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Potential of bio-indication of chironomid communities for assessment of running water quality in Flanders (Belgium)

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ABSTRACT. The distribution of chironomid species in small lowland rivers and brooks in the crenal zone of the Zwalm river basin (Flanders, Belgium) was studied. We examined whether a more refined identification of Chironomidae would result in an added value to the biological assessment of the Zwalm river basin, currently based on the Belgian Biotic Index. At the 18 sampling sites, a total of 31 different taxa of chironomids were identified. Identification was at species, aggregate, group, subgenus or genus level. The diversity of chironomid communities and their indicator role for assessment of particular river types and water quality were examined by means of multivariate analysis. Direct ordination of the identified chironomid taxa resulted into three groups of indicators related to the assessment of the water quality of a brook : (1) indicators of a good water quality, (2) indicators of waters enriched with nutrients and organic matter compounds and (3) taxa that were indifferent to water quality. The more refined identification levels provided useful information on the ecology of these organisms and their role as indicator organisms of specific water quality states. Because of the more labour-intensive procedure, however, chironomid identification at these levels will be more difficult to apply within a rapid bio-assessment protocol of running waters.

KEY WORDS : Chironomidae, macroinvertebrates, bio-indicators, brooks, rivers, biomonitoring.

INTRODUCTION

Numerous human activities have an impact on the quality of surface waters and consequently on the organisms living in these habitats. This aquatic fauna, therefore, can serve as convenient biological indicators of the various environmental stresses on these ecosystems (De Pauw & Hawkes, 1993). Unlike physical-chemical measurements, biological assemblages reflect long-term exposure to varying water quality conditions, and benthic macroinvertebrates in particular are well suited for use within rapid bioassessments (Rosenberg & Resh, 1993). Among freshwater macroinvertebrates, chironomid larvae are considered as promising indicators of water quality because of their ubiquity, high abundance and high diversity in aquatic ecosystems (Saether, 1979; Lindegaard, 1997). Moreover, the effects of pollution on chironomid communities have been extensively covered in literature and chironomid taxa have been shown to differ in their tolerance of specific pollution sources (Fitter & Manuel, 1986). Nutrient overload, for example, may serve as an extra food source but at the same time it will result in an oxygen depletion stress in slow running waters because of algal blooms (Lenat, 1983). As a consequence of their large differences in tolerance of eutrophication and organic enrichment, chironomids, in common with oligochaetes, will have indicative representatives in polluted and unpolluted waters (King & Bal, 1964; Ladle & Bird, 1980; Lenat, 1983; Rodriguez & Armas, 1983). Furthermore, the potential of chironomids as biological indicators of heavy-metal contamination has been assessed by several studies based on detected morphological mouthpart deformities (Meregalli et al., 2000; Martinez et al., 2002) and metal adaptation studies (Groenendijk et al., 2002). Finally, besides these water quality aspects, preference of chironomids for certain habitat characteristics (Buskens & Moller Pillot, 1992) can also provide information on the quality of particular hydro-morphological characteristics of a watercourse.

Ecological studies revealing preferences of organisms for certain environmental conditions are often carried out at the species level because of the detailed information contained at this level. Also for chironomid communities in rivers, various studies stress the response at the species level to natural- or human-caused disturbances in rivers (Bazzanti & Bambacigno, 1987; Verdonschot et al., 1992; Reinhold-Dudok van Heel & den Besten, 1999; Orendt, 2000).

Some biotic indices do indeed integrate the information of chironomid communities at the species level (Saether, 1979; Barzerque et al., 1989; Eulin et al., 1993; Evrard, 1996). In Flanders, Belgium, the response of chironomid species to environmental perturbation is, however, not well documented. The biological quality of waters is mainly assessed by means of the Belgian Biotic Index (BBI) (De Pauw & Vanhooren, 1983). This biotic index is based on the taxonomic diversity and the presence/absence of particular indicator taxa. For calculation of the BBI, macroinvertebrates are identified up to family, genus or group level. The family Chironomidae is split into two groups based on the presence or absence of thummi (the *thummi-plumosus* and the *non thummi-plumosus* group) in correspondence with their clearly different responses to the stress of oxygen depletion.

In the present study we examined whether a more refined identification of chironomids would result in an added value to the biological assessment of running waters in Flanders, Belgium. For this reason, the diversity of chironomid communities and their indicator role in assessment of particular river types were examined by means of multivariate analysis. The sampling sites were clustered based on their chironomid populations, and the principal environmental variables structuring these different chironomid communities were identified. Potential bio-indicators were identified, and the added value of the more refined identification in river assessment and ecological research discussed.

MATERIAL AND METHODS

Study area

The study was performed in the Zwalm river basin, which is part of the Upper-Scheldt basin (Flanders, Belgium), and consists mainly of numerous small brooks (Fig. 1). The Zwalm river basin has a total surface of 11650 ha. The Zwalm river itself has a length of 22 km. The southern part of the Zwalm river basin consists of small brooks situated in the crenal zone, where groundwater flows in the brooks at the source. These brooks are expected to be unpolluted. Because of the specific geomorphology in this area, they have a unique fauna (Goethals & De Pauw, 2001). The northern part is influenced by punctual and diffuse domestic pollution as well as diffuse pollution originating from agricultural activities. Habitat degradation of the watercourses in this region is mainly caused by erosion effects. Sampling sites in the Zwalm river basin are shown in Fig. 1.

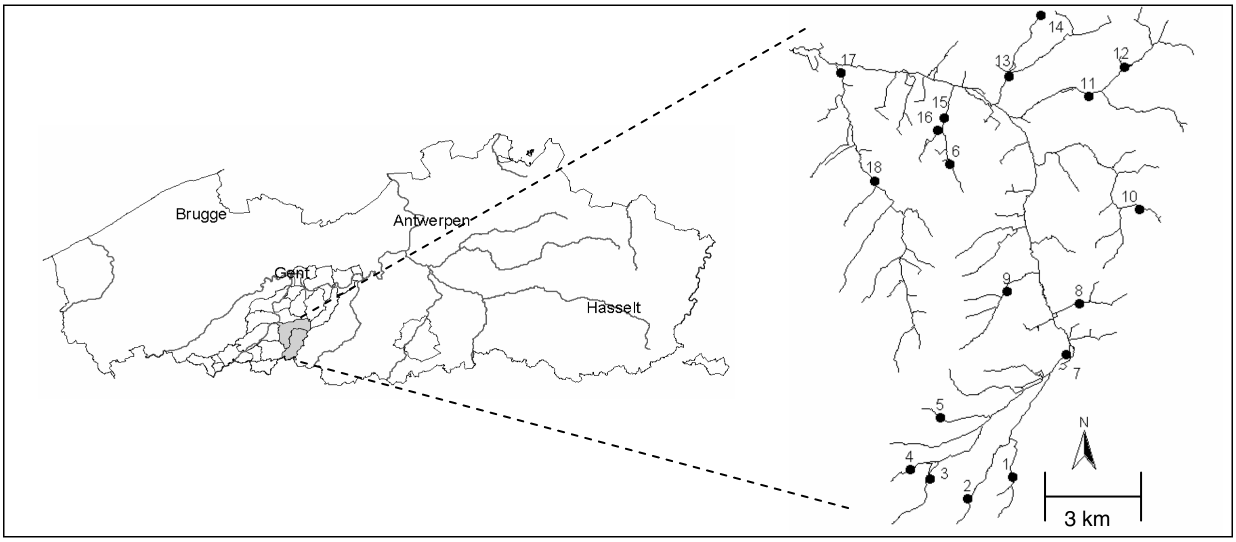

Fig. 1. – Location of (left) and sampling sites in (right) the Zwalm river basin in Flanders, Belgium.

Environmental variables

The measured physical-chemical variables and habitat characteristics are given in Table 1.

TABLE 1

Environmental variables, habitat characteristics and measuring units

Variables	Measuring units
temperature	°C
pH	- log [H+]
conductivity	µS/cm
suspended solids	mg/l
dissolved oxygen	mg O_2/l
chemical oxygen demand	mg O_2/l
total nitrogen	mg N/l
nitrate	mg NO_3^--N/l
ammonium	mg NH_4^+-N/l
total phosphorus	mg P/l
phosphate	mg PO_4-P/l
meandering	6 categories (1 (well developed) to 6 (absent))
hollow banks	6 categories (1 (well developed) to 6 (absent))
pools / riffles	6 categories (1 (well developed) to 6 (absent))

Biological water quality assessment

The biological water quality of the sampling sites was assessed using the Belgian Biotic Index (BBI) in which the macroinvertebrates were identified up to the genus, family or group level (De Pauw & Vanhooren, 1983; IBN, 1984). The BBI is based on taxa diversity as well as the sensitivity of particular groups in relation to pollution (De Pauw & Vannevel, 1993).

The BBI index values are divided into five water quality classes, ranging from very good (BBI value 9-10), good (BBI value 7-8), moderate (BBI value 5-6) to bad (BBI value 3-4) and very bad (BBI value 0-2) quality. These classes can be visually represented by a colour code (respectively blue, green, yellow, orange, red).

Chironomid taxa

Chironomids were identified up to species, aggregate, group, subgenus or genus level, depending on the external morphology of the instar stage of the chironomid. Sampling of the chironomids was done together with the other macroinvertebrate taxa by means of a handnet (mesh size

= 350µm) (De Pauw & Vanhooren, 1983) and samples were sieved the day after sampling. The following identification keys were used : Paine (1956), Klein (1967), Mason (1968), Moller Pillot (1978), Klink (1981), Cranston (1982), Klink (1983), Wiederholm (1983) and Moller Pillot (1984). Availability of suitable identification keys for the larval stages (instars) and the presence of larvae not reaching the 4th larval stage, were often the limiting factors. Chironomids that could not be identified up to species level were identified up to the lowest practical level attainable (i.e. aggregate, group, subgenus or genus level).

Data analysis

Data were processed based on the methodology described in Fig. 2.

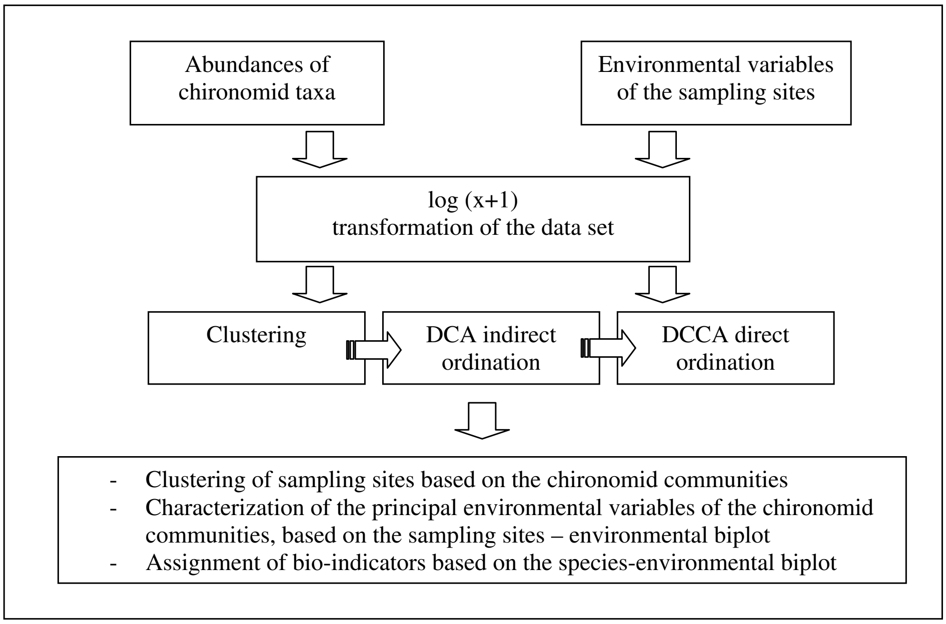

Fig. 2. – Treatment and methodology of multivariate analyses of the biological and environmental data.

Biological and environmental data were log(x+1) transformed, except for the categorical variables (meandering, pool/riffle, and hollow bed development) and the pH. The transformed data were processed by means of several multivariate analyses, more specifically a clustering by making use of FLEXCLUS (van Tongeren, 1986) as well as an indirect (Detrended Correspondence Analysis (DCA)) and a direct ordination (Detrended Canonical Correspondence Analysis (DCCA)) based on CANOCO (ter Braak, 1986; ter Braak & Smilauer, 1998).

Clustering with the programme FLEXCLUS (Van Tongeren, 1986) is based on the Sørensen similarity ratio (Sørensen, 1984) where the most similar samples of the biological data are placed next to each other based on the biological data. The Sørensen similarity ratio (*SR*) used for the clustering is as follows :

$$SRi_j = \sum_k y_{ki} y_{kj} / \left(\sum_k y_{ki}{}^2 + \sum_k y_{kj}{}^2 - \sum_k y_{ki} y_{kj} \right)$$

where y_{ki} = the abundance of the k^{th} species at site *i* and y_{kj} = the abundance of the k^{th} species at site *j*. The initial, non-hierarchical clustering is a means for handling noise and redundancy by combining several samples into groups following the algorithm of Sørensen (1984). Samples are fused into clusters when their similarity is higher than the given threshold value. Refinement of the initial clustering by reallocation leads to a final clustering, which is a combination of fusion and division of clusters based on the distance of a sample to the cluster centroid. The ordering of clusters is obtained by reciprocal averaging (Hill, 1973; Van Tongeren, 1986).

DCA was used for indirect ordination analysis and detrending was done by segments. Because species abundance or probability of occurrence is often a unimodal function of the environmental variables, for direct analysis we opted for the unimodal DCCA ordination method (ter Braak & Verdonschot, 1995) when the gradient length of the first DCA axis > 2. DCCA was used for direct unimodal analysis, and detrending was done by polynomials. In this analysis, habitat characteristics such as meandering-, pool/riffle- and hollow beds-development, were included as categorical variables.

RESULTS

Chironomid biodiversity and biological assessment

In total, 31 different chironomid taxa were found in the 18 sampling sites (Table 2).

Among these 31 taxa, *Macropelopia,* cf. *Conchapelopia* and *Prodiamesa olivacea* (Meigen, 1830) appeared in all samples. Group *Conchapelopia* consists of four different genera, each with a different habitat preference. Some taxa such as *Brillia modesta* (Meigen, 1830)*, Polypedilum* cf. *breviantennatum* (Tsjernovskij, 1949)*, Polypedilum* gr. *laetum, Polypedilum pedestre* agg. and *Zavrelimyia* were only found in the crenal zone of the brooks.

TABLE 2

Taxonomic level, taxon name and abbreviations of the monitored chironomid taxa in the Zwalm river basin

Taxonomic level	**Taxon name**	**Abbreviations**
Species	*Apsectrotanypus trifascipennis* (Zetterstedt, 1838)	Aspe trif
	Brillia longifurca Kieffer,1921	Bril long
	Brillia modesta (Meigen, 1830)	Bril mode
	Odontomesa fulva (Kieffer, 1919)	Odon fulv
	Parametriocnemius stylatus (Kieffer, 1924)	Para styl
	Prodiamesa olivacea (Meigen, 1818)	Prod oliv
	Psectrotanypus varius (Fabricius, 1787)	Psec vari
	Rheocricotopus fuscipes (Kieffer, 1909)	Rheo fusc
Aggregate (Agg.)	Eukiefferiella discoloripes agg	Euki disc
	Paraphaenocladius impensus agg.	Para impe
	Polypedilum pedestre agg.	Poly pede
	Paracladopelma camptolabis agg.	Para camp
Grouplevel (Gr.)	*Chaetocladius* gr. *piger,*	Chae piger
	Chaetocladius gr. *vitellinus,*	Chae vite
	Cryptochironomus gr. *defectus,*	Cryp defe
	Dicrotendipes gr. *notatus,*	Dicr nota
	Dicrotendipes gr. *nervosus*	Dicr nerv
	Polypedilum gr. *laetum*	Poly laet
	Polypedilum gr. *scalaenum*	Poly brev
Subgenus	*Procladius (Holotynapus)*	Proc holo
Genus	cf. *Conchapelopia,*	Cf. Concha
	Chironomus,	Chironom
	Limnophyes,	Limnophy
	Macropelopia,	Macropel
	Micropsectra,	Microspe
	Paratanytarsus,	Paratany
	Phaenopsectra,	Phaenops
	Rheotanytarsus,	Rheotany
	Stempellinella,	Stempeli
	Tanytarsus,	Tanytars

The biological water quality of the Zwalm river basin based on the BBI is illustrated in Fig. 3A. The results show that most of the sampling sites (13 of 18) were moderately polluted. Even for the brooks in the crenal zone, no classification as "very good" was reached. Two sampling sites, located in the small brooks of the crenal zone, reached the basic water quality standard for Flanders (BBI value ≥7). Bad conditions were present at two sites, located near and in the Zwalm river. One sampling site was depleted of macroinvertebrates and was classified as having a very bad quality.

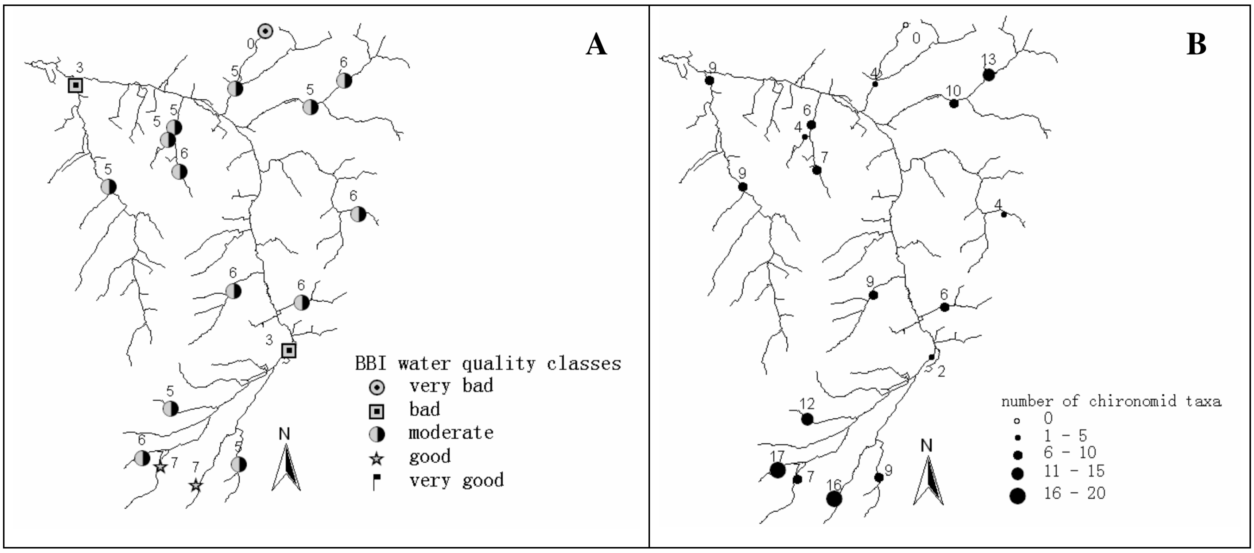

Fig. 3. – BBI water quality values (A) and number of chironomid taxa sampled (B) in 18 sites of the Zwalm river basin.

Fig. 3B also shows the number of chironomid taxa found in each site. A high chironomid biodiversity was found at the sites located near the source. This taxa richness, however, was not reflected by the BBI. For example, one of the sampling sites, classified as "good", contained only seven chironomid taxa, while another sample also classified as "good" had 16 taxa. Samples collected in the Zwalm river itself contained only chironomid taxa, present in low numbers, and no other macroinvertebrate taxa.

Multivariate analyses of the Zwalm river basin data

The output of the DCA analysis revealed a cumulative variance explained by the first two axes of respectively 22.3% and 31.6%. The gradient length of the first DCA axis was 2.331 and therefore a unimodal direct analysis (DCCA) was chosen.

The cumulative variance of the first two axes in the direct DCCA analysis, which explained the role of the environmental variables in the structure of the chironomid communities, was 24.4% and 35.6%, respectively. The eigenvalues of the first two DCCA axes (0.355 and 0.163, respectively) were very close to those obtained from the DCA analysis (0.360 and 0.150, respectively). Therefore, it can be said that the measured environmental variables are important parameters determining the structure of the chironomid communities. The DCCA biplot of sampling sites (assigned by cluster membership) and environmental variables is shown in Fig. 4.

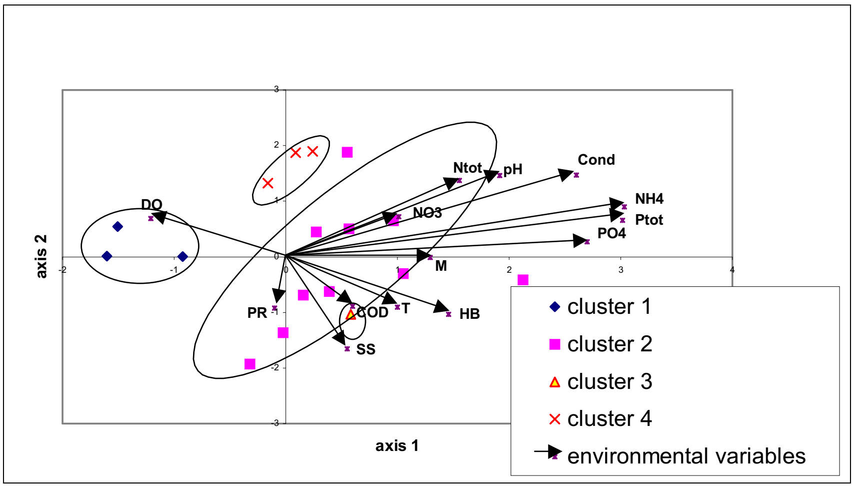

Fig. 4. – DCCA biplot of sampling sites, characterized by their cluster membership based on chironomid communities and environmental variables measured at 18 sites in the Zwalm river basin. (T = temperature, SS = suspended solids, DO = dissolved oxygen, COD = chemical oxygen demand, N tot = total nitrogen, Cond = electrical conductivity, NH4 = ammonium, P tot = total phosphorus, PO4 = phosphate, M = meandering development, HB = hollow beds development, PR = pool/riffle development).

On the basis of the chironomid abundance data, the sampling sites could be subdivided into four clusters by means of the Sørensen similarity ratio clustering, and these results were confirmed by the ordination method revealing the same clustering structure (Fig. 4). The main explanatory variables proved to be ammonium and phosphorus concentrations, electrical conductivity, dissolved oxygen concentration, and pH of the water. The cluster membership of the different sites in the Zwalm river basin is given in Fig. 5.

TABLE 3

Characterization of the different clusters of sampling sites in the Zwalm river basin, based on the chironomid communities

Cluster n°	Number of sampling sites	Number of chironomid taxa	Location in the Zwalm river basin	Environmental characterization of the cluster
Cluster 1	3	+++	near the source	*Fast running non-polluted streams* high dissolved oxygen concentrations low nutrient and organic concentrations
Cluster 2	10	++	small brooks near the mouth of the Zwalm	*Streams subjected to diffuse agricultural pollution* high nutrient level and organic contents high suspended solids concentrations high water temperature values high pH values
Cluster 3	1	---	the Zwalm river	
Cluster 4	3	--	head brooks in agricultural area	low ammonium concentrations high nitrate concentrations

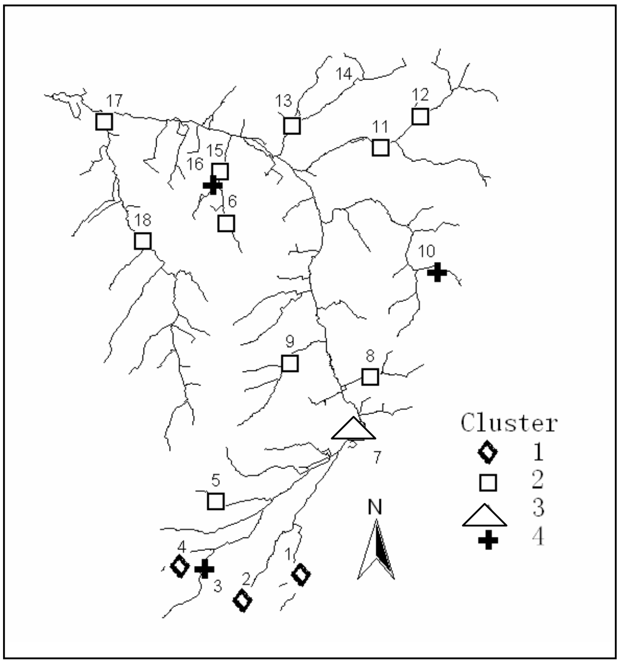

Fig. 5. – Cluster membership of the different sampling sites in the Zwalm river basin based on the Sørensen similarity ratio clustering of the chironomid data, based on FLEXCLUS.

An overview of the most important characteristics of each cluster based on the clustering and direct ordination analysis (Fig. 4) and their location in the Zwalm river basin (Fig. 5) is given in Table 3.

Cluster 1 contained *Brillia longifurca* (Kiefer, 1921), *Procladius holotanypus* (Robback, 1982) and *Tanytarsus*. *Brillia longifurca* was highly frequent and strongly positively correlated with dissolved oxygen concentration. In cluster 2, *Chironomus* was the most frequent taxon, positively correlated with organic load in the water. Cluster 3 contained only one site located in the river. At this site no macroinvertebrate taxa were found except for two chironomid taxa, i.e. *Chironomus* and *Prodiamesa olivacea*. Cluster 4 was not characterized by any specific chironomid taxon.

In Fig. 6, the DCCA biplot of chironomid taxa and environmental variables is shown. Environmental variables and sampling sites are plotted together in a two-dimensional space, oriented by the first two axes, which explain the most important part of the variation in the dataset.

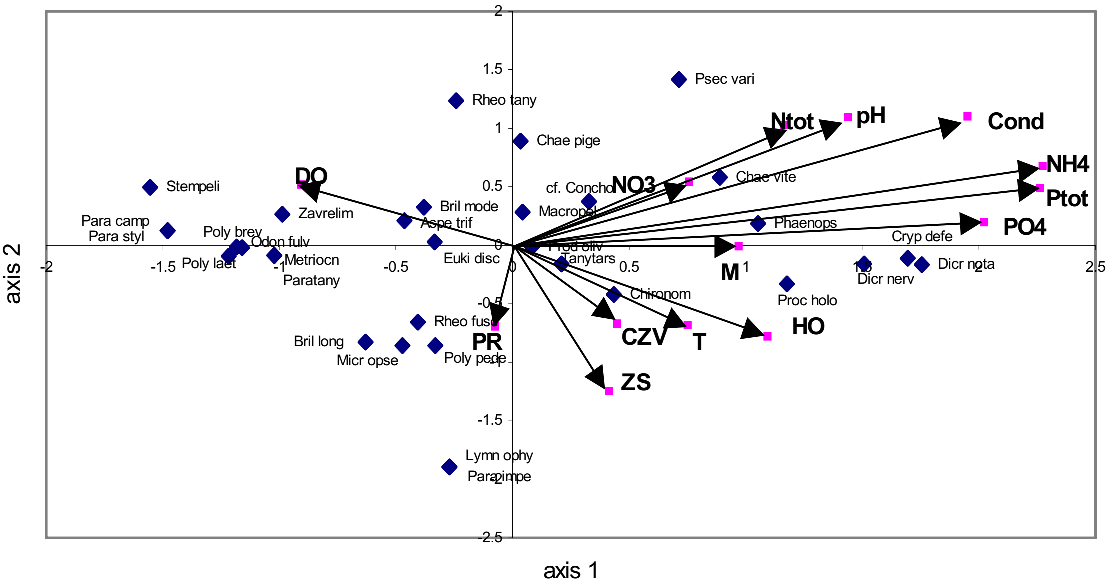

Fig. 6. – DCCA biplot of chironomid taxa and environmental variables monitored in the Zwalm river basin (T = temperature, SS = suspended solids, DO = dissolved oxygen, COD = chemical oxygen demand, N tot = total nitrogen, Cond = electrical conductivity, NH4 = ammonium, P tot = total phosphorus, PO4 = phosphate, M = meandering development, HB = hollow beds development, PR = pool/riffle development). The legend of the abbreviations of the chironomid taxa is given in Table 2.

DISCUSSION

Although distribution patterns of the family Chironomidae are well documented in Belgium (Goddeeris & Behen, 1991; Evrard, 1995a, 1995b), thorough knowledge about the major environmental factors that control their distribution is still lacking. In the present study, several taxa such as *Parametriocnemus stylatus, Limnophyes* (Eaton, 1875)*, Brillia modesta* and *Polypedilum* cf. *breviantennatum* were only found in the brooks in the crenal zone. In the study of Verdonschot (2000b), these taxa were assigned as source brook indicator taxa. Taxa characteristic of headwaters (cf. Verdonschot, 2000c; personal communication) are very scarce in the present study. This is probably due to the combination of erosion, diffuse pollution and habitat degradation in the Zwalm river basin, drastically reducing chironomid diversity. The typical succession of chironomid taxa from source to mouth can be recognized, but the higher the impact of water deterioration the less transparent was the succession in the Zwalm data (cf. ROSSARO, 1991).

No correlation could be found between the number of chironomid taxa and the BBI. This can be explained by (1) the absence of pollution-sensitive macroinvertebrate taxa. As do most of the biotic indices, the BBI assesses water quality on the basis of the taxonomic diversity of the benthic macroinvertebrate community and the presence or absence of indicator taxa (DE PAUW & VANHOOREN, 1983). Sensitive indicator taxa such as Plecoptera and Heptageniidae weigh the most heavily. These two taxa, however, are seldom found in the Zwalm river basin (e.g. between 2000 and 2002, Plecoptera were only found in two sampling sites in 2002, Heptageniidae were found only once in four sampling sites in 2000 and 2002; both taxa were found only twice and in very low abundance). The absence of these two taxa, which could partly be explained by the heterotrophy in the crenal zone, thus lowers the BBI values of the brooks located in the zone, where, however, the highest chrironomid diversity was found; (2) differences in response to environmental changes between chironomid taxa abundance and the whole macroinvertebrate community expressed as the BBI. Similar results have been reported by BAZAANTI & BAMBACIGNO (1987) who did not find a correlation between the number of chironomid taxa and any biological index applied on the Italian streams.

Multivariate analysis, such as ordination and clustering, is often used to analyse environmental preferences of macroinvertebrate communities (VERDONSCHOT et al., 1992; TER BRAAK & VERDONSCHOT, 1995; CAO et al., 1997; VERDONSCHOT, 2000a). In this way, river management can be focused on the mitigation of certain pollution sources that cause e.g. acidification, eutrophication, habitat degradation. The agglomerative clustering method FLEXCLUS allowed grouping of sampling sites, revealing the same pattern of groups as in the ordination analysis with CANOCO. In our study, some sites of the data matrix had a similar chironomid community but differed in abundance for a large part of the matrix (e.g. cluster 2 and cluster 4), and as such, clusters overlapped each other. This equalising effect is probably caused by pollution, which excludes specific chironomid taxa and promotes the dominance of tolerant ubiquitous chironomid taxa. This was also referred to in the research of VERDONSCHOT et al. (1992).

The ecological preferences of the taxa in our study within the different clusters have been compared with the ecological study of chironomids in the Netherlands (MOLLER PILLOT & BUSKENS, 1990). *Brillia longifurca*, although not very typical for brooks in the crenal zone, is, however, strongly correlated with dissolved oxygen concentration, a correlation that also could be deduced from our results. Although *Procladius holotanypus* (Robback, 1982) is highly frequent in different stream types, and is very tolerant for differing physical-chemical conditions, it was only found in three places, in one source brook. *Tanytarsus* species can be found in different water types under different conditions, and was found in our research at the brooks of the crenal zone and the mouth of the Zwalm river, probably representing different *Tanytarsus* species.

In general, natural chironomid communities in the brooks of the crenal zone could be separated from the other communities by means of clustering (Fig. 5). This agrees with the expected unpolluted conditions of the crenal zone (southern part) in the Zwalm river basin.

The present study shows that the main explanatory variables for interpreting the results of the direct ordination were ammonium and phosphorus concentrations, electrical conductivity and pH of the water (Fig. 4 and Fig. 6). Nutrient concentrations (e.g. ammonium and phosphorus) were also reported as the main explanatory variables in several other studies e.g. MOLLER PILLOT & BUSKENS (1990). Based on the DCCA species biplot of the Zwalm data (Fig. 6) and the ecological information provided by BAZZANTI & BAMBACIGNO (1987) and MOLLER PILLOT & BUSKENS (1990), indicator taxa for eutrophication, which can be of use for rivers in Flanders, can be suggested. Indicators of oligotrophic conditions are *Paracladopelma camptolabis* agg. and *Parametriocnemus stylatus*. Indicators of waters enriched with nutrients and organic compounds are *Chironomus, Psectrotnaypus varius* and *Dicrotendipes* gr. *nervosus* and taxa appearing in eutrophic as well as oligotrophic conditions are, for example, *Prodiamesa olivacea.* Beside these taxa, other chironomid indicator taxa were proposed by BAZZANTI & BAMBACIGNO (1987) and MOLLER PILLOT & BUSKENS (1990) and should receive attention in future research.

Besides the nutrients, the role of pH as an influencing variable for chironomid communities in running waters has been stressed (ORENDT, 1998, 2000). In our study, no specific pH indicator taxa were detected (Fig. 6). According to VERDONSCHOT et al. (1992) habitat variables are more important than physical-chemical variables influencing the distribution of chironomids, which was also noted by RAE (1985) and BUSKENS & MOLLER PILLOT (1992). A more detailed analysis of the role of chironomids as indicators of habitat quality will, therefore, be necessary in the future when habitat restoration becomes of greater importance in river management. More refined analysis of habitat preferences of chironomid species, e.g. for hydraulic and sediment characteristics, could yield important additional information (VERDONSCHOT et al., 1992).

It has been reported that a grab sampler is an appropriate instrument for collecting chironomid organisms from the bottom sediment (INT PANIS et al., 1995). From our results it appeared that the chironomid taxa, which are buried in the sediment, could also representatively be sampled with a 350µm handnet (e.g. *Chaetocladius* gr. *piger*). However, a biased view of the biological communities could be obtained because certain smaller chironomid taxa may seem absent when sampled with a handnet of 350µm (STOREY & PINDER, 1985). Regarding the sampling season, it has been demonstrated that during winter a lesser number of species can be found because of the formation of resting stages of some chironomid taxa (MACKEY, 1977; GODDEERIS, 1987; ROSSARO, 1991). Thus, sampling in summer, as was done in the present study, should be appropriate to ascertain chironomid biodiversity (MOLLER PILLOT, 1978).

In the present study, chironomid taxa were identified at the lowest level possible to analyse the ecological information gathered for the running waters in the Zwalm river basin. The more refined identification level of the chironomids could provide useful information for application within water quality assessment, but also for obtaining information about aspects such as the ecology of indicator taxa in specific water types and a better ecological characterization of the brooklets. The chironomid community structure can also serve as an indication of the habitat and the water quality of the river, based on the absence/presence of some indicator species (VERDONSCHOT, 2000b, 2000c). It could even be possible to construct specific chironomid indices, reflecting the habitat quality (VERDONSCHOT et al., 1992). One has to keep in mind, however, that an ecological evaluation based on chironomids should include type specific reference conditions.

The advantage of using species-level data to obtain more meaningful information for the assessment of the biological condition of a site has been addressed by several authors (BOWMAN & BAILEY, 1997; GUEROLD, 2000). The present study shows that identification of chironomids at a more detailed level than family level provides additional information on the water quality of the Zwalm river basin when compared to the BBI. However, for application of this refined identification in routine monitoring, time and effort (expertise/personnel) required for such work should be taken into consideration (personal communication). Identification of chironomids at a more detailed level can, therefore, probably not be part of a rapid bioassessment procedure for rivers in Flanders.

CONCLUSION

In this study, chironomid taxa could be assigned as indicators for natural running waters in Flanders (e.g. brooks in the crenal zone) and nutrient conditions. These results were obtained by multivariate analyses based on data collected within the Zwalm river basin. These techniques were very useful to detect relationships between chironomid taxa and environmental variables in a river basin. In the future, physical characteristics of the watercourses should also be included in such studies because of the importance of the habitat conditions for chironomid communities. A more refined identification of the chironomids provided useful information for various applications, including the study of the ecology of these indicator organisms in specific water types and a better ecological characterization of the brooklets where they were collected. Identification of the chironomid communities is, however, very laborious and as such, due to its relatively high energy-input, not directly suitable for rapid bio-assessments.

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