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New records of profundal Oligochaeta from Finnish lakes, with ecological observations

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Qualitative samples of aquatic Oligochaeta were taken from the deepest areas of 36 Finnish lakes. The commonest species were *Pelescolex ferox*, *Tubifex tubifex* and *Stylodrilus heringianus*. *Lamprodrilus isoporus*, *Stylodrilus heringianus*, *Peloscolex ferox* and *Psammoryctides barbatus* preferred oligotrophic lakes (oxygen content high and total phosphorus content low), whilst *Potamothrix hammoniensis* preferred eutrophy. *Tubifex tubifex*, *Chaetogaster diaphanus*, *Vejdovskyella comata* and *Slavina appendiculata* preferred more or less dystrophic waters. *Lamprodrilus isoporus* and *Psammoryctides barbatus* preferred deep lakes, while *L. isoporus*, *Stylodrilus heringianus* and *P. barbatus* preferred lakes that were both deep and large.

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Previous studies on the Oligochaeta of Finnish lakes mainly concern littoral species (Laakso 1967), but several recent studies also deal with the occurrence of profundal species (Särkkä 1968, Laakso 1969, Mölsä 1974, Jumppanen 1976) or with their quantitative distribution (Särkkä 1972a, 1972b). Little is yet known about the ecological requirements of the species. The taxonomic papers by Sperber (1948, 1950) and Brinkhurst & Jamieson (1971) contain little ecological information. Cekanovskaya (1962, 1965) briefly described the habitats of most North European species. Timm's (1970) paper contains only a few observations on the profundal of deeper lakes. Milbrink (1973) summarized the knowledge of Tubificidae and Lumbriculidae as indicators of pollution. Särkkä (in preparation) and Särkkä & Aho (in preparation) have made quantitative studies on the ecology of several species found in the littoral and profundal.

The present paper is based on samples taken mostly in connection with sampling of relict crustaceans (Särkkä 1976), mostly by qualitative methods. The National Board of Waters now publishes hydrographic data on the water quality of nearly all Finnish lakes, thus providing a good basis for assessing the relative importance of some of the major environmental factors.

1. Material and methods

Samples were taken with an aluminium net trawl resembling the Ockelman dredge (Särkkä 1976), with a quadrangular dredge or with an Ekman-Birge sampler (Table 1). The mesh of the sieve was 0.4 or 0.54 mm. Samples were taken in and around the deepest parts of each lake or basin (Fig. 1). The lakes were sampled in 1973—1977, except Päijänne (1969—1972) and Konnevesi (1970). The samples comprised about 3650 individuals of Oligochaeta. Hydrographic data were obtained from the National Board of waters (Vesihallitus 1977 and other publications, see Särkkä 1976), a minor part also from the Water Board of Central Finland.

2. Results

Data on the distribution and numbers of the species collected, with information on the lakes and their hydrography are given in Table 1. The hydrographic data presented are considered sufficient to indicate the trophic state and degree of eutrophication or pollution. The

Table 1. The occurrence of different species in different lakes or basins and the hydrographic data. × = dominant, + = present, – = absent. [1] Eutrophicated mainly by domestic sewage, * polluted by chemicals from the wood-processing industry. Sampling equipment: E = Ekman sampler, D = dredge and S = sledge.

		Lampr. isop. Mich. f. *variabilis* Sv.	*Stylodrilus heringianus* Claparède	*Chaetogaster diaphanus* (Gruithuisen)	*Uncinais uncinata* (Oersted)	*Nais pseudobtusa* Piguet	*Slavina appendiculata* d'Udekem	*Vejdovskyella comata* (Vejdovsky)	*Arcteonais lomondi* (Martin)	*Stylaria lacustris* (L.)	*Dero digitata* (Müller)	*Tubifex tubifex* (Müller)	*Limnodrilus hoffmeisteri* Claparède	*L. udekemianus* Claparède	*Psammoryctides barbatus* (Grube)	*Potamothrix hammoniensis* Michaelsen	*Peloscolex ferox* (Eisen)	Depth, m	Oxygen saturation % (see text)	Colour of water, mg Pt/l	Total phosphorus, mg/m^3	Area of lake, km^2	Sampling equipment	Number of individuals collected
1	Armisvesi	–	+	–	–	–	–	–	–	–	–	×	–	–	–	–	×	35	65	21	10	24	S	67
2	Hauhanjärvi	+	+	–	–	–	–	–	–	–	–	×	–	–	–	–	×	32	41	43	13	9	E, S	111
3	Iisvesi	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	35	23	32	8	66	S	5
4	Jäppäjärvi	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	+	11	43	200	25	3	S	5
5	Karankajärvi	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	×	20	11	180	30	9	S	18
6	Keitele, northern part	+	–	–	–	–	–	–	–	–	–	–	–	–	+	–	×	65	47	28	4		S	18
7	–»– central part	+	+	–	–	–	–	–	–	–	–	×	+	–	–	–	×	40	50	29	5	478	E, D	323
8	–»– Suolahti[1]	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	+	21	0	90	20		E, D	130
9	Keurusselkä	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	×	30	30	70	7	114	S	10
10	Kivijärvi	+	+	–	–	–	–	–	–	–	–	×	–	–	+	–	×	41	36	65	6	149	E, S	80
11	Koivujärvi	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	12	21	50	20	26	S	11
12	Kolima	+	×	–	–	–	–	–	–	–	–	+	–	–	+	–	×	59	65	49	6	100	S	49
13	Konnevesi	×	+	–	–	–	–	–	–	–	–	+	–	–	+	–	×	49	70	29	7	187	E, S	60
14	Kuuhankavesi	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	+	22	47	26	20	16	S	8
15	Kynsivesi	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	46	49	23	5	53	S	40
16	Kyyjärvi	–	–	–	–	–	×	+	–	+	–	×	–	–	–	+	+	16	3	270	15	16	E, S	70
17	Kyynämöinen	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	12	40	135	25	5	S	5
18	Leppävesi	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	+	40	9	248	10	62	E	20
19	Lievestuoreenjärvi*	–	–	–	+	–	–	–	–	–	+	×	+	–	–	–	+	41	0	175	29	40	E, D	22
20	Muuratjärvi	×	+	–	–	–	–	–	–	–	–	+	–	–	–	–	×	43	14	45	7	32	E, D, S	414
21	Pielavesi	–	+	–	–	–	–	–	–	–	–	+	–	–	–	–	×	27	64	37	9	110	S	9
22	Pihlajavesi	–	–	–	+	–	–	+	–	–	–	×	–	–	–	–	×	15	60	100	24	19	E, S	7
23	Päijänne, northern part	–	+	–	–	–	–	+	–	–	–	×	+	–	–	–	+	76	50	95	30		E, S	637
24	–»– central part*	–	–	–	–	–	–	–	–	–	+	×	+	–	–	–	–	40	40	90	25	1100	E, S	65
25	–»– southern part	+	×	–	–	–	–	–	–	–	–	+	–	–	+	–	×	69	85	45	9		E, S	290
26	Pääjärvi	–	+	–	–	–	–	–	–	–	–	×	–	+	–	–	+	15	20	180	31	31	S	32
27	Rutajärvi	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	×	10	93	45	17	12	S	4
28	Saarijärvi	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	+	25	20	128	10	14	E, D, S	75
29	Sinerväjärvi	–	–	+	–	–	–	+	–	–	–	×	–	–	–	–	+	31	59	135	10	4	S	53
30	Summasjärvi	–	–	–	–	–	–	–	–	–	–	×	–	–	–	–	+	41	28	81	20	22	S	6
31	Suontee	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	22	38	13	7	175	S	14
32	Suonteenselkä	×	+	–	–	–	–	–	–	–	–	+	–	–	–	–	×	74	52	33	10	63	S	21
33	Toisvesi	–	×	–	–	–	–	–	–	–	–	–	–	–	+	+	×	68	75	125	20	32	E, D	105
34	Vesijärvi, northern part[1]	–	–	–	–	–	–	–	–	–	–	+	–	–	–	×	–	34	12	34	20	68	E	778
35	–»– southern part[1]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	×	–	29	5	84	90	38	E	68
36	Ylä-Kintausjärvi	–	–	+	–	+	–	+	–	–	–	×	–	–	–	–	×	17	55	100	11	6	S	20
	Total																							3650

winter oxygen status at the deepest place (measured in March 1 m above the bottom) usually represents the minimum oxygen content of the lake. The colour of the water chiefly reflects the humus content, but in polluted lakes it also depends on the content of iron or on the amount of waste water from wood-processing industries (lakes Nos. 8, 18, 19, 23, 24). Total phosphorus (measured in surface water in March) was chosen to denote the trophic state of the lakes. A "dominant species" is a subjective concept meaning the most abundant

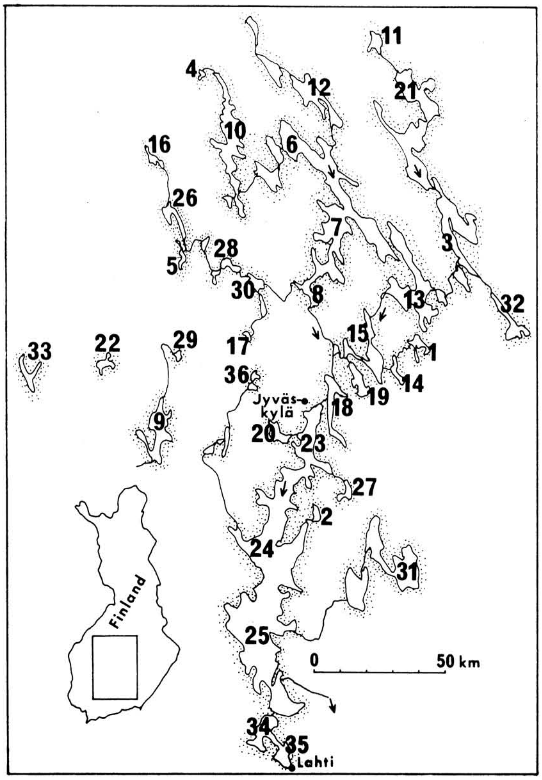

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Fig. 1. The lakes sampled and listed in Table 1.

species or one of the two most abundant species in each lake.

Table 2 shows the mean values for some environmental factors in localities where the most important species (four observations or more) were either dominant, present or absent. For each species the means of these classes were compared by the t test (Table 3). Although the lakes studied were not chosen at random, and although the samples were not equal in size, the method yields certain statistics for assessment of ecological differences between the species.

As Table 3 shows, *Lamprodrilus isoporus* and *Psammoryctides barbatus* prefer deep lakes. *Stylodrilus heringianus*, *P. barbatus* and *Peloscolex ferox* prefer a high oxygen content. *L. isoporus* prefers water of a light colour and *Tubifex tubifex* water of a dark colour. *L. isoporus* and *P. ferox* prefer a low content of total phosphorus and *Potamothrix hammoniensis* a high content. *L. isoporus*, *S.*

Table 2. The mean ($\bar{x}$), standard deviation (SD) and n (for depth, oxygen, colour and total phosphorus) for different environmental factors as classified for observations when the species in question were present, dominant or absent.

		Depth, m		Oxygen saturation %		Colour of water, mg Pt/l		Total phosphorus, mg P/m³			Area of lake, km²		
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1	*Lamprodrilus isoporus* present	52.4	14.8	51.1	20.7	40.7	12.2	7.4	2.8	9	265	368	8
2	dominant	55.3	16.4	45.3	28.6	35.7	8.3	8.0	1.7	3	94	82	3
3	absent	29.3	16.3	35.6	24.8	102.5	70.3	20.3	16.1	27	40	42	24
4	*Stylodrilus heringianus* present	48.3	19.4	52.9	21.0	61.2	46.0	12.5	8.9	13	193	313	12
5	dominant	65.3	5.5	75.0	10.0	73.0	45.1	11.7	7.4	3	411	598	3
6	absent	27.6	13.8	31.9	23.5	101.6	72.7	19.7	17.3	23	38	43	20
7	*Vejdovskyella comata* present	31.0	26.0	45.4	24.0	140.0	74.4	18.0	8.7	5	229	487	5
8	absent	35.7	17.7	38.5	24.9	78.5	62.4	16.9	15.9	31	72	96	27
9	*Tubifex tubifex* present	35.7	17.8	38.1	24.0	96.2	70.7	15.5	8.7	27	112	233	24
10	dominant	30.5	15.0	33.4	21.1	116.3	72.1	17.6	8.9	20	118	269	18
11	absent	33.2	22.3	43.4	27.2	53.2	40.8	21.8	26.7	9	51	54	8
12	*Limnodrilus hoffmeisteri* present	49.3	17.8	35.0	23.8	97.3	59.9	22.3	11.7	4	539	533	3
13	absent	33.3	18.3	40.0	24.9	85.8	68.2	16.4	15.4	32	51	52	29
14	*Psammoryctides barbatus* present	58.5	11.3	63.0	18.3	56.8	36.1	8.7	5.8	6	341	402	6
15	absent	30.0	16.8	34.7	23.1	93.1	70.0	18.8	15.8	30	40	41	26
16	*Potamothrix hammoniensis* present	36.8	22.2	23.8	34.4	128.3	101.6	36.3	35.9	4	38	22	4
17	absent	34.9	18.6	41.4	23.0	81.9	61.4	14.7	8.8	32	105	217	28
18	*Peloscolex ferox* present	35.2	19.5	41.3	24.4	88.6	69.0	14.6	8.5	33	99	211	30
19	dominant	37.3	20.1	49.3	22.0	59.0	43.0	11.8	7.5	22	132	246	21
20	absent	34.3	5.5	19.0	18.5	69.3	30.8	45.0	39.1	3	53	21	2
21	The total material	35.1	18.7	39.4	24.5	87.0	66.6	17.1	15.0	36	96	204	32

Table 3. The significance of the differences between the means for the environmental factors influencing the species presented in Table 2. Significances according to the t test: * = $P < 0.05$, ** = $P < 0.01$ and *** = $P < 0.001$. The numbers in the first column refer to the species listed in Table 2.

Difference between	Depth	Oxygen saturation	Colour of water	Total phosphorus	Area
1–3	–	–	*	*	* *
2–3	*	–	–	–	–
4–6	–	*	–	–	*
5–6	–	* *	–	–	* *
7–8	–	–	–	–	–
9–11	–	–	–	–	–
10–11	–	–	*	–	–
12–13	–	–	–	–	* * *
14–15	* * *	* *	–	–	* * *
16–17	–	–	–	* *	–
18–20	–	–	–	* * *	–
19–20	–	*	–	* * *	–

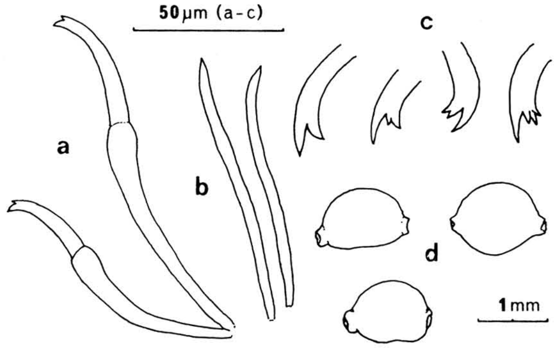

Fig. 2. Bundles of setae of *Stylodrilus heringianus* (a) and *Lamprodrilus isoporus* (b), tips of ventral setae of *Peloscolex ferox* (c) with and without intermediate teeth, and cocoons of *Peloscolex ferox* (d). All from Muuratjärvi.

heringianus, *Limnodrilus hoffmeisteri* and *P. barbatus* prefer large lakes.

The following survey summarizes the results for individual species and gives some comparative data. Some morphological features are also discussed.

Lumbriculidae

Lamprodrilus isoporus f. *variabilis*. Reported earlier from Päijänne by LAAKSO (1969) and also found by SÄRKKÄ & AHO (in preparation). The species is often found in the same samples as *Stylodrilus heringianus*, but can be distinguished from this by the following characters: Secondary annuli lacking, intersegmental furrows indistinct, surface smooth and glossy, external penes lacking, setae (Fig. 2) single-pointed and the nodulus not distinct, setae in a compact bundle (cf. CEKANOVSKAYA 1962, 1965). Mostly without genital organs, at least in summer. A very mobile species, which easily breaks into pieces (cf. TIMM 1970). One of the dominant species in the profundal of Lake Ladoga and Lake Onega, U.S.S.R., where it also lives in the littoral (CEKANOVSKAYA 1965). In Estonia TIMM (1970) found it only in shallow waters. I found the species in Päijänne at 1.5 m depth. Lumbriculidae spp. reported by SÄRKKÄ (1972a) from the deepest parts of Konnevesi also belong to *L. isoporus*.

Stylodrilus heringianus. The preference for large lakes rich in oxygen agrees with the observations of MILBRINK (1973) and SÄRKKÄ & AHO (in prep.).

Naididae

Naidids are found in the profundal only occasionally, but the following observations deserve mention.

Chaetogaster diaphanus. Two observations from dystrophic lakes. STIMPSON *et al.* (1975) found this species at 12 m depth.

Slavina appendiculata. Found in great numbers in Kyyjärvi, a shallow, dystrophic lake. CEKANOVSKAYA (1965) regarded this species as characteristic of *Sphagnum* bogs, so possibly it prefers brown waters.

Vejdovskyella comata. A slight but not significant preference for dystrophic waters (Tables 2—3). Also reported by CEKANOVSKAYA (1965) as living mostly in boggy waters.

Dero digitata. The finds from two sites indicate a preference for waters polluted with pulp mill wastes.

Tubificidae

Tubifex tubifex. Only the colour of the water seemed to affect the occurrence of this species (Table 3), which is much more common than *Potamothrix hammoniensis*. This agrees with MILBRINK's (1973) view that *P. hammoniensis* is characteristic of eutrophic lakes, whilst *T. tubifex* is a major component of large oligotrophic lakes. If the limit between oligotrophy and eutrophy is drawn at *ca* 20—25 µg P/l, the lakes dealt with in the present study are mostly oligotrophic. SÄRKKÄ & AHO (in preparation) also observed that *T. tubifex* prefers oligotrophic lakes, but it is difficult to assess its relation to the variables describing water quality. If the material is limited or consists of young individuals only, this species may be difficult to distinguish from *Potamothrix hammoniensis*.

Limnodrilus hoffmeisteri. The preference for large lakes (Tables 2 and 3) may be due to the presence of large collections from Keitele and Päijänne. In the profundal, especially at depths of 20 m or more, it is accidental (SÄRKKÄ & AHO, in prep., SÄRKKÄ, in prep.). As it occurs in oligotrophic lakes as well, although sparsely (e.g. SÄRKKÄ 1972a), its preference for eutrophic waters (e.g. MILBRINK 1973) does not appear clearly in material collected qualitatively.

Psammoryctides barbatus prefers large, deep lakes with a high oxygen content (Tables 2 and 3). The same was observed by SÄRKKÄ & AHO (in prep.). However, it is also found in small forest lakes (SÄRKKÄ 1968, cf. also VALLE 1927). In large lakes the species is not dominant, but occurs with others, e.g. *Peloscolex ferox*, *Tubifex tubifex* and *Stylodrilus heringianus*.

Potamothrix hammoniensis. Found only in four lakes. Total phosphorus was the only variable with a significant influence on this species (Table 3). Its optimum habitats seem to be shallow lakes which are either eutrophic or polluted (SÄRKKÄ & AHO in prep., MILBRINK 1973). Rarely occurs with *Tubifex tubifex*. The preference of *P. hammoniensis* for slow currents (CEKANOVSKAYA 1965) may partly explain the differences in distribution between these two species in lake channels.

Peloscolex ferox preferred oligotrophic lakes rich in oxygen (Tables 2 and 3), but its presence in nearly all the lakes investigated shows that this species is eurytopic.

Some or all of the ventral setae of full-grown individuals often have 3—5 branches, i.e. 1—3 intermediate teeth (Fig. 2), especially in the larger lakes (nos. 1, 5, 10, 12, 13, 17, 20, 25, 27, 28). The cocoons of *P. ferox* are easy to distinguish from those of *Tubifex tubifex*, *Potamothrix hammoniensis* and *Stylodrilus heringianus*: their hard shell is white or grey, and often somewhat asymmetric; it seems to be calcareous, whereas in the other species mentioned it is chitinous and elastic, and different in shape (see TIMM 1970). The old empty cocoons seem to remain on the bottom for some time.

3. Discussion

Of the possible sources of error the following should be mentioned. Different sampling procedures give somewhat different results. Thus, for instance, sampling with a sledge or dredge sometimes yielded more Lumbriculids than Tubificids, whereas the latter were more abundant in Ekman dredge samples. Secondly, the samples from different lakes were not equal in size, and a greater number of individuals usually also contained more species. Thirdly, in qualitative samples the sampling depth cannot be determined exactly, so meta- or epilimnetic material may sometimes have contaminated the hypolimnetic samples. The shallowest lakes have no profundal proper. Finally, errors in identification are possible, particularly if the Tubificids are small and immature. Further investigations of profundal depths may still reveal some of the species found by MILBRINK (1973) in Sweden, such as *Tubifex ignotus* and *Ilyodrilus templetoni*. It seems, however, that the Ponto-Caspian species (MILBRINK 1973) *Potamothrix heuscheri*, *P. vejdovskyi*, *P. moldaviensis* and *P. bedoti*, which seem to be extending their range, do not occur in Finland.

Lamprodrilus isoporus is obviously more common in Finnish lakes than has hitherto been assumed and, like *Stylodrilus heringianus*, *Psammoryctides barbatus* and *Peloscolex ferox*, can be regarded as a typical indicator of oligotrophy if preferences for a high content of oxygen and a low content of total phosphorus are accepted as criteria of oligotrophy. *Peloscolex ferox* is eurytopic, however, and *Tubifex tubifex* is not strict in its requirements, whereas *Potamothrix hammoniensis* seems to be a typical indicator of eutrophy.

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