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Effects of heavy pollution on the zoobenthos in Lake Vanajavesi, southern Finland, with special reference to the meiozoobenthos

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The qualitative and quantitative changes in the meiozoobenthos are described along a pollution gradient downstream from the Valkeakoski industrial area. Material was collected in late summer. The response of the meiozoobenthos to the industrial waste water load is compared with that of the macrozoobenthos. Reference material was also collected from an area loaded with municipal effluents and from the least polluted part of Vanajavesi.

The response of the meiozoobenthos to heavy pollution was in principle similar to that of the macrozoobenthos. The zoobenthos is either scarce or even totally eliminated below the pollution outfall. Cyclopoida is the only group which thrive on these anoxic bottoms. The most tolerant sedentary meiofaunal species were some nematods and *Rotaria neptunia,* which were found in low numbers at a station where the conditions were too extreme for the most tolerant macrofaunal species *Chironomus plumosus.* The diversity of both meiofauna and macrofauna increased downstream, where the oxygen conditions improved. The total abundance of both meiofauna and macrofauna reached a huge maximum in a zone where the oxygen concentration was 0—4 mg/l. Downstream from this point the abundance again decreased to a normal level.

The industrial effluents (mainly from the wood-processing industry) and the municipal waste waters caused similar changes in the meiozoobenthos. Potentially toxic effects are not easy to detect, because the oxygen depletion is the main limiting factor. There are, however, specific changes in the composition of the meiozoobenthos which may be valuable in the biological assessment of the degree of pollution, such as the composition of the macrofauna.

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1. Introduction

The general effects of eutrophication and pollution on the freshwater macrozoobenthos are well known. The benthic macrofauna has often played an important role in limnological lake classification and evaluation of a degree of pollution. Human influence is apparent in the composition and abundance of the zoobenthos of many Finnish lakes and watercourses (e.g. Järnefelt 1940, 1953, Bagge & Jumppanen 1968, Jumppanen 1976, Särkkä 1979, Kansanen & Aho 1981). The meiozoobenthos, however, has been neglected in most benthic surveys. In Finland, research on the meiozoobenthos of lakes was started in the beginning of the 1970s by the Lake Pääjärvi ecological research project (Holopainen & Paasivirta 1977). Lake Pääjärvi is a deep dys-oligotrophic lake in southern Finland. Studies on the profundal meiozoobenthos of eutrophicated or polluted lakes have been published by Särkkä and Paasivirta (1972), Särkkä (1975, 1979), Paasivirta & Särkkä (1978). The object of these studies was mainly the meiozoobenthos of Lake Päijänne.

The aim of this study was to describe the qualitative and quantitative changes produced in the meiozoobenthos by a heavy waste water load, and to compare the responses of meiofauna and macrofauna. The study area, Lake Vanajavesi, receives large amounts of both industrial effluents and municipal sewage and has become eutrophicated and partly polluted during the last two or three decades (Kansanen & Aho 1981).

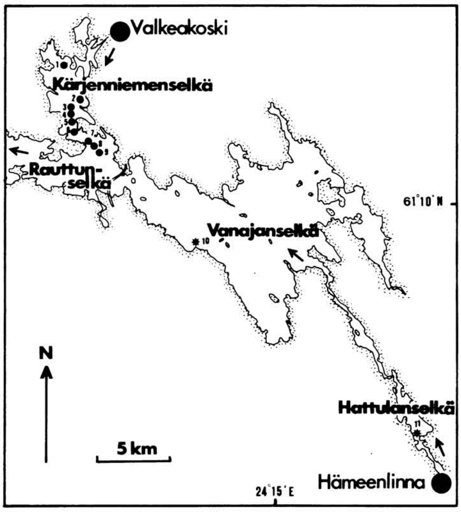


Fig. 1. The location of the sampling stations in the study area (stations 1—9, black dots) and in the reference areas (stations 10 and 11, black stars). Direction of the water flow is indicated by arrows.

2. Study area

Lake Vanajavesi is a part of the drainage basin of the river Kokemäenjoki. The study area comprises the open body of water Kärjenniemenselkä downstream from the Valkeakoski industrial area and the northern part of Rauttunselkä which receives polluted waters from Kärjenniemenselkä (Fig. 1). The total waste water load directed into Kärjenniemenselkä in winter 1973—1974 was: BOD_7 79 500, phosphorus 169, nitrogen 716 kg per day (Jokinen et al. 1974). The very high oxygen demand of these waste waters was mainly due to the effluents of pulp and paper mills. The effluents also contained toxic constituents. The effluents from a chemical fibre (rayon) factory, in particular, are toxic due to their contents of zinc and sulphur compounds. These waste waters are also very acid (pH 1.8—2.5).

Kärjenniemenselkä is a throughflow basin with a mean volume of approximately 50×10^6 m^3 and a mean discharge of 35 m^3/sec. The theoretical retention time is therefore only 16 days (Kajosaari 1964). Some physico-chemical and biological properties of the study area are presented in Table 1. The study area is described in greater detail by Kansanen & Aho (1981).

For reference material, the benthos was also sampled from two other parts of Vanajavesi (Fig. 1). Hattulanselkä, an area of open water, resembles Kärjenniemenselkä hydrologically. It receives waste waters from the town of Hämeenlinna (40 800 inhabitants). The load is, however, mainly of municipal origin without industrial, toxic constituents. This can be seen in the primary productivity values (Table 1) which are extremely high in Hattulanselkä, but clearly inhibited in Kärjenniemenselkä. In both areas the oxygen conditions are very poor.

The second reference area is the central basin of Vanajavesi, Vanajanselkä. It was the least polluted part of Vanajavesi during sampling in 1971 (Kansanen & Aho 1981). Although it was dys-eutrophic, the oxygen conditions were very satisfactory during summer in the whole body of water (Table 1). The critical period was the late winter with oxygen depletion in the hypolimnion.

3. Material and methods

Material was collected during the period 1.—5.IX. 1971. The locations of the 9 sampling stations in the study area and the 2 reference stations are presented in Fig. 1. At each station benthos samples were collected from several depths. Macrozoobenthos was collected at stations 1—9

Table 1. Some physico-chemical and biological characteristics of the study area and the reference areas in August 1971. Measurements made by the local association for water protection (Kokemäenjoen vesistön vesiensuojeluyhdistys 1972, Salonen 1972).

	Kärjenniemen-selkä (station 1)	Hattulan-selkä (station 11)	Vanajan-selkä (station 10)
Temperature[1] (°C)	16.9	14.0	16.7
Oxygen saturation[1] (%)	0	2	87
pH[1]	6.0	6.8	7.1
Colour[1] (mg Pt/l)	30	100	50
Specific conductivity[1] (μS/cm)	144	108	108
$KMnO_4$ consumption[1] (mg O_2/l)	177	63	50
Total phosphorus[2] (mg/l)	0.04	0.18	0.03
Total nitrogen[2] (mg/l)	0.63	—	—
Primary productivity[3] (mg C ass./m^3 / 18 h)	81	1 774	291

[1] Values measured at 9 m.
[2] Values measured at 1 m.
[3] Measured by the ^{14}C method using +20 °C and 5 000 lux, samples taken from a depth zone of 1—4 m.

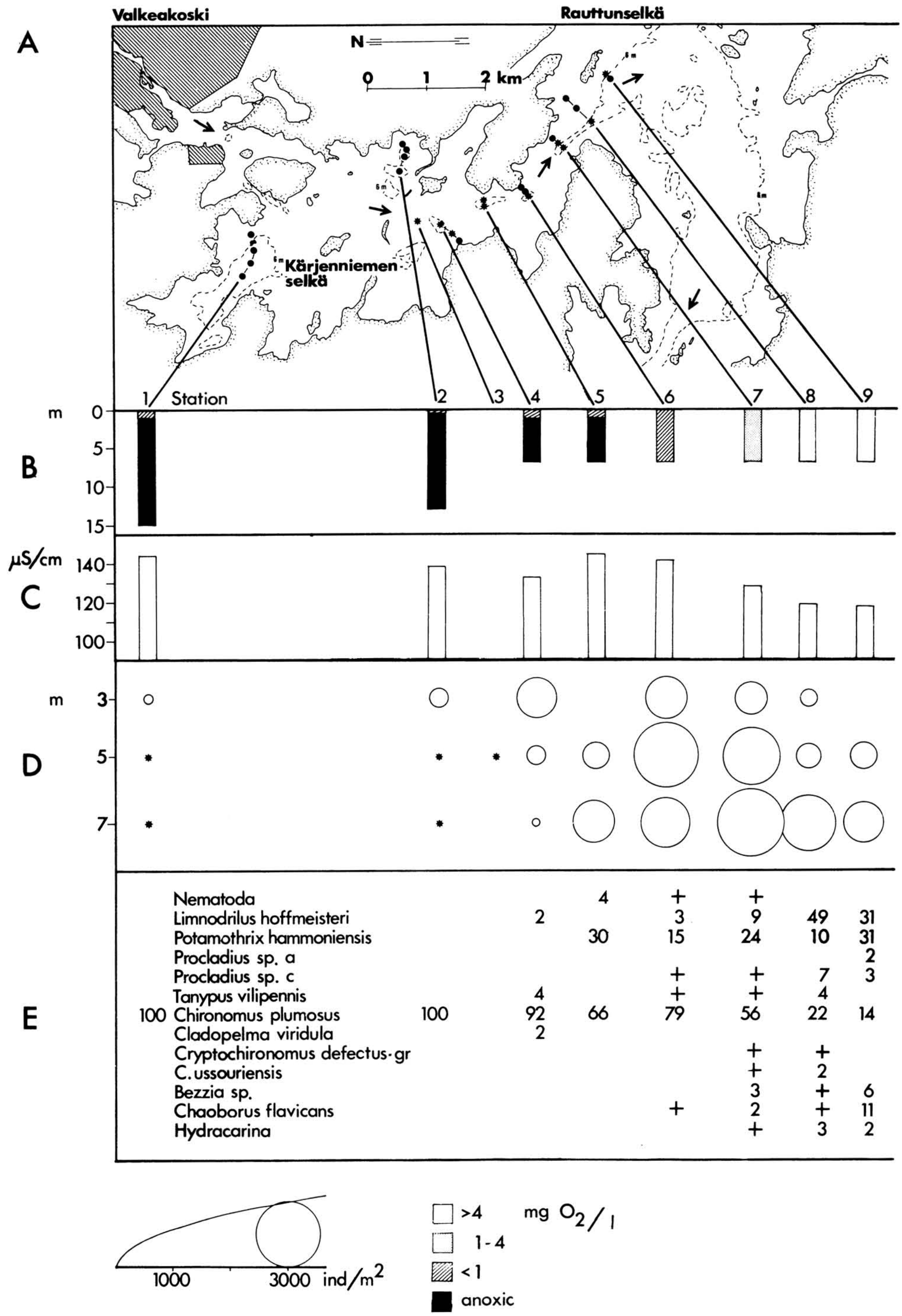
Fig. 2. A. Location of the stations 1—9 in the study area. Each station has several sampling depths, which are indicated by black dots (only macrofauna sampled) or black stars (both macrofauna and meiofauna sampled). The 6 m depth contour is indicated by the dotted line, direction of water flow by arrows.

B. The vertical oxygen stratification to the deepest point at each station. For an explanation of the shading, see the scale below the figure.

C. The specific conductivity (μS/cm +20°C) of the water at 7 m.

D. The population density of the macrozoobenthos (ind/m^2) at 3—7 m. Macrozoobenthos was not found at 10—15 m or at those depths indicated by black stars. See scale below the figure.

E. The average composition (%) of the macrofauna at each station.


A
Valkeakoski
Rauttunselkä
N
0 1 2 km
Kärjenniemen-selkä
1 Station 2 3 4 5 6 7 8 9
B
m 0 5 10 15
C
µS/cm 140 120 100
D
m 3 5 7
E
Nematoda 4 + +
Limnodrilus hoffmeisteri 2 3 9 49 31
Potamothrix hammoniensis 30 15 24 10 31
Procladius sp. a 2
Procladius sp. c + + 7 3
Tanypus vilipennis 4 + + 4
100 Chironomus plumosus 100 92 66 79 56 22 14
Cladopelma viridula 2
Cryptochironomus defectus-gr + +
C. ussouriensis + 2
Bezzia sp. 3 + 6
Chaoborus flavicans + 2 + 11
Hydracarina + 3 2
1000 3000 ind/m2
>4 mg O2/l
1-4
<1
anoxic

from 3, 5, 7 and 10 m, and the greatest depth (13 or 15 m). For practical reasons meiozoobenthos samples were taken only at stations 3—9 from depths of 5 and/or 7 m. The sampling depths at stations 1—9 are presented in Fig. 2 A. The reference samples were taken in Hattulanselkä from depths of 3, 5 and 7 m and in Vanajanselkä from 3, 5, 7, 10 and 15 m. Water samples were collected for oxygen analyses and measurements of specific conductivity at each station at intervals of 2 metres.

The methods used in sampling were almost identical to those used during the Pääjärvi research project (Holopainen & Paasivirta 1977). The meiozoobenthos was sampled with a three-unit Kajak multiple corer (one core 15.2 cm^2, Hakala 1971). Three hauls were taken at each depth and usually sieved separately in the laboratory with a water jet through a 100 μm mesh nylon net. The animals were counted with the aid of a grooved dish as described by Hakala (1971) under ×12 magnification. According to Särkkä & Paasivirta (1972) more than 99 % of individuals live in the uppermost 6 cm of the sediment. Therefore a 6 cm column was cut from each core to reduce the amount of sieving residue. In Kärjenniemenselkä, fibres and other detritus in certain places made it difficult to get reliable samples with this method. Therefore most samples had to be subsampled before counting with a sample splitter. For this reason, the total number of meiozoobenthos samples was also limited to 10 in the study area. Sources of error of this method are discussed by Holopainen & Paasivirta (1977).

The macrozoobenthos was sampled with the same three-core apparatus. Seven hauls were taken at each depth, combined and sieved immediately through a 0.6 mm sieve. The total sample area was then 319.3 cm^2. The animals were sorted on a white dish and preserved in 70 % alcohol.

The oxygen content was analysed using the standard Winkler method. Specific conductivity was measured with a Normameter RW conductivity measuring bridge and a Philips measuring electrode.

4. Changes along a pollution gradient between stations 1 and 9

4.1. Water quality

Below the pollution outfall there was a horizontal pollution gradient between Valkeakoski and the northern part of Rauttunselkä (Fig. 2). The environmental conditions were extreme in the northern part of Kärjenniemenselkä where the saprobic processes determined the character of the whole water body from the surface to the bottom. The water was totally anoxic below the depth of 1 m downstream as far as station 5, from where the oxygen conditions improved clearly towards Rauttunselkä (Fig. 2 B). The general improvement in the water quality can also be seen in the values of specific conductivity (Fig. 2 C).

This kind of pollution gradient is typical of heavily loaded flowing water (Hynes 1960). In lakes the main change in environmental conditions take place in a vertical direction. Because of the relatively small volume of Kärjenniemenselkä and the great amount of effluents, the dilution is ineffective and does not become complete until the polluted waters are mixed with the less polluted waters of Rauttunselkä.

4.2. Macrozoobenthos

Quantitative and qualitative changes in the macrozoobenthos are presented in Fig. 2 (D-E). The anoxic bottom of Kärjenniemenselkä was totally barren below a depth of 3 m downstream as far as station 4, where some larvae of a tolerant macrofaunal species *Chironomus plumosus* (L.) were found at depths of 5 and 7 metres. Small number of *C. plumosus* larvae were also the only animals able to live in the upper sublittoral of northern Kärjenniemenselkä. The fauna became more diverse downstream towards Rauttunselkä and the very clear dominance of *C. plumosus* decreased gradually. At the same time the oligochaetes became the most abundant group in Rauttunselkä. The relative importance of predatory invertebrates (*Procladius* spp., *Tanypus vilipennis* Meig., *Cryptochironomus* spp., *Bezzia* sp. and *Chaoborus flavicans* (Meig.) increased downstream.

There was a clear maximum abundance of the total macrozoobenthos at all depths at the station where the oxygen concentration was just above 0 mg/l. Downstream, the abundance decreased very much from this maximum. The maximum abundance at a depth of 7 m occurred at station 7 at a distance of about 8 km from the pollution outfall (3 292 ind/m^2). It is logical that the maximum at depths of 5 and 3 m was found to be nearer to Valkeakoski (about 7 and 5—6 km, respectively) because of the vertical oxygen gradient.

4.3. Meiozoobenthos

The composition and abundance of meiozoobenthos at stations 3—9 (5 and 7 m) is presented in Fig. 3. The total density was lowest at both depths at station 4 (39 283 and 112 847 ind/m^2, respectively). A very clear maximum was found at station 8 (629 601 ind/m^2), from where the density again decreased towards station 9. The most abundant group was Cyclopoida, especially at the most polluted stations where their

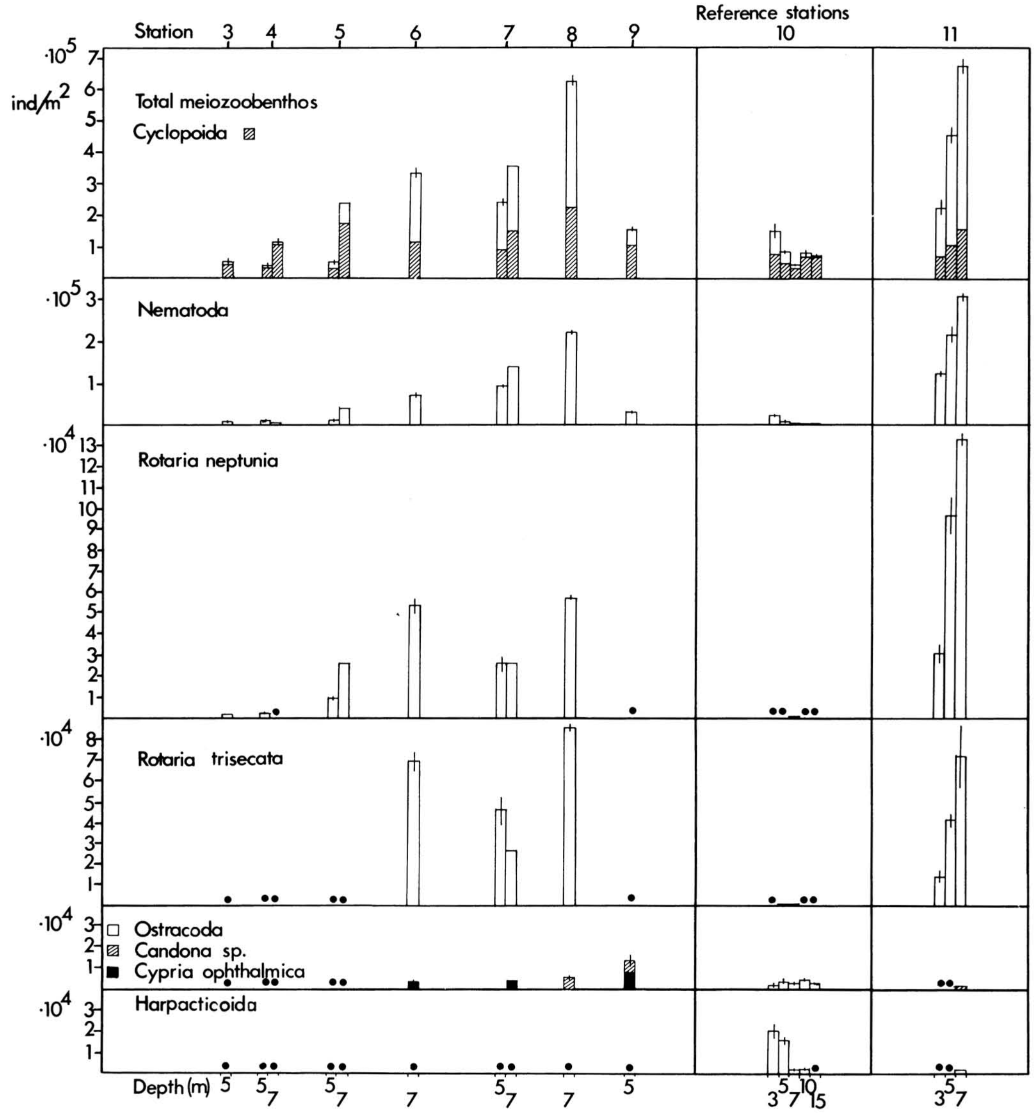


Fig. 3. The mean population density (ind/m², vertical bars = the standard error of the mean) of the total meiozoobenthos and its most important components at stations 3—9 and at the reference stations 10 and 11. Black dots indicate the absence of the species.

dominance was even over 90 %. The abundance of cyclopoid copepods seems to be rather constant along the pollution gradient and does not demonstrate a maximum in the same way as the total fauna.

The abundance of other meiofaunal groups seems to be dependent on the distance from the pollution outfall (Fig. 3). Nematodes, which were not determined to the species level, were found in every sample. At the most polluted stations their abundance was low (3 619 ind/m²). The density increased uniformly downstream to station 8 (221 709 ind/m²). The abundance was again lower at station 9, the least polluted station (Fig. 3).

The rotifer fauna comprised two species. Low numbers of *Rotaria neptunia* (Ehrenberg) were found (197 ind/m²), even at the most polluted

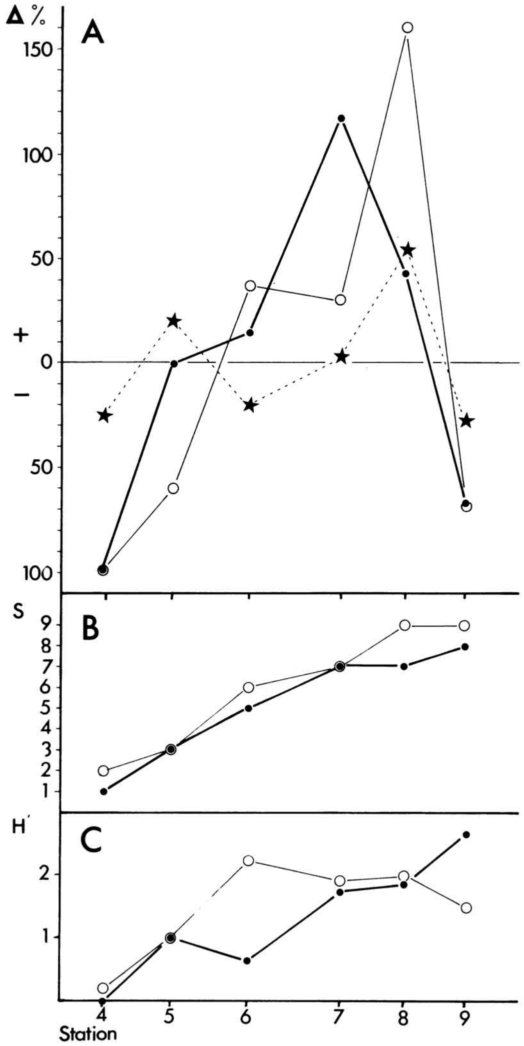


Fig. 4. A. The relative changes (expressed as percentages of the mean) in the abundance of the macrofauna (thick line, black dots), sedentary meiofauna (thin line, open circles) and non-sedentary Cyclopoida (broken line, stars) between stations 1 and 9.

B. The number of species per sample (S) in the macrofauna (thick line, black dots) and in the meiofauna (thin line, open circles).

C. The values of the Shannon index H'. The sampling depths were 7 m at each station, except at station 9 (5 m).

stations. The highest abundances occurred at stations 6 and 8 (57 238 ind/m^2), and the species was absent from station 9. *Rotaria trisecata* (Weber) was not found at the most polluted stations, but was more abundant than *R. neptunia* at stations 6—8 (max. 85 526 ind/m^2). This species was also absent from station 9.

Ostracods were found in low numbers at stations 6—9. Of the two species found in samples, *Cypria ophthalmica* Jurine seems to tolerate more severe conditions than *Candona* sp. (probably all *C. candida* O. F. Müller-Vávra), which were found only at stations 8 and 9. Other meiozoobenthos groups (Ciliata, Turbellaria, Oligochaeta, Cladocera, juvenile stages of Chironomidae) were found only occasionally.

The quantitative changes in the meiozoobenthos and macrozoobenthos are compared in Fig. 4. The non-sedentary group Cyclopoida is presented separately from the sedentary meiofauna. The relative changes in both the sedentary meiofauna and macrofauna seem to take place in a very similar way along the pollution gradient. The peak of macrofaunal density occurs nearer to the pollution source than that of meiofauna. It is interesting to note that low numbers of the sedentary meiofauna are able to survive under conditions which are too severe for the macrofauna (station 3). Cyclopoida is the most indifferent group to the pollution. Their abundance varies rather irregularly between stations 3 and 9.

The changes in the diversity of meiozoobenthos and macrozoobenthos are compared in Fig. 4. Diversity is measured here by the number of species (taxa) per sample and by the Shannon index

$$H' = - p_i \sum_{i=1}^{s} \log_2 p_i ,$$

where p_i = proportion of the abundance of species i and s = number of species). The species number increases uniformly in both meiofauna and macrofauna downstream from the pollution source. The pattern of change in the Shannon index is not as regular. The dominance diversity of the macrofauna increases from 0 to 2.5 at station 9. However, the maximum diversity of the meiofauna was reached at station 6, from where H' decreases a little downstream. Furthermore, it should be noted that, in contrast to the macrofauna, the meiofauna was only partly identified to the species level.

5. The meiozoobenthos in the reference areas

The abundance and composition of the meiozoobenthos in the reference areas is presented in

Fig. 3. Because the main area of interest in this study was the meiozoobenthos, only the dominant groups of the macrofauna are mentioned here. The macrozoobenthos of Lake Vanajavesi is described in more detail by Kansanen & Aho (1981). During sampling in 1971 Vanajanselkä was characterized by a clear dominance of *Chironomus anthracinus* Zett., especially in the profundal zone (44 %). Another important member of the benthos was *Chironomus ?corax* K.. Hattulanselkä was quite similar to Rauttunselkä. In both areas the dominant groups were oligochaetes, *Chaoborus flavicans* and *Chironomus plumosus*.

The sublittoral meiozoobenthos of the organically polluted Hattulanselkä (station 11) most resembled that of stations 6—9 in Kärjenniemenselkä. The total density was even higher in Hattulanselkä (max. 676 760 ind/m^2). The dominance of nematodes in both areas was much higher than elsewhere. In Hattulanselkä they formed the most abundant group with a maximum density of 310 100 ind/m^2. The abundance of Cyclopoida was a little lower in Hattulanselkä. Rotifers were abundant in both areas. Of the two species, *Rotaria trisecata* was in almost equal numbers and *R. neptunia* more abundant in Hattulanselkä (max. 132 900 ind/m^2). Ostracods were scarce in Hattulanselkä. Harpacticoid copepods, which were absent from Kärjenniemenselkä, occurred in low numbers in Hattulanselkä.

The occurrence of Harpacticoida (max. density 19 757 ind/m^2) was typical of the sublittoral zone of Vanajanselkä (station 10). The total abundance was much lower than in the polluted areas. The cyclopoid copepods were again the most abundant group. Nematodes were important members of the sedentary fauna, but their density was low. The same rotifer species were also present here, but in very low numbers. The ostracods were relatively important in the meiofauna, but the specific composition was partly different from that elsewhere (exact species determinations were not made). The juvenile stages of chironomids were more abundant here than elsewhere.

The profundal meiozoobenthos of Vanajanselkä was both quantitatively and qualitatively poorer than the sublittoral fauna. The clear dominance of Cyclopoida was typical of the profundal. Of the sedentary groups only the numbers of Ostracoda and Chironomidae were the same as in the sublittoral zone. Nematoda and Harpacticoida were found sparsely. Rotifers were totally absent from the profundal.

6. Discussion

The described horizontal pollution gradient is probably typical of polluted Finnish watercourses, which are usually narrow chains of lakes with small volumes of water. The influence of waste waters can extend as much as scores of kilometres downstream in the watercourse, as in rivers. There are many papers dealing with the pollution ecology of such gradients in rivers. The best examples are the saprobic systems, which classify pollution zones by different degrees of self-purification according to their flora and fauna (Hynes 1960). Such systems have been criticized by many authors. One of the weaknesses of such systems is that the ecological factors which really determine the occurrence of a species are usually insufficiently known. Most attention has been paid to the direct abiotic effects (oxygen depletion, toxic effects) which eliminate certain organisms. However, the indirect effects, e.g. altered predator prey interactions, may be very important in this respect (c.f. Eriksson et al. 1980).

The response of the meiozoobenthos to the high degree of water pollution seems to be very similar to that of the macrozoobenthos in Lake Vanajavesi. The zoobenthos is either scarce or totally eliminated just below the pollution outfall, where the abiotic conditions may be too severe for all higher forms of life. The cyclopoid copepods are the only group which can be abundant on these anoxic bottoms. It should be noted, however, that probably all the cyclopoids of the polluted areas are pelagic species (c.f. Paasivirta & Särkkä 1978, Sarvala 1979, Särkkä 1979), which are not dependent on the benthic conditions in the same way as sedentary groups. There are, however, in both the meiozoobenthos and macrozoobenthos, sedentary species which are able to tolerate anoxic conditions for some time. In the study area the most tolerant sedentary invertebrates were nematodes, *Rotaria neptunia* and *Chironomus plumosus*. The abundance of the most tolerant species reaches a huge maximum in a zone where the abiotic conditions are still too severe for most predators and where, on the other hand, there is plenty of food available. When the conditions improve further downstream, the predation pressure caused by fish and invertebrates increases, new, less tolerant species appear in the fauna and the diversity increases. As a result the total abundance decreases to a normal level. In the study area this decrease began earlier in the macrofauna than in the meiofauna. One possible explanation for this is that the predation caused by fish, which is probably a very efficient limiting factor within this 'improvement' zone (stations 7—9), is directed more effectively to the large-sized species (c.f. Eriksson et al. 1980).

The industrial (mainly wood-processing industry) effluents and the municipal waste waters seem to cause similar changes in the zoobenthos. Both the faunal composition and abundance were much alike in Kärjenniemenselkä and Hattulanselkä. In both areas the maximum meiofaunal densities were as high as over 600 000 ind/m^2. This similarity is probably due to the fact that the oxygen saturation of water is of enormous ecological importance to the zoobenthos (c.f. Jonasson 1972). Possible toxic effects are easily masked by oxygen depletion.

The highest meiofaunal density reported by Särkkä (1979) from Lake Päijänne was 538 000 ind/m^2 at a depth of 35 m. At 10 m, which is best comparable to Vanajavesi, the pooled seasonal densities varied between 62 900 and 138 000 in 'heavily polluted' or eutrophicated areas. In the unpolluted oligotrophic areas the density was lower. The main groups in the eutrophicated areas were Cyclopoida, Harpacticoida, Nematoda and Ostracoda. The situation is thus comparable to that in Vanajanselkä. In the deep, oligotrophic Lake Pääjärvi the mean annual population density of the meiozoobenthos was between 80 000 and 230 000 ind/m^2 in the profundal and littoriprofundal (2.5—5.5 m). In the littoral, which was not included in this survey, the densities were much higher: 400 000—600 000 ind/m^2 (Holopainen & Paasivirta 1977). The main groups were the same as in Vanajanselkä or Päijänne. These high population densities in the meiozoobenthos indicate that it might be even more important quantitatively speaking than the macrozoobenthos. For example, in the profundal of Lake Pääjärvi the ratio between the biomasses of the meiozoobenthos and macrozoobenthos was 2—3:1.

Some changes occur in the species composition of the meiozoobenthos which may have some value in the biological assessment of a degree of pollution. In general, benthic lake classifications are based on the profundal macrofauna. Paasivirta & Särkkä (1978) give a list of profundal meiofaunal species which are typical of various degrees of pollution. The littoral and sublittoral zones do not characterize a lake as a whole in the same way as the profundal zone, but merely a local habitat of the lake. The material of this study was collected mainly from the sublittoral zone. It is thus not reasonable to give such a list here, but some conclusions from the pollution ecology of the meiozoobenthic species can be drawn.

According to Paasivirta & Särkkä (1978) typical species in the most polluted profundal areas with a yearly minimum oxygen saturation of 0—10 % are e.g. *Chironomus plumosus, Rotaria neptunia* and Cyclopoida. Species typical of areas where the oxygen minimum is c. 30 % are e.g. *Chironomus anthracinus, Candona* sp., *Cypria ophthalmica,* Tardigrada and two nematode species. Species occurring exclusively in areas where the oxygen minimum is over 30 % are e.g. *Mysis relicta*, a harpacticoid copepod *Paracamptus schmeili* and some nematode species.

Next to the 'eutrophic' *Chironomus plumosus* type the profundal macrofauna in Vanajavesi belonged in Rauttunselkä and Hattulanselkä, to the 'moderately eutrophic' *Chironomus anthracinus* type in Vanajanselkä, and Kärjenniemenselkä was a 'dead' basin (Kansanen & Aho 1981). Species typical of oligotrophic conditions were scarce.

In Vanajavesi the occurrence of Cyclopoida is rather irregular in relation to the environmental factors and has little indicator value. The abundance of Nematoda seems to be dependent on the degree of pollution. The group includes tolerant, detritus feeding species which are favoured by organic sedimentation in the same way as the oligochaetes (Pennak 1953). The occurrence of Harpacticoida as a group seems to indicate better oxygen conditions in Vanajavesi. This is in good agreement with the results of Paasivirta & Särkkä (1978). A more accurate analysis on a species level would be useful. The occurrence of rotifers is closely related to heavy pollution, as in the lakes of central Finland (Paasivirta & Särkkä 1978). *Rotaria neptunia* which is an indicator of the polysaprobic zone in the saprobic system of Liebmann (1962) tolerates even more severe conditions than *R. trisecata.* In Lake Pääjärvi rotifers were scarce (max. 3 600 ind/m^2). Nearly all belonged to the sessile *Dissotricha* species. The ostracods *Cypria ophthalmica* and the *Candona* spp. seem to be common in eutrophied waters, but do not tolerate as severe oxygen conditions as these rotifers. Of these, the occurrence of *Candona* (*candida* group) is not closely related to eutrophic or polluted conditions, because it is also very common in oligotrophic lakes, as in Pääjärvi (up to 80 000 ind/m^2). *Cypria* species were not found in Pääjärvi (Holopainen & Paasivirta 1977).

In conclusion, the meiozoobenthos should be included in benthic monitoring surveys of lakes. It may be quantitatively more important than the macrozoobenthos and a careful species level analysis can give useful information on the general state and degree of pollution of the lake ecosystem. The meiozoobenthos is able to live in areas where conditions are too severe for the macrozoobenthos, thus enabling more accurate assessment of the general state of heavily loaded waters.

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