From the author

Ann. Zool. Fennici 9: 141 – 146. 1972

The bottom macrofauna of the oligotrophic Lake Konnevesi, Finland

JUKKA SÄRKKÄ [1]

SÄRKKÄ, J. 1972: The bottom macrofauna of the oligotrophic Lake Konnevesi, Finland. – Ann. Zool. Fennici 9: 141 – 146.

The abundance of the bottom fauna of this lake is lowest around the thermocline and in the greatest depths (> 35 m). The dominant species of the profundal zone is *Pisidium conventus*, and larvae of Chironomids dominate in the sublittoral. The abundances of the dominant species, the total numbers of individuals and the biomasses were practically the same in the different parts of the lake. The glacial relicts *Gammaracanthus lacustris*, *Pallasea quadrispinosa*, *Pontoporeia affinis*, and *Mysis relicta* are new records for lake Konnevesi. Diversity indices were calculated to compare the different sub-areas. The values of these indices and the factors affecting them are discussed. It is suggested that the low abundances observed for the greatest depths are chiefly due to the low oxygen content in winter. It is difficult to classify this lake on the basis of its bottom fauna into any one of the conventional limnological lake types.

1. Introduction

The oligotrophic Lake Konnevesi, one of the great lakes of the Kymijoki watercourse, is still in a relatively natural state, because its water is not noticeably polluted and because the water level is not regulated. Collecting of data on changes has been started in many Finnish lakes which seem to have changed essentially, e.g. at the large Lake Päijänne. Lake Konnevesi is a good example of the original state, and a study of its fauna provides interesting data for comparison.

2. Hydrography and bottom

The area of Konnevesi is 201 km^2, the drainage basin at the outflow 5780 km^2, the mean depth 9.2 m, and the volume 1850 million m^3 (Vesi-Hydro 1967). The water level is 95 m above sea level. According to observations by the Water Board of Central Finland, the oxygen curve is orthograde during the summer and the oxygen saturation is over 77 % even at the deepest point (49 m). In winter the oxygen content diminishes below 40 m and in March the saturation percentage falls to 27 % (mean value for 1965 – 1971, see Fig. 2). The colour of the water is 24 – 34 mg Pt/l, pH 6.4 – 6.9, conductivity ($\varkappa_{18}$) 35 – 39 μ S, and the Secchi disc transparency 4.0 – 8.1 m (mean 5.4 m). In the hypolimnion the bottom is usually somewhat softer than, for instance, in the neighbouring Lake Päijänne; in Konnevesi the Ekman sampler often sinks 10 – 12 cm, in Päijänne usually only 6 – 10 cm (SÄRKKÄ & PAASIVIRTA 1972). The profundal sediment is brownish grey

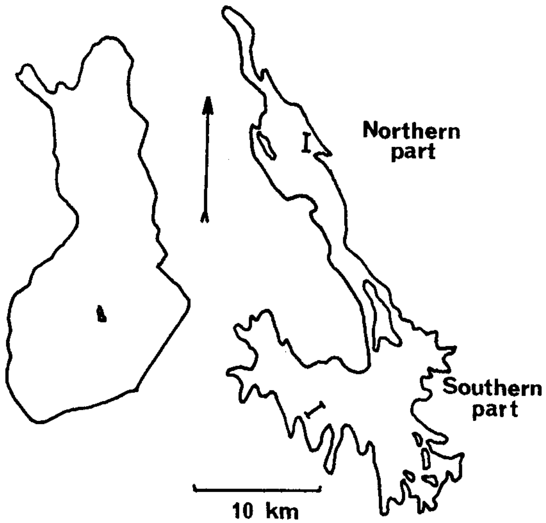

Fig. 1. Lake Konnevesi and the sampling lines.

[1] Department of Biology, University of Jyväskylä, Vapaudenkatu 4, 40100 Jyväskylä, Finland.

gyttja, the brown colour being strongest right at the surface. In the sublittoral lake ore is abundant in places, even in the profundal at about 20 m depth. The lake is well stocked with benthic macrophytes to the depth of at least 3 m.

3. Sampling technique

On five trips between 25 May and 12 October 1970 samples were taken from 2.8 – 45 m depth, 17 samples from the southern part of the lake and 11 from the northern part (see Fig. 1), that is from an area of 2.0 m^2. The samples were taken with an Ekman grab, each sample consisting of three hauls (= 1/12 m^2) except at a few of the shallowest places. The samples were sieved through 0.8 mm mesh, each sample of 3 hauls at the same time. The animals were picked out with the aid of a magnifying glass.

To collect deep-water species samples were taken from the greatest depths of the southern and northern parts of the lake with a miniature trawl especially designed for this purpose. This trawl is lowered backwards, so no animals enter the bag on the way down. It is pulled along the bottom for about 100 m, then raised a few metres above the bottom, and turned backwards with a messenger, so no animals can get into the bag when the trawl is lifted to the surface. The contents of the bag were then investigated in the usual way. The mouth of the bag was 20×50 cm = 0.1 m^2, so that theoretically about 10 m^3 water during a sweep of 100 m just above the bottom is filtered through the bag and the sampler wanders over an area of 50 m^2.

The trawl is especially effective in collecting big relict crustaceans, but it also takes other bottom animals (see Table 3). *Pontoporeia* was found in many bottom samples, but no in trawl samples, whilst *Gammaracanthus* was caught only with the trawl. *Pallasea*, *Mysis* and larvae of *Chaoborus flavicans* were obtained both with the Ekman grab and in the trawl samples. Valle (1936) reported that *Pontoporeia* is caught most effectively with ordinary bottom samplers, *Pallasea* with a trawl but not with the Ekman grab, *Mysis* and *Chaoborus* with a trawl, but the latter rather frequently with the bottom sampler too.

The design of the trawl used in this study ruled out the possibility that for instance *Chaoborus* from the pelagic

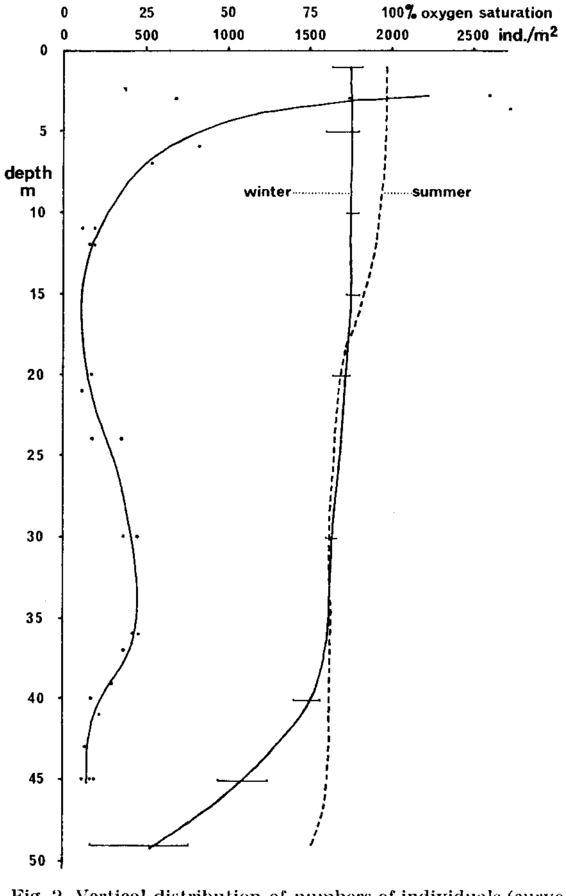

Fig. 2. Vertical distribution of numbers of individuals (curve drawn by eye), and curves of oxygen saturation in summer and in winter. The horizontal lines across the oxygen curve of winter express the range.

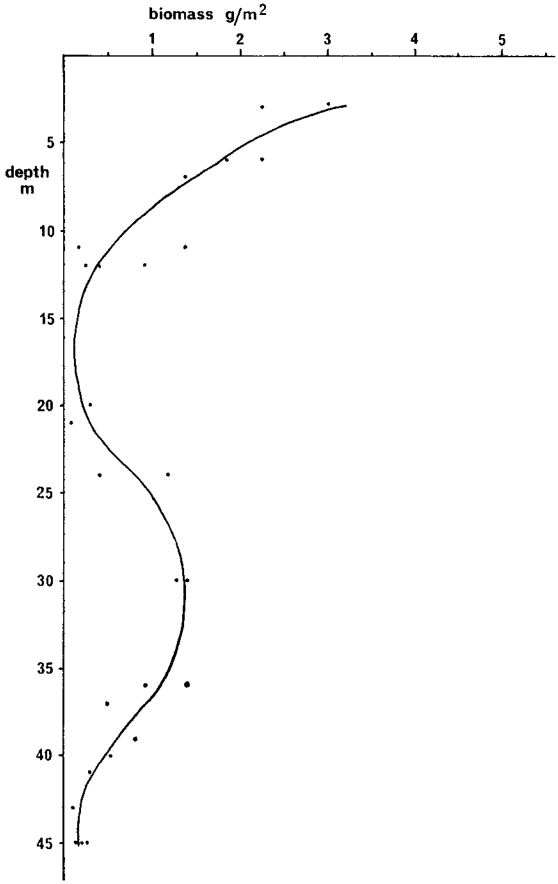

Fig. 3. The vertical distribution of biomasses. The curve is drawn by eye.

Table 1. Average numbers of individuals of the species or groups of bottom fauna in different depth zones and in the southern and northern parts of the lake

Depth zone	Average abundances exx./m² Southern part > 20 m	6 – 12 m	3 m	Northern part > 20 m	6 – 12m	3 m
Turbellaria	–	–	–	2.2	–	49.3
Nematoda	1.1	–	–	–	–	–
Peloscolex ferox (Eisen)	11.2	2.5	9.0	63.8	3.9	29.6
Psammoryctes barbatus (Grube)	–	11.3	26.9	–	–	29.6
Limnodrilus hoffmeisteri (Clap.)	–	–	–	–	–	36.1
Tubifex tubifex (Müller)	1.1	–	9.0	2.2	–	–
Stylodrilus heringianus (Clap.)	3.6	–	–	5.9	–	–
Lumbriculus variegatus (Müller)	–	6.4	9.0	–	–	55.8
Lumbriculidae spp.	31.7	–	–	73.9	22.1	49.3
Enchytraeidae	–	–	–	–	–	149
Pisidium spp.	–	7.9	35.8	–	–	106.8
Pisidium conventus Clessin	49.6	16.3	–	77.6	3.9	–
P. subtruncatum Malm	9.6	7.9	–	4.0	--	18.1
P. lilljeborgi Clessin	2.5	46.4	26.9	–	3.9	36.1
P. henslowanum (Sheppard)	–	15.3	9.0	–	5.9	6.6
P. casertanum (Poli)	–	6.4	69.4	–	–	–
P. hibernicum Westerlund	–	–	35.8	–	–	6.6
Valvata cristata Müller	–	–	–	–	–	6.6
V. piscinalis Müller	–	–	35.8	–	–	–
Gyraulus albus Müller	–	–	69.4	–	–	–
Pontoporeia affinis Lindström	25.4	8.9	–	–	6.2	–
Pallasea quadrispinosa Sars	1.8	–	–	2.2	12.0	–
Mysis relicta Lovén	2.5	–	–	–	–	–
Asellus aquaticus (L.)	–	15.3	273	–	36.1	749
Copepoda	5.4	11.3	–	2.2	–	–
Eurycercus lamellatus Müller	–	–	35.8	–	–	18.1
Hydracarina	–	36.5	17.9	2.2	–	–
Tanypodinae	11.6	30.6	195	9.9	44.0	18.1
Tanytarsini	46.0	83.4	522	9.9	3.9	73.9
Orthocladinae	1.1	16.3	53.7	24.0	16.0	–
Chironomini, no blood gills	14.5	30.6	298	24.0	70.0	24.6
Chironomini, with „ „	–	3.9	17.9	–	–	–
Chironomidae, other larvae	1.1	84.3	132	–	16.0	11.5
Chir., pupae & adults	2.5	26.6	98.5	4.4	–	24.6
Ceratopogonidae	–	11.3	80.6	–	12.0	–
Chaoborus flavicans Meigen	1.1	–	–	–	–	–
Diptera, larvae spp.	–	2.5	–	–	–	6.6
Polycentropidae	–	–	9.0	–	–	–
Trichoptera, others	–	–	17.9	–	–	107
Ephemera vulgata (L.)	–	11.3	44.8	–	24.1	29.6
Caenis spp.	–	–	71.6	–	–	–
Sialis spp.	–	–	35.8	–	–	–
Exx./m²	223	493	2238	308	280	1642
Biomass g/m²	0.45	1.13	7.06	0.87	0.96	2.64
Number of samples	10	5	2	6	3	2
Total area of samples m²	0.81	0.36	0.07	0.50	0.17	0.09

zone would be caught when the apparatus was lowered or raised.

The biomasses of the samples were weighed to the nearest mg after preservation in alcohol.

4. The bottom fauna

The vertical differences in numbers of individuals and biomasses are seen in Figs. 2 and 3. The vertical distribution of oxygen saturation in summer and in winter is seen in Fig. 2.

Table 1 shows the abundances of the species or groups in different depth zones in the southern and northern parts of the lake. Table 2 lists the species or groups in which the percentage of the total number of individuals of each partial area exceeds 5 % (or, in the littoral, 10 %). The material is divided into three depth zones: the profundal (> 20 m), the sublittoral (6 – 12 m) and the littoral zone (2.8 – 3.5 m).

If the southern and northern parts of the lake are compared, the species or groups whose average number exceeds 10 % of the total number of individuals show no differences at the < 5 % level of significance (t-test), neither were differences observed between the total numbers of individuals and the biomasses of the corresponding depth zones of the southern and northern parts.

In the profundal the most abundant species is *Pisidium conventus*, followed by the Lumbriculidae, partly consisting of mature *Stylodrilus heringianus*. In the sublittoral the larvae of different groups of Chironomidae constitute more than half the number of individuals of the macrofauna. The material from the littoral is meagre,

Table 2. Average abundances and percentages of dominant species or groups, and standard errors of mean (m). Values are given for groups exceeding 5 %, and in the littoral 10 %.

	Southern part			Northern part		
	%	Exx./m²	± m	%	Exx·/m²	± m
Profundal						
Pisidium conventus	22.3	49.6	11.4	25.3	77.6	22.1
Lumbriculidae	15.8	35.3	16.7	25.9	79.8	22.1
Tanytarsini	20.7	46.0	15.4	–	–	–
Peloscolex ferox	5.0	11.2	5.8	20.8	63.8	25.9
Chironomini, no blood gills	6.5	14.5	3.8	7.8	24.0	12.7
Pontoporeia affinis	11.4	25.4	16.9	–	–	–
Tanypodinae	5.2	11.6	4.5	–	–	–
Orthocladinae	–	–	–	7.8	24.0	9.8
Total fauna	100.0	223	23.3	100.0	308	50.0
Biomass g/m²	–	0.45	0.15	–	0.87	0.15
Sublittoral						
Chironomidae, undetermined	17.2	84.3	46.3	5.7	16.0	10.6
Tanytarsini	16.9	83.4	41.2	–	–	–
Chironomini, no blood gills	6.2	30.6	12.4	25.0	70.0	55.1
Tanypodinae	6.2	30.6	25.5	15.7	44.0	32.7
Pisidium lilljeborgi	9.4	46.4	22.9	–	–	–
Asellus aquaticus	–	–	–	12.9	36.1	29.1
Hydracarina	7.4	36.5	23.8	–	–	–
Ephemera vulgata	–	–	–	8.6	24.1	24.0
Lumbriculidae	–	–	–	7.9	22.1	4.3
Orthocladinae	–	–	–	5.7	16.0	16.0
Total fauna	100.0	493	177	100.0	280	132
Biomass g/m²	–	1.13	0.39	–	0.96	0.11
Littoral						
Asellus aquaticus	12.2	273	224	45.7	749	–
Tanytarsini	23.4	522	117	–	–	–
Chironomini, no blood gills	13.3	298	126	–	–	–
Total fauna	100.0	2338	531	100.0	1642	1061
Biomass g/m²	–	7.06	1.59	–	2.64	0.38

but *Asellus aquaticus* and Chironomid larvae are clearly the most abundant. Of the forms in the littoral zone, *Asellus*, the Enchytraeids and Gastropods as well as Trichoptera and Ephemeroptera are absent from the deep sections of the lake.

Glacial relicts. SEGERSTRÅLE (1956) reported *Myoxocephalus quadricornis* as the only relict species from Konnevesi. Four relict crustaceans living in Finnish lakes in or near the bottom (*Gammaracanthus lacustris*, *Pallasea quadrispinosa*, *Pontoporeia affinis*, and *Mysis relicta*) were found in Konnevesi during the present study (see Tables 1 and 3). According to SEGERSTRÅLE, these four crustaceans are known to live together in only four Finnish lakes (Päijänne, Kallavesi, Lohjanjärvi, and Pyhäjärvi/Artjärvi). *Mysis*, *Pallasea* and *Pontoporeia* occur in several Finnish lakes, but SEGERSTRÅLE (1956) reported *Gammaracanthus* only from live additional lakes. It has later also been found in Pääjärvi, Lammi.

Table 3. Samples taken with the trawl on 1 June 1970.

Area Depth, m	S 45	N 36	N 36
Peloscolex ferox	–	–	7
Stylodrilus heringianus	–	–	3
Lumbriculidae spp.	–	1	–
Pisidium conventus	1	–	–
Pallasea quadrispinosa	–	–	1
Gammaracanthus lacustris	1	–	–
Mysis relicta, juv.	10	–	–
M. relicta, > 1-year-old	6	–	–
Tanytarsini	1	–	–
Chaoborus flavicans f. *alpinus*, pupae	4	–	–
C. flavicans, larvae	5	–	–

Species diversity indices. Indices of species diversity were calculated from the formula by SHANNON & WEAVER (1963), where diversity

$$H' = -\Sigma p_i \log_2 p_i$$

($p_i = n_i/n$, n_i = number of individuals per taxon, n = total number of organisms).

With the aid of diversity indices animal communities of different areas or species lists of different investigators or different studies can be compared. The index expresses the relative importance of each species in the community and indicates the amount of information contained in the material as binary units per individual (PIELOU 1966). The indices calculated for the bottom macrofauna from the present material are seen in the tabulation below:

Depth zone	Southern part	Northern part
> 20 m	3.28	2.89
6 – 12 m	4.05	3.34
3 m	3.83	3.10

It is seen that the diversity indices vary between 2.89 and 4.05. The values of the sublittoral are the highest and those of the profundal the lowest. These diversity indices are typical of a clean bottom. In Lake Päijänne, for instance, certain parts of which are heavily polluted, the index for the cleanest areas is > 3, whilst in the most polluted areas it is < 1 (Särkkä 1972). Similarly, Wilhm (1970) reported that at the cleanest stations of polluted streams the indices are between 3 and 4, at the polluted stations usually < 1.

For two reasons the diversity indices for Konnevesi are somewhat too low. Firstly, identification of the material down to species level could not be made for all groups, and thus some taxons consist of several species. Secondly, the actual number of species, especially in the littoral zone, is too low because of the small number of samples. A further factor affecting the indices in the same direction is the fact that many species and individuals, particularly the very small ones, are lost owing to the sieving technique. The highest values of the diversity indices for the sublittoral zone may partly be due to the fact that both littoral and profundal faunal elements occur in this zone.

5. Discussion

In Konnevesi the littoral, if defined according to the average Secchi disc transparency (Valle 1927), reaches a depth of 5.4 m. The lower limit of the higher aquatic vegetation (= lower limit of the littoral according to Allee *et al.* 1950, Järnefelt 1953) was not studied. A typical littoral animal, *Asellus aquaticus*, is still found at 6 – 7 m. The samples from depths of 6 – 12 m can thus be regarded as representative of the sublittoral zone, the samples from about 3 m as the littoral zone, and the samples from over 20 m as the profundal zone.

The numbers of individuals and the biomasses are clearly highest in the littoral zone, lowest at 12 – 20 m and higher again in the profundal zone down to about 35 m (Figs. 2 and 3). In the deepest profundal zone the numbers and biomasses are again lower, probably because of the low oxygen content in late winter (see Fig. 2), and also because the organic matter produced in the epilimnion may already be too decomposed to provide enough food for the bottom fauna. The correlations between the abundance of bottom fauna and the environmental factors are very complicated, because, for instance, an increase in the amount of food often results in a decrease of the oxygen content. According to Järnefelt (1955), it is because so many environmental factors affect the bottom fauna that no regular pattern is seen in the vertical distribution of animals in the deep oligotrophic lakes of Northern Europe.

According to the lake type classification of Järnefelt (1953), Lake Konnevesi resembles the relict crustacean type or the Pisidium type.

Of the lake types described by Valle (1927), Konnevesi does not conform to any of the oligotrophic types. But according to the bottom fauna it resembles the mesotrophic Lumbriculus – relict lakes, provided that *Stylodrilus heringianus* was included in *Lumbriculus* by Valle as seems probable. On the other hand, Konnevesi might also represent the eutrophic Tubifex – Pontoporeia lakes, if »*Tubifex*» means *Peloscolex ferox*. This shows that, instead of classifying lakes more of less arbitrarily on the basis of the entire bottom fauna, it is better to examine the composition of the animal communities of different depth zones and in different parts of a lake, with special attention to the dominant species.

Acknowledgements. I am indebted to the Water Control Association of Northern Päijänne (Pohjois-Päijänteen Vesiensuojeluyhdistys r.y.) for financial support, to Jyväskylä Hydrobiological Research Institute for working possibilities, and to the Research Team for Konnevesi (Konneveden kalatutkimus r.y.), which has co-ordinated a research programme for this lake. I am also indebted to Mr. Väinö Varis, Mr. Kalle Karhu, and the late Mr. August Hänninen who assisted in the sampling. Dr. Lauri Koli has checked my identifications of *Pisidium*, for which my special thanks are due.

References

Allee, W. C., Emerson, A. E., Park, O., Park, T. & Schmidt, K. P. 1950: Principles of animal ecology. – 837 pp. Philadelphia.

Järnefelt, H. 1953: Die Seetypen in bodenfaunistischer Hinsicht. – Ann. Zool. Soc. Zool.-Bot. Fennicae Vanamo 15 (6): 1 – 38.

Järnefelt, H. 1955: Die vertikale Verteilung der Bodenfauna im Profundal. – Mem. Ist. Ital. Idrobiol. 8 (Suppl.): 165 – 181.

Pielou, E. C. 1966: Species-diversity and pattern-diversity in the study of ecological succession. – J. Theor. Biol. 10: 370 – 383.

SÄRKKÄ, J. 1972: Päijänteen nykytila ja siihen johtanut kehitys. II. Biologiset selvitykset. Pohjaeläimistö. (Summary: Biological research on Lake Päijänne, Finland. Bottom fauna). – Vesihallituksen Tiedonantoja (in the press).
SÄRKKÄ, J. & PAASIVIRTA, L. 1972: Vertical distribution and abundance of the macro- and meiofauna in the profundal sediments of Lake Päijänne, Finland. – Ann. Zool. Fennici 9: 1–9.
SEGERSTRÅLE, S. G. 1956: The distribution of glacial relicts in Finland and adjacent Russian areas. – Soc. Scient. Fennica, Comment. Biol. 15 (18): 1–35.
SHANNON, C. E. & WEAVER, W. 1963: The mathematical theory of communication. – 117 pp. Urbana.
VALLE, K. J. 1927. Ökologisch-limnologische Untersuchungen über die Boden- und Tiefenfauna in einigen Seen nördlich vom Ladoga-See. – Acta Zool. Fennica 2: 1–180.
– » – 1936: Fortgeführte boden- und tiefentierökologische Untersuchungen in einigen südostfinnischen Seen. – Ann. Zool. Soc. Vanamo 4 (4): 1–45.
Vesi-Hydro 1967: Pohjois-Päijänteen vesistön käyttö- ja hoitosuunnitelma. – 286 pp. Helsinki.
WILHM, J. L. 1970: Range of diversity index in benthic macroinvertebrate populations. – J. Water Pollution Control Feder. 42: R221–224.

Received 17. I. 1972
Printed 28. IX. 1972