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CHIRONOMID LARVAE (DIPTERA, CHIRONOMIDAE) AS INDICATORS OF WATER QUALITY IN ESTONIAN STREAMS

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Abstract. Of the 184 taxa of chironomid larvae, recorded from Estonian running waters in 1987–97, a total of 26 proved to be related to water quality as measured by biological oxygen demand (BOD_5). Out of these 26, the following 18 taxa of larval chironomids were identified at the species level: *Paramerina cingulata* (Tanypodinae); *Diamesa carpatica*, *Pseudodiamesa nivosa* (Diamesinae); *Odontomesa fulva* (Prodiamesinae); *Acricotopus lucens*, *Corynoneura scutellata*, *Cricotopus sylvestris*, *Eukiefferiella brevicalcar*, *Nanocladius bicolor*, *Paracladius conversus*, *Synorthocladius semivirens*, *Tvetenia calvescens*, *T. discoloripes* (Orthocladiinae); *Chironomus cingulatus*, *Ch. plumosus*, *Glyptotendipes glaucus*, *G. gripekoveni*, and *Microtendipes rydalensis* (Chironomini). Methodological problems related to division of indicator species between saprobic classes and to the arrangement of these species within saprobic classes are discussed considering presence/absence data.

Key words: chironomid larvae, BOD_5, water quality, indicators, streams, Estonia.

INTRODUCTION

Larvae of the dipteran family Chironomidae have been considered the most promising indicators of water quality among freshwater macroinvertebrates because of their very high species richness and ecological specificity. Some 100 species of larval chironomids, mainly from Central Europe, have been incorporated in the saprobic system (Wegl, 1983; Margreiter-Kownacka et al., 1984; Golubeva, 1988).

However, the use of the saprobic system in monitoring declined already in the 1980s (Washington, 1984). As the main drawbacks of the saprobic system, its inconvenience in practical use but also the fact that species lists and saprobic values are not applicable to other geographical localities have been pointed out (Hynes, 1974; Metcalfe-Smith, 1996).

The present paper deals with chironomid larvae collected from Estonian streams. The aim of the study was to find out chironomid species whose distribution is related to the level of biological oxygen demand (BOD_5) in water, one of the most important variables in sanitary engineering.

MATERIAL AND METHODS

Chironomid larvae collected from 444 sites of 173 Estonian streams were studied in 1987–97 (Seire, 2000). The material for the present paper was drawn from the 389 sites of 155 streams where BOD_5 was measured in 1989 and in 1991–97 (Fig. 1). Six streams and 28 sites were studied twice, the interval between the studies being five or seven years. The list of the investigated streams with the indication of the year(s) of study is given in Seire (2000).

The material comprises 416 measurements of BOD_5 and 441 samples of the macrofauna, of which 416 are qualitative samples and the remaining 25, quantitative samples. BOD_5 data were evaluated by Peeter Pall, chironomid larvae were collected and identified by Ado Seire. All 184 taxa of chironomid larvae registered from Estonian streams in 1987–97 (Seire, 2000), except for *Diamesa stylata* Chernovskij and *Glyptotendipes imbecilli* Walker, were subjected to analysis. These two species were absent from all 389 sites discussed in the present paper.

The study was based on the presence/absence data for larval chironomid taxa at the sites. In case a taxon occurred twice at the same site, both measurements of BOD_5 were taken into consideration. The field and laboratory procedures used for chironomid research are described in Seire (2000).

Water quality was estimated according to BOD_5 values employing the saprobity scale by Sládeček (1973): <1.0 mgO_2/L xenosaprobic, 1.0–2.4 mgO_2/L oligosaprobic, 2.5–4.9 mgO_2/L β-mesosaprobic, 5.0–9.9 mgO_2/L α-mesosaprobic, and >10.0 mgO_2/L polysaprobic. The Kruskal–Wallis ANOVA test was used to find out whether the distribution of a certain taxon was related to the BOD_5 values of water. BOD_5 values for the river reaches where the taxon was present were compared with those from where it was absent. In case the test result was statistically significant ($p < 0.05$), it was considered that BOD_5 had an effect on the distribution of the relevant taxon.

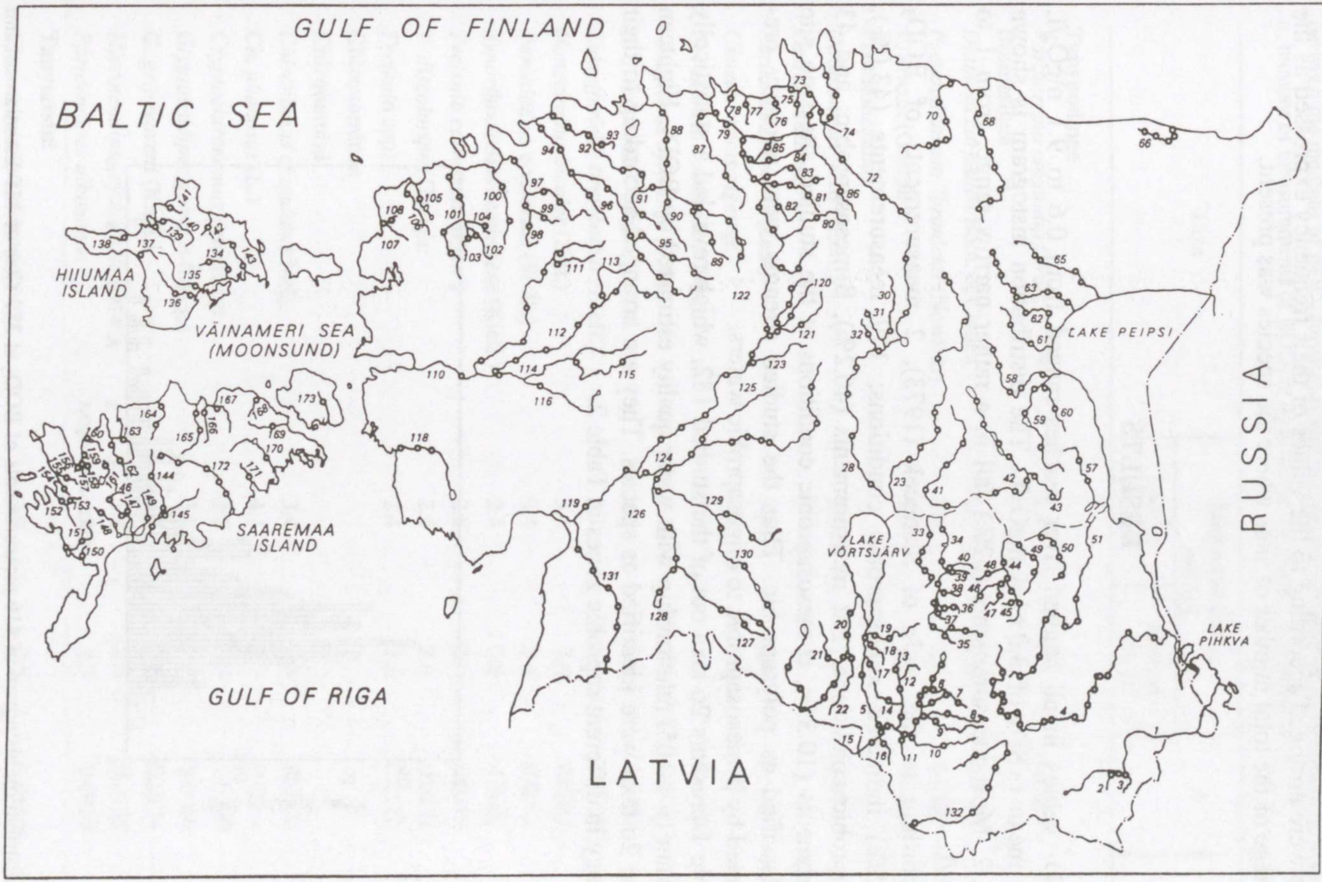

Fig. 1. The 389 sites of 155 Estonian streams selected for sampling in 1989 and in 1991–97. The numbers indicate the names of the investigated streams, given in Seire (2000).

The species was considered to prefer the saprobic zone where the number of its findings was higher than in the other saprobic zones. Within a saprobic zone, species were arranged according to the values of their frequency expressed as the percentage of the total number of sites where the species was present.

RESULTS

BOD_5 values in all studied river reaches ranged from 0.6 to 9.1 mgO_2/L with a mean (±SD) of 3.0±1.4 mgO_2/L. The distribution histogram is shown in Fig. 2. Most measurements (62%) fall in a rather narrow range, from 1 to 3 mgO_2/L.

According to the scale of Sládeček (1973), 2 measurements of BOD_5 (or 0.5%) indicated xenosaprobic conditions; 179 measurements (43.0%), oligosaprobic conditions, 192 measurements (46.2%), β-mesosaprobic; and 43 measurements (10.3%), α-mesosaprobic conditions at the studied sites; no site was classified as polysaprobic. Thus the studied streams were strongly predominated by β-mesosaprobic to oligosaprobic waters.

Table 1 presents 26 taxa out of the studied 182, which revealed a statistically significant ($p < 0.05$) relationship with water quality estimated by BOD_5. Eighteen of these 26 taxa were identified as species. They are arranged according to their frequency in different saprobic zones in Table 2.

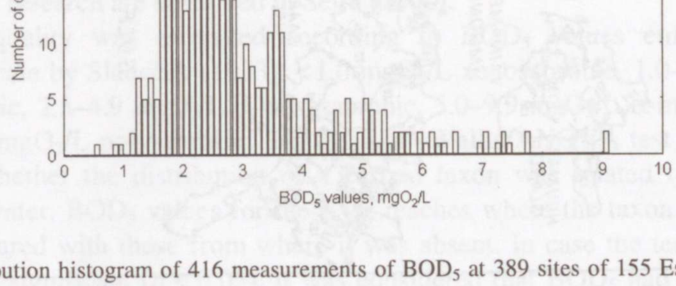

Fig. 2. Distribution histogram of 416 measurements of BOD_5 at 389 sites of 155 Estonian streams studied in 1989 and in 1991–97.

Table 1. List of larval chironomid taxa as related to water quality in Estonian streams on the basis of presence/absence data. BOD_5, biological oxygen demand; *p*, probability values of the differences between the medians of BOD_5 for sites where the species was present and from where it was absent; *n*, number of measurements of BOD_5 at sites where the species was present

Taxa	Median of BOD_5, mgO_2/L		*p*	*n*
	Species present	Species absent		
Tanypodinae				
Paramerina cingulata (Walk.)	2.4	2.7	0.0285	111
Diamesinae				
Diamesa carpatica Botn. et Cindea	2.3	2.6	0.0196	21
Pseudodiamesa ?branickii (Nowicki)	1.6	2.6	0.0407	2
P. nivosa (Goetgh.)	1.6	2.6	0.0137	5
Prodiamesinae				
Odontomesa fulva (Kieff.)	3.0	2.6	0.0137	63
Orthocladiinae				
Acricotopus lucens (Zett.)	3.8	2.6	0.0020	18
Chaetocladius piger gr.	3.4	2.6	0.0481	16
Corynoneura scutellata Winn.	3.2	2.6	0.0378	19
Cricotopus sylvestris (Fabr.)	3.1	2.5	0.0015	50
C. ?vierriensis Goetgh.	3.5	2.6	0.0483	27
Eukiefferiella brevicalcar (Kieff.)	2.1	2.6	0.0002	43
Nanocladius bicolor (Zett.)	3.4	2.6	0.0051	16
Paracladius conversus (Walk.)	3.4	2.5	0.0011	49
Synorthocladius semivirens (Kieff.)	2.4	2.8	0.0086	173
Tvetenia calvescens (Edw.)	2.8	2.6	0.0364	67
T. discoloripes Goetgh.	2.4	2.6	0.0103	62
Tvetenia spp.	2.4	2.6	0.0123	58
Chironominae				
Chironomini				
Chironomus cingulatus Meig.	3.4	2.6	0.0070	23
Ch. plumosus (L.)	4.1	2.6	0.0064	7
Cryptochironomus defectus gr.	2.9	2.5	0.0190	66
Glyptotendipes glaucus (Meig.)	3.9	2.6	0.0080	10
G. gripekoveni (Kieff.)	5.3	2.6	0.0174	4
Microtendipes rydalensis (Edw.)	1.9	2.6	0.0195	7
Paratendipes albimanus gr.	2.7	2.5	0.0059	135
Tanytarsini				
Cladotanytarsus mancus gr.	2.9	2.5	0.0118	96
Paratanytarsus spp.	3.6	2.6	0.0058	20

Table 2. Frequency of larval chironomid species in Estonian streams in 4 different ranges of BOD_5. Frequency is expressed as a percentage of the total number of BOD_5 measurements at sites where the species was present (*n*). x, xenosaprobity; os, oligosaprobity; β-ms, β-mesosaprobity; α-ms, α-mesosaprobity

Species	BOD_5, mgO_2/L				*n*
	<1 (x)	1–2.4 (os)	2.5–4.9 (β-ms)	5.0–9.9 (α-ms)	
Microtendipes rydalensis		**86**	14		7
Pseudodiamesa nivosa		**80**	20		5
Eukiefferiella brevicalcar		**63**	30	7	43
Diamesa carpatica		**57**	43		21
Tvetenia discoloripes		**53**	42	5	62
Paramerina cingulata	1	**50**	43	6	11
Synorthocladius semivirens	1	**50**	41	9	173
Tvetenia calvescens		37	**45**	18	67
Odontomesa fulva		35	**52**	13	63
Paracladius conversus		29	**53**	18	49
Acricotopus lucens		17	**61**	22	18
Chironomus cingulatus		17	**61**	22	23
Cricotopus sylvestris	2	24	**62**	12	50
Corynoneura scutellata		26	**63**	11	19
Glyptotendipes glaucus		10	**80**	10	10
Nanocladius bicolor		13	**81**	6	16
Chironomus plumosus			**86**	14	7
Glyptotendipes gripekoveni			**50**	**50**	4

DISCUSSION

The most important prerequisite for correct use of the saprobic system (*Saprobiensystem*) is quantitative sampling. However, in the case of the bottom fauna, especially in flowing waters whose spatial heterogeneity is very high, one is faced with a serious technical problem: the technique which is suitable for one species or habitat may be hopelessly biased for another (Chandler, 1970).

Modern methods of biological assessment of the pollution status of streams, based on the species composition of macroinvertebrates, make use of qualitative or semi-qualitative sampling with respect to presence and absence of selected species and/or data on their relative abundance (Friberg & Johnson, 1995; Metcalfe-Smith, 1996). In the case of this approach, lists of both indicator species and biotic indices are employed. The latter are usually developed on the basis of several groups of bottom animals; however, one can focus also on a single taxonomic group. Thus Bazerque et al. (1989) compiled a 'Chironomid Index' for running waters of Central Europe. First of all, it is necessary to establish the species of larval chironomids that are sensitive to water quality in streams.

Using the original method, we succeeded in isolating 26 chironomid taxa related to the water quality in Estonian streams. Eighteen of them were identified to the species, the remaining eight, to the genus. Six species out of the 18 (Table 1), *Eukiefferiella brevicalcar*, *Diamesa carpatica*, *Microtendipes rydalensis*, *Odontomesa fulva*, *Tvetenia calvescens*, and *T. discoloripes* occur, according to the literature (Hirvenoja, 1973; Illies, 1967; Pankratova, 1970, 1977, 1983; Pinder, 1976; Shilova, 1976; Sæther, 1977), only in running waters. The remaining 12 species inhabit both running and standing waters. Out of these eight, identified to the genus, larvae of *Tvetenia* are confined to running waters, whereas *Pseudodiamesa*, *Chaetocladius*, *Cricotopus*, *Cryptochironomus*, *Paratendipes*, *Cladotanytarsus*, and *Paratanytarsus* are found in various habitats of lentic and lotic water bodies as well (Wiederholm, 1983).

It is noteworthy that also in our material *Chironomus riparius*, registred by us at 17 sites, does not belong to the species positively correlated with organic pollution. Formerly (Thienemann, 1954; Hynes, 1974), *Chironomus riparius* (Meigen) (= *Ch. thummi* Kieffer) was regarded as the most typical indicator of organically polluted water. More recent studies, however, consider *Ch. riparius* an opportunistic species with a remarkably wide range of ecological tolerance, by no means restricted to polluted waters only (Pinder, 1986).

According to the saprobic system no single indicator species can be a representative of only one saprobic zone; its distribution will follow rather a normal curve over a range of zones reflecting its tolerance (Metcalfe-Smith, 1996). Yet, as demonstrated in the chironomid studies of Japanese rivers and lake littoral, several chironomid taxa may have a distribution range limited exclusively to a single saprobic zone, namely oligosaprobic waters (Kawai et al., 1989).

We did not succeed in finding in Estonian streams such chironomid species that are sensitive to water quality but occur in only one saprobic zone. Usually, sensitive species occurred in 2–4 saprobic zones, but, judging by the values of frequency, preferred one of these zones (Table 2).

Several larval chironomid species suggested by us as potential qualitative indicators of water quality are referred to in earlier pollution studies. However, in many cases their pollution ecology is not known. Of the seven species characteristic of oligosaprobic waters, *Microtendipes rydalensis* had the highest frequency (86%). Larvae of this midge were described only in 1976 (Pinder, 1976); adults of the species have been found in Great Britain, Germany, France, and Ireland (Ashe & Cranston, 1990). Data on the ecology of the larvae are not available in the literature. Larvae of *Pseudodiamesa nivosa* are considered to be crenophilous (Thienemann, 1954). Larvae of *Eukiefferiella brevicalcar* are inhabitants of cold-water rivulets (Pankratova, 1970); in mountain streams and rivers in Tyrol they prefer β-mesosaprobic waters (Margreiter-Kownacka et al., 1984). Larvae of *Diamesa carpatica* have so far been found in Roumanian rivers only (Pankratova, 1970). In two oligosaprobic mountain trout streams in former Czechoslovakia one of the characteristic species was *Tvetenia discoloripes* (Losos, 1984). Larvae of *Paramerina cingulata* are eurythermic (Pankratova, 1977), in the Netherlands their presence is regarded as indication of high water quality (Moller Pillot & Buskens, 1990). In Tyrol, larvae of *Synorthocladius semivirens* prefer oligosaprobic waters (Margreiter-Kownacka et al., 1984), while in rivers of Central Russia a slight preference of the β-mesosaprobic zone was reported (Golubeva, 1988).

Out of the ten representatives of larval chironomid species suggested by us as qualitative indicators of the β-mesosaprobic zone, the larvae of *Tvetenia calvescens* in Tyrol were characteristic of oligosaprobic and β-mesosaprobic waters, with a slight preference of the former (Margreiter-Kownacka et al., 1984). In the River Trent (England) larvae of *Tvetenia calvescens* dominated in stations with clean water and a diverse fauna (Wilson, 1987). Larvae of *Odontomesa fulva* inhabit mostly cold-water streams (Pankratova, 1970), in the Netherlands they belong to indicators of high water quality (Moller Pillot & Buskens, 1990). In flowing waters of the Netherlands, larvae of *Paracladius conversus* are known to tolerate slight organic pollution, while in standing waters their presence is interpreted as indication of very high water quality (Moller Pillot & Buskens, 1990). Larvae of *Acricotopus lucens* inhabit primarily cold-water ponds and rivulets (Pankratova, 1970). Larvae of *Chironomus cingulatus* have not been referred to in pollution studies until now. Presence of *Cricotopus sylvestris* in recovery regions of organically polluted rivers was observed by Thienemann (1954); the same phenomenon was reported by Davies & Hawkes (1981) from the River Cole (England). No literature data are available on the pollution ecology of *Corynoneura scutellata*, *Glyptotendipes glaucus*, and *Nanocladius bicolor*. Being a quantitative indicator, *Chironomus plumosus* is a typical polysaprobe (Wegl, 1983).

No species was found to have a maximum frequency in the α-mesosaprobic zone. Compared with other species this zone appeared to be inhabited more frequently by *Glyptotendipes gripekoveni*, but the larvae of this species displayed the same value of occurrence (50%) also in the β-mesosaprobic zone.

It should be stressed, however, that boundaries between the species groups given in Table 2 should be regarded as a highly tentative attempt to outline a gradation of chironomid larvae from clean-water species to pollution favouring midges. The main reason for such a reservation is the lack of samples from polysaprobic waters in our material. From the methodical point of view it would have been better if all saprobic zones had been represented equally in the study. However, fulfilment of this precondition was not possible, as the initial data for the present paper did not originate from pollution-oriented studies but were the by-product of a more comprehensive research programme on the inventory of the biota of Estonian running waters. The programme focused on more or less naturally clean waters and neglected severely polluted sites.

However, water quality is not the only ecological factor that controls the distribution patterns of chironomid larvae in running waters. Another well-known key factor that determines the presence/absence as well as the community composition of larval chironomid species in aquatic biotopes is water temperature (Thienemann, 1954; Rossaro, 1991). Also, flow regime, nature of the substratum, availability of food, and impact of other animals are mentioned in this connection (Pinder, 1986; Armitage et al., 1995).

Our aim was to delineate a range of larval chironomid species whose more detailed investigation, including performance of rearing experiments under various sets of ecological conditions, would be perspective in search for larvae of midges that could be applied in the study of the water quality of Estonian streams.

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HIRONOMIIDIVASTSED (DIPTERA, CHIRONOMIDAE) KUI VEE KVALITEEDI INDIKAATORID EESTI JÕGEDES

Ado SEIRE ja Peeter PALL

Eesti vooluvetes aastatel 1987–97 leitud 184-st hironomiidivastsete taksonist 26 levikut mõjutavaks teguriks osutus vee kvaliteet väljendatuna biokeemilise hapnikutarbe kaudu. Neist 26-st õnnestus liigini määrata 18 hironomiidivastse taksonit: *Paramerina cingulata* (Tanypodinae), *Diamesa carpatica*, *Pseudodiamesa nivosa* (Diamesinae), *Odontomesa fulva* (Prodiamesinae), *Acricotopus lucens*, *Corynoneura scutellata*, *Cricotopus sylvestris*, *Eukiefferiella brevicalcar*, *Nanocladius bicolor*, *Paracladius conversus*, *Synorthocladius semivirens*, *Tvetenia calvescens*, *T. discoloripes* (Orthocladiinae), *Chironomus cingulatus*, *Ch. plumosus*, *Glyptotendipes glaucus*, *G. gripekoveni* ja *Microtendipes rydalensis* (Chironomini). Nimetatud 18 bioindikatsiooniks sobivat liiki on jaotatud saproobsusklassidesse ja järjestatud klassisiseselt originaalmetoodika alusel.