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ECOLOGICAL STUDIES ON THE FAUNA OF SUBARCTIC WATERS IN FINNISH LAPLAND

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I. INTRODUCTION

A quantitative benthic survey and qualitative studies on the littoral fauna of two subarctic lakes and some tarns and rivers in Finnish Fjeld Lapland were carried out during the summers of the years 1962—1964.

The purpose of this work was to determine the composition and quantity of the aquatic fauna in subarctic waters and to find out some of the ecological factors which can influence organisms in these circumstances. The standing crop of the benthos was determined on the basis of the weight of preserved specimens and problems concerning productivity have been discussed.

The term «subarctic« has been used here according to THOMASSON (1956). He states that arctic lakes are those situated in the tundra north of the tree limit and that the lakes situated on the border between taiga and tundra (in the zone of the subalpine birch forests in northern Fennoscandia) can be called subarctic. Further THOMASSON mentions that especially in the mountain area of northern Fennoscandia no clear distinction can be drawn between the concepts of subarctic and alpine lakes.

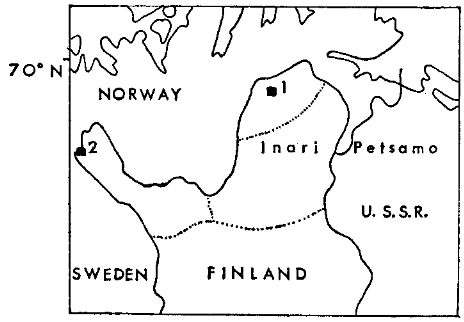


Fig. 1. The study areas. 1 = Lake Kevojärvi in Utsjoki, 2 = Lake Kilpisjärvi in Enontekiö.

The areas in which the fauna of subarctic lakes has been investigated include northern Sweden (THIENEMANN, 1954, BRUNDIN, 1956, PEJLER, 1957 and GRIMÅS, 1961), Petsamo (JÄRNEFELT, 1934) and the Kola Peninsula and Siberia (cf. ZHADIN and GERD, 1963). Hydrographic investigations of the waters of the subarctic region have been made in N. Sweden (EKMAN, 1957), in Canada (RAWSON, 1950) and in Finnish Lapland (JÄRNEFELT, 1956 and 1963).

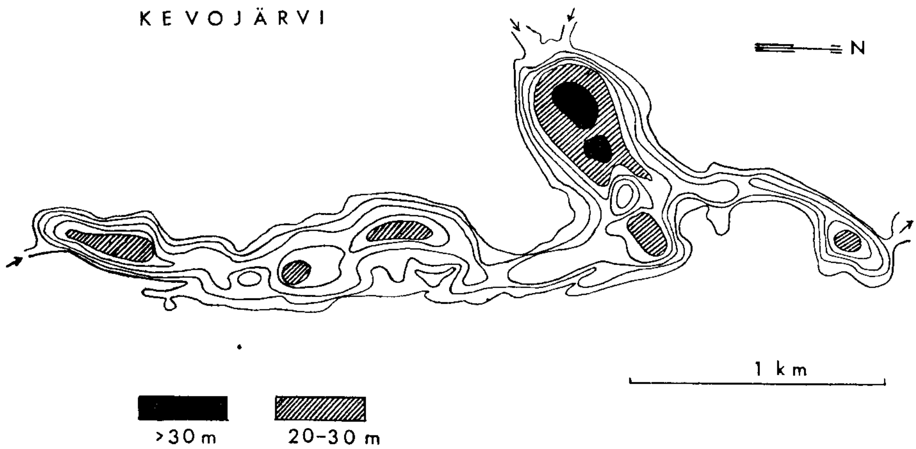
II. THE WATERS STUDIED

Two lakes, 11 tarns and about 10 rivers or brooks were investigated during the summers of the period 1962—1964. The habitats studied are divided into three categories according to altitude and the zone of vegetation (cf. PEJLER, 1957). The silvatic bodies of water in Utsjoki (Fig. 3) lie 83—105 m above sea-level, and the alpine waters about 220—350 m above sea-level. Only two subalpine tarns and some rivers were studied in Utsjoki and they are situated 170—220 m above sea-level.

The habitats are further divided into lotic and lenitic waters.

The lakes: Lake Kilpisjärvi (69° N, 20° 55′ E) in northwestern Finnish Lapland belongs to the water system of the River Tornionjoki, which flows into the Bothnian Bay. The morphometry of the lake has been discussed by LAGERCRANTZ (1953), and the plankton and hydrography by JÄRNEFELT (1956). The lake is a typical mountain lake and lies in a deep tectonic valley. Owing to its tectonic character the lake is rather deep (Table 1, Fig 5). The drainage area of the lake is 260 km² and is characterized by Paleozoic schists. Owing to the sharp sloping terrain the number of bogs is small. The lake consists of a northern and a southern basin which are connected by a shallow straight (2—3 m).

Lake Kevojärvi (69° 45′ N, 27° E) in N. E. Finnish Lapland (Fig. 1 and 2) belongs to the water system of the rivers Utsjoki and Tana, which flow into the Arctic Ocean. The lake is a typical lowland lake situated 75.5 m above sea-



Fiig. 2. The depth chart of Kevojärvi (according to PETÄJÄ, 1964).

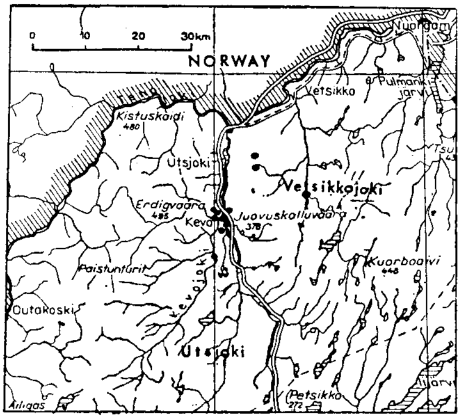
level in a deep canoyon. The drainage area of the lake is characterized by the old Precambrian peneplain with gently sloping fjelds which reach an altitude of about 300—400 m. Some morphometric features of the lake are seen in Table 1.

Table 1. The morphometric values of the two lakes (partly according to LAGERCRANTZ, 1953 and PETÄJÄ, 1964).

	Area km²	m above sea-level	A/B	Max. breadth km	Max. depth m	Average depth m	Volume of water km³
Kilpisjärvi	37	463	2.7	3.0	50	15.9	0.59
N. basin	23		2.1	3.0	35	13.6	0.32
S. basin	14		2.2	1.9	50	19.5	0.27
Kevojärvi	1.8	75.5	1.6	0.9	35.5	—	—

A = the greatest breadth in km
B = 2 r in the circle which has an area equal to that of the lake

Bottoms. In the upper littoral zone of the lakes coarse sand or stony bottoms dominate. In Lake Kevojärvi they continue to a depth of 1—1.5 m except at the mouth of the Rivers Kevojoki and Tsharsjoki (Fig. 6) where sandy bottoms can be found down to a depth of 8—9 m. Below the erosion zone the bottoms consist of decaying organic debris (Fig. 6 d) at 1.5—3 m and in the deepest areas of the lake. Brown minerogenous deposits with small iron-manganese concretions occur in the lake at depths of 10—25 m. These brown gyttja bottoms dominate in Lake Kilpisjärvi, although the concretions were not observed there. The amount of organic matter and allochthonous deposits is great in Kevojärvi, but in Kilpisjärvi they are mainly restricted to shallow bays and the southern



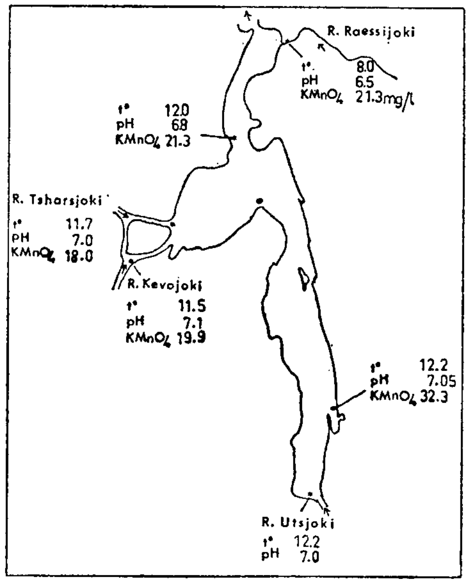


Fig. 3 (above). The location of the habitats studied in Utsjoki.
Fig. 4 (right). Some hydrographic values of surface water in Kevojärvi and its feeders on July 30, 1962.

part of the north basin. According to the quality of the sediments dominating in the profundal zone, Kilpisjärvi can be grouped among the mountain lakes of Northern Scandinavia (cf. LUNDQVIST, 1940). In these lakes fine minerogenous sediments dominate and the fossils consist of *Diatomae* and *Cyanophyceae*.

The tarns: Of the 11 tarns studied 4 are situated in the silvatic zone west of

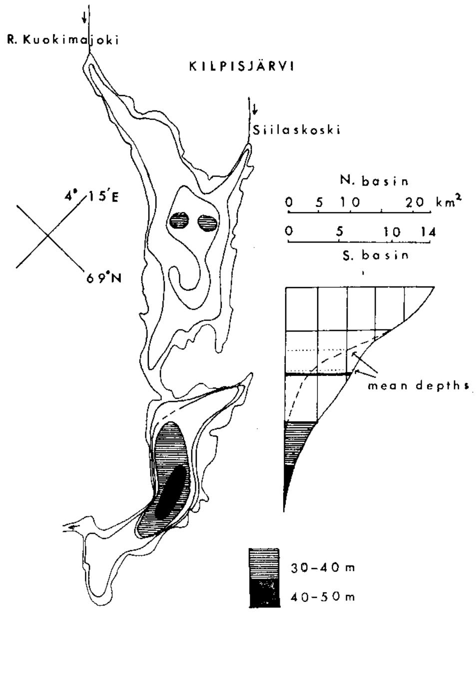


Fig. 5. The depth chart of Kilpisjärvi (partly according to LAGERCRANTZ 1953).

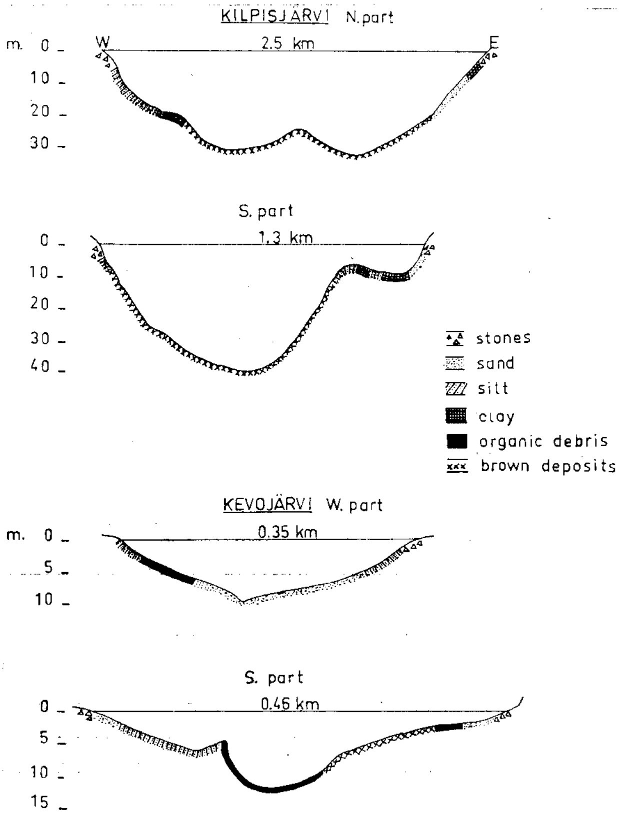


Fig. 6. **Transversal sections of the lakes studied.**

Table 2. Some hydrographic measurements of the waters of Utsjoki in July, 1963.

	Kevo-järvi	Tarns in silvatic region	Tarns in subalpine region	Tarns in alpine region	Kilpis-järvi
m. above sea-level	75.5	83—105	170—220	220—350	463
area (hectares)	150	0.09—2.3	0.09—0.1	0.05—0.2	3700
greatest depth m	35.5	1—8	0.5—4.0	0.5—5.0	50
t° C	13.9	15.7—17.2	10.4—11.4	10.2—11.0	8.0—12.5
O_2 mg/l	9.8	9.53—10.18	10.4—11.4	10.3	c.9.7
pH	6.9	6.2—6.7	6.7—6.87	5.95—6.9	c.7.4
SBV-	0.12	0.04—0.14	0.04	0.04—0.14	c.0.1
HCO_3 ppm/l	18	7	—	—	—
CaO mg/l	3.36	1.13—3.92	1.12	1.12—3.92	c.3.2
$KMnO_4$ cons. mg/l	18	13.9—32.5	13.0—34.0	19.2—41.2	c.13.0
Secchi disc value m	4.5	—	—	(1.5)	c.9.8
Cl mg/l	1.6	1.6—1.7	—	—	c.2.1

The values of the surface water of Kilpisjärvi were measured by JÄRNEFELT (1956).

Kevojärvi, 2 in the subalpine zone (on the slope of the Jesnalvaara fjeld), and 5 in the alpine zone (on the slope of the Jesnalvaara fjeld and east of Lake Mantojärvi in Utsjoki) (Fig. 3.). Some morphometric and hydrographic features of these tarns are very variable. Table 2. Considerable mixing of their water may occur during heavy rainfall and storms. During winter they may freeze down to the bottom or the volume of water may decrease so seriously that there may be a shortage of oxygen. This kind of phenomenon has been observed in some eutrophic tarns in N. Sweden (EKMAN, 1957) and in Siberia (ZHADIN and GERD, 1963).

Rivers and brooks: Some rivers flowing into Kevojärvi were investigated in July 1962 and 1963. The sampling stations are seen in Fig. 3. Hydrographic analyses were made in them on July 30, 1962 (Fig. 4). Alpine brooks were studied in the fjeld area east of Mantojärvi.

III. MATERIAL AND METHODS

Bottom samples. 121 samples were taken in the lakes with a bottom dredge (Petersen type) on July 1962 and 1964. The area of bottom studied amounts to 2.5 sq. m in Lake Kilpisjärvi and 1.4 sq. m. in Lake Kevojärvi. The samples were taken at different depths all over the lakes. The errors due to the small number of samples per locality (usually 2) are partly eliminated by grouping together all samples taken in the same depth zone. A sieve with a mesh size of 0.6 mm was used.

Altogether 3791 specimens were found in the bottom samples. They were preserved in 70 % alcohol or in a mixture of alcohol and formaldehyd. Special methods for identifying midge larvae were used. The heads of these larvae were boiled in a KOH solution and mounted through an alcohol series on slides, so that the hypostomium with its special features could be seen. The oligochaetes were manipulated in an ammon-lactophenol solution (BRINKHURST, 1963) before identification. Several slides with the mouth parts and gills of the nymphs belonging to the orders *Ephemeroptera* and *Plecoptera* were prepared as well (BAGGE, 1965).

The wet weight of the animals preserved in alcohol was determined. No correction was made for loss of weight during preservation.

Littoral samples. Qualitative samples in the littoral zone of lakes, rivers and tarns were taken with a net (mesh size 1 mm) at 30 localities (Fig. 3). On stony bottoms the animals were picked up by hand.

Some analyses of the food contained by fishes caught in the lakes were also made

Water samples. Physical and chemical analyses of the water were made for Kevojärvi and some adjacent waters in July 1962—1963.

A Ruttner type sampler was used. Temperature was measured with a mercury thermometer within the sampler. Secchi disc values were measured at noon with a white plate. $KMnO_4$ consumption of water was determined by the method of KAARTOTIE and RYHÄNEN (1957). Owing to the small consumption of the titriment (n/100 $KMnO_4$ solution) in the titration, no dilution of samples was necessary. Alcalinity (SBV) of water was determined by titrating samples of 100 ml with a n/10 HCl solution, and by using methyl-orange as an indicator solution. CaO content of water was calculated from the SBV values by multiplying them by 28. pH was measured *in situ* with the Radiometer t. PHM 24 c. Cl was determined using the Mohr titration.

IV. THE QUANTITY OF THE BOTTOM FAUNA IN THE LAKES STUDIED

The average density of the whole bottom fauna is 1185 ind/m² in Kilpisjärvi and only 541 ind/m² in Kevojärvi. The large numerical value in the former lake is mainly due to the presence of small larvae of *Orthocladiinae* in every depth zone of the lake, these larvae being rare in Kevojärvi.

The average biomass of the bottom fauna (wet weight of preserved specimens) amounts to 3.32 g/m² in Kevojärvi, while it is only 1.25 g/m² in Kilpisjärvi. In the former lake large specimens, such as the larvae of caddis-flies and gastropods, were relatively common in the littoral zone, thus increasing the total biomass.

The values of the standing crop or biomasses of the bottom fauna (g/m²) are seen in Table 3, where the values from the subarctic lakes studied are compared with oligotrophic Lake Päijänne (Central Finland) (cf. VALOVIRTA, 1959).

This table shows the maximum biomass values for every lake, in the upper littoral zone (at a depth of 0—1 m in Kevojärvi). A remarkable decrease in the biomass values is observed at depths of 3 m and 15 m in Kilpisjärvi and at a depth of 7.5 m in Kevojärvi. In oligohumic Lake Keitele (Central Finland) the corresponding decrease in biomass was observed at a depth of 7.5—10 m (BAGGE & JUMPPANEN, 1968). The change in the biomass values found in these lakes coincides with a similar change in quality of the sediments, and may also mark the boundary between the littoral and profundal zones. In large oligohumic lakes (like Kilpisjärvi) littoral conditions can be found at a greater

Table 3. Standing crop or biomass of benthic animals (g/m²).

Depth (m.)	L. Kilpisjärvi 1964	L. Kevojärvi 1962	L. Päijänne (VALOVIRTA, 1959)
0—1	—	6.04	
1—2	4.5	7.3	
2—3	5.1	2.1	1.58 (1—4 m.)
3—4	2.0	1.5	
4—5	2.1	0.9	0.502 (4—7 m.)
5—7.5	2.3	2.9 (0.84)	
7.5—10.0	2.06	0.6	0.675 (7—14 m.)
10—15.0	1.6	0.6	
15—20.0	0.85	—	
20—25.0	0.33	0.3	
25—30.0	0.35	0.2	
30—35.0	0.26	0.2	
35—40.0	0.24		
40—45.0	0.12		
over 45.0			1.064

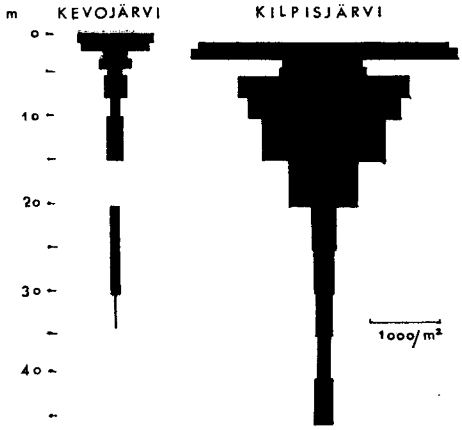


Fig. 7. The bathygraphic distribution and density (ind/m²) of the bottom fauna in the lakes.

depth than in meso- and polyhumic lakes. This fact is also shown by SVÄRDSON & NILSSON (1964) in some Swedish lakes.

The high value for Kevojärvi at the depth zone of 5—7.5 m. is due to a large *Lymnaea peregra* specimen found there. The value 0.84 in brackets (snail excluded) gives a more accurate picture of the actual situation.

Table 4. The bathygraphic distribution and density ind/m² of benthic animals in L. Kevojärvi.

Depth zone m	0—1	1—2	2—3	3—4	4—5	5—7.5	7.5—10	10—15	20—30	—35
Vorticella sp	+	+	—	+	+	—	+	+	—	—
Spongilla lacustris	18.6	2.8	7.7	—	6.2	—	10.3	—	—	—
Nematoda	6.2	25.2	7.7	15.4	6.2	—	—	—	—	—
Oligochaeta	2728.0	646.8	77.7	107.8	68.2	103.0	41.3	46.5	18.6	—
Hirudinea	24.8	—	—	—	—	31.0	—	—	—	—
Copepoda	6.2	5.6	—	—	—	—	—	—	—	—
Cladocera	31.0	14.0	15.4	—	—	—	—	15.5	—	—
Gammarus lacustris	18.6	14.0	15.4	—	6.2	—	—	—	—	—
Ostracoda	—	2.8	—	—	—	—	—	—	—	—
Ephemeroptera	18.6	5.6	—	—	—	—	—	—	—	—
Sialis spp.	—	5.6	—	38.5	—	—	—	—	—	—
Trichoptera	68.2	58.8	7.7	15.5	6.2	10.3	—	—	—	—
Diptera (Tipulidae)	—	2.8	—	7.7	—	10.3	—	—	—	—
Dipt. (Chironomidae)	213.0	126.0	124.0	161.7	43.4	133.9	72.0	108.5	56.0	31.0
Coleoptera	24.8	—	—	—	—	—	—	—	—	—
Hydracarina	6.2	5.6	—	—	—	—	—	—	—	—
Pisidiae	235.0	106.4	53.9	84.7	18.6	—	10.3	31.0	—	—
Gastropoda	142.6	14.0	38.5	23.1	24.8	10.3	—	—	—	—
Average density	1103.0	1036.0	346.5	469.5	186.0	298.7	133.9	201.5	74.4	31.0

Table 5. The bathygraphic distribution and density ind/m² of benthic animals in L. Kilpisjärvi.

Depth zone m	1—2	2—3	3—4	4—5	5—7.5	7.5—10	10—15
Vorticella sp.	—	+	+	—	+	—	+
Turbellaria	53.9	341.0	31.0	—	40.3	31.0	20.4
Nematoda	207.9	77.5	—	46.5	95.2	156.0	119.0
Oligochaeta	1686.3	852.5	310.0	356.5	362.3	300.0	492.0
Cladocera	15.4	31.0	—	—	47.6	206.8	13.6
Copepoda	15.4	15.5	—	15.5	11.0	10.3	—
Ostracoda	—	31.0	—	—	—	5.2	—
Ephemeroptera	7.7	—	—	—	residues	—	residues
Trichoptera	7.7	—	—	—	—	—	3.4
Diptera (Tipulidae)	23.1	15.5	62.0	—	7.3	10.3	3.4
Dipt. (Chironomidae)	1409.1	1643.0	465.0	666.5	1753.0	1364.9	1023.4
Hydracarina	77.0	372.0	186.0	155.0	73.2	41.4	20.4
Pisidiae	107.8	387.5	—	31.0	32.9	41.4	47.6
Gastropoda	—	46.5	31.0	15.5	7.4	5.2	—
Bryozoa	—	15.5	31.0	residues	3.7	31.0	3.4
Average density	3603.6	3828.5	1116.0	1266.5	2462.6	2197.0	1744.2

Depth zone m	15—20	20—25	25—30	30—35	35—40	40—45
Vorticella sp.	+	—	+	—	+	—
Turbellaria	12.4	—	—	—	—	—
Nematoda	37.2	19.6	11.6	11.6	31.0	7.7
Oligochaeta	316.2	110.0	108.4	89.0	38.7	79.5
Cladocera	6.2	2.8	—	—	—	7.7
Copepoda	6.2	8.4	—	—	—	—
Ephemeroptera	residues	—	—	—	—	—
Trichoptera	«	—	—	—	—	—
Diptera (Chironomidae)	508.4	160.5	100.6	85.2	108.5	61.9
Hydracarina	24.8	14.1	7.7	31.0	—	61.8
Pisidiae	34.1	8.4	23.2	—	15.5	7.7
Bryozoa	12.4	5.6	3.9	3.9	—	—
Average density	961.0	330.0	255.4	220.6	193.7	224.7

Apart from Lake Päijänne, all the lakes mentioned in Table 6 are situated in the subarctic area. Lake Katterjaure is situated 690 m, Blåsjön, Kilpisjärvi and Ankarvattnet 435—463 m and Kevojärvi only 75.5 m above sea-level. Except for Kevojärvi all of them have clear, cold water with a high oxygen tension near the bottom throughout the year. The dominant animal group in the profundal zones is the family of *Orthocladiinae*. The percentage of the larvae of this family in the whole chironomid fauna tends to increase with increasing altitude (BRUNDIN, 1949). Owing to the high densities of these larvae in the mountain lakes, the total density of the bottom fauna is somewhat greater there than in Kevojärvi and Päijänne.

Table 6. The mean density of benthic animals ind/m² at different depths in some Fennoscandian lakes.

Depth m.	L. Kevojärvi 1962	L. Päijänne 1959 (VALOVIRTA)	L. Kilpisjärvi 1964	L. Blåsjön 1961 (GRIMÅS)	L. Ankarvattnet 1961 (GRIMÅS)	L. Katterjaure 1956 (BRUNDIN)
0—1	1103.0	—	—	938	9652	—
1—22	1036.0	1120.0	3603.0			—
2—3	346.5	«	3828.5	1550	7882	—
3—4	469.7	«	1116.0			3800—4700
4—5	186.0		1286.5	2017	5497	—
5—6	298.7	338 (4.5—7 m)	2462.6	3187		—
6—7	«		«	5275	4596	—
7.5—10	133.9	399 (7—14 m)	2197.2	4090	4444	ab. 2000
10—15	201.5	«	1744.0	2905	3708	ab. 1000
15—20	—		961.0	1474	2717	ab. 750
20—25	74.4		330.0	750	1599	ab. 435
25—30	«		255.4	«	«	
30—35	31.0		220.6			ab. 435
35—40			193.7	717	1243	
40—45			224.7			
50—70		531 (14—90 m)		ab. 884		390

V. SYSTEMATIC ECOLOGICAL SURVEY OF THE FAUNA

Porifera

Spongilla lacustris (L.) is widespread in the waters of the silvatic region in Utsjoki. In Kevojärvi it was common in the *Isoëtes* zone, living on silt bottoms or on pieces of wood. The vertical distribution of the species in the lake was from 0.2 to 8.0 m, but spiculae were found in bottom samples at every depth. JÄRNEFELT (1934) found them in Lake Kivijärvi in Petsamo.

The absence of the species from all the subalpine and alpine waters studied can be due to low temperature and to the mechanical action of ice especially in shallow tarns. According to JEWELL (1935 in MACAN, 1963), the species is better adapted to living in waters with a small SiO_2 content than other *Spongilla* species.

Ephydatia fluviatilis (L.) was found in a lake outlet biocoenose in the River Kuokimajoki which flows into Kilpisjärvi. According to MÜLLER (1954), the species is common in some forest rivers in N. Sweden, being specially adapted to lake outlet biocoenoses, where the speed of the current varies from 0.3 to 1.2 m per second. Other species found in the same locality in the Kuokimajoki were *Rhyacophila nubila* and *Simulium* larvae.

Turbellaria

Flatworms were found in Lake Kilpisjärvi at depths of 1.0 to 15 meters. The dominant species was *Otomesostoma auditivum* (Plessis). Some specimens of *Mesostoma platy-*

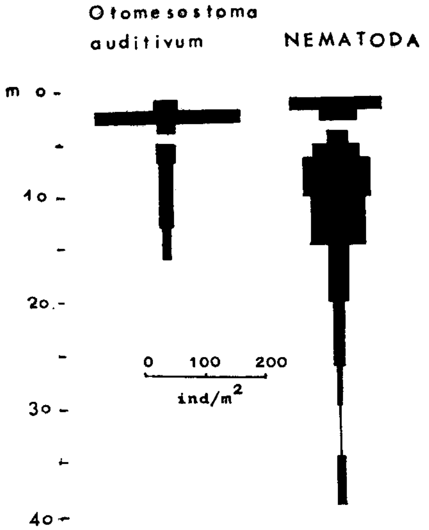


Fig. 8. The density of *Nematoda* and *Otomesostoma auditivum (Turbellaria)* at different depth zones in Kilpisjärvi.

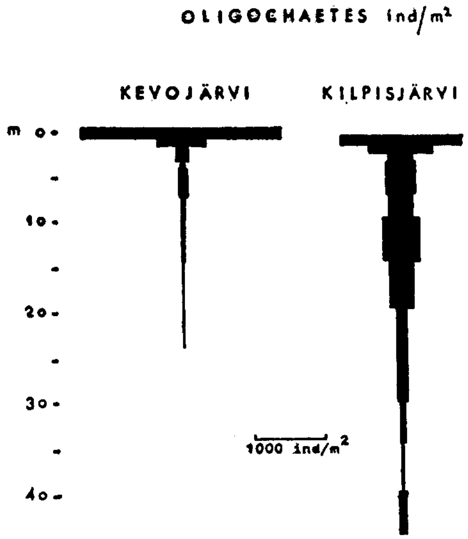


Fig. 9. The density and bathygraphic distribution of oligochaetes in the lakes studied.

gastricum Hofsten were also collected in the littoral of the lake. The vertical distribution of flatworms in Kilpisjärvi is seen in Fig. 8. The absolute maximum density of *Otomesostoma auditivum* was 651 ind./sq.m at a depth of 2.5 m. In the lakes Blåsjön and Ankarvattnet (GRIMÅS, 1961) the maximum density of the group also occurred in the upper littoral zone. Von HOFSTEN (1911) states that they are found at the greatest depths of some alpine lakes in Switzerland.

Otomesostoma auditivum is assumed to be a cold stenothermal species inhabiting deep, cold moutain lakes in Europe. LUTHER (1960), however, mentions it from the lakes Lohjanjärvi, Hormajärvi and Tvärminneträsk in S. Finland. STEINBÖCK (1942 in LUTHER, 1960) states that the species cannot tolerate low oxygen tensions. It is usually found living in the upper stratum of bottom sediments and it does not penetrate to the interstitial spaces of sediments which are poor in oxygen.

Mesostoma platygastricum has previously been found in a tarn on the slope of the Saana fjeld (LUTHER, 1963), moreover it has been reported from Novaya Zemlja and Alaska.

LUTHER (1960, 1961 and 1963) lists about 20 species in the Kilpisjärvi region. The most common of them in brooks are *Grenobia alpina* (Dana) (found in Utsjoki too), *Mesostoma maculatum* Hofsten and *Ascophora elegantissima* Findenegg. In the dystrophic tarns in the alpine region *Catenula lemnae* Ant. Dugès, *Rhynchomesostoma rostratum* (Müller) and several *Gastrada* species were frequently observed. In the littoral zone of Kilpisjärvi some species such as *Stenostomum leucops leucops* (Ant. Dugés) were observed.

Almost all of the species found are cold stenothermal and have an arctic or high boreal distribution area.

Nematoda

In Kilpisjärvi nematodes were observed at every depth, but they were absent from the profundal zone of Kevojärvi. In Kilpisjärvi their maximum density was 651 ind/m² at a depth of 8 m. In Kevojärvi the absolute maximum density of the group was found in the *Isoëtes* zone (311 ind/m²). The densities of nematodes in Finnish subarctic lakes accord well with those found in the Jämtlandic lakes (GRIMÅS, 1961). In Lake Blåsjön a clear decrease of the Nematoda fauna was found after the beginning of regulation.

Compared with the density values recorded in the lakes of S. Sweden (BRUNDIN, 1949), the Nematoda fauna is rather sparse in subarctic waters. Parasitic species were collected in the stomachs of grayling.

The bathygraphic distribution of Nematoda is seen in Fig. 8.

Nematomorpha

Owing to the littoral nature of the group no specimens were found in the samples from soft bottoms. In Kevojärvi some specimens of *Gordius aquaticus* Dujardin were collected in the *Myriophyllum* zone. JÄRNEFELT (1934) found this species once in Lake Haukilampi in Petsamo.

A large number of Nematomorpha were found in the stomachs of some grayling collected in the River Vetsikkojoki and also in in the stomachs of char caught in Lake Jehkatsjärvi northeast of Kilpisjärvi. All the specimens discovered in the stomachs of fishes belonged to the genus *Gordionus* (G. W. Müller). The features of some male specimens studied accord well with those of *Gordionus lapponicus*, described by MONTEN (1951 p. 165) from the Virihaure area. Like *G. alpestris* (Villot) mentioned by LEVANDER (1908) from Finnish Lapland, it may belong to the cold stenothermal faunal element. The large number of Nematomorpha found in the stomachs of grayling and char indicate that they have been directly devoured by these fish.

Oligochaeta

Together with midge larvae, oligochaetes dominated in the bottom fauna of the two lakes. Their mean density is 317.8 ind/m² in Kilpisjärvi and 244.2 ind/m² in Kevojärvi. Owing to the differences in the species composition between the lakes the average biomass of Kevojärvi is somewhat greater than that of the former lake (0.80 and 0.63 g/m² respectively). The densities found in these subarctic lakes are rather high compared with those of many other Fennoscandian lakes (VALLE, 1927 and JÄRNEFELT, 1934). (Table 7).

The remarkable differences found in the densities of oligochaetes are mainly due to different dominant species prevailing in the lakes and to the physical and chemical characters of the water and sediments. In the subarctic lakes the cold stenothermal species *Peloscolex ferox* and *Stylodrilus heringianus* play a dominant rôle. In the lakes of Jämtland (GRIMÅS, 1961), as in the lakes of S. Sweden (BRUNDIN, 1949), small specimens belonging to the family Naididae are abundant. In the lakes north of Lake Ladoga *Tubifex tubifex, Peloscolex ferox* and *Limnodrilus* species are the most common oligochaetes (VALLE, 1927).

In Kilpisjärvi, as in the lakes of Jämtland (GRIMÅS, 1961), oligochaetes were found at every depth (Fig. 9). In Kevojärvi, as in many lakes studied by VALLE and JÄRNEFELT,

Table 7. The average density and percentage of oligochaetes in the bottom fauna of some Fennoscandian lakes.

			ind/m²	% of the bottom fauna
VALLE (1927):				
Eutrophic lakes north of L. Ladoga			24—136	10—55.9
Mesotrophic lakes north of L. Ladoga			0— 96.7	0—72.5
Oligotrophic lakes north of L. Ladoga			only in the littoral zone	
OLSTAD (1925): Mountain lakes of Norway			3—1719	
JÄRNEFELT (1934): Lakes of Petsamo				
	Laukketjaur	littoral	69—127.8	
		profund.	15— 23	
	Pazzjaur	littoral	27.6—134	
		profund.	9.2— 46	
	Kiddjaur	littoral	30.7— 55.4	
		profund.	0— 27.6	
	Treffonjaur	profund	18.4— 46.0	
	Kiephnukkesjaur		129.4—545.8	
GRIMÅS (1961): Lakes of Jämtland				
	Ankarvattnet		718	12.8
	Blåsjön		405	13.1
This investigation: Lakes of Finnish Lapland				
	Kilpisjärvi		317.8	27.0
	Kevojärvi		244.2	44.0

oligochaetes were not recorded in the deepest profundal zone. This may partly be de due to the poor oxygen conditions prevailing in the mud-water interface especially in poly- and mesohumic lakes. Oxygen deficiency limits the distribution of the cold stenothermal species in particular. It is worth noting that the profundal zone of Kevojärvi is inhabited by *Tubifex* species (*Tubifex tubifex* included), which can tolerate low oxygen tension. (LINDROTH, 1947).

As is seen in Fig. 9, a remarkable decrease in the densities of the oligochaetes is found at a depth of 2 metres. The species especially favouring the upper littoral zone in the subarctic lakes are *Tubifex* species. and *Enchytraeidae* (Table 8).

Naididae. This group seems to be rare in the subarctic waters of Finnish Lapland although it dominates in the lakes of Jämtland (GRIMÅS, 1961). Only two specimens belonging to the genus *Nais* were collected in Kilpisjärvi.

Stylaria lacustris (L.). One specimen was collected in the vegetation zone of Kevojärvi. The species is widely distributed in Sweden (SPERBER, 1948) and has been collected in the lakes of Swedish Lapland. According to BRINKHURST (1963) the species is found in England in both fresh and brackish waters but is more common in lakes.

Tubificidae are more common in »mesohumic« Lake Kevojärvi than in oligohumic Kilpisjärvi. A great deal of the specimens collected in the profundal zone of the former lake belong to *Tubifex tubifex* (Müll.). The species is euryoxybiontic and favours soft bottoms rich in nutrients (VALLE, 1927). According to LENZ (1928), it can be included among species of the so-called Baltic lake type. The lack of *Tubifex* species in the small waterbodies studied and their scanty distribution in ultraoligotrophic Kilpisjärvi may indicate that they can not compete with cold stenothermal species in these cold waters poor in

Table 8. The density and bathygraphic distribution of *Oligochaeta*-species in the lakes studied.

Depth zone m		0—1	1—2	2—3	3—4	4—5	—7.5	—10	—15	—20	—25	—30	—35	—40	—45
Nais sp.	K	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Ki	—	—	—	—	—	—	—	3.4	3.1	—	—	—	—	—
Enchytraeus sp.	K	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Ki	—	947	15.5	—	—	—	—	—	—	—	—	—	—	—
Tubifex spp.	K	1054	260	23.1	54.0	25.0	—	—	—	—	18.6	—	—	—	—
	Ki	—	—	—	—	—	3.7	—	55.0	3.1	—	—	—	—	—
Peloscolex ferox	K	620	336	15.4	15.4	37.0	41.2	10.0	46.5	—	—	—	—	—	—
	Ki	—	693	744.0	279.0	341.0	318.4	300.0	423.5	257.3	70.5	77.0	50.0	15.0	48.5
Limnodrilus sp.	K	6	22	—	38.5	6.0	—	10.0	—	—	—	—	—	—	—
	Ki	—	7.7	—	—	—	7.3	—	3.4	6.2	11.0	19.0	3.9	7.7	—
Stylodrilus heringianus	K	868	22.4	—	—	—	61.8	20.6	—	—	—	—	—	—	—
	Ki	—	15.4	46.5	—	—	32.9	—	6.9	24.8	19.6	11.6	34.8	15.5	31.0
Lumbriculus variegatus	K	12.4	5.6	38.7	—	—	—	—	—	—	—	—	—	—	—
	Ki	—	23.1	46.5	31.0	15.5	—	—	21.7	8.4	—	—	—	—	—

Ki = Lake Kilpisjärvi (no samples were taken in the depth zone from 0 to 1 meter)
K = Lake Kevojärvi

nutrients. BRUNDIN (1956), however, has collected them in arctic Lake Katterjaure where they lived with *Peloscolex ferox.*

Peloscolex ferox (Eis.) is widespread in Finland favouring oligotrophic waters. The maximum density of the species in the subarctic lakes is found in the upper littoral zone while in the lakes of S. Finland the species is restricted to the profundal area (VALLE, 1927. Apart from being found in the lakes it also occurred in small silvatic tarns in the vicinity of Kevojärvi.

A *Limnodrilus* species was common in the profundal zone of Kilpisjärvi (Table 8).

Lumbriculidae. Stylodrilus heringianus (Clap.) was found both in the lakes and in small tarns of the alpine region in Utsjoki. In Kevojärvi the species was restricted to the upper littoral zone, while in Kilpisjärvi it was almost eurybathic. The species like *Peloscolex ferox* is assumed to be cold stenothermal because it is widely distributed in arctic and alpine lakes (cf PIQUET, 1919). He collected it in the lakes of N. Sweden at depths of 30—130 metres. BRINKHURST (1963) mentions it as living in England in both lotic and lenitic habitats, especially on sandy bottoms in oligotrophic waters. In Germany it is reported in the vegetation zone of some lakes (MICHAELSEN, 1900 in VALLE, 1927), and in some Polish lakes it is found in the sublittoral zone (RZOSKA, 1937). The last-mentioned finds of this species indicate a remarkable wide range of tolerance of temperature and depth factors.

Lumbriculus variegatus (Müll.) was found in all the lenitic habitats studied. It was especially common in the *Isoëtes* zone in Kevojärvi, where it was only found down to a depth of 2 m. In Kilpisjärvi the greatest depth at which the species was recorded was 39 m. In some Swiss lakes it has been collected at a depth of 35 m (UDE, 1929) and in the lakes north of Lake Ladoga (VALLE, 1927) it is found down to a depth of 20.5 m. The species is very eurytopic in the fresh waters of Finland. PIQUET found it living in small dystrophic tarns on the slope of the Sarek fjeld in N. Sweden. The greatest altitude at which the species was found there was 780 m above sea level.

Lumbricidae. Eiseniella tetraedra (Sav.). 1 specimen was found in the littoral zone of Kilpisjärvi among the *Carex* vegetation. The northernmost record of the species in Finland hitherto was near Oulu (KARPPINEN & NURMINEN, 1964).

Hirudinea

Leeches seem to occur only in Kevojärvi and some adjacent tarns in the silvatic region of Utsjoki. The absolute maximum density was recorded in the lake at a depth of 6 m (93 ind/m^2) among the *Nitella* vegetation.

According to BRUNDIN (1949), leeches are inhabitants of the littoral and sublittoral zones in the lakes of S. Sweden. Their maximum density was recorded in polyhumic Lake Skärhultsjön, where 820 ind/m^2 were found at a depth of 0.2 m. In oligohumic Lake Innaren some species were found down to a depth of 17 m. In the lakes of the Petsamo area they were found only in the littoral zone (JÄRNEFELT, 1934).

Glossiphonia complanata (L.) was the most common Hirudinean species in the area. The length of the specimens collected in July and August 1962 varied from 5 to 15 mm. At the end of July some juvenile specimens were found. All the specimens collected in Utsjoki seemed to belong to f. *concolor* (Apathy) which was also found by Järnefelt in the Petsamo area.

According to BOISEN-BENNIKE (1943), the species has an almost cosmopolitan distribution. The northernmost record is from near Tromsø (N. Norway). The species is eurytopic and favours stony bottoms. It was not recorded in waters with a high humus content and low pH. According to BOISEN-BENNIKE the species tolerates a pH range between 6.3 and 7.2, and a Ca-content below 9 mg CaO/l. As with other leeches, the factors limiting the distribution of the species in the subarctic waters are temperature, and probably lack of food. The bathygraphic distribution in lakes is limited by the lack of hard substrates below the vegetation zone. The species seems to favour bottoms with a large amount of decaying leaves and detritus.

Helobdella stagnalis (L.) was found only in Kevojärvi, where it lived down to a depth of 6 m. The length of the specimens collected in July and August varied from 6 to 8 mm.

According to BOISEN-BENNIKE, the species has an almost global distribution. It has been reported in a hot well in Island (+32°C) (BRUUN, 1938 in BOISEN-BENNIKE, 1943), as well as in glacier lakes. It can also tolerate water with a high humus content and low pH-values.

Like *Glossiphonia complanata*, the species is found in Petsamo (JÄRNEFELT, 1934) and in the arctic Virihaure area in N. Sweden (WINGSTRAND, 1951). In the waters of Utsjoki it seems to be less common than *Glossiphonia*.

Euphyllopoda

Polyartemia forcipata Fisch. was found in both areas studied, living in permanent subalpine tarns. Some specimens were collected in Lake Maasseljärvi east of Kilpisjärvi, where it was also recorded by KOLI (1956). According to LEVANDER (1901), on the Coast of Murman the species seems to favour temperate water-bodies. The material collected on July 20 in Utsjoki consists of 38 males and 39 females. They are distributed by size class as follows:

length mm	6	7	8	9	10	11	12
males	2	5	15	12	4	—	—
females	—	—	2	5	17	12	3

All the females were ovigerous. According to LEVANDER, the maximum length of females on the Coast of Murman may be 19 mm. The length of the specimens collected in the Virihaure area (WINGSTRAND, 1951) varies within the same range as that of the Utsjoki specimens.

Cladocera

The percentage of this group in the benthos of Kilpisjärvi is only 2 %, and the biomass is minute. The most numerous species in all the lenitic habitats studied was *Eurycercus lamellatus* O. F. Müller, which was found in Kevojärvi down to a depth of 10 m and in Kilpisjärvi to a depth of 23.5 m. The greatest density was 31 ind/m^2 in the former and 206.8 ind/m^2 in the latter lake. Besides being found at the bottom of the two lakes the species was abundant in the vegetation zone of all the tarns studied. WINGSTRAND (1951) mentions it as the most common water-flea in the waters of the arctic Virihaure area.

In the bottom samples from the littoral zone of Kevojärvi *Alonopsis elongata* G. O. Sars and *Daphnia longispina* O. F. Müller were also recorded. One specimen of *Polyphemus pediculus* (L.) was found in a sample taken at a depth of 40 m. in Kilpisjärvi. It was not listed in the plankton samples taken from the lake by JÄRNEFELT (1956).

Altogether 9 species of water-fleas were recorded in the waters studied. Their distribution in different habitats is seen in Table 9. Owing to the large mesh size of the net used (1 mm) many small species and specimens may have been missed.

Table 9. The distribution of water-fleas in the waters studied.

	Kevojärvi	Kilpisjärvi	silvatic region	subalpine region	alpine region
Bosmina longirostris	+	+	+	—	—
Eurycercus lamellatus	+	+	+	?	+
Daphnia longispina	+	+	++	—	—
Daphnia pulex	—	—	+	—	—
Alonopsis elongata	+	—	+	—	+
Scapholeberis mucronata	—	—	—	+	—
Ophryoxus gracilis	—	—	—	+	+
Polyphemus pediculus	—	+	—	—	—
Chydorus sphaericus	+	—	+	—	+

According to the Table 9, the most eurytopic species in the area are *Eurycercus lamellatus* and *Alonopsis elongata.* The cosmopolitan species *Chydorus sphaericus* also seems to be widely distributed in the waters studied but, like *Scapholeberis mucronata,* it favours waters with a rather high humus content.

Amphipoda

The only representative of this group in the waters studied is *Gammarus lacustris* Sars. It was found in Kevojärvi and in some silvatic and subalpine tarns in Utsjoki and in subalpine tarns in the Kilpisjärvi region. In Kevojärvi it occurs down to a depth of 4.5 m (BAGGE, 1964). Locally the density of the species exceeded 200 ind/m^2, but the mean value was below 20 ind/m.^{2} The greatest biomasses were found in localities rich in detritus. The densities of *Gammarus* populations in small tarns were often much higher than those in the lake. It is probable that the presence of fish limits the density of the species especially in small tarns. In the tarns on the slope of the Jesnalvaara fjeld the species inhabited the upper tarns, but was absent from the lower tarns, where a rich stock of perch existed. All the tarns mentioned are connected to each other by small brooks. According to NILSSON (1961), in some lakes of Jämtland, *Gammarus lacustris* may constitute up to 40 % of the food consumed by trout and char. In the stomach of one *Salvelinus alpinus* caught in Lake Jehkatsjärvi in the Kilpisjärvi region, 45 specimens of *G. lacustris* were found.

Owing to the great importance of the species in the food chains of subarctic waters and its high value as fish food it should be useful to plant it out in different waters.

The stock of the species in Kevojärvi seems to fluctuate from year to year. After existing in great numbers in 1962 it had almost totally disappeared in 1964 (SUORMALA, 1965 pers.comm.).

In the Petsamo area (JÄRNEFELT, 1934) the species was abundant in the shallow Lake Peurajärvi, which is rich in nutrients owing to a large population of water fowl.

Copepoda

The group is of small importance in the benthos of the lakes studied. Moreover a great deal of specimens may have been lost during the washing procedure. In the lakes Blåsjön and Ankarvattnet in N. Sweden the group constitutes 3.2 and 3.7 % respectively of the whole bottom fauna (Grimås, 1961). In Kilpisjärvi the bathygraphic distribution of the copepods ranged from 0 to 20 m. The absolute maximum density was about 40 ind/m². *Diaptomus graciloides* was recorded at depths of 10—20 metres only. In the littoral zone some specimens belonging to the genera *Diaptomus* and *Cyclops* (C. strenuus) were found. In the bottom samples from Kevojärvi *Acanthocyclops capillatus* occurred at depths of 0.5—1.6 m. Some specimens of this species like some *Cyclops* specimens were collected in the tarns of the alpine and subalpine regions in Utsjoki.

Ephemeroptera

Only a few nymphs belonging to this order were collected on the soft bottoms of the lakes. The maximum density 62 ind/m² was observed in the *Carex* zone of Kevojärvi. The species dominating there was *Siphlonurus aestivalis* Eaton. In Kilpisjärvi it was recorded only once in the bottom samples at a depth of 1 m. Other species collected in the bottom samples of Kevojärvi were *Leptophlebia vespertina* L. and *Ephemera vulgata* L. The last-mentioned species seems to be rare in the subarctic waters (Bagge, 1965).

Some remains of nymphs of this order were found at the considerable depth of 15—20 m in Kilpisjärvi, but living specimens were restricted in both lakes to the upper littoral

Table 10. Distribution of the nymphs of mayflies in the waters studied.

	Kilpisjärvi (lake)	Kilpisjärvi (tarns)	Kuokimajoki (river)	Kevojärvi (lake)	Tarns in silvatic region	Tarns in alpine region	Rivers	Alpine brooks
Ephemera vulgata	—	—	—	+	—	—	—	—
Heptagenia fuscogrisea	+	?	—	—	—	—	—	—
H. dalecarlica	—	—	+	—	—	+	+	—
Arthroplea congener	—	—	+	—	—	—	—	—
Siphlonurus aestivalis	+	++	+	+	+	—	+	—
S. lacustris	—	—	—	+	+	—	+	—
Ameletus alpinus	++	+	+	—	—	—	+	—
Baëtis pumilus	—	—	+	—	—	—	+	—
B. rhodani	++	—	—	—	—	—	+	—
B. macani	+	+	—	—	—	++	—	+
Centroptilum diaphanum	—	—	—	+	—	—	—	—
Leptophlebia vespertina	+	+	—	+	—	+	—	++
L. marginata	+	—	—	—	—	—	—	++
Chitonophora aurivillii	—	—	—	—	+	—	+	—
Ephemerella ignita	—	—	—	—	—	+	—	—
Metretopus borealis	—	—	+	—	—	—	—	—

(+ = rare, ++ = common)

zone. In the lakes of Jämtland mayflies have also been observed to inhabit the littoral zone down to a depth of 7 m, the maximum density being found at depths of 0—2 m (GRIMÅS, 1961).

Nymphs were frequently found in the small bodies of water in the study area. Their distribution among different habitats is seen in Table 10.

In addition to the ephemeropteran and plecopteran fauna of Utsjoki (BAGGE, 1965) *Ephemerella ignita* Poda should be mentioned. It was found in July 1963 in subalpine Lake Taabmukjärvi. Altogether the material from Utsjoki comprises 13 and that from the Kilpisjärvi region 11 species of mayfly. A great deal of them were identified by Mr. Michael Saaristo, M. Sc.

The nymphs which were identified by me to belong to *Ephemerella notata* Eat. (BAGGE, 1965 p. 106), seem to belong to *Chitonophora aurivillii* Bengts.

The most eurytopic species in subarctic waters seem to be *Leptophlebia vespertina* L. and *L. marginata* L. which occurred at every altitude. *Siphlonurus aestivalis* Eaton was common in all kinds of lenitic habitats and also in slow-running waters in Utsjoki, but in Kilpisjärvi only one specimen was found.
The genus *Siphlonurus* is well adapted to living in cold subarctic waters owing to the thick reticular chorion which shelters its eggs (BENGTSSON, 1913 in GRIMÅS, 1961).

Heptagenia dalecarlica Bengts., *Arthroplea congener* Bengts., *Metretopus borealis* Eaton, and *Baëtis pumilus* (Burm.) were observed in running waters alone.

The following species were collected in Kevojärvi and adjacent waters in the silvatic region: *Centroptilum diaphanum* Müll., *Chitonophora aurivillii* Bengts., and *Siphlonurus lacustris* Eaton. The last-mentioned species was called *Siphlonurus zetterstedti* Bengts. in my list of the ephemeropteran fauna of Utsjoki (BAGGE, 1965), but according to BREKKE (1965 p. 12) *Siphlonurus zetterstedti* Bengts. is a synonym for *Siphlonurus lacustris* Eaton.

The nymphs belonging to *Baëtis macani* Kimmins were numerous in some alpine tarns and brooks in Utsjoki (BAGGE, 1965). In July 1964 they were found in three localities in the littoral of Kilpisjärvi. The locus typicus (Lake Saanajärvi) of the species (KIMMINS, 1957) is situated only one mile east of Kilpisjärvi. MÜLLER-LIEBENAU (1965) mentions some finds of the nymphs of this species made by BENGTSSON in Swedish Lapland in the early twenties. According to her review of BENGTSSON's material, the species *Baëtis wallengreni* Bengts. which is recorded from the subarctic area by BREKKE (1938) and TIENSUU (1939) among others, is a synonym for *Baëtis rhodani* Pict. The nymphs collected by me in subarctic waters in Finnish Lapland accord well with MACAN,s description of the species *B. rhodani* (MACAN, 1961). According to BREKKE (1965 p. 12 and 13) *Ameletus alpinus* Bengts. may be a synonym for *Ameletus inopinatus* Eaton.

The nymphs and adults of mayflies play a remarkable rôle in the food chains leading to fish in the subarctic waters. Mouth parts and wings of mayflies were frequently found in the stomachs of grayling and brook trout caught in the running waters of Utsjoki. Especially the species *Heptagenia dalecarlica* and *Baëtis* spp. are frequently recorded in the alimentary canals of fish (BAGGE 1965).

Plecoptera

The nymphs of stoneflies were totally absent from the soft bottoms of the two lakes. Nor were any found in the silvatic tarns in Utsjoki. Altogether 15 species (most in running waters) were collected in the area. They are distributed among different habitats as follows (Table 11).

Table 11. Distribution of the nymphs of stoneflies in the waters studied.

					Utsjoki	
	Kevojärvi (lake)	Kilpisjärvi (lake)	Kilpisj. tarns rivers	alpine tarns	rivers streams	alpine brooks
Protonemura meyeri	—	++	+	—	—	—
Nemoura sulcicollis	—	+	+	—	+	—
N. borealis	—	—	—	—	+	—
N. cinerea	—	+	++	+	++	+
N. flexuosa	—	—	—	—	+	—
N. avicularis	—	+	+	—	—	—
N. sahlbergi	—	+	++	—	—	—
Nemurella picteti	—	—	+	—	—	—
Capnia atra	—	+	+	—	—	—
Arcynopteryx compacta	—	+	?	—	—	—
Diura bicaudata	—	+	+	—	+	—
D. nanseni	—	—	—	—	+	—
Isoperla grammatica	—	+	—	—	—	—
I. obscura	+	+	—	—	+	—
Chloroperla burmeisteri	—	—	—	—	+	—

(+ = rare, ++ = common)

In addition to the species mentioned above, some imagos belonging to *Capnia pygmaea* Zett. were collected on the shore of Kilpisjärvi in July, 1964. In the Virihaure area in N. Sweden, stoneflies were found both in the littoral zone of the lakes (0.3 % of the whole aquatic fauna) and in streams (1.3 %) (Brinck, 1949).

According to Table 11, the most eurytopic plecopteran species in the area studied are *Nemoura cinerea* Retz. and *Isoperla obscura* Zett. *Nemoura cinerea* is very widespread in Finland (Meinander, 1965) and seems to tolerate waters with a high humus content and low pH very well; it is often found living in boggy pools and ditches in S. Finland (Bagge, unpubl.) *Nemoura sulcicollis* Steph. and *Diura dicaudata* L. are also, rather eurytopic in the subarctic waters, though they were absent from Kevojärvi.

Although stoneflies in general seem to favour lotic habitats, several species were frequently found in lakes and tarns in the study area. The most common of them in Kilpisjärvi are *Diura bicaudata* L., *Protonemura meyeri* (Pict.) and *Isoperla obscura* Zett. The nymphs of the last two species were found especially in *Scorpidium* carpets, while the nymphs of *Diura bicaudata* favoured stony bottoms.

Five males belonging to *Nemoura sahlbergi* Mort. were collected on the shore of Kilpisjärvi. It is possible that some Nemoura nymphs found in the south basin of the lake and in Lake Maasseljärvi belong to this species. Their habitus is like that of the nymphs of *Nemoura arctica* Esp. Pet. (Brinck, 1952 p. 106), but on the outer side of the galea are some short hairs and the distal part of the lacinia is deeply toothed. According to Meinander (1965), the species is known in the Kilpisjärvi area and in Utsjoki and Petsamo.

The plecopteran fauna of the Kilpisjärvi region is characterized by the occurrence of some arctic species which are called by Illies (1953) »nördliche Gletscherrandarten«. The most common of them are *Arcynopteryx compacta* Klap. and *Diura bicaudata* L. The brachypterous males of these species were frequently found on the walls and windows of the Biological Station in July. Both the species mentioned above, like *Capnia atra* Mort. and *Nemurella picteti* Klap., occur in the mountain waters of Scandinavia up to 1000 m. above sea-level. (BRINCK, 1951).

In the waters of the Utsjoki region (BAGGE, 1965) the «Gletscherrand« species *Diura nanseni* Kemp. was observed. It should be mentioned that *Nemoura erratica* Claassen (reported by me from Utsjoki) is *Nemoura flexuosa* Aubert (MEINANDER, 1965). Outside Utsjoki it is found in Finland in southern Lapland, Uusimaa and the river system of the Kymijoki (MEINANDER, 1965 p. 17).

As is shown by BRINCK (1949), the percentage of stoneflies in the whole aquatic fauna of the arctic Virihaure area is remarkably high. The very great affinity found there between the fauna of mountain lakes and streams is to a great extent due to the stoneflies which are common to both habitats. In addition, in the Kilpisjärvi region, the plecopteran fauna of the lake and running waters is rather similar. In the Kevo area the affinity between the fauna of the lake and the rivers is not so marked, which may be due to the smaller size, higher temperature and more sheltered position of the lake compared with Kilpisjärvi.

Megaloptera

The larvae of alder-flies were absent from the soft bottoms of Kilpisjärvi while they were locally common in Kevojärvi. The bathymetric distribution of the larvae ranged there from 0.5 to 3.5 m. The maximum density was found at the mouth of the River Kevojoki (217 ind/m^2) at a depth of 3.5 m. In addition, some larvae were collected in alpine and subalpine tarns in Utsjoki. The skin of a Sialis larva was found on the ice of Lake Saanajärvi on July 20 1964.

All the specimens collected belonged to the genus *Sialis* but were different from any larvae which had previously been described. According to MEINANDER (1962), 4 Sialis species are known from Utsjoki. The most common of them are *Sialis morio* Klst. and *S. sordida* Klst.

Trichoptera

The maximum density of the larvae of caddis-flies was found in the upper littoral zone in both lakes studies. Their bathymetric distribution is the following:

Depth zone	L. Kevojärvi	L. Kilpisjärvi
0—1 m	68.2 ind/m^2	?
1—2	58.8 «	7.7 ind/m^2
2—3	7.7 «	—
3—4	15.4 «	—
4—5	6.2 «	—
5—7.5	10.3 «	—
7.5—10	—	—
10—15	—	3.4 «

In the samples from soft bottoms *Molanna albicans* Zett. and *Molannodes tincta* Zett. were the most common species in Kevojärvi. Some specimens belonging to the genus *Limnophilus* were collected in the bottom samples too. Among them (at least 4 species) only the larvae of *Limnophilus nigriceps* Zett. and *L. borealis* Zett. could be identified. In

Kilpisjärvi only some specimens belonging to the genus *Limnophilus* were found on soft bottoms. A pupa was observed at a depth of 10.5 m.

Brundin (1949) states that the group is littoral in its distribution in Swedish lakes. The bathygraphic distribution of the larvae was wider in oligohumic lakes (in Lake Innaren down to 19 m) than in meso- or polyhumic lakes (down to 11 m and 6 m respectively). In the lakes of S. Sweden the species living in deep water belong to the family *Hydroptilidae*. They seem to be rare or absent in subarctic waters. The greatest depth at which the larvae of caddis-flies were found in the lakes of Jämtland was 13 m (Grimås, 1961). Järnefelt (1934) found them in the littoral zone of the lakes of Petsamo. In Lake Saimaa in E. Finland I have collected some *Phryganean* larvae at a depth of 19 m in winter 1963.

The species favouring hard bottoms in Lake Kevojärvi were *Potamophylax stellatus* Curt., *Limnophilus borealis,* and *Athripsodes annulicornis* Steph. On July 7, 1962, the pupae of *Potamophylax stellatus* were very common in the lake (29 pupae were found on a stone with an area of 30 cm^2). Moreover some larvae belonging to the genera *Apatania* and *Mystacides* were frequently found among stones in the lake.

In addition to being found in the lakes the larvae of caddis-flies were frequently observed in lotic habitats. Uusi-Honko (1960) has found together 15 species of caddis-flies in the rivers and streams of Utsjoki, and considers lotic habitats to be the optimum biotope for the group. According to him common species in streams are *Arctopsyche ladogensis* Kol., *Apatania wallengreni* Mc Lach., *A. stigmatella* Zett., and *Plectrocnemia conspersa* Curt. He quotes the following species as occurring in rivers only: *Molanna angustata* Curt., *Athripsodes excisus* Mort., and *Polycentropus flavomaculatus* Pict. In my material collected in rivers in 1962 the larvae of *Rhyacophila nubila* Zett., *Potamophylax stellatus* Curt.,

Table 12. The distribution of the larvae of caddis-flies in the waters studied.

	L. Kevojärvi	tarns in silvatic region	tarns in subalpine region	tarns in alpine region	silvatic streams	silvatic rivers	alpine brooks
Rhyacophila nubila	—	—	—	—	+	++	—
Hydropsyche sp.	—	—	—	—	+	+	—
Plectrocnemia conspersa	—	—	—	—	—	+	++
Polycentropus flavomaculatus	+	—	—	—	—	++	—
Neureclipsis bimaculata	—	—	—	—	—	+	—
Athripsodes annulicornis	+	—	—	—	+	+	—
Mystacides nigra	+	—	—	—	—	—	—
Molannodes tincta	+	+	+	+	—	+	—
Molanna albicans	+	—	+	+	—	—	—
Molanna angustata	+	—	—	—	—	—	—
Apatania spp.	+	+	—	—	—	+	—
Limnophilus borealis	++	—	—	—	—	—	—
Limnophilus nigriceps	+	—	—	—	—	—	—
Limnophilus spp.	+	+	—	—	+	+	+
Potamophylax stellatus	++	+	—	++	+	+	+
Chaetopteryx sp.	—	+	—	—	—	?	—
Lepidostoma hirtum	—	+	—	—	—	—	—
Grammotaulius signatipennis	—	—	—	+	—	—	—

(+ = rare, ++ common)

Molannodes tincta Zett. and *Neureclipsis bimaculata* L. occurred rather frequently. The latter species was restricted to brooks with a rather high humus content. Some larvae of *Rhyacophila nubila* were found in the River Kuokimajoki in July, 1964. *Polycentropus flavomaculatus* which was assumed by UUSI-HONKO to be a lotic species, and whose pupae were very common in the Rivers Kevojoki and Tsharsjoki in July, 1962, was found in Kevojärvi too.

According to the table, the most eurytopic species in the Kevo area are *Potamophylax stellatus* and *Molannodes tincta,* which were found in lotic and lenitic habitats at every altitude. The species which seem to be restricted to the alpine waters are *Grammotaulius signatipennis* Mc Lach., and *Philopotamus montanus* Pon. UUSI-HONKO (1960) found the arctic species *Lenarchus productus* Mort. and *Asynarchus contumax* Mc Lach. in the brooks of the alpine region of Utsjoki. *Philopotamus montanus* which has a flying period in the early summer in Utsjoki (UUSI-HONKO, 1961) has a northern and partly eastern distribution in Finland (NYBOM, 1960 map 5).

In the animal communities of the subarctic lakes caddis-flies are not of great importance outside a narrow littoral zone. Most of the species found in lakes are eruciform vegetarians except *Polycentropus flavomaculatus* which is a carnivore. In the lotic habitats of the area especially, the campodeidform larvae of caddis-flies and swarming imagos play an important role as food organisms for fish. In the stomachs of grayling caught in the River Vetsikkojoki chitin parts of larvae and wings of adult caddis-flies were frequently found.

Odonata

The nymphs of dragon-flies were not found in the two lakes but they were common in small dystrophic tarns at every altitude in Utsjoki.

Of the three species found, the most common was *Aeschna juncea* L. which lived in both the silvatic and alpine regions. ANDER (1951) mentions the species from the Abisko area in N. Sweden, but it was absent from the arctic Virihaure area, possibly on account of the lack of dystrophic waters. The length of the nymphs collected in July 1963 in the Kevo area ranged from 14 to 44 mm; the smallest specimens being found in the alpine region. According to VALLE (1952) the distribution of this species like that of the other two covers the whole of Finland, but all three are most common in the North.

Aeschna coerulea Ström was found in subalpine and alpine waters in the area. ANDER (1951) states it to have a boreoalpine distribution in Europe.

Somatochlora arctica Zett. One nymph was found in a silvatic tarn on the slope of the Jesnalvaara fjeld. ANDER records it from the arctic Virihaure area.

Hemiptera

The group is absent from the lakes studied, but hemipteran nymphs are locally very numerous in small bodies of water in Utsjoki. Especially, nymphs belonging to the genera of *Gerris* and *Corixa* were frequently found in small alpine tarns.

The most eurytopic species in the Kevo area is *Gerris asper* Fieb. which was observed at every altitude. Some specimens were found in slow-running water in the Kevojoki too. *Gerris lacustris* L. and *G. odontogaster* Zett. were observed only in the silvatic tarns in Utsjoki.

Although the nymphs of *Corixa* were common in small alpine tarns in July 1963, adult specimens were collected only in the silvatic region. They belonged to *Corixa carinata* C.

Sahlb. This species like the other hemipteran species mentioned above has been found in Petsamo (LINDBERG, 1931) and in Enontekiö Lapland (LINDBERG, 1927).

Coleoptera

In the bottom samples taken in the vegetation zone of Kevojärvi some adult specimens belonging to *Haliplus fulvus* Fabr. and some *Agabus* larvae were found. The average density of water beetles in the depth zone 0—1 m of the lake was 24.8 ind/m². The species mentioned above together with *Deronectes multilineatus* are the only coleopterans found in Kevojärvi. In the small bodies of water especially in dystrophic tarns in Utsjoki the coleopteran fauna was rich in species (Table 13.).

Table 13. The distribution of water beetles in the waters studied.

	L. Kevojärvi	Tarns in the silvatic region	Tarns in the alpine region	River pools	Streams	Rivers	Alpine brooks
Haliplus fulvus	++	++	—	+	+	+	+
Hydroporus palustris	—	++	+	+	—	—	—
H. striola	—	+	—	—	—	—	—
H. erythrocephalus	—	—	—	+	—	—	—
Deronectes multilineatus	—	—	—	+	+	—	—
Ilybius angustior	—	++	+	+	+	—	—
I. fenestratus ?	—	+	—	+	—	—	—
Colymbetes dolabratus	—	—	—	+	—	—	—
Coelambus 9-lineatus	—	+	—	+	—	—	—
Agabus congener	+	+	—	+	+	—	—
A. sp.	+	+	+	+	+	—	—
Dytiscus lapponicus	—	++	++	+	—	—	—
Gyrinus opacus	—	+	—	+	—	—	—
Rhantus suturellus	—	—	+	++	—	—	+

The above list is not complete because not all the coleopteran material collected was identified. The most eurytopic species in the study area are *Haliplus fulvus* and *Rhantus suturellus;* wide spread are also *Dytiscus lapponicus* and *Agabus congener.* The species belonging to the genera *Hydroporus* and *Ilybius* were chiefly observed in waters with a high humus content. All the species listed above were found in the waters of the Petsamo area too (LINDBERG, 1933).

Diptera

Empididae. One adult specimen belonging to this family was caught at a depth of 7 m in Kilpisjärvi. GRIMÅS (1961) mentions the group from the littoral zone of the lakes of Jämtland (Blåsjön and Ankarvattnet).

Tipulidae. Some larvae were found in the littoral of both lakes studied. The greatest depth at which they were recorded in Kilpisjärvi was 6 m. Most of the larvae collected belong to the genus *Tipula*. Larvae of this genus were numerous in some silvatic tarns in Utsjoki too. Moreover some larvae of the genera *Dixa* and *Dicranota* were found in the River Raessijoki and in some alpine tarns in Utsjoki. A larva of a *Pedicia* species was observed in the littoral zone of Kilpisjärvi.

Tabanidae. Some larvae were collected at a depth of 8 m in Kilpisjärvi.

Simuliidae. Larvae of gnats were not found in the two lakes but they were very numerous in some stony streams and brooks at widely varying altitudes in Utsjoki, especially in the silvatic region. MÜLLER (1954) mentions the group as being rheophilous and favouring swiftly running water in small forest rivers in N. Sweden. NIELSEN (1950) states that some species of the genus *Simulium* are adapted to small temperate rapids while others can live among the aquatic vegetation in streams. An important limiting factor for the existence of the larvae is a low oxygen tension.

Chaoboridae. Some larvae belonging to the species *Chaoborus crystallinus* were found in small silvatic tarns in Utsjoki.

Chironomidae. Together with oligochaetes, midge larvae predominate among the soft bottom fauna of both lakes. Numerically, they constitute 55.3 % of the whole bottom fauna in Kilpisjärvi and 27.8 % in Kevojärvi. In the subarctic lakes of N. Sweden the percentages of midge larvae are as follows: Ankarvattnet 32.2 %; Blåsjön 31.9 % (before the regulation of the water level) and 54.1 % (during the regulation of the water level), Jormsjön 29.7 %, Kvarnbergsvattnet 36.1 % and Semnigsjön 35.3 % (GRIMÅS, 1961). The percentage for Kilpisjärvi is very high compared with that of the other lakes.

The average density of midge larvae in Kilpisjärvi is 655.6 ind/m^2 and the biomass 0.51 g/m^2. In Kevojärvi the figures are 116.6 ind/m^2 and 0.35 g/m^2, respectively. Compared with some lakes in S. Finland (VALLE, 1927 and JÄRNEFELT, 1921), the subarctic waters show a high density of midge larvae. This may be due to the dominance of small *Orthocladiinae* larvae in the subarctic waters and to the fact that a smaller mesh size was used here (0.6 mm) than that (1.0 mm) used by VALLE (cf. JONASSON, 1955).

The greatest absolute densities of the different groups of midge larvae in the lakes studied are as follows:

	Kilpisjärvi		Kevojärvi	
	depth m	ind/m^2	depth m	ind/m^2
Tanypodinae	5.5	806	1.0	155
Orthocladiinae	7.0	2790	0.5	186
Chironomini	5.0	620	0.5	465
Tanytarsini	1.0	961	1.0, 8.0	93

In Kilpisjärvi, larvae of all the groups mentioned above occurred below a depth of 32 m, while in Kevojärvi only the larvae of *Sergentia coracina Zett.* (Chironomini) were found below a depth of 30 m.

The bathygraphic distribution of the midge larvae in Kevojärvi (Fig. 10) is like that found in the lakes of the Petsamo area (JÄRNEFELT, 1934). Especially in the lakes in the area of acid Precambrian bedrock (Lakes Pazzjaur and Kiddjaur) the density of Chironomidae is low. In some of these lakes strong dystrophy and siderotrophy have been observed (JÄRNEFELT, 1934) which have a limiting effect on the bottom fauna. The greatest densities of midge larvae in the Petsamo area were found in Lake Laukketjaur, lying on amphibolite bedrock. In June the density ranged from 324 to 1804 ind/m^2 at depths of 2.4—6.0 m and from 278 to 555 ind/m^2 at depths of 10—12 m. The groups dominating in the lake were *Monotanytarsus* and *Paratanytarsus* in the littoral zone, and *Stictochironomus* at a depth of 10 m.

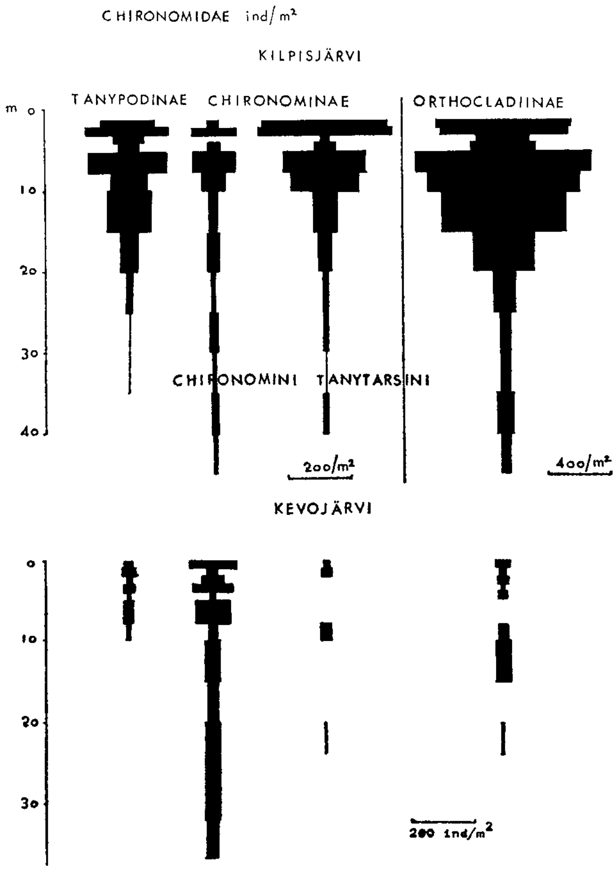


Fig. 10. The bathygraphic distiribution and density (ind/m^2) of the main groups of *Chironomidae* in the lakes studied.

The Chironomidae fauna of Kilpisjärvi is more like the fauna in Scandinavian mountain lakes than the fauna of lowland lakes in the Petsamo area. The great affinity of Kilpisjärvi to the mountain lakes is seen in the dominance of Orthocladiinae and in the small number of species and specimens belonging to the group Chironomini. When the midge fauna of Kevojärvi and Kilpisjärvi are compared, a trend similar to that observed by Brundin (1949) in the Lakes of Jämtland, is revealed; the percentage of the group Orthocladiinae increases with increasing altitude.

The percentages of the midge larvae of different groups in the two lakes are as follows:

	Kevojärvi	Kilpisjärvi
Tanypodinae	15.8	12.1
Orthocladiinae	20.6	68.1
Chironomini	51.8	5.8
Tanytarsini	11.8	14.0

Table 14. The density and bathygraphic distribution of midge larvae in some oligotrophic lakes.

Depth m.	L. Kilpisj. 1964	L. Kevoj. 1962	L. Päijänne VALOVIRTA 1959	Lakes in Petsamo: Pazzjaur JÄRNEFELT 1934	Kiddjaur
0—1	—	212.8	—	—	40—231
1—2	1409	126	2216	92—323	
2—3	1643	124	595		92—462
3—4	465	161.7	539		
4—5	666.5	43.4	ca. 232	46—555	
5—7.5	1753	133.9	297	46	46—139
7.5—10	1365	72.1	ca. 140	46	
10—15	1023.4	108.5	ca. 252	46	74—231
15—20	508.4	—	ca. 229	0	
20—25	160.5	55.8	547		
25—30	100.6	—			
30—35	85.2	31.0	63		
35—40	108.5				
40—45	61.9		91		
over 45			0—98		

Owing to taxonomical difficulties, only the group can be mentioned in many cases.

Tanypodinae. The larvae were almost equally distributed between the two lakes. They seem to have a wide distribution in the subarctic area, although the densities are low compared with those of other midge groups. According to THIENEMANN (1954), the larvae are carnivores and their food includes larvae of *Anopheles, Orthocladiinae* and *Tanytarsus.* In the littoral of the lakes they can feed on zooplankton.

Ablabesmyia monilis L. was found in Kevojärvi in the vegetation zone down to a depth of 3.5 m, but in Kilpisjärvi its bathymetric distribution is wider and it was found on silt and clay bottoms as well. The maximum density of the species was 156 ind/m² in both lakes. It was also found in alpine tarns and in slow-running waters in Utsjoki. According to BRUNDIN (1949), the species is very eurytopic and has a cosmopolitan distribution.

Ablabesmyia costalis group. Some larvae were found at a depth of 0.5 m in Kevojärvi and down to 11 m in Kilpisjärvi. The maximum density was 124 ind/m² at a depth of 5.5 m in the latter lake. JÄRNEFELT (1934) found them living in the lakes of Petsamo, and THIENEMANN reported them from some dystrophic lakes in Ireland.

Ablabesmyia spp. Larvae belonging to other groups than those mentioned above were seldom found. In Kilpisjärvi some *Ablabesmyia* larvae were observed down to a depth of 16 m; their maximum density being 124 ind/m².

Anatopynia sp. (= *Macropelopia* sp). was found in Kilpisjärvi at depths of 4—16 m. The maximum density was 186 ind/m². In Kevojärvi only one specimen was observed in the *Nitella* zone at a depth of 4.5 m. BRUNDIN (1949) mentiones three *Macropelopia* species from N. Sweden. The most common of them is *M. nebulosa* Meig. JÄRNEFELT found *Macropelopia* larvae in the littoral of many lakes in Petsamo.

Anatopynia trifascipennis (Zett.) was found in Kevojärvi on silt bottom at a depth of 3.5 m. According to THIENEMANN (1954), the larvae of this species live on soft bottoms in both lenitic and lotic habitats. BRUNDIN (1949) states that they are frequently found in the subarctic waters of Jämtland. In Finland he found the species in Lake Puruvesi (E. Finland) where it was numerous.

Psilotanypus sp. Two larvae were observed in the profundal zone of Kilpisjärvi. Their features agree well with KORENEVA's description of the larvae of the genus *Psilotanypus* (KORENEVA, 1957 in BRYCE, 1960 p. 53).

Procladius spp. The members of this genus were frequently found in the lenitic waters studied. They were more common in Kilpisjärvi than in Kevojärvi. The maximum density in the former lake was 682 ind/m^2 and the larvae occurred down to a depth of 5.5 m. BRUNDIN (1949) lists about 10 *Procladius* species from N. Sweden. The most common of them are *P. barbatus* Brund. and *P signatus* Zett.

Orthocladiinae. As mentioned above, the larvae of this subfamily dominated in ultra-oligotrophic Kilpisjärvi (Fig. 10). The larvae of the genera *Monodiamesa, Heterotrissocladius* and *Trissocladius* were the most numerous midge larvae in the lake. In view of the large numbers of these larvae the lake can be grouped with lakes of the Heterotrissocladius subpilosus type (cf. BRUNDIN, 1958).

Monodiamesa sp. The larvae of this genus were common in Kilpisjärvi especially in the profundal zone. According to BRUNDIN (1949), the species *M. ekmani* Brund. is typical of the ultraoligotrophic lakes in N. Sweden. *M. bathyphila* Pag. may also occur in the subarctic lakes of Finnish Lapland, since it has been found in N. Sweden (GRIMÅS, 1961).

Chironominae: Chironomini. The larvae of the tribe Chironomini dominated at every depth in Kevojärvi (Fig. 10). Especially the species *Sergentia coracina* Zett. was common in the profundal zone of the lake.

Chironomus anthracinus Zett. was found in the vegetation zone of Kevojärvi and some tarns in Utsjoki. The maximum density in the lake occurred at a depth of 0.5 m (495 ind/m^2). The mean length of the larvae collected in July was 13 mm. BRUNDIN (1949) mentions the species as being very eurytopic and having a circumpolar distribution. In eutrophic lakes in S. Sweden it inhabits the profundal zone, but in subarctic lakes it seems to be littoral. It is said by BRUNDIN to avoid waters with a high humus content.

Chironomus dorsalis Meig. One larva which, according to the description by BRYCE (1960 p. 41), belongs to this species was found in the littoral zone of Kevojärvi. BRUNDIN reports it from N. Sweden.

Chironomus hyperboreus Staeg. Two larvae belonging to this species (cf. ANDERSEN-SÖGAARD, 1937) were found at a depth of 0.5 m in Kevojärvi. THIENEMANN (1954) mentions the species in some lakes of Abisko Lapland (N. Sweden). It is also known in Spitsbergen, around Hudson Bay and in Greenland (BRUNDIN, 1949) where it lives in arctic or subarctic tarns and lakes.

Cryptochironomus camptolabis group. Larvae probably belonging to this group (cf. BRYCE, 1960) were observed in Kilpisjärvi at depths of 6—45 m. The maximum density occurred at a depth of 16 m on clay bottom (93 ind/m^2).

Cryptochironomus defectus group. One larva was observed in the *Isoëtes* zone of Kevojärvi. According to BRUNDIN (1949), several species belonging to this group have been collected in the lakes of N. Sweden. The most common of them are *C. supplicans* Meig. and *Demicryptochironomus vulneratus* Zett.

Glyptotendipes sp. was collected in the littoral zone of Kilpisjärvi. JÄRNEFELT (1934) reports it from Lakes Poarjaur and Pazzjaur in Petsamo. BRUNDIN (1949) mentions three *Glyptotendipes* species which are found in the lakes of Jämtland. The most widely distributed of them are *G. pallens* Meig. and *G. gripenkoveni* Kieff.

Lenzia sp. There is one record of larvae of this genus in the littoral zone of each of the lakes studied. BRUNDIN (1949) mentions *L. punctipes* Wied. as being widely distributed in the subarctic waters of Fennoscandia.

Microtendipes sp. In Kevojärvi the larvae occurred at depths of 2.5—15.0 m. The maximum density was 62 ind/m².

Paratendipes sp. There are several finds of the larvae of this genus in the littoral zone of Kevojärvi at depths 0—6 m. JÄRNEFELT (1934) found them in Lake Laukketjaur in Petsamo. According to BRUNDIN (1949), especially *P. albimanus* Meig. is common in the littoral area of some lakes in Jämtland.

Polypedilum sp. In Kevojärvi larvae were observed at a depth of 6 m and in Kilpisjärvi at 7 m. The maximum densities were 248 and 217 ind/m² respectively. The most common species in the lakes of Jämtland is *P. pullum* Zett. (BRUNDIN, 1949).

Sergentia coracina Zett. As mentioned above, the larvae of this species were found at every depth in Kevojärvi. The maximum desity was 372 ind/m² at a depth of 3 m. In the deepest basin (30—35.5 m) of the lake the species was the only bottom-living animal to be found. In Kilpisjärvi it was found down to a depth of 13 m. According to BRUNDIN (1949), the species is cold stenothermal and has a northern distribution. He reports that is is restricted to the littoral in subarctic lakes, but is only found in deep water in more southern lakes.

Stictochironomus rosenschöldi (Zett.) Edw. is rather common in the littoral and upper profundal zone in Kevojärvi down to a depth of 10 m. The maximum density of the larvae was found in *Nitella* vegetation. In Kilpisjärvi only two larvae were observed. Like *Sergentia coracina* the species is a cold stenothermal, steno-oxybiontic species and has a northern distribution (BRUNDIN, 1949).

Tanytarsini: Larvae of *Tanytarsus inermipes* group were numerous in Kilpisjärvi at depths of 1.5—25.5 m. The maximum density (775 ind/m²) was observed at a depth of 6 m. In Kevojärvi these larvae were found only in the upper littoral zone. A common species in Kevojärvi was *Micropsectra groenlandica* Aners. (cf. ANDERSEN—SÖGAARD, 1937). According to BRUNDIN (1949), it is wide spread in the arctic and subarctic lakes of N. Sweden.

Larvae of *Tanytarsus gregarius* group were wide spread in all the waters studied. The maximum density in Kilpisjärvi (806 ind/m²) was observed at a depth of 9 m. In Kevojärvi the larvae occurred down to 24 m. According to JÄRNEFELT 1934), these larvae were collected in most of the lakes studied in Petsamo.

Larvae of *Tanytarsus lauterborni* group were found in Kevojärvi at a depth of 0.5—1.0 m. The maximum density in Kilpisjärvi occurred at a depth of 11 m.

Lundstroemia praecox Meig. Five larvae, whose features fit BRYCE's (1960) description of Lundstroemia praecox were collected at depths of 6 and 13 m in Kilpisjärvi. BRUNDIN (1949) mentions the group *Microspectra* sp. praecox ? in some lakes of Jämtland.

Hydracarina

In Kilpisjärvi water-mites were observed at every depth, the maximum density being 279 ind/m² at a depth of 2.5 m. In Kevojärvi they were found only in the littoral zone. In the lakes of Petsamo, water-mites have often been found in plankton samples (JÄRNEFELT, 1934). In the bottom fauna of the lakes of Petsamo their density ranged from 46 to 184 ind/m² in the littoral zone. GRIMÅS (1961) mentions water-mites as living at every depth in the lakes of Jämtland, but most of the species were restricted to the littoral. In Lake Blåsjön, which was regulated they were common and seemed to be favoured by the regulation of the water-level. According to BRUNDIN (1949), water-mites are common on open bottoms in the profundal or sublittoral zones of the lakes of S. Sweden. The maximum density of *Hydracarina* in these lakes was observed in the summer.

The most numerous species in Kilpisjärvi was *Neobrachypoda ekmani* Walt., which occurred at every depth. Its maximum density was found at a depth of 2.5 m (217 ind/m^2). According to GRIMÅS (1961), the species constituted 5 % of the whole *Hydracarina* material collected in Blåsjön, where it lived at depths of 6—140 m.

Lebertia spp. were collected twice in the littoral zone of Kevojärvi. In Kilpisjärvi they were common down to a depth of 32 m. The maximum density there occurred at a depth of 2.5 m (217 ind/m^2). GRIMÅS mentions them as living at depths of 2—60 m in the lakes of Jämtland.

An *Atractides* species was found in Kilpisjärvi at a depth of 13 m.

Frontipoda setosa f. *ekmani* Thor. In Kilpisjärvi the species was found down to a depth of 18 m, the maximum density occurring at 2.5 m (124 ind/m^2). The species is common in the lakes of N. Sweden (LUNDBLAD, 1962), and constitutes 27 % of the whole *Hydracarina* fauna in Blåsjön (GRIMÅS, 1961).

Hygrobates longipalpis (Herm.) In Kevojärvi the species was found in the upper littoral zone and in Kilpisjärvi to a depth of 13 m. GRIMÅS (1961) records *H. foreli* Leb. from the lakes of Jämtland.

Megapus sp. One specimen was observed at a depth of 14 m in Kilpisjärvi.

Not all the *Hydracarina* material collected was identified. The larvae of water-mites were found on several invertebrates including water beetles and Trichopteran larvae.

Bryozoa

Communities of moss animals were found in Kilpisjärvi at depths of 6—30.5 m. Most of them, however, were dead. Their maximum density (93 ind/m^2) was observed at a depth of 16 m. In the lakes of Jämtland densities of over 200 ind/m^2 were recorded at 8—10 m (GRIMÅS. 1961).

The most numerous species in Kilpisjärvi was *Fredericella sultana* (Blumenbach). According to BORG (1941), it is the most common *Bryozoa* species in oligotrophic and dystrophic lakes in Sweden. EKMAN (1915) mentions it as occurring down to a depth of 50 m in Lake Vättern in Sweden. In Kilpisjärvi the greatest depth at which it was recorded was 30.5 m.

Paludicella articulata (Ehrenberg) was found in Kilpisjärvi at a depth of 16 m. BORG (1941) states that it lives under stones and on aquatic plants in both lotic and lenitic habitats throughout the whole of Sweden. It can even be found in swiftly running brooks among *Fontinalis* carpets.

Sphaeridae

The maximum density of pea-mussels per depth zone in Kevojärvi was 236 ind/m^2 in the 0—1 m zone, and the average density in the whole lake was 72 ind/m^2. In Kilpisjärvi corresponding numbers were 387.5 ind/m^2 at a depth of 2—3 m and 36.3 ind/m^2. The maximum depth at which they were found was 10 m in Kevojärvi and 40 m in Kilpisjärvi. The dominant species in the latter lake was *Pisidium conventus* Cless.

Table 15. The average density and dominance of pea-mussels in the bottom fauna of some Fennoscandian lakes:

	Depth zone	Ind/m²	Percentage of the whole fauna
VALLE (1927): Lakes north of L. Ladoga			
Eutrophic lakes	profundal	0—12	0—4.5
Mesotrophic lakes	«	21.7—186.7	66—94.9
Oligotrophic lakes	«	0—12	0—85.7
VALOVIRTA (1959): Lake Päijänne			
	littoral	11—47	
	profundal	4—6	
JÄRNEFELT (1934): Lakes of the Petsamo area			
Laukketjaur	littoral	9.2—10.6	
	profundal	0—34.5	
Pazzjaur	littoral	36.8	
	profundal	0	
Haukilampi	littoral	379.2—1119.4	
Kiddjaur	littoral	9.2—83.2	
	profundal	0	
Treffonjaur	littoral	—	
	profundal	9.2—61.3	
GRIMÅS (1961): Lakes of Jämtland			
		ind/m²	%
L. Blåsjön	the whole lake	185	6.04
L. Ankarvattnet	«	298	5.51
This investigation:			
L. Kevojärvi	the whole lake	72	13.3
L. Kilpisjärvi	«	36.3	3.6

The greatest densities of pea-mussels in the lakes listed above were found in Lake Haukilampi, which according to JÄRNEFELT has some mesotrophic features. In the lakes studied by VALLE (1927) the densities were also greatest in meso- or polyhumic mesotrophic lakes. The great percentage of pea-mussels in the whole bottom fauna of Kevojärvi thus indicates a slight mesotrophy. The average standing crop was, however, small (0.19 g/m²).

Altogether 6 *Pisidium* species were found in Kevojärvi and the adjacent waters. In subalpine Kilpisjärvi only 3 species were recorded. The distribution of Sphaeridae in the waters studied is seen in Table 16. The specimens were identified by Lic. L. Koli.

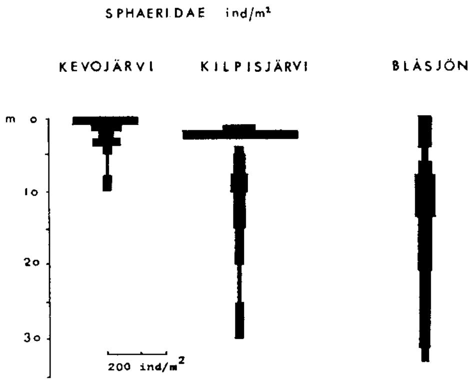


Fig. 11. The density and bathygraphic distribution of *Sphaeridae* in some subarctic lakes.

Table 16. The distribution of Sphaeridae in the waters studied.

	L. Kevojärvi	L. Kilpisjärvi	river pools	Utsjoki alpine brooks	silvatic tarns	rivers
Pisidium nitidum	—	—	+	—	—	—
P. subtruncatum	+	—	+	—	+	—
P. lilljeborgi	+	+	+	+	+	—
P. casertanum	+	+	+	—	—	—
P. obtusale	+	—	—	—	+	+
P. conventus	—	+	—	—	—	—
P. milium	+	—	—	—	—	—

According to the table, *Pisidium lilljeborgi* Cless. is the most eurytopic species in the study area. Its maximum density was found in Kevojärvi at a depth of 1—2 m (92.4 ind/m²). The greatest depth at which the species was recorded was 14 m in Kilpisjärvi. *Pisidium conventus* Cless. was found in every depth zone in Kilpisjärvi. According to ODHNER (1951), it is a cold stenothermal species with an arctic-alpine distribution. In S. Finland and S. Sweden it is often found in the profundal of deep lakes, but in subarctic lakes it seems to be eurybathic in its distribution (BRUNDIN, 1956, GRIMÅS, 1961).

Pisidium obtusale v. *lapponica* Cless. has a northern distribution too, although the species *P. obtusale* Pfeiff. occurs throughout the whole of Sweden (ODHNER 1951).

The migration history of pea-mussels in northern Finland has been discussed by VASARI et al. (1963) and by SALMI (1963). According to them, remains of the species *Pisidium lilljeborgi* have been found in calcareous deposits of the Boreal period in Kuusamo and Kittilä.

Gastropoda

The group was well represented in the bottom fauna of Kevojärvi especially in the vegetation zone. The maximum density of snails was 142.6 ind/m² at a depth of 0—1 m. In Kilpisjärvi the density of 46.5 ind/m² was recorded at a depth of 2—3 m.

GRIMÅS (1961) states that the group is abundant in the littoral zone of the lakes of Jämtland, but in Blåsjön a remarkable decrease in the snail population was found after the beginning of the regulation of the water-level. In the lakes of Petsamo the densities of the snails were as small as in Kilpisjärvi (JÄRNEFELT, 1934).

Lymnaea peregra Müll (= L. limosa (L.)) was found in both lakes. In Kevojärvi the maximum density (93.5 ind/m^2) occurred at a depth of 0.5 m. The greatest depth at which it was collected in this lake was 6.0 m. In Kilpisjärvi one specimen was found at a depth of 18 m. KOLI (1955) mentions that a juvenile specimen was found in the lake at a depth of 21 m. In the small bodies of water adjacent to Kevojärvi the species was absent although it was often found in slow-running waters in Utsjoki. The species is an important food organism for the fish of the area. It was frequently found in the stomachs of grayling in the River Vetsikkojoki. Three juvenile specimens were found in the alimentary canal of a *Salvelinus alpinus,* caught near Kilpisjärvi. BRINCK and WINGSTRAND (1951) also found the species in the stomachs of the same fish species in the arctic Virihaure area. According to ODHNER (1951), *L. peregra* is one of the most common aquatic gastropods in Scandinavia. HUBENDICK (1947) considers it to be a eurytopic littoral species, which is absent from running waters. He mentions that it lives in both hard and soft waters with a CaO range of from 10 to 20 mg/l and a pH range of from 5.8 to 9.3 (ZHADIN in HUBENDICK, 1951.). ALSTERBERG (1930) mentions that the low oxygen tension of the water near the bottom limits the bathymetric distribution of the species. Adult specimens can, however, obtain all the oxygen they need from the water, provided the temperature does not exceed + 12°C.

Lymnaea stagnalis (L.) Two specimens were found in the littoral zone of Kevojärvi.

Gyraulus acronicus (Férussac) The maximum density of the species was found among *Carex* vegetation in Kevojärvi, where 434 ind/m^2 were counted. The greatest depths at which it was collected were 4.5 m in Kevojärvi and 7.0 m in Kilpisjärvi. Apart from the lakes, the species was found in some silvatic tarns in the vicinity of Kevojärvi. Both keeled and unkeeled specimens were collected in the lakes. The diameter of 50 specimens collected in July 1962 varied from 3.1 to 7.0 mm, the average value being 4.7 mm. The smallest specimens inhabited the upper littoral. ODHNER (1951) gives the maximum breadth of the specimens found in N. Sweden as 5.8 mm. According to him, ecological factors, such as temperature, amount of food, and exposed position of the habitats, cause a great variation in the body form of the species. The species has a northern distribution area in Fennoscandia (HUBENDICK, 1947). In Finland it has been found sporadically throughout the whole country. KOLI (1955) states it to be the second commonest aquatic gastropod in Finnish Lapland. It favours cold and oligohumic waters with a pH ranging from 6.8 to 9.3 and a CaO content of from 25 to 30 mg/l (HUBENDICK, 1951).

Valvata piscinalis (Müller) The species was found only in Kevojärvi and in the mouth of the River Kevojoki. Only two specimens were obtained from the bottom samples at a depth of 0.5 m. According to HUBENDICK (1951), the species is found throughout the whole of Fennoscandia, apart from Norway where it occurs only in the vicinity of Oslo. JÄRNEFELT (1934) mentions *Valvata borealis* in some lakes of the Petsamo area. It seems possible that this is actually V. piscinalis. HUBENDICK gives the pH range of the waters where the species lives in S. Sweden as 7.2—8.3 and the CaO content as about 20 mg/l. According to LEVANTO (1940), the optimum depth of the species in Lake Vesijärvi (south of Lake Päijänne) ranges from 1.5 to 3.0 m, and it seems to favour habitats rich in organic debris.

Some notes on the migration history of aquatic gastropods may be found in the paper of SALMI (1963). He discovered remains of *Gyraulus acronicus* and *Lymnaea peregra* in calcareous deposits of the pre-Boreal and Boreal periods in Kittilä. *L. peregra* was also found in the similar deposits in Kuusamo (VASARI et al., 1963).

VI. THE INFLUENCE OF SOME ECOLOGICAL FACTORS ON THE FAUNA OF THE SUBARCTIC WATERS

In the preceding chapters the qualitative and quantitative distribution of the aquatic fauna was discussed but only a few scattered references were made to the ecological background.

In the quantity and distribution of the species we can see a clear difference between the faunae of the two lakes. In most animal groups the number of species is noticeably lower in alpine waters than in water-bodies of the silvatic region. The ecological demands of most subarctic and boreal species are unknown, but some correlations may be seen in the following chapters.

According to Odum (1959) the limiting factors of special importance in fresh water are the following: temperature, light, transparency, current, concentration of respiratory gases and concentration of biogenic salts. The last-mentioned factor is of great importance for the production of phytoplankton and the growth of aquatic plants, and thus indirectly for the organisms which consume them. It must be stated here that the quality as well as quantity of the food produced is important to different organisms. The following chapters will contain some remarks on the synecological and historical factors affecting the distribution of the fauna.

1. *Light and temperature*

No exact measurements of the light in the different depth zones of the lakes studied are available. Thomasson (1965) has contributed a theoretical discussion on the distribution of solar radiation in arctic and subalpine lakes. According to him the amount of energy lost through reflection is about 4 % of the total energy received at noon in June and July at the latitude of Utsjoki, but at other times the losses are greater. As regards the longer period of daylight in the north in summer, it should be remebered that lakes lying in deep valleys do not receive radiation energy throughout the whole of the day. As the sun approaches the horizon its rays are cut of from such lakes by the surrounding hills. Thus the rhythm of illumination in these lakes in N. Finland may not deviate much from that found in lakes in the south of the country. During the winter the subarctic lakes are covered by ice and snow, which effectively prevent the penetration of light. In large deep lakes like Kilpisjärvi the ice breaks up around June 15—20 when the radiation energy is at its maximum. During the short summer they have not time to warm up much above 10°C.

The absorption of radiation energy by humus colloids is well known. It is for this reason that the Secchi-disc values of polyhumic waters are small, and such lakes warm up quickly during the summer. The waters of the subarctic region are usually clear with a small humus content, and the penetration of light in them is good. Measurements made with a Secchi-disc, however, show a great variation even in the waters of Fjeld Lapland.

According to JÄRNEFELT (1956), the Secchi-disc values of Kilpisjärvi vary from 9.35 to 9.85 m during the summer while those of Lake Inarinjärvi vary from 4.1 to 4.8 m. In the lakes of Petsamo values ranging from 5.0 to 8.0 m have been recorded (JÄRNEFELT, 1934). The Secchi-disc values of Kevojärvi in 1962 varied from 4.2 to 4.8 m, being highest in June. In some alpine tarns in Utsjoki low values of about 1.5 m were observed after heavy rainfall in August, 1963. In general the Secchi-disc values seem to be greater in lakes with a small drainage area.

The primary production of lakes depends to a large extent on the transparency of their water. The thickness of the euphotic zone can be calculated from the Secchi-disc values by multiplying them by 5 (VERDUIN, 1956). RAWSON (1950) proposes a coefficient of 4.3 when the Secchi-disc value is 1 m, and states that the coefficient decreases with increasing transparency. In view of the high Secchi-disc values in the subarctic waters studied, we can calculate the thickness of the euphotic zone to be ca 30—40 m in Kilpisjärvi and ca 20 m in Lakes Kevojärvi and Inarinjärvi.

The primary production in subarctic waters is, however, limited by the short vegetative period, the small amount of biogenic salts, and the low temperature even during the summer. During the winter the production of autotrophic organisms is inhibited by darkness. It has, however, been supposed that in winter some organic matter is produced in subarctic waters by μ-ulgae which can use energy liberated from organic substances (RODHE, 1955). The amount of these algae can be very great (1—10 millions of cells/1) and large quantities of organic matter can be produced heterotrophically.

Some remarks concerning the thermal economy of the subarctic waters have been made above. Besides the general climatic and geographical factors, the morphometry of the lakes is important in this respect. Lakes with a large volume of water react more slowly to varying temperatures than small water-bodies. In small tarns remarkable variations in temperature can be seen even during the course of one day.

The daily variation in the temperature of the surface water of Kevojärvi is seen in Fig. 12, which is made according to measurement by Miss E. Käck in 1962. The surface temparature of the lake was above 10°C from June 21 to August 27, the maximum value (14°C) occurring in the beginning of July. The surface temperatures of Kevojärvi and some surrounding waters in July 1963 are seen in Table 2. The highest values were observed in the silvatic tarns (15.7—17.2°C) and the lowest in some alpine tarns and brooks (10.2—11.0°C). No

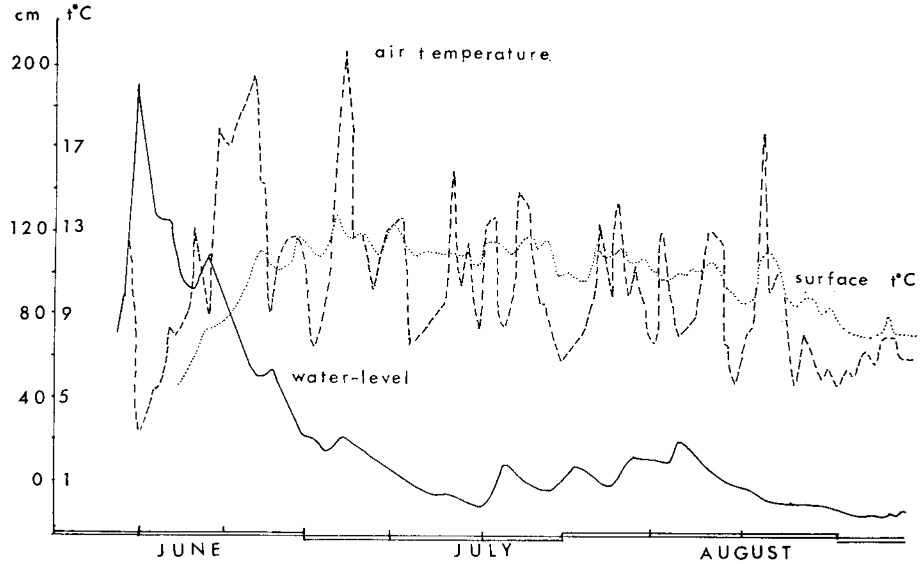


Fig. 12. The fluctuations of water-level, air temperature and the temperature of surface water in Kevojärvi in summer 1962.

thermic stratification was observed when these small waters were studied, though a clear thermocline was noted in summer in the lakes. In 1952 thermical stratification began on June 20 in Kilpisjärvi, but could not longer be observed on August 26 (Järnefelt, 1956).

The bathygraphic distribution of temperature in the two lakes is seen in Figs. 13—15.

On the whole we can assume temperature to be one of the most important ecological factors in subarctic waters because its influence affects the whole ecosystem. Temperature is also an important autecological factor in the waters studied, especially in small tarns and in the littoral zone of the lakes where the maximum fluctuations are observed. Temperature conditions in the profundal of subarctic lakes do not deviate much of those found in the lakes of S. Finland. In winter the temperature of the water near the bottom of Kilpisjärvi does not exceed 3°C (Fig. 15).

The fact that the biomasses of the subarctic lakes of this study do not deviate much from those found in the lakes of S. Finland is due to the great number of cold stenothermal species which are well adapted to living in subarctic lakes. Among such species in Kilpisjärvi are *Otomesostoma auditivum* and several other flatworms (Luther, 1960—62), *Heterotrissocladius* spp., *Monodiamesa* spp., *Stylodrilus heringianus, Pisidium conventus* and *Neobrachypoda ekmani.* In the littoral zone of the lakes cold stenothermal species such as *Baëtis macani,*

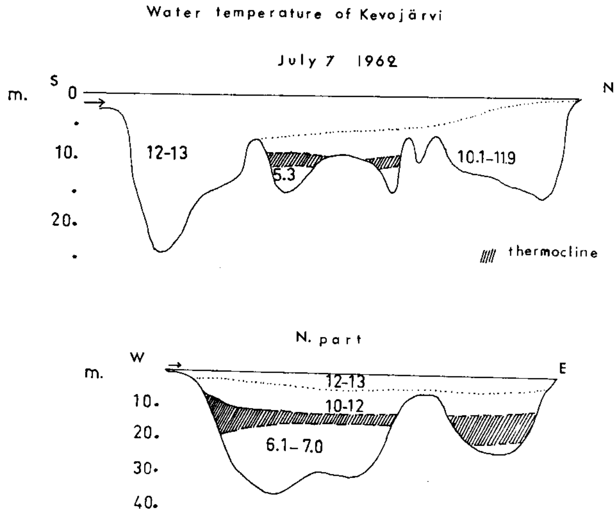


Fig. 13. Water temperature in Kevojärvi.

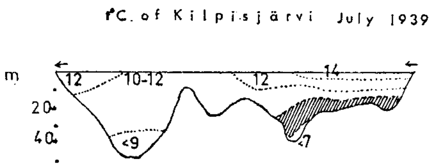


Fig. 14. The thermic stratification of Kilpisjärvi in July, 1939 (according to LAGERCRANTZ 1953).

Nemoura sahlbergi, Diura bicaudata, Arcynopteryx compacta, Pisidium conventus, Salvelinus alpinus etc. are frequently found.

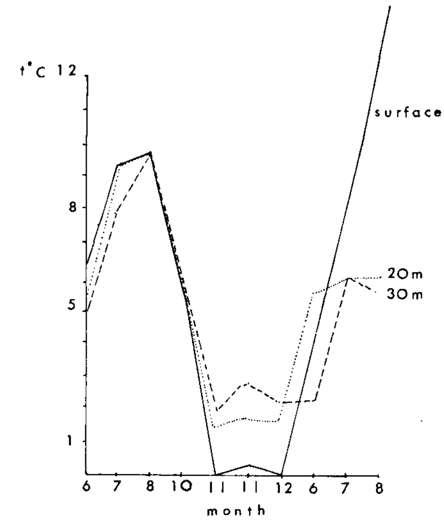
There are few cold stenothermal species in the profundal of Kevojärvi, but they are frequentely observed in the littoral zone of the lake. The most common of them are *Sergentia coracina, Stictochironomus rosenschöldi, Micropsectra groenlandica, Gammarus lacustris, Stylodrilus heringianus, Molannodes tincta, Molanna albicans* and some mayfly and stonefly species.

The percentage of cold stenothermal species is greater in the bottom fauna of Kilpisjärvi than that of Kevojärvi.

Among species only found in the waters of the silvatic region in Utsjoki are *Spongilla lacustris, Stylaria lacustris, Ephemera vulgata, Chironomus anthracinus* and *C. dorsalis, Helobdella stagnalis, Glossiphonia complanata* and *Perca fluviatilis.*

The species *Grammotaulius signatipennis, Baëtis macani* and *Polyartemia forcipata* seem to be restricted to alpine and subalpine waters in Utsjoki.

The influence of the cool climate with its brief warm period is seen in the reproduction and life cycles of many invertebrates in the subarctic waters. Many species such as the leeches *(Helobdella stagnalis* and *Glossiphonia complanata)* have only one generation per summer in subarctic waters, although they have



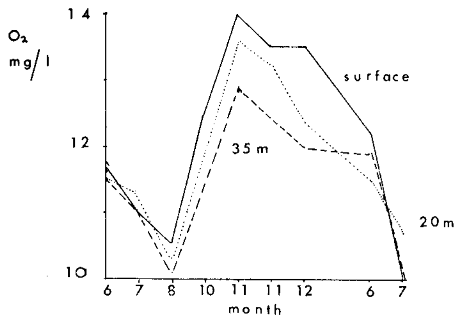


Fig. 15. (left) The seasonal fluctuations of water temperature at different depths in Kilpisjärvi (according to JÄRNEFELT, 1956).
Fig. 16. (above) The seasonal fluctuations of oxygen (mg/1) in Kilpisjärvi (according to JÄRNEFELT, 1956).

two or more generations in more southern waters (cf. BOISEN-BENNIKE, 1943). The flight period of many insects is very short in the subarctic area, and the importance of the nymph or larva stages in their life cycle is still more pronounced than in more southern waters. The growth of nymphs and larvae is often retarded in the subarctic waters. For example the growth of the nymphs of stoneflies is at its maximum here in the summer, while in more southern waters the speedest growth is observed in spring and autumn (BRINCK, 1952). Owing to their retarded growth and low fecundity, the species living at their northern limit in subarctic waters may easily disappear from the community especially during cool summers.

2. *pH and humus content*

The humus content of the waters studied is small compared with that of Finnish lakes in general (JÄRNEFELT, 1963). This is mainly due to small precipitation, slow production of organic matter and the absence of large bogs in the vicinity of the lakes, especially Kilpisjärvi. The $KMn0_4$ consumpion of the waters is usually below 20 mg/l (Table 2). Only in some tarns in Utsjoki were values over 40 mg/l observed after heavy rainfall in 1963. The influence of the humus colloids on the transparency of the water has been discussed earlier in this study.

The humus acids also influence the pH values. In small tarns the pH varied from 5.95 to 7.1 and in Kevojärvi from 6.3 to 7.1. The lowest value in the lake was measured at a depth of 35.5 m (Fig. 18). A slight increase was noted in the pH values of the surface water (from 6.7 to 7.1) during summer 1962.

The pH values of Kilpisjärvi ranged from 7.0 to 7.2 at every depth in 1952 and 1953 (JÄRNEFELT, 1956). The highest values were measured in July and August.

As it composes the great amount of allochthonous matter brought by rivers to Kevojärvi causes, a decrease in the oxygen tension in the water near the bottom of the lake, thus limiting the vertical distribution of the bottom fauna. Besides the accumulation of allochthonous matter, which is rapid in the *Myriophyllum* zone and in deep basins, a slight formation of iron-manganese nodules was observed in the lake. The chironomid fauna in particular may suffer from pathological features such as sidetotrophy and dystrophy, as has been observed in the lakes of Petsamo (JÄRNEFELT, 1934).

In the dystrophic lakes of East Carelia and the Kola Peninsula oligochaetes and pea-mussels dominate instead of the cold stenothermal midge larvae and relict crustaceans found in oligohumic lakes (ZHADIN & GERD, 1963).

In the profundal area of Kevojärvi only few cold stenothermal steno-oxybiontic species were found.

In Kilpisjärvi as in most of the shallow waters studied in Utsjoki, no limitation of the fauna by humus matter and other allochthonous matter was observed. In the most dystrophic waters in Utsjoki the groups *Orthocladiinae, Ephemeroptera* (except the *Leptophelebia* species), *Plecoptera* (except *Nemoura cinerea*) and large crustaceans were not found. The fauna consists of other chironomids and nymphs of *Odonata,* water beetles (especially of the *Ilybius* and *Hydroporus* species) and cladocerans (*Chydorus sphaericus* and *Scapholeberis mucronata*).

3. *Oxygen*

As is mentioned above, the decomposition of humus and other allochthonous matter in the mud-water interface of Kevojärvi, with rather high BOD, is an important ecological factor for the bottom-living animals of the lake (cf. BRUNDIN, 1951). Owing to low temperature and small organic content most of the waters of the subarctic area show no severe depletion of oxygen. The amount of oxygen available at three different depths in Kilpisjärvi during one year is seen in Fig. 16. According to JÄRNEFELT (1956) the amount of 0_2 at a depth of 35 m was 12.9 mg/l on November 11 1952 and 12 mg/l on May 13 1953. The consumption of 0_2 during 7 months was thus about 1 mg/l if no change of water had occurred. During the same time the temperature fell from 2.9 to 2.2°C. The BOD at that depth would thus be about 8 % of the amount of 0_2 available in November 1952.

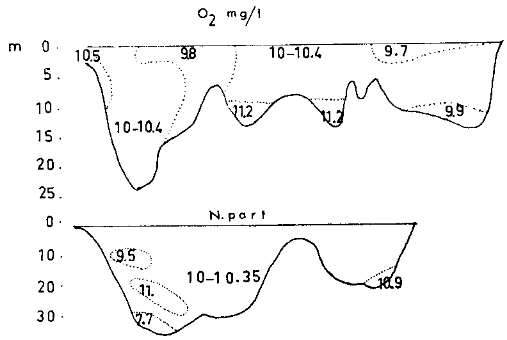


Fig. 17. Oxygen (mg/l) in Kevojärvi on July 4, 1962.

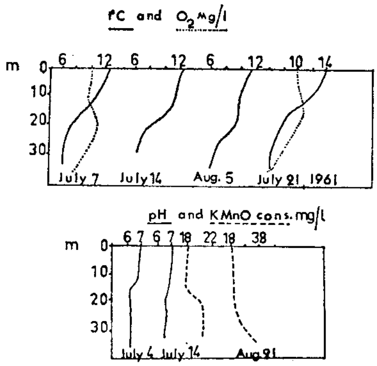


Fig. 18. Some hydrographic values of water at the deepest locality of Kevojärvi in July 1962 and 1963.

The vertical distribution of O_2 in Kevojärvi in July and August 1962 is seen in Fig. 17. No winter measurements are available from this lake but the BOD of the water near the bottom is probably conciderably higher than in Kilpisjärvi. A measurement in July 1963 at a depth of 35 m showed the saturation of oxygen to be only 52.5 % in the deepest basin of the lake.

4. *Currents*

In all the lotic habitats studied the speed of the current did not exceed 0.5 m/sec. However, the values measured in July only show the situation at that time; during the spring floods the speed increases greatly and the erosive effect is stronger.

According to the existence of current, the habitats and their fauna can be divided into two main groups: lotic and lenitic ones. One further group can be distinguished among the fauna: indifferent species (which occur in both types of habitat). Some of the latter species in Utsjoki are *Siphlonurus lacustris, S. aestivalis, Ameletus alpinus, Nemoura cinerea, Isoperla obscura, Molannodes tincta, Polycentropus flavomaculatus, Haliplus fulvus, Rhantus suturellus, Pisidium lilljeborgi, P. subtruncatum* and most fish species found in the area such as *Phoxinus aphya* and *Thymallus vulgaris.*

Completely lotic (rheophilous) species in Utsjoki are *Heptagenia dalecarlica, Nemoura flexuosa, Diura dicaudata, Rhyacophila nubila, Plectrocnemia conspersa* and several other caddis-flies, while among such species in the Kilpisjärvi region are *Ephydatia fluviatilis, Rhyacophila nubila, Arthroplea congener* and *Metretopus borealis.* Most of the species mentioned above belong to the *lithorheophilic* animal community, in which the larvae of *Simulium* dominate in both areas. In gently running waters with rich vegetation a phytorheophilic community is maintained (cf. ZHADIN & GERD, 1963). The species dominating in the latter community in Utsjoki are *Lumbriculus variegatus, Lymnaea peregra, Valvata piscinalis, Siphlonurus aestivalis* and *Leptophlebia* species.

The limit between lotic and lenitic habitats is not clearly defined because many so-called rheophilous species live in the littoral zone of the lakes.

5. *SBV and calcium*

Determinations of the alcalinity were made according to WELCH (1948) by titrating the samples of 100 ml with n/50 H_2SO_4 solution. The method gave positive results only when methyl-orange was used as an indicator solution, which shows that the carbonates in the waters existed as HCO_3- ions.

Determinations made with the waters of Utsjoki in July 1963 showed that the SBV values range from 0.04 to 0.14 and the CaO values from 1.12 to 3.92 mg/1 (Table 2). In Kilpisjärvi CaO values of 2.92—3.5 mg/l were measured in the surface water (0—5 m) and 3.0—3.4 mg/l at a depth of 35—40 m (JÄRNEFELT,, 1956).

The low CaO values show that the waters studied belong to «soft water group« where the Ca content is below 7 mg/l (MANN, 1955). The small amount of calcium in these waters is a common feature of Finnish waters (excluding brackish water) and is a factor limiting the distribution of many crustaceans and molluscs (MACAN, 1963 pp. 246—253). A large volume of water can, however, compensate for the scarcity of calcium in the case of many gastropods (MACAN, 1963). The ranges of calcium mentioned by MANN, MACAN, and HUBENDICK (1947) as necessary for many invertebrates in England and Scania (Sweden), do not correspond to those prevailing in waters with Finnish populations of the same species and are usually higher.

It should be stated here that the Ca content of the sediments and food may be of greater importance for the bottom-living animals than that of the water.

The absence of *Dendrocoelum lacteum* and *Asellus aquaticus* from the waters studied may partly be due to soft water (cf. MACAN). The former species is known from the waters of Petsamo (JÄRNEFELT, 1934) and is fairly common in the littoral zones of the lakes of S. Finland (LUTHER, 1961). *Asellus aquaticus* is only found in England in waters where the Ca content is above 5 mg/l (REYNOLDSON, 1961 in MACAN) but in Finland it lives both in dystrophic waters and in the Baltic Sea. The absence of the species from the subarctic waters may also be due to its migration history or to low temperature; though the adults can tolerate widely varying temperatures the eggs fail to hatch in waters where the summer temperature falls below 10—12°C (BIRSTEIN, 1961).

The «calciphilous« species *Heptagenia fuscogrisea* (cf. MACAN, 1963) was only found in Kilpisjärvi, where the sediments may locally have a high Ca content (cf. JÄRNEFELT, 1956).

On the other hand species such as *Lymnaea stagnalis* and *Helobdella stagnalis* which live only in hard waters in England (MACAN), have been found in soft waters in Utsjoki. For the Ca requirements of aquatic gastropods see p. 60.

6. *Animal communities in different habitats*

As mentioned above the number of species in most aquatic animal groups is lower in smaller bodies of water than in lakes. In the littoral zone of Kevojärvi ca 80 species were found. In the silvatic tarns the number of the species collected totals 38 and in the alpine tarns 41 (the groups *Nematoda* and *Orthocladiinae* were disregarded). The ratio of the species in the lake to those in the tarns is 2 : 1. In the following table the differences in the numbers of species in some animal groups are seen:

	Kevojärvi	Silvatic tarns	Alpine tarns
Oligochaeta	5	1	2
Hirudinea	2	1	0
Ephemeroptera	5	3	3
Plecoptera	1	0	1
Coleoptera	3	11	14
Pisces	7	1	1

The numbers of beetles in small tarns are noticeably high compared with the figure for the lake. A similar situation is reported by BRINCK & WINGSTRAND (1949) in the Virihaure area, N. Sweden. Compared with the figures for the Virihaure area and Kilpisjärvi the number of Plecoptera species is small in the lenitic waters of Utsjoki. The fact that the numbers of species shown by the tarns are lower than the figures for the lake may be due to the correspondingly lower number of suitable ecological niches to be found in these somewhat unfavourable habitats (cf. THIENEMANN, 1920 p. 10). Small bodies of water are readily affected by environmental changes and their pH, temperature and water volume varies even during the course of one day.

In the lakes environmental conditions are more stable and are optimal for the majority of species.

Owing to the hardness of the substratum the soft bottom fauna is weakly represented in the small tarns. Since fish are usually lacking, carnivore beetles and their larvae constitute the top level of the food chains in these tarns. The algal ooze often found on their bottoms provides rich nourishment for detritus and algal feeders such as *Gammarus lacustris* and the larvae of caddis-flies. However, most of the tarns in this study had mineral bottoms and the lack of food in them may be a limiting factor for the fauna.

PEJLER (1957) mentions that the number of *Rotatoria* specimens is lower in small bodies of water than in lakes. Critical habitats for the group in the Abisko area in N. Sweden are, according to him, small ground tarns, mountain tarns lying on acid Precambrian bedrock and rapid brooks.

In Table 17, a comparison of the fauna of different habitats in Utsjoki was made by calculating the number of species common to two habitats as a precentage of the total number of species found in the two habitats. The heterogeneity found in the affinity values is mainly due to the decrease in the number of species with increasing altitude and to variations in the intensity of the investigations. The affinity values between the fauna of Kilpisjärvi and adjacent waters may be somewhat missleading, on account of the small number of samples taken from the latter waters.

Table 17. Similarity between the species composition of the littoral fauna of waters studied (percentage of affinity = (n—a)/n).

	Ki	Ks	Ksa	Kisa	Ka	Kni	Ksu	Ki	Kp
Ke	38.5	23.0	8.7	19.8	17.3	22.2	24.1	16.8	8.0
Ki		15.3	4.9	27.7	16.5	15.8	23.9	15.9	14.5
Ks			20.0	16.4	*38.8*	8.0	16.4	11.1	7.3
Ksa				14.3	20.4	7.3	13.3	3.7	9.7
Kisa					16.2	25.5	10.0	27.6	23.8
Ka						13.8	20.7	14.7	21.7
Kni							*40.5*	*42.2*	23.5
Ksu								26.0	21.0
Kj									22.7

Compared with the fauna of the waters of the Virihaure area (BRINCK & WINGSTRAND, 1949) the fauna of different aquatic habitats in Utsjoki show a considerable heterogeneity. The highest affinity values are seen here between the fauna of streams and river pools, on the one hand, and between the fauna of streams and rivers, on the other; i.e. in waters where the current is a dominant ecological factor. The faunal similarity between the littoral zones of the two lakes is greater than that between the lakes and other bodies of water.

A great similarity in the composition of the ephemeropteran and plecopteran fauna is seen between the littoral of Kilpisjärvi and adjacent waters, and between alpine tarns and brooks in Utsjoki (Table 18).

Table 18. Similarity of the ephemeropteran and plecopteran fauna of the waters studied (affinity % = (n—a)/n).

	Ki	Ks	Kisa	Ka	Kni	Ksu	Ki	Kp
Ke	22.2	25.0	9.0	9.1	20.0	14.3	17.6	9.1
Ki		5.9	*61.8*	17.6	17.6	6.6	21.7	25.0
Ks			5.5	0	14.3	33.3	13.0	0
Kisa				21.4	13.3	8.3	31.6	30.8
Ka					11.1	0	12.5	42.8
Kni						20.0	20.0	0
Ksu							7.7	0
Kj								12.5

n = total number of species living in the two habitats
a = number of species not common to both habitats
Ke = L. Kevojärvi, Ki = L. Kilpisjärvi, Ks = silvatic tarns, Ksa = subalpine tarns in the Kevo area, Kisa = subalpine tarns in the Kilpisjärvi area, Ka = alpine tarns (in the Kevo area), Kni = streams, Ksu = river pools, Kj = rivers, Kp = alpine brooks

Table 19. Affinity coefficients (%) between the fauna of different depth zones in L. Kevojärvi (calculated according to the quantity of species).

Zone (m)	1—2	2—3	3—4	4—5	5—10	10—20	20—35
0—1	41.5	49.0	40.0	49.2	33.3	26.6	14.6
1—2		36.2	36.4	*58.8*	27.0	40.9	25.5
2—3			46.4	50.5	18.6	44.3	26.2
3—4				41.7	15.3	22.0	37.1
4—5					35.5	44.9	31.0
5—10						19.0	14.3
10—20							14.3

The affinity values in Table 19 were calculated according to the formula of Renkonen (1938). The great heterogeneity between the fauna of different depth zones in Kevojärvi is mainly due to a decrease in the number of species with increasing depth. The deepest areas (20—35 m) have a fauna poor in species and show a small affinity to other depth zones apart from 3—4 m zone (37.1 %). The affinity to the latter zone may be due to similar bottom conditions; both have black ooze and detritus bottoms.

VII. THE MIGRATION HISTORY OF THE AQUATIC FAUNA.

In the previous chapters the distribution and abundance of the fauna of the subarctic waters studied were compared with those of the aquatic fauna in N. Sweden (Grimås, 1961 and Brundin, 1956) and with the Petsamo area (Järnefelt, 1934). Moreover comparisons were made with the fauna of other subarctic waters and of some oligotrophic lakes situated in S. Finland. The great similarity between the species composition of the bottom fauna of Kilpisjärvi and the mountain lakes of Scandinavia was discussed.

The fauna of Kevojärvi has a greater resemblance to the fauna of oligotrophic lakes of S. Fennoscandia, the Soviet Union and Poland (cf. VALLE, 1927, ZHADIN & GERD, 1963 and RZOSKA, 1937) than to the fauna of Kilpisjärvi. The difference of the fauna of the two lakes may, however, be due more to ecological than to historical factors.

The history of the spread of fresh water fauna to the subarctic area of Finnish Lapland is almost unknown. A great part of this area lay outside the region which was flooded after the Ice Age (SAURAMO, 1939), except the basin of Lake Inarinjärvi.

It is possible that the major part of the aquatic fauna spread to Utsjoki via this basin from the east or northeast.

In southern Lapland the remains of many molluscs have been found in the calcareous deposits of the pre-Boreal an Boreal period (SALMI, 1963 and VASARI et al., 1963). The Boreal period may have been favourable for the dispersal of many calciphilous species since the alcalinity of the waters was higher then than nowadays (VASARI et al., 1963). The process leading to dystrophic conditions was accelerated during the Atlantic period.

Owing to the fact that the region of Finnish Fjeld Lapland was not flooded during any postglacial stage by the Baltic, glacial relicts are lacking in this area. They have not been found in the Petsamo area either (JÄRNEFELT, 1934). The northernmost limit of relict crustaceans in eastern Fennoscandia follows the 68 th parallell of latitude (SEGERSTRÅLE, 1957). In the lakes of the Kola Peninsula some relicts such as *Pallasea quadrispinosa, Mysis relicta, Pontoporeia affinis* and *Coregonus albula* have been recorded (SEGERSTRÅLE, 1957, ZHADIN & GERD, 1963).

Some species such as *Gammarus lacustris* and some arctic insects may have spread to Finnish Lapland from Norway, where they survived the Ice Age in various refuges (cf SEGERSTRÅLE, 1956, BAGGE, 1964). The finds of *Arianta arbustorum* in the Kilpisjärvi region provide proof of a recent migration of animals from Norway to Finnish Lapland.

The River Tana and its tributaries, although flowing into the Arctic Ocean, may also have had some importance as a migration route for some aquatic animals in Utsjoki. This natural highway is nowadays used by anadromous fishes such as *Salmo salar* and *Anquilla vulgaris.* Water fowl and gulls such as *Larus canus, Larus ridibundus* and sometimes *Larus marinus* have also been observed to follow this route to the interior.

It is possible that the species *Gammarus lacustris* and *Gasterosteus aculeatus* (which is of the *leiurus* type in Kevojärvi VARIS, 1964 pers. comm.) have spread by this route too.

The rivers Tornionjoki and Muonionjoki flowing into the oligohaline Bothnian Bay may have played an important rôle for aquatic animals as a migration route to Kilpisjärvi. On the other hand the affinity between the fauna of this lake and that of the lakes in the Scandinavian mountain area points clearly to migration from that direction.

VIII. THE LIMNOLOGICAL LAKE TYPE CONCEPT AND ITS APPLICATION TO THE WATERS STUDIED

One of the two lakes studied, Kilpisjärvi, belongs to the ultraoligotrophic lake type (cf. BRUNDIN, 1958 and ZHADIN and GERD, 1963). The greatest depth of the lake is 50 m, which does not quite fit ZHADIN and GERD's definition of ultraoligotrophic lakes (they postulate a depth of over 100 m), but many other features of the lake such as great average depth, clear and cold water, a high oxygen tension even in the water near the bottom and weakly developed higher vegetation accord well with the concept of ultraoligotrophy.

The importance of the depth factor for ultraoligotrophy seems to decrease in the subarctic area, where primary production is limited by the short growing period, low summer temperatures, the small amount of biogenic salts and the slow decomposition of organic matter.

The plankton of the lake is poor in species (JÄRNEFELT, 1956) and the productivity is rather small compared with many of the more southern lakes. Dominant species in the phytoplankton are the μ *algae, Ankistrodesmus falcatus, Melosira distans* and *Cyclotella* species (JÄRNEFELT, 1956). The last-mentioned were also dominant in the plankton of Lake Kevojärvi together with *Tabellaria* species in July 1963.

According to the quality of the bottom sediments, the lake belongs to the group of Scandinavian mountain lakes. Although the lake is situated in an area rich in calcium, the Ca content of the water is small, varying from 2.9 to 3.5 mg/l at depths of 0—5 m and from 3.0 to 3.4 mg/l in the profundal zone (JÄRNEFELT, 1956). The calcium brought by the waters flowing into the lake may soon sink to the bottom.

The high oxygen tension and low temperature throughout the year (Figs 16 and 17) are favourable ecological factors for the existence of cold stenothermal steno-oxybiontic species in the lake. According to the animal community inhabiting the profundal zone of the lake, it can be included among the Heterotrissocladius subpilosus lakes which are described by BRUNDIN (1958) as characteristic of the arctic area of Europe. According to him, some of the species typical of such lakes are *Protanypus caudatus* Edw., *Monodia-*

mesa ekmani Brund., and *Heterotrissocladius subpilosus* (Kieff.). In view of their great abundance in Kilpisjärvi the species *Pisidium conventus* Cless., *Neobrachypoda ekmani* Walt., and *Otomesostoma auditivum* (Plessis) also appear to be indicator species for this lake type.

The number of species is small in the profundal zone of the lake, but the densities are great (Table 6) compared with those with many other Finnish lakes. In the littoral the number of species is greater and the fauna consists of both eurybathic cold stenothermal species and eurytopic species such as *Lumbriculus variegatus* Müll., *Pisidium lilljeborgi* Cless etc. Although the densities of the bottom fauna are great, the standing crop is smaller here than in the littoral of Kevojärvi on account of the small amounts of molluscs and large insect larvae (Table 3). According to the dominant species, the littoral zone of Kilpisjärvi can be considered as representing the Tanytarsus lugens community (cf. BRUNDIN 1958).

The average densities and biomass values of the bottom fauna of Kilpisjärvi show a remarkable decrease at depths below 15—20 m, where the quality of sediments changes (Fig. 6). In this zone the boundary between the animal communities mentioned above can also be observed.

The fauna of the stony bottoms of the lake is poor in species and consists of larvae and nymphs of Trichoptera, Plecoptera, Coleoptera and Ephemeroptera. A great part of them have a high boreal or an arctic distribution area, and among the stoneflies several «Gletscherrand« species (ILLIES, 1955) can be seen. The high number of these species in the lake is due to the cold oxygen-rich water of the littoral zone and is thus a result of the combined influence of the high altitude and large area of the lake.

Kevojärvi is oligotrophic but has some mesotrophic features such as a well-developed zone of aquatic vegetation. Considering the broad *Myriophyllum* zone in the lake, we can assume the primary production to be very high in the littoral. The littoral fauna is also rich consisting of both eurybathic cold stenothermal and eurytopic littoral species. The standing crop of the littoral fauna is somewhat higher than in the littoral zone of Kilpisjärvi. The number of arctic and high boreal stoneflies and mayflies is, however, small here owing to a weakly developed surf zone.

Other features which distinguish the lake from Kilpisjärvi are its small average depth and low transparency, an oxygen deficiency in the deepest basin, and a great amount of detritus and other allochthonous matter, especially in sediments at a depth of 2.5 m and below 10 m. The depletion of oxygen during the decomposition of the allochtonous matter and a slight siderotrophy are pathogenic factors limiting the bottom fauna of the lake. Owing to them the densities of the bottom-living organisms are low below a depth of 10 m. However, no great difference is seen between the biomasses of the profundal zones of the two lakes (Table 4).

The dominant species in the profundal zone of Kevojärvi are *Sergentia coracina* Zett. and *Tubifex* species. In the littoral and upper profundal zones the species *Stictochironomus rosenschöldi* Zett., *Chironomus anthracinus* Zett., and *Pisidium* species are common. According to the dominance of these species and to the bathygraphic distribution of the whole bottom fauna, Kevojärvi can be considered as one of the T a n y t a r s u s l u g e n s lakes (cf. BRUNDIN, 1958).

In the small bodies of water the soft bottom fauna is weakly presented. The ecological conditions obtaining in these waters are often very unusual and the number of ecological niches is small. Their fauna shows only a small affinity to the littoral fauna of the two lakes (Table 17).

Owing to the boggy environment a slight dystrophy is found in many small tarns in Utsjoki. The dystrophy seems to be a remarkable ecological factor causing similarity between the faunae of tarns at different altitudes. The dominant species in all dystrophic habitats in the area are water beetles and their larvae, nymphs of dragon-flies and some cladoceran species. The cold stenothermal species, however, are more numerous in the alpine tarns than in the silvatic area, which may be due to the temperature factor (Table 2).

IX. SUMMARY

In this paper the ecology, abundance and distribution of the aquatic macrofauna in the subarctic waters of Finnish Fjeld Lapland have been discussed. The material was collected during the summers 1962, 1963 and 1964 in two lakes, eleven tarns, and several habitats in rivers, streams and brooks, especially those in the Utsjoki region. Hydrographically the waters studied are rather uniform. Except for Kevojärvi and some alpine tarns (after heavy rainfall) all of them have a clear, cold water with a high oxygen tension near the bottom throughout the year. A slight oxygen deficiency owing to the decomposition of the allochthonous matter and a slight siderotrophy are pathogenic features limiting the bathygraphic distribution of the bottom-living animals in Kevojärvi.

In the quantity and distribution of the species there is a clear difference between the faunae of the two lakes. According to the animal community inhabiting the produndal zone of the lakes, Kevojärvi can be included among the *Tanytarsus lugens* lakes and Kilpisjärvi among the *Heterotrissocladius subpilosus* lakes. The standing crop of the former lake had an average value of 3.32 g/m^2, being only 1.25 g/m^2 in Kilpisjärvi. The average densities, however, were much higher in the latter lake owing to the high numbers of *Orthocladiinae* present at every depth zone. The predominant animal groups in both lakes were midge larvae which constituted 55.3 % of the whole bottom fauna in Kilpis-

järvi and 28.7 % in Kevojärvi, oligochaetes 27 % in Kilpisjärvi and 44 % in Kevojärvi, and pea-mussels 3.6 % in Kilpisjärvi and 13.3 % in Kevojärvi. Compared with the fauna of the waters in the Virihaure area (N. Sweden; BRINCK & WINGSTRAND, 1949) the fauna of different aquatic habitats studied show a considerable heterogeneity. The highest affinity values are between the fauna of streams and river pools, on the one hand, and between the fauna of rivers and streams, on the other; i.e. in waters where the current is a dominant ecological factor. The faunal similarity between the littoral zones of the two lakes is greater than that between the lakes and other bodies of water. The dystrophy was found to be a remarkable ecological factor causing similarity between the faunae of tarns at different latitudes.

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REFERENCES

ALSTERBERG, G., 1930: Wichtige Züge in der Biologie der Süsswassergastropoden. 130 pp. Lund.

ANDER, K., 1951: Odonata, (in BRINCK and WINGSTRAND, 1951) — Lund Univ. Årsskr. N.F. 2:46, 123—126.

ANDERSEN-SÖGAARD, F., 1937: Über die Metamorphose der Ceratopogoniden und Chironomiden Nordost-Grönlands. — Medd. om Grönl. 116:1, 1—95.

BAGGE, P., 1964: A freshwater Amphipod Gammarus lacustris Sars. in Utsjoki, Finnish Lapland. — Ann. Univ. Turku. A, II:32 (Rep. Kevo Subarct. Sta. 1), 292—294.

„ 1965: Observations on some mayfly and stonefly nymphs (Ephemeroptera and Plecoptera) in Utsjoki, Finnish Lapland. — Ann. Ent. Fenn. 31:2, 102—108.

„ & JUMPPANEN, K., 1968: Hydrography and bottom fauna of Lake Keitele (Central Finland) in relation to eutrophication. — Ann. Zool. Fenn. (in press).

BIRSTEIN, J. A., 1951: Fresh water Isopods (Asellota). — Fauna of USSR. Crustacea 7:5, 148 pp. Moscow.

BOISEN-BENNIKE, S. A., 1943: Contributions to the ecology and biology of the Danish fresh-water leeches (Hirudinea). — Folia Limnol. Scand. 2, 1—109.

BORG, F., 1941: Über die Süsswasserbryozoen Schwedens. — Zool. Bidr. från Uppsala. B. 20. (Festskrift), 479—494.

BREKKE, R., 1938: The Norwegian Mayflies. — Norsk Ent. Tidskr. 5, 55—73.

„ 1965: Bidrag till kunnskapen om Norges døgn-, sten- og vårfluer (Ephemeroptera, Plecoptera, Trichoptera). Ibid. 13:1, 11—15.

Brinck, P. & Wingstrand, K. G., 1949: The mountain fauna of the Virihaure area in Swedish Lapland I. General account. — Lund Univ. Årsskr. N.F. 2:2, 69 pp.

„ 1951: Ibid. II. Special account. — Ibid. 2:46, 173 pp.

Brinck, P., 1952: Bäcksländor, Plecoptera. — Svensk Insektfauna 15, 126 pp. Stockholm.

Brinkhurst, R. O., 1963: A guide for the identification of British aquatic Oligochaeta. — Sci. Publ. of the Freshw. biol. Assoc. 22, 52 pp.

Brundin, L., 1949: Chironomiden und andere Bodentiere der Südschwedischen Urgebirgsseen. — Rep. Inst. Freshw. Res. Drottningholm 30, 914 pp.

„ 1951: The relation of O_2-microstratification at the mud surface to the ecology of the profundal bottom fauna. — Ibid. 32, 33—42.

„ 1956: Die bodenfaunistischen Seetypen und ihre Anwendbarkeit auf die Südhalbkugel. Zugleich eine Theorie der produktionsbiologische Bedeutung der glazialen Erosion. — Ibid. 37, 186—235.

„ 1958: The bottom faunistical lake type system and its application to the southern hemisphere. Moreover a theory of glacial erosion as a factor of productivity in lakes and oceans. — Verh. internat. Ver. Limnol. 13, 288—297.

Bryce, D., 1960: Studies on the larvae of the British Chironomidae (Diptera), with keys to the Chironominae and Tanypodinae. — Transact. Soc. Brit. Ent. 14:2, 19—62.

Ekman, S., 1915: Die Bodenfauna des Vättern, qualitativ und quantitativ untersucht. — Int. Rev. ges. Hydrobiol. Hydrogr. 7, 275—425.

1967: Die Gewässer des Abisko-Gebietes und ihre Bedingungen. — Kgl. Svenska Vetensk. Akad. handl. IV:6:6, 172 pp.

Grimås, U., 1961: The bottom fauna of natural and impounded lakes in northern Sweden (Ankarvattnet and Blåsjön). — Rep. Inst. Freshw. Res. Drottningholm 42, 183—237.

Hofsten, N. von., 1911: Neue Beobachtungen über die Rhabdocölen und Allöocölen der Schweiz. — Zool. Bidr. från Uppsala 1, 1—84.

Hubendick, B., 1947: Die Verbreitungsverhältnissen der limnischen Gastropoden in Südschweden. — Ibid. 24, 419—559.

Illies, J., 1955: Die Beteutung der Plecopteren für die Verbreitungsgeschichte der Süsswasserorganismen. — Verh. internat. Ver. Limnol. 12, 643—653.

Jonasson, P. M., 1955: The efficiency of sieving techniques for sampling fresh water bottom fauna. — Oikos 6:2, 183—207.

Järnefelt, H., 1921: Untersuchungen über Fische und ihre Nahrung im Tuusulasee. — Acta Soc. F. Fl. Fenn. 52.

„ 1934: Zur Limnologie einiger Gewässer Finnlands XI. Petsamo. — Ann. Soc. Zool. Bot. Fenn. 'Vanamo' 14:10, 172—347.

„ 1956: Zur Limnologie einiger Gewässer Finnlands. XVII. Ibid. 18:2, 1—61.

„ 1963: Zur Limnologie einiger Gewässer Finnlands. XX. Ibid. 25:1, 1—52.

Kaartotie, T. & Ryhänen, R., 1957: Kalavesitutkimus I. Fysikaalisia ja kemiallisia määrityksiä. — Suomen Kalastusyhd. Opaskirjasia 26, 99 pp.

Karppinen, E. & Nurminen, M., 1964: Records of Lumbricids (Oligochaeta) in Finland. — Ann. Zool. Fenn. 1, 44—47.

Kimmins, D. E., 1957: A new lenitic species of the genus Baëtis (Ephemeroptera) from North Finland. — Not. Ent. 37, 27—29.

Koli, L., 1955: Enontekiön Lapin kotilofaunasta. — Luonnon Tutkija 59: 4.

„ 1956: Beiträge zur Kenntnis der Euphyllopoden-fauna Finnlands. — Arch. Soc. 'Vanamo' 11:2, 108—111.

LAGERCRANTZ, M. A., 1953: An essay of the hydrography of the Lake Kilpisjärvi. — Fennia 76:2, 1—17.

LENZ, Fr. 1928: Ökologische Chironomidentypen. — Biol. Listy 14, 413—422.

LEVANDER, K. M., 1901: Beiträge zur Fauna and Algenflora der süssen Gewässer an der Murmanküste. — Acta Soc. F.Fl. Fenn. 20:8, 1—35.

LEVANTO, T., 1940: Über die Molluskenfauna des Sees Vesijärvi. — Ann. Zool. Soc. 'Vanamo' 8:3, 1—44.

LINDBERG, H., 1927: Zur Kenntnis der Subalpinen und alpinen Hemipterenfauna von Enontekis-Lappland. — Mem. Soc. F.Fl. Fenn. 1, 63—68.

„ 1931: Die Hemipterenfauna Petsamos. — Ibid. 7, 193—235.

„ 1933: Untersuchungen in N-Petsamo über die Käferfauna hochnordischer Biotopen. — Ibid. 9, 103—125.

LINDROTH, A., 1947: Vattenförorening och vattenfaunans andningsproblem. — Vattenhygien 3:2, 32—44.

LUNDBLAD, O., 1962: Die Hydracarinen Schwedens II. — Ark. för Zool. 14 (andra serien), 1—635.

LUNDQVIST, G., 1940: Zur Mikroskopie der Binnenseesedimente. — Verh. internat. Ver. Limnol. 9, 111—144.

LUTHER, A., 1960: Die Turbellarien Ostfennoskandiens I. (Acoela-Proseriata). — Soc. F.Fl. Fenn. Fauna Fennica 7.

„ 1961: Die Turbellarien Ostfennoskandiens II. Tricladida. — Ibid. 11.

„ 1963: Die Turbellarien Ostfennoskandiens III. Neorhabdocoela 1. — Ibid. 12.

MACAN, T. T., 1961: A key to the nymphs of the British species of Ephemeroptera. — Sci. Publ. of the Freshw. biol. Assoc. 20, 63 pp.

„ 1963: Freshwater Ecology. 338 pp. London.

MANN, K. H., 1955: Some factors influencing the distribution of freshwater leeches in Britain. — Verh. internat. Ver. Limnol. 12, 582—587.

MEINANDER, M., 1962: The Neuroptera and Mecoptera of eastern Fennoscandia. — Soc. F.Fl. Fenn. Fauna Fennica 13.

„ 1965: List of the Plecoptera of Eastern Fennoscandia. — Ibid. 19, 38 pp.

MONTEN, E., 1951: Nematomorpha (in BRINCK and WINGSTRAND, 1951) — Lund Univ. Årsskr. 2:46.

MÜLLER, K., 1954: Faunistisch-Ökologische Untersuchungen in nordschwedische Waldbächen. — Oikos 5, 77—93.

MÜLLER-LIEBENAU, I., 1965: Revision der von Simon Bengtsson aufgestellten Baëtis-arten (Ephemeroptera). — Opusc. Ent. 30:1—2, 79—124.

NIELSEN, A., 1950 b: The torrential invertebrate fauna. — Oikos 2:2, 176—196.

NILSSON, N-A., 1961: The effect of water-level fluctuations on the feeding habits of trout and char in the lakes Blåsjön and Jormsjön, North-Sweden. — Rep. Inst. Freshw. Res. Drottningholm 42, 238—261.

NYBOM, O., 1960: List of Finnish Trichoptera. — Soc. F.Fl. Fenn. Fauna Fennica 6.

ODHNER, N. H., 1951: Swedish high mountain Mollusca. (in BRINCK and WINGSTRAND, 1951) — Lund Univ. Årsskr. N.F. 2:46.

ODUM, E. P. and ODUM, H. T., 1959: Fundamentals of ecology. Philadelphia.

OLSTAD, O., 1925: Örretvand i Gudbrandsdalen. — Nytt Mag. f. Naturvid. 63, 1—201.

PEJLER, B., 1957: Taxonomical and ecological studies on planktonic Rotatoria from Northern Swedish Lapland. — Kgl. Svenska Vetensk. Akad. handl. IV:6:5, 52 pp.

PETÄJÄ, A., 1964: Depth charts of some lakes in Utsjoki, Finnish Lapland. — Ann. Univ. Turku A, II:32. (Rep. Kevo Subarctic Sta. 1), 346—349.

PIQUET, E., 1919: Wasserbewohnende Oligochaeten der nordschwedischen Hochgebirge. — Naturw. Unters. d. Sarekgebirges in Schwed. Lappland gel. von Dr. A. Hamberg. 4, 779—804.

RAWSON, D. S., 1950: The physical limnology of Great Slave Lake. — Jour. Fish. Res. Bd. Canada 8:1, 1—66.

RENKONEN, O., 1938: Statistisch-ökologische Untersuchungen über die terrestrische Käferwelt der Finnischen Bruchmoore. — Ann. Zool. Soc. 'Vanamo' 6, 1—231.

RODHE, W., 1955: Can plankton production proceed during winter darkness in subarctic lakes? — Verh. internat. Ver. Limnol. 12, 117—122.

RZOSKA, J., 1937: Über die Ökologie der Bodenfauna im Seenlitoral. — Arch. Hydrobiol. Ichtyol. 10, 76—122. (Rybactwa).

SALMI, M., 1963: On the subfossil Pediastrum algae and Molluscs in the Late-Quaternary sediments in Finnish Lapland. — Arch. Soc. 'Vanamo' 18:2, 105—120.

SAURAMO, M., 1939: The mode of the land upheveal in Fennoscandian during Late-Quaternary time. — Fennia 66:2, 1—26.

SEGERSTRÅLE, S. G., 1956: The freshwater Amphipods, Gammarus pulex (L.) and G. lacustris G. O. Sars, in Denmark and Fennoscandia — a contribution to the late and post-glacial immigration history of the aquatic fauna of Northern Europe. — Commentat. Biol. Soc. Scient. Fenn. 15, 1—91.

„ 1957: On the immigration of the glacial relicts of Northern Europe, with remarks to their prehistory — Ibid. 16, 117 pp.

SPERBER, C., 1948: A taxonomical study of the Naididae. — Zool. Bidr. från Uppsala 28, 296 pp.

SVÄRDSON, G. & NILSSON, N.-A., 1964: Fiskebiologi. 253 pp. Halmstad.

TIENSUU, L., 1939: A survey of the distribution of mayflies (Ephemerida) in Finland. — Ann. Ent. Fenn. 5, 97—124.

THIENEMANN, A., 1920: Die Grundlagen der Biocoenotik und Monards faunistische Prinzipien. — Festschr. f. Zschokke, 4, 1—14.

„ 1954: Chironomus. Leben. Verbreitung und wirtschaftliche Beteutung der Chironomiden. — Die Binnengewässer 20, 834 pp.

THOMASSON, K., 1956: Reflections on arctic and alpine lakes. — Oikos 7:1, 117—143.

UDE, H., 1929: Oligochaeta. Die Tierwelt Deutschlands 15.

UUSI-HONKO, M., 1960: Piirteitä Utsjoen vesiperhosista. — Manuscript in the archives of the Department of Zoology, University of Turku.

VALLE, K. J., 1927: Ökologisch-Limnologische Untersuchungen über die Boden- und Tiefenfauna in einiger Seen nördlich vom Ladoga-See I. — Acta Zool. Fenn. 2, 1—179.

„ 1952: Die Verbreitungsgruppen der Ostfennoskandischen Odonaten. — Ann. Ent. Fenn. 10, 55—56.

VALOVIRTA, E. J., 1959: Quantitative Untersuchungen über die Bodenfauna des Sees Päijänne, Mittel Finnland. — Ann. Zool. Soc. 'Vanamo'. 20:2, 1—50.

VASARI, Y., VASARI, A. and KOLI, L., 1963: Purkuputaanlampi- a calcareous mud series from Kuusamo, North East Finland. — Arch. Soc. 'Vanamo' 18:2, 96—104.

VERDUIN, J., 1956: Primary production in lakes. — Limnol. Oceanogr. 1, 85—91.

WELCH, P. S., 1948: Limnological methods. — 381 pp. Philadelphia.

ZHADIN, V. I. & GERD, S. V., 1963: Fauna and Flora of the rivers, lakes and reservoirs of the U.S.S.R. — 626 pp. (Moscow 1961) Jerusalem 1963.