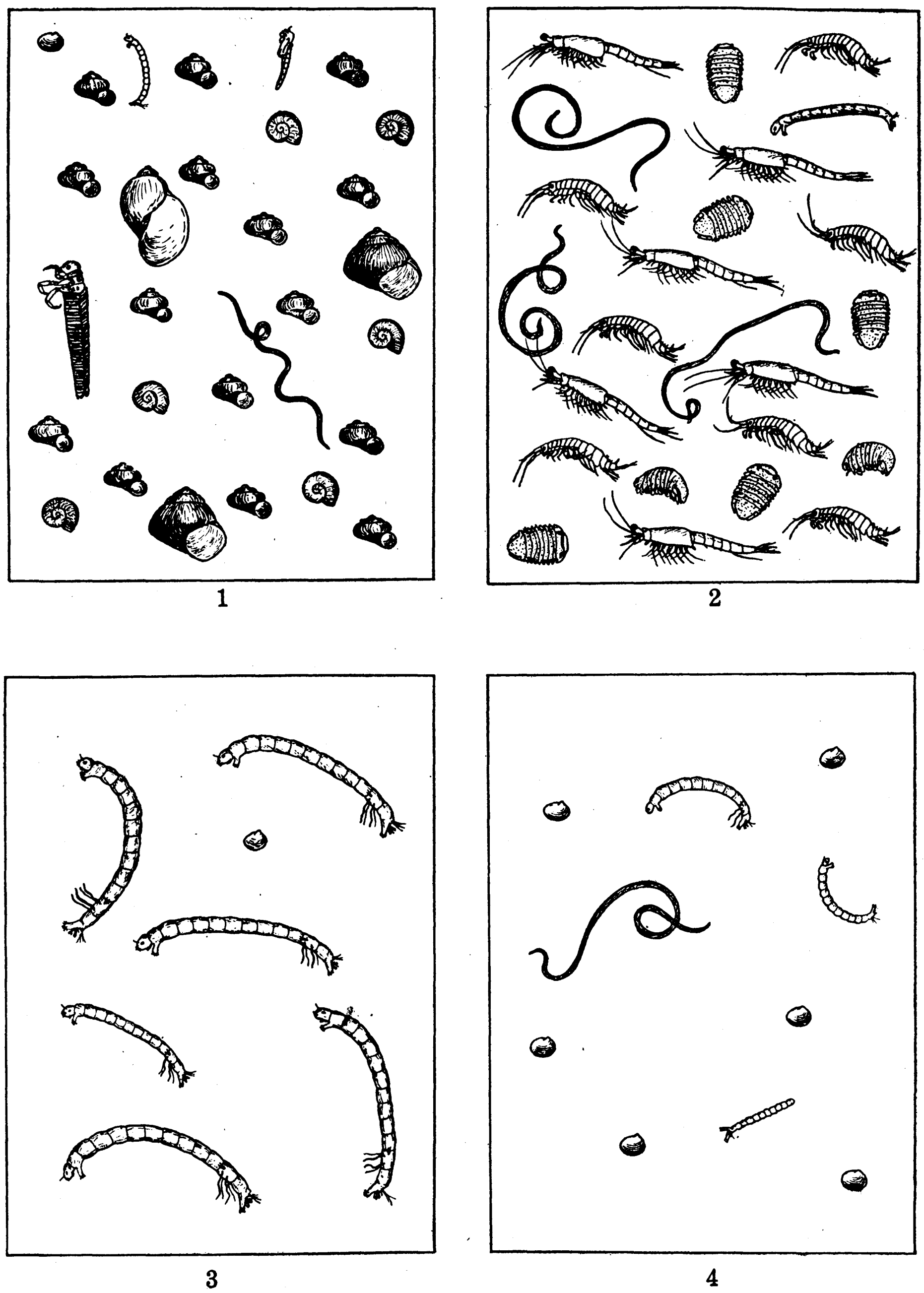

Fig. 3.

2. **Abasiri-gawa (Abasiri river)**

a) General Features of the River

Abasiri-gawa which is the effluent of Abasiri-ko extends some 7 km from its source to the estuary on the Ochotsk Sea. Rising in the north-eastern corner of Abasiri-ko, it flows north about 1 km; turning west it runs for more than 1 km, and then after a remarkable curve it turns again eastward, passing through the town of Abasiri where it empties into the sea. It is not fed by any branch streams. For the most parts, the course of the river is lined by beautiful forest of deciduous trees, but some parts of the middle of the course have been somewhat cleared for field crops or pasture. At the great curve, however, the actual course of the river is bordered by a vast area of *Phragmites*-association. The width of the river is usually less than 100 m and the depth does not exceed 4.5 m at any point during the course. The volume of flow is, according to TAKAYASU's determination on October 1, 1926, 46.35 m^3 per minute.

The whole course of the Abasiri river is shown on the sketch map in fig. 4; each station at which observations and collections were made is noted. The cross-section observations made at the seven sections are indicated on the map by the Roman numerals, thus: I–VII. The bottom of the upper course, sections I and II, is of sand and gravel, but the deep central region of section III which is bordered by a swampy area with growths of *Phragmites communis* consists of blackish grey sandy mud. The bottom of the middle and lower course is mostly sand or sandy mud, except the region above the bridge "d" which consists of only gravel and stones. The lower course near the estuary, sections V, VI and VII, contains deposits of black sapropelic soft mud containing

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Fig. 3. Schematic representation of the arrangement of animals on four different bottoms of Abasiri-ko. Number per 225 cm^2.

1. Yellow grey mud bottom at 1m depth in Memanbetu-wan; presence of *Potomogeton*. Animals are: Tanypodinae, larva 1 and pupa 1; Brachycentrinae, larva 1; *Limnodrilus* 1; *Anisus albus spirillus* 6; *Valvata piscinalis japonica* 15; *Lymnaea* 1; *Viviparus malleatus*, young 2; *Pisidium cinereum nikkoense* 1; total number 29 (1276 per m^2), total weight 0.12 g (5.28 g per m^2).
2. Sandy mud bottom at 1.5 m depth in the southern part of the main basin; presence of *Potamogeton*. Animals are: *Sergentia*, larva 1; *Limnodrilus* 3; *Anisogammarus kygi* 7; *Exosphaeroma oregonensis* 6; *Neomysis intermedia* 6; total number 23 (1112 per m^2), total weight 0.11 g (4.4 g per m^2).
3. Blackish brown mud bottom at 2 m depth in Yobito-wan. Animals are: *Chironomus plumosus*, larva 6; *Pisidium pulchellum* 1; total number 7 (308 per m^2), total weight 0.19 g (8.36 g per m^2).
4. Grey mud bottom at 7 m depth in the main basin. Animals are: Orthocladiariae, larva 1; Tanypodinae, larva 1; *Chironomus plumosus*, larva 1; *Limnodrilus* 1; *Pisidium cinereum nikkoense* 6; total number 10 (440 per m^2), total weight 0.06 g (2.64 g per m^2).

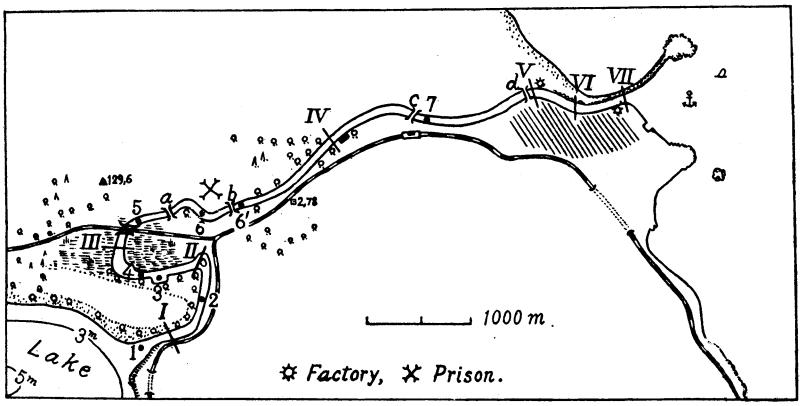


Fig. 4. Sketch map of the Abasiri river.

a large amount of fatty substances. Débris is also most abundant in this part. Such a peculiarity of the bottom in this region is chiefly due to the constant stagnation of the sea water on the deep hollowed bottom below the bridge "d", and to the contamination drained from the fish-markets and canning factories standing on both banks. The river bottom does not support a notable flora of aquatic plants at any point during the course.

b). Physical and Chemical Results

The determinations of water-temperature, dissolved oxygen, hydrogen-ion concentration and chlorine content were done on the field. Transparency was determined by a white disc of 25 cm diameter in the same way as used in the lakes. Besides the observations on the surface water, 7 series of vertical observations were made at different points of each cross-section. The results are shown in Tables V, VI.

All the observations were made at low tide. The water was usually brown, somewhat turbid, the transparency being rather slight. The temperature of the water shows no marked variation through the course, but the surface temperatures are usually a little lower in the centre of the river than near the banks. In the lower course the bottom water is much colder than the surface water, owing to the stagnation of cold sea water. This evidence is also shown by the difference of the pH-values. They fluctuate from 7.0 to 7.2 almost throughout the course not only on the surface but also in the bottom water. In the lower course below bridge "d" the bottom water is remarkable alkaline. This is mainly due to the fact that the sudden increase of depth

TABLE V

Abasiri-gawa; surface water. 28. VIII. 1936.*

Station		Transparency in metres	Temp. °C	pH	Hour	Remarks
1		> 1.6	22.8	7.1	12:00	
I	a		22.6	7.2		
	b	> 1.5	22.3	7.15		
	c		22.4	7.1		
2			22.4	7.0		
II	a		22.5	7.0		
	b	2.5	22.4	7.0		
	c		22 5	7.0		
3		> 1.2	23.8	7.4		Small bay at the left side
4		> 1.5	22.4	7.0		
III	a		22.6	7.0		
	b	2.5	22.5	7.0		
	c		22.8	7.1		
5		2.5	22.6	7.1	15:00	
6			22.5	7.1		
IV	a		22.7	7.2	16:00	
	b	2.3	22.7	7.2		
7		2.5	22.8	7.0	17:00	
V	a	2.4	22.7	7.1		
	b		22.7	7.1		
	c		22.6	7.0		

* At each cross section, from the left bank to the right the stations were taken as *a*, *b*, *c*, of which *b* is always the centre or deepest point of the river.

below the bridge is a check to the upstream flow of tidal water which retains its high salinity on the deeper layer in this region at ebb. The dissolved oxygen in the deep water of this region is rather diminished. In the upper course the river flow is freshwater, its chlorine content not exceeding 2 g per liter even at the bottom, but in the lower course the chlorine quantity of the bottom water was estimated as being almost similar to that of sea water.

TABLE VI

Abasiri-gawa. Vertical Observations.

Date (1936)	Station	Depth in metres	Temp. °C	pH	O_2 cc/l	O_2 %	Chlorine g/l	Observer*
29. VIII.	I	0	22.20	7.1			0.17	Y
		2	21.94	7.2	5.39	87	0.18	
"	II	0	22.20	7.2			0.17	Y
		3	22.04	7.2	5.22	85	0.17	
"	6′	0	22.30	7.3			0.18	Y
		2	22.12	7.3	5.59	91	0.18	
"	IV	0	22.10	7.3	5.60	91	0.18	Y
		1.8	22.15	7.3	5.60	91	0.18	
31. VIII.	V	0	22.10	7.0			0.21	U, Y
		3.5	21.70	8.2	2.97	48	0.32	
"	VI	0	22.10	7.1				U, Y
		4	19.80	8.2				
	VII	0	22.10	7.2	5.37	87	0.73	U, Y
		4.3	16.80	8.2	4.00	58	17.93	

* U = UÉNO; Y = YOSHIMURA.

c) Bottom Fauna

i) *Composition and distribution of the bottom fauna.* Some 15 species of animals inhabiting the bottom were found in the river. The important components widely distributed through the course are larvae and pupae of the Chironomidae, an isopod crustacean *Exosphaeroma oregonensis* DANA, an amphipodan *Grandidierella japonica* STEPHENSEN (1938) and a polychaete annelid *Nereis japonica* IZUKA. The distribution of these forms is shown in the accompanying figure.

The Chironomidae larvae, mostly Orthocladiariae and *Sergentia* and at least two more species in very small numbers, increase from cross-section II, reaching the largest population at section III, and then decrease and disappear at section V. Section III is most favourable for these larvae because the bottom of that part consists of abundant mud. The rapid decrease below section IV is caused by the marked change of bottom materials from sandy mud to gravel and by the stenohaline nature of these larvae. The density of the Chironomidae fluctuates from 300 to 500 per m^2 in section II–IV, and the largest population of 968 individuals per m^2 was found in IIIb (Table V).

Exosphaeroma oregonensis is the most important component of the bottom fauna of the river under consideration. It appaers to prefer a sandy bottom,

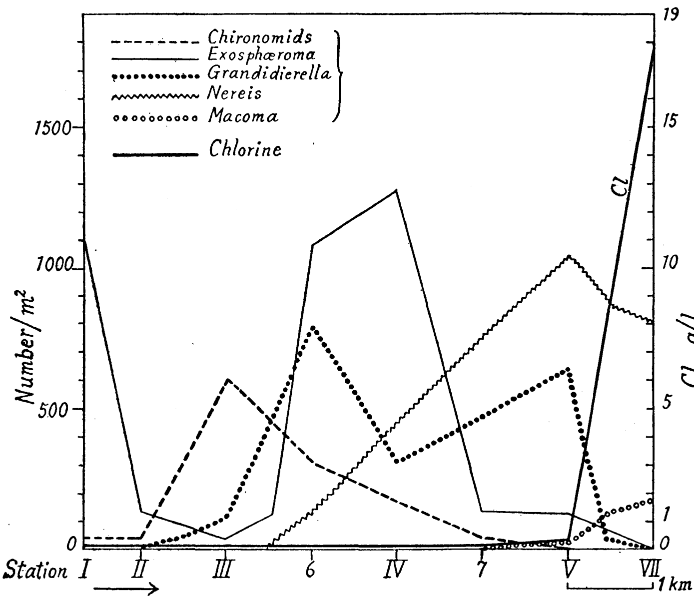


Fig. 5. Distribution of the bottom fauna in the Abasiri river.

in contrast with the Chironomidae larvae. Its distribution, as shown in fig. 5, amply demonstrates this relationship. In the sandy bottom of the source of the river as many as 1276 per m^2 were found, but in the muddy bottom of section III only a very few individuals live in the marginal parts which are richer in sand. However, in several other stations with sandy bottoms it again increases remarkably, attaining more than 1200 per m^2. Such a difference was also observed in a cross-section, as can be seen from the following examples (Table VII).

Exosphaeroma oregonensis is an euryhaline species which usually inhabits brackish water lakes and rivers but has good adaptability to freshwater. In Abasiri-gawa as well as in Abasiri-ko, as stated already, it abounds in quite freshwater and in the former it entirely disappears at the estuary.

TABLE VII

Abasiri-gawa.

Section	Station	Depth in metres	Sand	Animals number/m²
III	left	1.8	+	0
	center	3.8	+	0
	right	0.8	+	44
IV	left	1.4	++	1276
	center	3.2	+	0
V	left	3.8	+	220
	center	4.2		0
	right	3.0		44

The brackish water amphipod *Grandidierella japonica* also survives from the middle to the lower course, attaining as many as 100 per m^2, at one time 2552 being found at section IV. This species does not occur in Abasiri-ko, while it is found rather abundantly in Mokoto-numa, as will be shown in the next chapter.

The polychaete annelid *Nereis japonica* is an animal most abundant in the lower course especially below the bridge "d" (sect. V), inhabiting not only the sandy bottom but also the sapropelic black mud. The upper limit of its range appears to be station 6 in the neighbourhood of the Abasiri prison, where it was found dwelling in the shallow sandy bottom near the bank. The individual number per m^2 in the main area of occurrence attains 1850.

Mollusks are of only two species, *Macoma baltica* and *Paphia variegata.* These are found only in the lower course near the estuary and appear to increase in numbers toward the sea (44–176 per m^2). This is to be expected as those mollusks are marine animals.

Mokoto-numa (Lake Mokoto)

a) General Features of the Lake

Close to the coast of the Ochotsk Sea in the neighbourhood of the town of Abasiri, there are four shallow lakes of various sizes, of which Mokoto-numa is ecologically the most striking. It is a small lake with a maximum length of only 2 km and a maximum depth of 5.8 m. Its longer axis extends in a NE-SW direction and the widest part is in the northern half. The north-eastern and south-western margins are bordered by low terraces, while the northern and southern parts are large swampy areas. The influent Mokoto-gawa is a rather long river that runs down from Mt. Mokoto, some 35 km south of the lake, and flows into the lake at its southern part where it forms a rather large delta. The lake discharges at the north-eastern end ; the effluent meanders about 1 km through low dunes and empties into the Ochotsk Sea. The basin of this lake is probably a drowned valley, and the lake was possibly created when the Mokoto-gawa was dammed by a sand dune at its estuary.

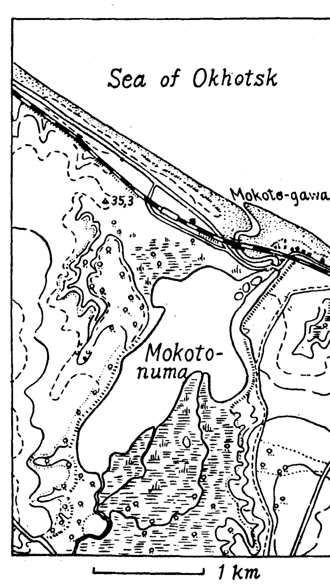


Fig. 6. Mokoto-numa.

Bottom deposits. Bottoms shallower than 1 m consist of sand; sandy mud at 1–2 m, blackish brown mud at 2–4 m. Bottoms deeper than 4 m are entirely covered with black cream-like soft mud which gave off a very strong odor of hydrogen sulphide. The temperature of this mud was 13.8°C in the upper 1 cm zone and 13°C in the zone 3 cm below the surface of the mud, when the water just above the surface of mud was 14°C. This black mud is quite similar to that found in the deep bottom of Abasiri-ko previously described.

b) Physical and Chemical Results

The water was dark greenish brown and markedly turbid, a SECCHI's white disc being invisible at a depth of only 0.7 m. The water temperature and several chemical results obtained by Dr. YOSHIMURA collateral to the writer's work are shown in Table VIII.

As could be known from the chlorine content of the water, the surface layer is quite fresh, while the water deeper than 2 m is remarkably saline due to the underlying of heavy sea water. Such a marked stratification of the density of the water produces great effects upon the stratification of the water-temperature and other chemical components. Of these, the absence of dissolved oxygen and the occurrence of hydrogen sulphide in deep water are the most important because of their effect upon the distribution of the bottom inhabitants.

TABLE VIII.

Mokoto-numa. 30. VIII. 1936.

Depth in metres	Temp. °C	pH	O_2 cc/l	O_2 %	H_2S mg/l	Chlorine g/l	Remarks
0	17.70	7.0	5.70	85	0	0.17	lake proper
0.5	15.57	7.6	—	—	—	—	
1	20.92	8.0	6.68	106	—	—	
1.5	21.01	8.0	6.21	99	—	9.9	
2	19.98	7.9	5.00	78	0	—	
3	18.12	7.7	0.49	7	0	15.5	
4	16.12	7.6	0	0	0.5	16.1	
5	14.17	7.6	0	0	12.2	16.6	
5.3	14.00					16.8	
0	19.8	7.6	6.41	99		1.0	effluent, under the bridge
1.2	19.71	7.6	5.90	91		1.05	
0	19.8	7.6					effluent, middle course

Transparency: 0.7 m (in the lake).

c) Bottom Fauna

The bottom fauna of Mokoto-numa and its effluent Mokoto-gawa consists of four groups of animals, of which the polychaete annelids and a bivalve *Corbicnla* are the most important components of the fauna, as will be seen from the following table.

	%
Corbicula sadoensis	29.7
Macoma 3 spp.	14.8
Theora lubrica	0.6
Paphia variegata	1.5
Grandidierella japonica	9 0
Anisogammarus kygi	0.6
Polychaete Annelida	43.2
Chironomidae (larvae and pupae)	0.6
	100.0

1. *Chironomidae.* A few (44-88 per m^2) of the larvae and pupae of the Orthocladiariae and of *Sergentia* were found at a depth of 0.6 m which is about

the lower boundary of the freshwater.

2. *Crustacea.* Of the three species found, *Exosphaeroma oregonensis* was collected only in the effluent, reaching 264 per m^2. *Anisogammarus* (*Eogammarus*) *kygi* was more abundant in the effluent than in the lake, being enumerated at more than 880 per m^2. The other crustacean *Grandidierella japonica* STEPHENSEN (1938), which is the same species as was found in the Abasiri river, was collected in both the lake and the effluent, but was confined chiefly to the bottoms shallower than 1 m, reaching 484 per m^2.

3. *Mollusca.* The following seven species of bivalves (det. by KURODA) were found in the lake and its effluent:

1. *Corbicula sadoensis* PILSBRY
2. *Paphia variegata* SOWERBY
3. *Sanguinolaria* (*Nuttalia*) *nuttali* CONRAD
4. *Macoma nasuta* CONRAD
5. *M. incongrua* VON MARTENS
6. *M. baltica* LINNÉ
7. *Theora lubrica* GOULD

Of these, the first-named is the dominant species, being very abundant in the shallow sandy bottom of the freshwater area especially in the northern half of the lake. In numbers it averages about 500 per m^2 and often numbers as many as 1000. In the effluent, however, it does not exceed 250 per m^2. *Macoma baltica* ranks second to the above species; it is most abundant in the 2 m bottom, where it attains to 830 per m^2. The three species of *Macoma* as well as *Theora lubrica*, all of which are of course marine mollusks, appear to be confined to the 2 m bottom where the chlorine content of the water is 15 g per litre. *Sanguinolaria* did not occur in the lake proper, but in the effluent it was found in the bottom sand under water 0.5–1 m deep; its number per m^2 did not exceed 132.

4. *Polychaete Annelida.* Two species were found:

Nereis japonica IZUKA
Prionospio japonicus OKUDA

These polychaetes were most abundant in sandy bottoms shallower than 2 m, particularly 1 m, where there were as many as 748 per m^2. In the effluent there were found 600 per m^2. It is of interest that these two polychaetes, of which *Nereis japonica* is dominat, are confined to the region of less salinity, as in the case of the Abasiri river. *Prionospio japonicus* was collected for the first time in this lake (OKUDA 1937).

The density of population is greatest on the freshwater area bottoms shallower than 1 m; it suddenly decreases below that depth, the number of

TABLE IX

Average number of bottom inhabitants per square metre in Mokoto-numa[1]. 11. VIII. 1936.

Depth in metres	Mollusca	Crustacea	Chironomidae	Polychaeta	Total
0—1	735	220	15	600	1570
1—3	968	0	0	132	550
3—4	0	0	0	59	59
4—6	0	0	0	0	0
Total :	1703	220	15	791	2179

Note.— 1) Total number of samples: 18.

animals per unit area in 2-4 m being as small as 1/30 of that at 0-1 m. The bottom of black mud deeper than 4 m, such as that of Abasiri-ko, is entirely azoic due to the presence of a large amount of hydrogen sulphide.

The bottom consisting of sand or sandy mud supports most of the inhabitants, among which *Nereis japponica* is the largest in number (Table X). A marine bivalve, *Macoma baltica*, on the contrary, is found most abundantly in mud bottoms that are below sandy bottoms.

TABLE X

Mokoto-numa. 11. VIII. 1936.

Average Number per square metre.

Bottom	Depth in metres	Number of samples	*Sergentia*	*Aniso-gammarus*	*Grandidie-rella japonica*	*Macoma baltica*	*Nereis japonica*
Sand / Sandy mud	0-1.5	4	11	11	154	22	600
Mud	1.5-3.5	3	0	0	0	278	220
Black mud	4-5.6	6	0	0	0	0	0

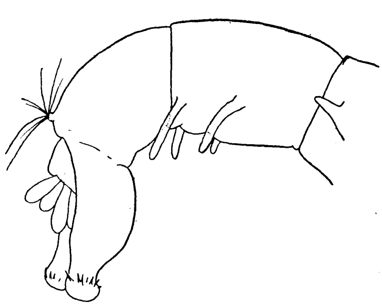
Discussion

a) Nature of Bottoms and the Salinity of Water

The nature of the bottom plays an important rôle in the distribution and the abundance of the bottom fauna. This is seen in Abasiri-ko and Mokoto-numa, and more clearly in Abasiri-gawa (Tables III and X; fig. 5). Ecologically the most noticeable bottom deposit of the lakes studied is that of black mud. This is similar in character to those of certain coastal lakes with shallow thresholds, in which the dissolved oxygen of deep water always disappears in summer. In Japan such a black mud is found not only in coastal lakes but also in either certain lakes such as Nikko volcanic ranges (MIYADI 1931) or rarely in an extremely eutrophic lake (UÉNO 1936). Recently MÜNSTER STRÖM (1936) studied similar black mud deposits in 30 land-locked fjords in the Norwegian coast between Oslo and Sogne-fjord, and discussed their genesis under anärobic conditions and their change during late quarternary times. It appears from previous investigations that the black mud deposits are found as a rule at the bottoms of more or less enclosed seas, of bays, fjords or coastal lakes with weak tidal action. Analyzing the ecological factors of the Palearctic black shales of New York, RUEDEMANN (1935) formulated some ecological criteria concerning black mud formation. He pointed out that "the controlling factor is the relative lack of oxygen and the accumulation of organic matter faster than it can be oxidized". The black mud in the two lakes considered in the present paper as well as in certain other coastal lakes in Japan also formed under conditions such as were suggested by RUEDEMANN.

The toxic quality of the bottom water, owing to the lack of dissolved oxygen and the presence of hydrogen sulphide that was formed from the reduction of sulphates contained in the underlying sea water, makes it impossible for animals to inhabit the black mud deposits.

In this connection it is of great interest that on one occasion in Abasiri-ko three larvae of *Chironomus plumosus* were taken up from a depth of 14.6 m, where the the bottom deposit was a typical black mud which gave off an odor of H_2S and the water just above the bottom contained 8 g per litre of chlorine. These larvae were very large in size, more than 2 cm long, remarkably blood-red when they were alive, and were unusual in having on the last abdominal



Fi H abdominal segments of a larva of *Chironomus plumosus* with short "tubuli", taken up from the deep bottom of Abasiri-ko.

segment very short "tubuli" which extend downward a little beyond the abdomen. The correlation between the length of the "tubuli" or so-called blood-gills of the *Chironomus*-larvae and the salinity of their habitats has been discussed by several workers (cf. LENZ 1937). LENZ (1931) found many *Chironomus*-larvae without "tubuli" in the stomach-content of a flamingo which had been caught in a brackish water lake, Bahira, in Tunis of Africa. PAGAST (1936) has shown that under experimental conditions the anal gills of the larvae of a mosquito *Aëdes aegypti* became shorter in length when they were kept in water rich in NaCl, and became longer in acid water. Recently LENZ (1937) has reported that chironomid larvae of the *plumosus*-type (*Ch. palpalis* JOHANSEN) collected in sulphuretted mineral springs and other acid waters in Java have remarkably long "tubuli". It is of interest in contrast with the above statement that in the marine larvae of certain chironomids (genera *Pontomyia*, *Clunio*, *Paraclunio*, *Camptocladius*, *Tanytarsus* and so on) the "tubuli" or so-called "blood-gills" are entirely absent (cf. TOKUNAGA 1932, p. 52). To corroborate the fact that the "tubuli" or anal gills of chironomids are shortened in water rich in salts, a detailed experimental study under laboratory conditons as well as a comparative study in natural habitats would be required.[1]

As already stated, the polychaete annelid *Nereis japonica* survives in Mokotonuma and in Abasiri-gawa. In the latter it dwells in the sandy mud bottom some 5 km distant from the estuary, but it has not been found in Abasiri-ko. In the Abasiri river just above its uppermost habitat the water is quite fresh, while its lowermost habitat has a salinity similar to that of the sea. This polychaete can survive to some extent the most extreme fluctuations in salinity, as has been demonstrated in connection with certain other species of *Nereis*. In an experimental study, NOMURA (1930) has found that *Nereis japonica* taken from the shallow sea bottom at Asamusi is better adapted to polyhaline than to oligohaline or mesohaline waters, and that it maintains its activity in normal sea water better than in a diluted sea water which contains 13.55 g per litre of chlorine (about 70 % of sea water) and shows the pH-value 8.2. In the present case, however, it was found even in water of pH 7.3 and of chlorine content only 0.18 g per litre. Burrowing forms such as *Nereis japonica* could probably well survive in low salinity owing to the fact that the interstitial water of the bottom sand retains its high salinity at ebb, as has been suggested by certain investigators (cf. ALEXANDER et al. 1932).

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1) Recently KOCH (1938) has concluded in an experimental study that in *Chironomus* and *Culex* "the difference in size of the anal papillae of larvae from different biotopes or reared in different salt solutions is a functional adaptation to salt absorption from these media".

b) Biological Types of the Lakes and the River Studied.

1. *Lakes*. Abasiri-ko and Mokoto-numa are regarded as eutrophic. In the former the oxygen curve in summer is of the typical form designated as eutrophic; a rather pronounced water-bloom consisting chiefly of *Aphanizomenon flos-aquae* (cf. NEGORO 1937) appears in mid-summer; the bottom fauna, besides

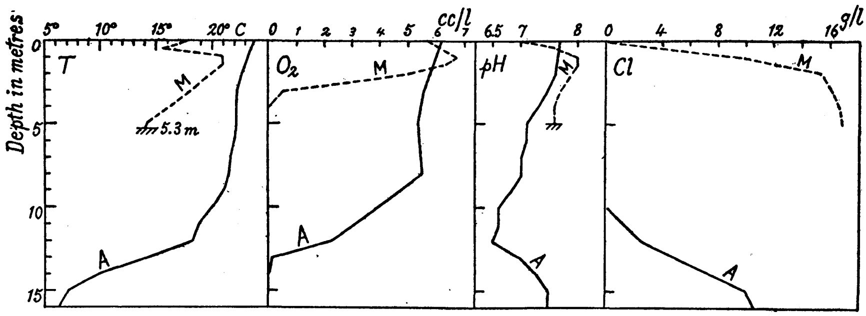

Fig. 8. Temperature and chemical stratifications in Abasiri-ko (A) and Mokoto-numa (M).

the abundance of mollusks usually characteristic of the coastal lakes of Hokkaido, is characterized by the occurrence of *Chironomus plumosus*, though smaller in numbers than in the case of other chironomids such as Orthocladiariae. So far as the bottom fauna is concerned, Abasiri-ko is the Mollusca-*plumosus* type designated by MIYADI (1933), though in less advanced eutrophic condition than several lakes in Hokkaido such as Tōro-ko which is a typical polytrophic *plumosus* lake (MIYADI 1932; UÉNO, a forthcoming paper).

Mokoto-numa is, on the contrary, apparently of the Mollusca type, but is characterized by the presence of polychaete annelids which consist chiefly of *Nereis japonica* comprising nearly 50 % of the total bottom fauna. Such a type, i.e. the Mollusca-*Nereis* type, may be one of the characteristic types of coastal lakes with a remarkable tidal action, thoguh no suitable classification of such kinds of lakes has been established. Mokoto-numa has essentially brackish water though its upper layers are quite fresh.

2. *Classification of rivers*. NAUMANN (1932) tried to apply his classification of lakes based on biological production to various kinds of inland waters including rivers. There are, however, certain difficulties in dividing rivers into eutrophic and oligotrophic or so on, owing to the much more incessant change of milieu factors in rivers than in closed bodies of water such as lakes. SHELFORD and EDDY (1929) suggested that it is helpful to use dominant species of fishes or aquatic insect larvae for the classification of stream communities, but

such a method is not always applicable to various kinds of flowing waters especially from the regional point of view. THIENEMANN (1912) divided the course of a mountain stream of Sauerland on the basis of the dominant species of fishes inhabiting it, i.e. the springs and spring-fed brooks, the trout-beck, and the region where the cyprinid fishes were dominant. It is difficult to classify regionally different streams by this method because fish not only differ among streams but also change seasonally up and down the course of the same stream. Accordingly, NAUMANN's suggestion (l.c.) that the classification be based on various milieu factors as well as on biological production appears to be the most rational, if it were possible technically to carry out easily.

In a study written in Japanese on the lakes and streams of the Nikko mountain range, UÉNO (1934) suggested a method applicable to the classification of flowing waters. According to this method, the physiographical and physical factors, such as types of bottom, speed of current, volume of flow, temperature of water, light intensity, and also the chemical properties of the water, especially its hardness and the quantity of nutritive substances such as nitrogenous compounds, phosphorus and silicates should be determined. Parallel to the seasonal study of these factors, the periodicity and abundance of aquatic vegetation, particularly the minute algae on the river beds, should be examined; then the relation of these algae and aquatic insect larvae as food for fishes should be studied.

Based upon such a comprehensive ecological examination, i.e. the causal analytical standpoint of biological production, the streams under consideration could be classified most rationally. There is, however, still another important matter to be noted. A stream that receive either strongly acid water from a mineral spring (cf. UÉNO 1933) or remarkably polluted water due to the decomposition of organic matters, may greatly restrict production or it may be entirely impossible for organisms to exist in it. According to the presence or absence of such factors, the streams may be divided into two major types, *harmonic* and *inharmonic*, as has been suggested by THIENEMANN (1931) on the classification of lakes. Under these two major groups the designation of certain types according to trophic degrees should be possible, but in regard to the harmonic group the standardization of each type, oligotrophic or eutrophic and certain others, is still somewhat difficult. It is also to be noted that certain toxic salts often play an important rôle in the production of certain organisms. HARVEY (1933) has pointed out that a salt is a "growth-promoting factor"; iron salts are usually toxic upon organisms even in minute quantities, but they often have promoting effects upon the growth of certain diatoms.

In this connection, RICKER's classification of certain Canadian streams is most ecological and seems to be not far from our ideal scheme. RICKER (1934) has classified certain Ontario streams on the basis of the following factors: the "chemical composition of the basic rocks and of the region through which the river flows; type of soil and vegetation of the watershed; speed of current; type of bottom; width and depth (which with speed of current determine volume of flow); temperature of the water; oxygen and carbon dioxide content of the water; flora and fauna". He pointed out that "the distinctions between swift-stony and slow-muddy types are, perhaps, the most fundamental from the point of view of the biota, ... " (l.c. p. 16).

Certain streams in Hokkaido previously visited by the writer resemble in some respects those of the Ontario types shown by RICKER. In the Abasiri river described in the foregoing pages, there are also some points which resemble RICKER's types, especially his "B 1 a", that is, the slow trout streams:—volume greater than 0.28 m^3 per sec. on June 1; mud over most of bottom; maximum summer temperature not excess of 24°C; principal piscivorous fish, *Salvelinus fontinalis*. The Abasiri river differs, however, from RICKER's in that it is much wider and empties into the sea. Three species of fishes are common in the Abasiri river, namely, *Tribolodon hakuensis ezoë* OKADA et IKEDA, *Platichthys stellatus* (PALLAS) and *Oncorhynchus masou* (BREYOORT). The first-named white-mullet is well-adapted to both fresh and saline waters; the second-named flat-fish is regarded as a freshwater tolerant. The last, the common Pacific salmon, was found to be an anadromous fish. Such types of rivers are not found south of Hokkaido.

Summary

1. The bottom faunae of two lakes and one river on the coast of Hokkaido facing Ochotsk sea were studied in the late summer of 1936. Both lakes, Abasiri-ko and Mokoto-numa, are remarkable in having black mud deposits which make it impossible for organisms to inhabit them.

2. The important components of the bottom fauna of the lakes mentioned are chironomid larvae, mollusks and crustaceans. The relatively large proportion of the latter two groups, especially of the mollusks, to the total bottom population is a special characteristic of the lakes. Such a composition of the bottom fauna is usually met with in the lakes north of Hokkaido and not in those south of it.

3. Owing to the bottom features and to the underlying water of high salinity, the bottom inhabitants of both lakes are concentrated in the shallow littoral zones especially in the areas of sandy or muddy sand bottom.

4. The distribution of the bottom fauna in the Abasiri river from its source to the estuary is largely controlled by the bottom features and the difference of salinity in the different parts of the course. The fauna consists largely of brackish water crustaceans in the greater parts of the course and of the marine species in the lower course.

5. Both lakes mentioned are regarded as eutrophic. As far as the bottom fauna is concerned, Abasiri-ko is the Mollusca-*plumosus* type and Mokoto-numa is the Mollusca-*Nereis* type which is for the first time designated.

6. A critical discussion is made of the ecological classification of streams. It seems possible to classify rivers, when it is done from the causal analytical standpoint of biological production.

摘　　要

北海道網走湖及びその近隣陸水の底棲動物

北見國網走湖及びその排出河網走川、並に藻琴沼の昭和10年晩夏に於ける底棲動物を記述した。これら兩湖の底棲動物は貝類及び甲殼類特に前者が卓越し、何れも淺い湖底に夥しい。網走川に於ては底質と底水の鹹度の相違により、底棲動物の顯著なる分布が見られた。網走湖は底棲動物による Mollusca-*plumosus* 型、藻琴沼は Mollusca-*Nereis* 型である。

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