CHIRONOMIDAE (DIPTERA, NEMATOCERA) FAUNA IN THREE SMALL STREAMS OF SKANIA, SWEDEN

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Abstract. Two unpolluted streams and one chemically and thermally polluted stream in Skania, Sweden, were investigated in summer 1995 for their temporary chironomid fauna and the occurrence of buccal deformities. The unpolluted streams 'Övedsan' and 'Skäralidbäcken' each contained, respectively, 13 and 16 taxa, with a dominance of *Microtendipes pedellus* group and *Micropsectra* spp., respectively. Most taxa were found in the pebbles and the submerged vegetation. Deformities were insignificant. The degraded stream Ybbarpsan in Perstorp contained 5 taxa, dominated by *Procladius choreus*. This species had 14% deformed larvae, interpreted as an effect of the chemical pollution. Shannon H and equitability J reflected the differences in chironomid community structure between the two unpolluted and the polluted sites. The Belgian Biotic Index scored maximally '10' in Skäralid, however only '6' in Öved and '5' in Perstorp. The combination of rapid assessment of macrobenthos and description of communities of Chironomidae, with mention of deformed larvae, adds a bonus of information about the temporary state of a stream.

Keywords: biomonitoring, Chironomidae deformities, community, *Procladius*, stream pollution, Sweden

1. Introduction

The use of communities of Chironomidae in describing and monitoring lotic systems still lacks much inferring power, due to a lack of knowledge on the ecological niches and the distribution of many chironomid species (Lindegaard, 1995). The presence of deformed individuals amongst chironomid larvae indicates toxic stress (Janssens de Bisthoven, 1999). Therefore, their inclusion in community assessment adds inferring power to assess ecosystem health (Diggins and Stewart, 1998). The advantages and limitations of combining faunistic description and deformity rates in chironomid larvae ought to be better documented and understood.

In biomonitoring with deformities, the focus is mainly on deformities in single species or species groups of *Chironomus* (Chironominae) or *Procladius* (Tanypodinae), typical for eutrophic conditions (in North America: e.g. Warwick, 1985; Dermott, 1991; Warwick, 1990; Lenat, 1993), or for lowland streams and rivers (in Europe: e.g. Van Urk *et al.*, 1992; Janssens de Bisthoven *et al.*, 1992, 1995; Vermeulen, 1998). Both taxa are benthic and morphologically sensitive to contaminant

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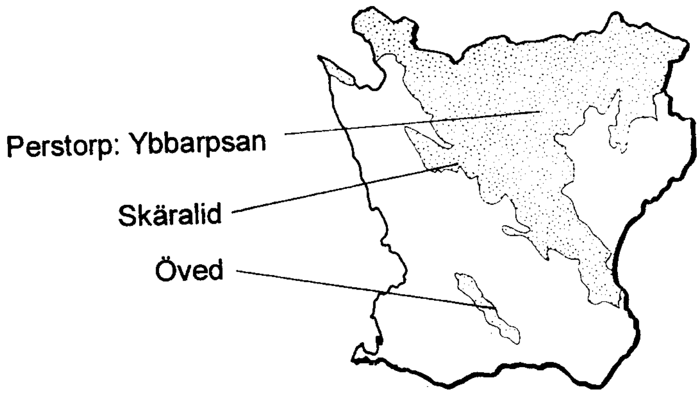

Figure 1. Location of the sites in Skania, Sweden. The dark areas represent ancient bedrock geology, the white areas, recent sediments.

stress and *Chironomus* often occurs in high densities below organically rich sewage effluents. However, experience in Belgian lowland rivers shows that these ecosystems which might be affected by anthropogenic stress, in 40% of the cases do not have the adequate ecological conditions and hence lack sufficient numbers of these two indicator taxa (Janssens de Bisthoven, 1999). Ideal conditions should include silty organically enriched substrate (Gower and Buckland, 1978; Ferrington and Crisp, 1989; Janssens de Bisthoven *et al.*, 1995).

Therefore, there is a strong need to investigate other chironomid taxa for possible use in community assesment in combination with deformity screening (Hudson and Ciborowski, 1996), in order to fully cover the potential offered by this very species-rich insect family. It is equally important to document and understand possible intrinsic dependencies between community structure and the presence of 'deformity-indicators' or morphologically sensitive species in that community.

Attempts to work on deformities of a variety of chironomid taxa have been undertaken in North America (e.g. Warwick and Tisdale, 1988; Bird, 1994; Dermott, 1991; Dickman and Rygiel, 1996; Diggins and Stewart, 1993), and in Kenya (Janssens de Bisthoven and Van Speybroeck, 1994). In Europe, studies exist on subfossils from the great lakes of Sweden (Wiederholm, 1984), on stream-inhabiting midges in the U.K. (Ashton, 1998) and on *Prodiamesa olivacea* of small streams, which was investigated in NW-Spain (Servia and Gonzales, 1998).

The aim of the present study was to describe the temporary larval chironomid fauna (Diptera: Chironomidae) in different habitats of three small streams of Skania (Southern Sweden): one was an unpolluted lowland stream, one an unpolluted highland stream and one was a polluted highland stream. Community metrics were compared with the scores obtained from the Belgian Biotic Index, which is a rapid assessment method for macrobenthos (De Pauw and Vanhooren, 1983), and complemented with observations of morphological deformities in chironomid larvae.

2. Materials and Methods

2.1. Site Characterization

Samples were taken in July and August 1995 (Figure 1). Macroinvertebrates were collected in 3 small aquatic systems in Skania (Sweden). The sites were chosen for their small scale, lotic character, location, land use and the existing information about their characteristics (Gerhardt, 1996; Gerhardt *et al.*, 1998; Gerhardt, unpubl. data) (Table I).

The first site was the humic second order stream 'Ybbarpsan' flowing through hills covered with mixed forest (4 m wide, up to 2 m deep). The riverbed was muddy or sandy substrate covered with detritus. Sand and detritus covered >80% of the river. Due to poor water transparency and the rather homogenous nature of the river bed, the mud-sand was taken as one habitat to be sampled. This sample was taken 200 m below a chemical factory (thermal pollution of 25 °C, heavy metals and organics) in Perstorp (Figure 1) and characterized by increased conductivity (250 μS cm^{-1}), P (199 μg L^{-1}) and N (2 mg L^{-1}) (Gerhardt, 1996).

The second site was the unpolluted first order highland stream, 'Skäralidbäcken' (3–4 m wide, <0.8 m deep), flowing through *Fagus sylvatica* forest in the Skäralid nature reserve, where 4 types of habitats were clearly distinguished: pool (20%), gravel (20%), pebbles (60%) and 'submerged plants', including mostly moss, which made up 20% of the total surface.

The third site was a relatively unpolluted lowland first order tributary of the River 'Övedsan' (up to 5 m wide, <1 m deep), with slightly alkaline pH and NO_3 loads of 350 mg L^{-1} (Gerhardt, 1996), draining mixed agricultural and forest land. Three different habitats were distinguished: fine sediments (60%), submerged plants (10%, mostly filamentous algae) and pebbles (30%).

TABLE I

Chemical characteristics of the locations

Parameter		Location		
		Skäralid	Öved	Ybbarpsan
pH		6.0–6.8[b]	8.1	6.4
Al	(mg L^{-1})	0.2	<0.01	0.1
Fe	(mg L^{-1})	0.8	0.5	0.3
Cu	(mg L^{-1})	0.002[a]	0.07	0.01
Pb	(mg L^{-1})	0.001[a]		0.02
Zn	(mg L^{-1})	0.03	0.004	0.03

Data after Gerhardt (1996).
[a] Gerhardt *et al.* (1998).
[b] Gerhardt, unpublished.

2.2. SAMPLING

The sampling protocol for gravel, sand, mud or detritus consisted of sweeping through the substrate with a 250 μm meshsize handnet over a distance of 15 m for 15 min. Submerged plants were taken in 5 L buckets in Öved (filamentous algae) and Skäralid (moss) and were taken to the laboratory for screening under the binocular stereo-microscope at 10–40× magnification. Macroinvertebrates were also collected with soft brushes from the under-surfaces of 10 pebbles (including periphyton and micro-algae) situated in riffles (pebble length 10–20 cm × thickness 5–15 cm). Samples were fixed in 4% formalin, stored in 70% ethanol and coloured with rose of bengal.

2.3. CHIRONOMIDAE

In the case of 'Skäralid plants' and 'Öved sediment', >300 larvae were present at first visual estimation, therefore subsamples were taken as 1/2 of the original samples to pick out larvae. All Chironomidae larvae were picked out under binocular microscope from the (sub)samples, in order to calculate relative abundances. Chironomidae larvae were identified to genus level and in some cases to species level, according to the keys in Wiederholm (1983). Small early instars, small Orthocladiinae and other small larvae were left as 'unidentified larvae'. The larvae of *Procladius* from Ybbarpsan were left to emerge to imagines in the laboratory (Gerhardt and Janssens de Bisthoven, 2000). They were identified according to Langton (1991) for the pupal exuviae and to Pinder (1978) for the male imagines as *Procladius choreus*. In Skäralid two unidentified larvae of *Polypedilum* species occurred. The *Polypedilum* sp. 2 found in the gravel differed from the larvae of *P.* sp. 1 found in the submerged plants by a bifid medial mentum tooth flanked on both sides by a smaller tooth, compared to a simple bifid medial mentum tooth in *P*. sp. 1. The Shannon Index H (based on natural ln), the Index of Equitability J and the number of taxa S were calculated for the Chironomidae in each sample according to Begon *et al*. (1986).

All chironomid head capsules were mounted for light microscopical identification. Larvae smaller than 5 mm were mounted *in toto.* The head capsules were mounted ventral side up and squeezed under a cover slip until maximum visibility of antennae, mentum (ligula for the Tanypodinae) and mandibles was achieved. These three structures were systematically screened for morphological deformities. Any anomaly resulting from mounting or natural mechanical damage was excluded. We refer to Janssens de Bisthoven and Ollevier (1989) for a discussion on mechanical damage. Deformity frequencies were calculated as the relative number of deformed larvae for a given taxon per sample.

2.4. Macroinvertebrates

Macroinvertebrates were recorded as presence/absence data in the samples, all habitats pooled and were identified mostly to family or genus level, from the keys of the Freshwater Biological Association and De Pauw and Vannevel (1991). These data allowed for calculation of the Belgian Biotic Index (BBI: worst quality = 0 to best quality = 10), according to De Pauw and Vannevel (1991). Given the fact that the present study focused on Chironomidae, the identification of macrobenthos was limited for the calculation of the BBI.

2.5. Statistics

In order to explore the inter- and intra-site variability of the chironomid fauna, a Multidimensional Scaling was performed on a Pearson correlation matrix between chironomid frequencies per habitat, after arcsin($x^{1/2}$) transformation. Deformity frequencies were compared by Chi-square-test.

3. Results

3.1. Chironomidae community

In the *Skäralid* site, *Tvetenia* was clearly dominant in the submerged plants and the pebbles, while *Micropsectra* dominated the gravel and the pool habitats (Table II). Other taxa having some significance in Skäralid were *Micropsectra*, the unidentified larvae and *Thienemannimyia* in the plants, *Coryneura lobata* in the pebbles and *Paratendipes* in the pool.

In the stream in *Öved*, the three dominant taxa in decreasing order were *Microtendipes pedellus* group, *Eukiefferiella* sp., and *Tanytarsus* sp. In the plants, unidentified larvae were represented with 26.5%, followed by 6 other taxa with >6%. In the pebbles, larvae of *Eukiefferiella* sp., which may include *Chaetocladius* sp. or *Lymnophyes* sp., made up two thirds of the local chironomid fauna.

In the *Ybbarpsan* in Perstorp, the chironomid fauna was composed of 3 tanypodine taxa and 2 Orthocladiinae. The dominant taxon was *Procladius choreus*.

The site of Skäralid scored the highest for number of chironomid taxa and had a similar H as the site in Öved. In terms of equitability J, the submerged plants in Öved showed the best spreading of number of larvae over the different taxa without strong dominances (Table III). In both sites pebbles and submerged plants contained the most species. The site in Ybbarpsan showed the lowest H and J. The coefficients of variation for the means of H and J over the habitats (Table III) show that the chironomid community metrics were less dependent on habitat in Öved than in Skäralid. The species richness (number of taxa and H) and equitability (J) within the chironomid community ranked the sites in decreasing order as following: Skäralid, Öved and Ybbarpsan.

TABLE II

List of chironomid taxa ranked according to dominance per site and habitat. Number of larvae (N), relative abundance (%) in each habitat, number of deformed larvae (D)

	N	%	D
Ybbarpsan mud			
Procladius choreus	29	63	4
Psectrotanypus	12	26	1
Tanypodinae	3	6.5	
Heterotrissocladius marcidus	1	2.2	
Chaetocladius	1	2.2	
Skäralid pool			
Micropsectra sp.	50	86.2	1
Paratendipes sp.	4	6.9	
Coryneura lobata	1	1.7	
Symposiocladius lignicola	1	1.7	
Prodiamesa olivacea	1	1.7	
Unidentified larvae	1	1.7	
Skäralid plants			
Tvetenia sp.	49	41.9	
Micropsectra sp.	31	26.5	
Thienemannimyia sp.	13	11.1	
Unidentified larvae	13	11.1	
Coryneura lobata	7	6.0	
Polypedilum sp. 1	2	1.7	
Acamptocladius	1	0.9	
Orthocladius sp.	1	0.9	
Skäralid pebbles			
Tvetenia sp.	43	58.9	
Coryneura lobata	9	12.3	
Micropsectra sp.	5	6.8	
Rheopelopia	5	6.8	
Paralimnophyes sp.	4	5.4	
Microtendipes pedellus group	3	4.1	
Polypedilum sp. 1	2	2.7	
Paramerina sp.	2	2.7	

TABLE II
(continued)

	N	%	D
Skäralid gravel			
Micropsectra sp.	32	94.1	
Polypedilum sp. 2	1	2.9	
Paralimnophyes sp.	1	2.9	
Öved sediment			
Microtendipes pedellus group	81	62.3	
Tanytarsus sp.	39	30	
Unidentified larvae	10	7.7	
Öved plants			
Unidentified larvae	9	26.5	
Cricotopus C. trifascia	6	17.6	
Tanytarsus sp.	4	11.8	
Coryneura lacustris	4	11.8	
Micropsectra sp.	3	8.8	
Polypedilum sp.	3	8.8	1
Cricotopus C. bicinctus	2	5.9	
Microtendipes sp.	1	2.9	
Psectrocladius limbatellus group	1	2.9	
Öved pebbles			
Eukiefferiella sp.	62	60.2	1
Synorthocladius sp.	19	18.4	
Tanytarsus sp.	6	5.8	
Microtendipes sp.	5	4.9	
Unidentified larvae	5	4.9	
Coryneura sp.	4	3.9	
Rheocricotopus sp.	1	0.9	
Thienemannymyia sp.	1	0.9	

The estimation procedure of Multidimensional Scaling converged after 39 iterations and resulted in a cluster of all four Skäralid habitats plotted on the first axis between the values 0 and –1 and along the second axis between +0.1 and –0.4, a

TABLE III

Number of chironomid larvae in the sample (N), number of chironomid taxa (S), Shannon Index (H) and Index of Equitability (J) for the chironomid taxocoenoses in the different sites and habitats. $Def._1(n)$ = % deformed larvae in the most dominant taxon (number of screened larvae for that taxon), $Def._2(n)$ = idem for the next dominant taxa, number of macroinvertebrate taxa (Sm), Belgian Biotic Index (BBI), and dominant chironomid taxa

Site	Habitat	N	S	H	J	$Def._1(n)$	$Def._2(n)$	Sm	BBI	Dominant chironomid taxa
Ybbarpsan										
	Mud	46	5	0.72	0.45	13.8 (29)	1/12	9	5	*P. choreus, Psectrotanypus*
Skäralid								21	10	
	Pool	58	6	1.44	0.80	2 (50)	0/4			*Micropsectra*
	Subm. plants	117	8	1.51	0.73	0 (49)	0 (31)			*Tvetenia, Micropsectra*
	Pebbles	73	8	1.46	0.70	0 (43)	0/9			*Tvetenia, Coryneura lobata*
	Gravel	34	3	0.26	0.13	0 (32)	0/1			*Micropsectra*
Total		284	16	1.84	0.66	0.85 (118)	0 (92)			*Micropsectra, Tvetenia*
Coeff. of var.				52%	52%					
Öved								14	6	
	Sediments	130	3	0.85	0.77	0 (81)	0 (39)			*M. pedellus* gr., *Tanytarsus*
	Subm. plants	34	9	1.95	0.89	0/9	0/6,0/4,0/4,1/3			Unidentified larvae
	Pebbles	103	8	1.30	0.63	1.6 (62)	0 (19)			*Eukiefferiella, Synorthocladius*
Total		262	13	1.85	0.72	0 (86)	1.6 (62)			*M. pedellus* gr., *Eukiefferiella*
Coeff. of var.				40%	17%					

cluster of all three Öved habitats plotted along the first axis between –0.2 and +1.1 and along the second axis between 0 and –1, and the Perstorp site with coordinates (+1.3, +0.9).

3.2. Deformities

Only one out of 68 screened *Micropsectra* sp. larvae in Skäralid showed a deformed mandible (one inner tooth missing). In Öved, one larva out of three *Polypedilum* sp. from the submerged plants lacked an inner lateral mentum tooth, and one larva from 62 *Eukiefferiella* sp. from the pebbles had an amorphous mandibular apical end. In the Ybbarpsan site, 4 out of 29 *Procladius choreus* larvae were deformed: 2 with a reduced antenna and 2 with a hypopharyngeal pecten having an unusual number of teeth or a distorsion. Out of 12 larvae of *Psectrotanypus* sp., one displayed a ligula with an additional medial tooth. The site Perstorp had significantly more deformed larvae than the sites Öved and Skäralit (Chi-square > 5.6, $p < 0.03$).

3.3. Macroinvertebrates

The site in the '*Skäralidbäcken*' contained the highest number of macroinvertebrate taxa and scored the best BBI, followed by Öved and Ybbarpsan (Table III). Especially Plecoptera (Leuctridae), Ephemeroptera (Baetidae, Heptageniidae) and Trichoptera (5 subfamilies: Hydropsychidae, Limnephilidae, Sericostomidae, Phrygaeniidae, Rhyacophilidae) influenced the diversity in Skäralid. It also included *Gammarus pulex, Pisidium* sp., *Ancylus fluviatilis*, Simuliidae, Limoniidae and Ceratopogonidae. Coleoptera were represented by Elminthidae and Dryopidae, and Annelida by one Hirudinea and Oligochaeta. The site in the '*Övedsan*' contained both crustaceans *Gammarus pulex* and *Asellus aquaticus*, Baetidae, Hydropsychidae, Plathyelminthes, Nematoda, Dytiscidae, the dipterans Tipulidae, Ceratopogonidae, Simuliidae, and the leeches *Erpobdella octoculata* and *Helobdella stagnalis*. The site in the '*Ybbarpsan*' contained *Physa fontinalis*, Oligochaeta, Hirudinea, *Gammarus pulex*, Ceratopogonidae, Dytiscidae, Zygoptera and high densities of adult and young Hydropsychidae.

4. Discussion

The chironomid community metrics in the present study could have been underestimated, because most chironomid larvae could only be identified to the generic level and some genera could contain several species. Also, high number of taxa and low number of larvae in 'Öved submerged plants' suggested that this site could contain more taxa. However, the metrics were functional for descriptive and comparative purposes, since the sampling effort in each site was similar.

The macroinvertebrates reflected well data obtained from previous unpublished studies (Gerhardt, unpub.). Rapid assessment of macrobenthos (BBI), chironomid community and deformity rate could separate the polluted Perstorp site from the two other sites, while chironomid taxa made further distinctions between the two unpolluted sites. Chironomid deformities rather reflect 'sediment toxicity' than 'water quality', and both are not always correlated (Janssens de Bisthoven, 1999). The site in Skäralid contained the uncommon *Symposiocladius lignicola*, which is a miner of hard woods (Bass, 1986) and from unpublished data (Gerhardt, unpubl.) we know about the occurrence of the large plecopteran *Dinocras cephalotes*.

In Skäralid the dominant *Micropsectra* and *Tvetenia* did not contain deformed larvae, except for 1 larva. However, Wiederholm (1984) and Bird (1994) found these taxa with deformity rates of up to 17 and 5%, respectively, in polluted environments. This shows that these genera normally respond to pollution with deformed morphology, although intrageneric differences in sensitivity between species can never be excluded. The genus *Thienemannimyia*, present in Skäralid and Öved, appears not to respond morphologically to pollution in other studies (Bird, 1994; Ashton, 1998). Larvae of *Prodiamesa olivacea, Paratendipes, Polypedilum*, and *Microtendipes*, all found in Skäralid and Öved, were reported to display deformities in polluted environments (Warwick, 1988; Diggins and Stewart, 1993; Bird, 1994; Hudson and Ciborowski, 1998; Servia *et al*., 1998), but in our study were in too low numbers for deformity screening, except for *Microtendipes* spp. (81 larvae with 100% normal individuals in Öved sediment). The site in Öved, with the somewhat poorer macroinvertebrate fauna, indicated some unknown stress. However, absence of significant deformity rates indicated lack or low levels of heavy metals or pesticides. Deformities in *Psectrotanypus* (Ybbarpsan) and *Eukiefferiella* (Öved) are the first reports for literature.

Low number of larvae, the few taxa and the presence of deformed *Procladius* larvae at the Ybbarpsan site can be interpreted as effects of pollution. Other field studies (Diggins and Stewart, 1993, 1998; Warwick, 1991) reported similar incidences of deformed *Procladius* larvae in polluted sediments. However, the absence of *Procladius* in the uncontaminated sites, probably due to oligosaprobity (Skäralid) or trophic interactions (Öved) (Baker and McLachlan, 1979; Kajak, 1980) make inter-site comparisons difficult.

The preponderance of Tanypodinae in the polluted Ybbarpsan site is similar to results from Winner *et al*. (1980) who found an increase of predaceous Tanypodinae in the species pool of a metal-contaminated river. In the Ibbarpsan, Petersen and Petersen (1983) reported increasing net anomalies in Hydropsychidae (Trichoptera) in function of decreasing distance to the pollution source. Gerhardt (1996) demonstrated a decrease in survival of *Gammarus pulex* exposed *in situ*, and behavioral responses to water from the Perstorp site, compared to control water, in *G. pulex* and *Hydropsyche angustipennis*.

Although larvae of *Chironomus* and *Procladius* are very useful in assessing the response by benthic fauna to pollutants (Dermott, 1991), they may not always be in sufficient numbers, as in studies of Lenat (1993) and Janssens de Bisthoven (1999). This may be caused by inadequate substrate and organic matter or by lethal sediment toxicity (Janssens de Bisthoven *et al.*, 1995). Therefore, biomonitoring has to rely on other genera as well (Servia *et al.*, 1998), or in the case of total absence of chironomids, on other methods or on *in situ* exposures (Gerhardt, 1996). However, sites with higher species diversity tend to produce not enough larvae for statistical analysis per taxon (e.g. *Polypedilum* in Öved), as was the case in studies by Dickman *et al*. (1992) and Dickman and Rygiel (1996).

There is a need to elaborate a stream classification system based on chironomid larvae, as was done for lake trophic level (Saether, 1979; Warwick, 1980), in which studies on ecological range (e.g. Lehman, 1971; Bass, 1986; Moller Pillot and Buskens, 1990; Nolte, 1991; Lindegaard, 1995), or on pollution effects at the community level (Smith and Cranston, 1995) could be integrated. Meanwhile, number and frequency of chironomid taxa, even at generic level, combined with deformity screening has value in describing the temporary state of a stream, which is complementary to rapid macrobenthos assessment methods, such as the BBI.

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