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Epiphytic chironomids on rigid hornwort (*Ceratophyllum demersum* L.) – the relation between the community structure and lake status

Monika Tarkowska-Kukuryk[1]

Department of Hydrobiology, University of Life Sciences in Lublin
ul. Dobrzańskiego 37, 20-262 Lublin, Poland

Key words: epiphytic Chironomidae, *Ceratophyllum demersum*, lake status, shallow lakes

Abstract

Studies on the role of *Ceratophyllum demersum* L. as a substratum for epiphytic midges in relation to lake status were conducted within two shallow polymictic lakes of Polesie Lubelskie. Lake Skomielno is classified as macrophyte dominated (MD), clear water state and Lake Syczyńskie represents phytoplankton dominated (PD), turbid water state. The results demonstrated that lake status is a determinant of community composition of epiphytic chironomids. Both species richness and abundance showed significantly higher values in the macrophyte dominated lake. The studied ecosystems differ in the composition of dominant chironomid taxa. In the clear state lake, the group of dominants included four taxa: *Psectrocladius* sp. (gr. *sordidellus), Glyptotendipes* sp., *Ablabesmyia phatta* and *Paratanytarsus austriacus*, the contribution of which changed during the studied months. In the turbid state lake two midge taxa dominated: *Cricotopus* sp. (gr. *sylvestris*) and *Endochironomus albipennis*. The CCA ordination

[1] Corresponding author: *monika.kukuryk@up.lublin.pl*

showed the important differences between the studied lake types. In the MD lake, four environmental factors (temperature, chlorophyll-*a*, total P, P-PO_4) influenced mostly the distribution and composition of epiphytic chironomids. In the MD lake, five variables (periphyton biomass, total suspension, N-NH_4, total P, pH) affected the structure of midges.

INTRODUCTION

The structure of phytophilous invertebrates is closely related to habitat conditions, among them the distribution and species composition of macrophytes and associated epiphytic algae become the most important ones (Brodersen 1995; van den Berg 1997; Weatherhead, James 2001). The species composition and biomass of macroinvertebrates usually differ between plant species. Macrophytes are diverse in their morphology based on the number, morphometry and arrangement of stems, branches and leaves (Lillie, Budd 1992; Jackson 1997). Many previous studies stressed the role of macrophytes with dissected leaves in supporting the high density of epiphytic fauna (Cattaneo, Kalff 1980; Dvorak, Best 1982; Cyr, Downing 1988, Cheruvelil et al. 2000). Dissected plants have a higher surface area to plant mass ratio, and therefore, may provide more habitat for macroinvertebrates, more food in the form of periphyton for grazing fauna. The ability and the quality of food resources can structure the phytophilous community, which constitutes mostly of grazers and filter-feeders, such as chironomids larvae, zygopteran nymphs, grazing mollusks (Russo 1988; Kornijów, Gulati 1992; Pelli, Barbosa 1998). The larvae of Chironomidae usually dominated epiphytic communities (Bergey et al. 1992; Cattaneo et al. 1998, Tarkowska-Kukuryk, Kornijów 2008). As very productive organisms, larvae of midges may control the biomass of periphytic algae and recycle detritus, utilizing them as food (Cooper, Knight 1985; Kornijów et al. 1995; Dvorak 1996).

The paper presents the structure of epiphytic chironomids associated with rigid hornwort (*Ceratophyllum demersum* L.). It is a non-rooted, perennial submerged plant with finely dissected leaves. The species grows commonly in inland ponds, lakes and slow moving rivers. The plant tolerates hard water (high calcium content), high nutrients' concentrations and low light level. It forms anchoring adventitious roots or modified leaves that can absorb nutrients from sediments, but nutrient uptake is almost entirely foliar (Toetz 1971; Denny 1972). The foliar uptake becomes increasingly important as nutrients' concentrations in the water column increases (Carignan 1982; Rattray et al. 1991). The ability of foliar uptake enables the presence of *C. demersum* in lakes representing different status. *C. demersum,* as the other submerged species, constitutes an important habitat for young fish, small aquatic animals, and aquatic insects (Chilton 1990; Cattaneo et al. 1998). The species is often restricted to highly polluted lakes, where it forms typical free-floating mats (Succow, Kopp 1985; Melzer 1999).

The main objective of the study was to evaluate the role of rigid hornwort as a substratum for midges in relation to lake status. Environmental conditions (oxygen content, water transparency, light and nutrients availability, species composition and distribution of submerged macrophytes) may influence the variance and distribution of epiphytic fauna (Demeke, Ahma 1999; Zimmer et al. 2000; Elizabeth et al. 2003; Roberts et al. 2003; Peter et al. 2004). Two shallow lakes of Polesie Lubelskie were selected for the study. The first lake is macrophyte-dominated and represents the clear water state. The second lake is phytoplankton dominated, hypertrophic, with submerged plants reduced to small patches of *C. demersum*.

MATERIALS AND METHODS

The studies were carried out in two shallow lakes: Skomielno (51°29'N, 23°0'E; the surface area of 75 ha, max. depth 6.5 m) and Syczyńskie (51°17'N, 23°14'E; the surface area of 5.9 ha; max. depth 2.9 m) in the region of Polesie Lubelskie. Lake Skomielno represents the macrophyte dominated (MD), clear water state; Lake Syczyńskie - phytoplankton-dominated (PD) turbid water state (Table 1).

Water samples for chemical analysis were collected at the water surface at the same time as the periphyton and midges samples. The analysis included: temperature, pH, conductivity, dissolved oxygen, total suspension, chlorophyll-*a*, ammonium-nitrogen, nitrate-nitrogen, total phosphorus and dissolved orthophosphates. Temperature, conductivity, pH and dissolved oxygen were recorded *in situ* using YSI 556 MPS electrode. Chlorophyll-*a* from epiphytic algae was determined by spectrophotometric analysis of the acetone extract of algae (Golterman 1969).The remaining factors were analyzed in the laboratory (Hermanowicz et al. 1976).

The biomass of epiphytic algae from *C. demersum* shoots was estimated by cutting off a plant fragment in the water column and putting it into a plastic bag. The content of each bag was transferred into a plastic bottle filled with 300 ml of distilled water. Epiphytic algae were separated from a plant by vigorous shaking of a plant fragment for 2 minutes. The suspension was filtered through a 300 µm mesh size to avoid contamination of small plant fragments or occasional invertebrates. From this sample, 100-ml of aliquot was fixed with Lugol`s solution and used for algal biomass estimation.

The biomass of *C. demersum* was estimated using the Bernatowicz rake with the surface area of 0.16 m^2 (Bernatowicz 1960). The obtained biomass was calculated per m^2 of the bottom surface (Table 2).

Table 1

Physical and chemical characteristic of water on sampling sites of *C. demersum* in 2007 (mean values for studied months).

	MD Lake Skomielno						PD Lake Syczynskie					
	Jan	Mar	May	Jul	Sep	Nov	Jan	Mar	May	Jul	Sep	Nov
Temperature (°C)	1.8	5.3	14.6	24.0	10.8	5.6	2.8	7.2	14.2	22.1	16.8	6.4
Secchi depth (m)	1.4*	1.5*	1.5*	1.4*	1.2*	1.4*	0.52	0.65	0.72	0.40	0.37	0.27
pH	7.3	7.4	7.5	7.4	7.9	7.6	8.2	7.6	7.9	8.1	7.5	7.8
Conductivity (µS cm^{-1})	317	323	331	268	296	336	544	602	563	323	477	437
Dissolved oxygen (mg dm^{-3})	10.2	9.5	10.8	8.8	7.3	8.0	12.9	15.9	9.2	12.0	9.1	10.6
Total suspension (mg dm^{-3})	2.2	2.1	1.9	3.9	3.6	2.0	19.30	18.6	11.1	19.20	41.0	13.2
$N\text{-}NH_4$ (mg dm^{-3})	0.025	0.081	0.128	0.285	0.658	0.277	0.226	0.228	0.166	0.485	0.531	0.900
$N\text{-}NO_3$ (mg dm^{-3})	0.198	0.127	0.103	0.027	0.208	0.112	0.090	0.250	0.036	0.045	0.166	0.112
P_{tot} (mg dm^{-3})	0.015	0.162	0.038	0.045	0.042	0.017	0.398	0.608	0.168	0.321	0.252	0.761
$P\text{-}PO_4$ (mg dm^{-3})	0.011	0.077	0.007	0.008	0.011	0.002	0.180	0.350	0.047	0.028	0.186	0.340
Chlorophyll-*a* (µg 100 g^{-1} DW)	5.60	5.02	2.89	18.85	6.53	2.43	114.76	36.95	44.13	125.88	52.54	61.35
Biomass of periphyton (µg 100 g^{-1} DW)	12.14	8.15	23.63	4.84	15.62	16.81	64.35	56.28	127.09	93.95	275.81	237.97

* to the bottom, MD-macrophyte dominatem, PD-phytoplankton dominated

Table 2

Biomass of *C. demersum* (g m^{-2} WW) in Skomielno Lake and Syczyńskie Lake in studied months in 2007.

		Jan	Mar	May	Jul	Sep	Nov
MD Skomielno Lake	mean	49.2	456.5	1002.9	1197.7	695.6	326.7
	range	131.2-820.6	197.4-814.2	543.3-1934.3	703.2-2812.8	236.8-1480.0	111.2-979.8
PD Syczyńskie Lake	mean	131.4	106.6	209.4	285,6	196.2	82.5
	range	912-401.7	78.4-336.8	89.5-606.3	101.4-654.2	96.8-459.3	61.2-240.6

Samples of epiphytic fauna were collected bimonthly from January to November 2007. In both lakes, three sampling sites were distinguished in the *C. demersum* bed. At each site three samples were collected every month. Phytophilous chironomids were collected by means of a cylindrical apparatus, with openings covered by a net of mesh size 250 µm (Kornijów 1998). The open apparatus was lowered into the *C. demersum* bed; when macrophytes were put very gently inside the cylinder using a small floristic fork. The sampler was closed very slowly to minimize the water movement and raised in horizontal position up to the surface. The protruding shoots along the sampler's edges were cut off. The water from the cylinder was poured out, the sampler was opened and the plant material was transferred into a plastic bag. Next, the sampler was put in the vertical position and flushed with water to rinse animals remaining on the net into the bottom of the cylinder where they can be easily collected. Field samples were transported to the laboratory. At the laboratory, the larvae of midges were removed from *C. demersum* leafs and preserved in 4% formaldehyde solution, counted and identified. The nomenclature of Chironomidae larvae was accepted according Chernovsky (1949) and Wiederholm (1983). The density was calculated per 100 g of DW of a plant.

The analysis included the taxonomic composition, the number of taxa and the density of epiphytic chironomids on rigid hornwort.

The test of Kołmogorow-Smirnow was used to verify the normal distribution of the collected data. The influence of the lake and the season on the density of chironomids was verified using the two-way analysis of variance (ANOVA). Pearson`s correlation coefficients were calculated to specify the relations between the environmental factors (Secchi disc visibility, dissolved oxygen, concentrations of chlorophyll-*a*, total P, P-PO_4, N-NO_3 and N-NH_4, biomass of epiphytic algae and *C. demersum* biomass) and the density of particular chironomid taxa. The analysis was performed using GLM and CORR procedures of SAS Software (2001).

The Canonical Correspondence Analysis was used to specify which of 13 environmental variables affects mostly the abundance of phytophilous midges in the studied lake types. The analysis was performed using the average values of density and environmental parameters, applying MVSP 3.1 for Windows by Kovach Computing Services.

RESULTS

Altogether, in the macrophyte dominated (MD) Skomielno Lake, 13 taxa of epiphytic midges were recorded. In the phytoplankton-dominated (PD) Syczyńskie Lake, this value was almost two times lower - 8 taxa (Table 3). In both lakes, the number of taxa changed seasonally, but not significantly.

Density of epiphytic chironomids on *C. demersum* was affected by the lake (ANOVA, $F = 14.98$, $p = 0.003$) and the season (ANOVA, $F = 10.32$, $p = 0.004$), and showed significantly higher values in the macrophyte dominated lake (ANOVA, $F = 58.19$; $p < 0.001$) (Fig. 1). The number of individuals in the studied months ranged from 35 ind. up to 180 ind. 100 g^{-1} DW in the MD lake and from 13 to 30 ind. 100 g^{-1} DW in the PD lake.

The relative abundance of epiphytic chironomids, changed through the sampling period. In the MD lake, the dominant taxon depended on the season (Table 3). In January, midges on rigid hornwort were dominated by *Psectrocladius* sp. (gr. *sordidellus*) – 47 ind. 100 g^{-1} DW; in March and September the most numerous were larvae of *Glyptotendipes* sp. (61 and 94 ind. 100 g^{-1} DW, respectively). In July, the community of epiphytic midges was represented mostly by *Ablabesmyia phatta* (51 ind. 100 g^{-1} DW) and in November - by larvae of *Paratanytarsus austriacus* (57 ind. 100 g^{-1} DW). In the PD lake, chironomids on *C. demersum* were dominated by two taxa: *Cricotopus* sp. (gr. *sylvestris*) and *Endochironomus albipennis*. The larvae of *C. silvestris* dominated in January, March, May and July; its density ranged from 9 ind. 100 g^{-1} DW up to 19 ind. 100 g^{-1} DW. In the remaining months (September and November), larvae of *E. albipennis* dominated (6 and 10 ind. 100 g^{-1} DW, respectively).

The analysis of the relations between the environmental variables and densities of chironomids taxa showed the influence of three variables ($N\text{-}NH_4$, chlorophyll-*a* and macrophyte biomass) in the MD lake and six variables (dissolved oxygen, TP, $P\text{-}PO_4$, $N\text{-}NO_3$, chl-*a*, periphyton biomass, *C. demersum* biomass) in the PD lake (Tables 4 and 5). In the MD lake, the density of *Cricotopus* sp. (gr. *sylvestris*) correlated negatively with biomass of *C. demersum* ($r = -0.84$; $p = 0.03$). Density of *Parachironomus* sp. (gr. *varus*)

Table 3

Structure and abundance (number of ind. 100 g^{-1} DW) of epiphytic chironomids taxa on *C. demersum* in lakes Skomielno and Syczynskie in studied seasons.

Taxa	MD Lake Skomielno						PD Lake Syczynskie					
	Jan	Mar	May	Jul	Sep	Nov	Jan	Mar	May	Jul	Sep	Nov
Ablabesmyia phatta (Eggert)				51		7						
Cricotopus sp. (gr. *sylvestris*)			5				14	9	19	11		3
Psectrocladius sp. (gr *sordidellus*)	47		16		29	27	8	2	7	3		
Parachironomus sp. (gr. *varus*)		9							3			
Dicrotendipes sp.	25	15	8		8	42				3	3	
Endochironomus albipennis (Meigen)					20		5	3	3	10	6	10
Glyptotendipes sp.		61	6		94	9	3	4			2	
Microtendipes sp. (gr. *pedellus*)			10									
Phaenopsectra flavipes (Meigen)				9								
Polypedilum sordens (v.d.Wulp)	13	8	16		29			2	3	4	4	
Paratanytarsus austriacus Kieffer		32		9		57					4	
Cladotanytarsus mancus (Walker)	21		6			7						
Tanytarsus sp.		9	5	17		8						
No. of taxa per season	4	6	8	4	5	7	4	5	5	5	5	2
Total number of taxa	13						8					

was affected negatively by the content of N-NH_4 ($r = -0.84$; $p = 0.03$). The abundance of *Dicrotendipes* sp. negatively correlated with chlorophyll-*a* concentration ($r = 0.88$; $p = 0.008$); the density of *Polypedilum sordens* showed a positive correlation with *C. demersum* biomass ($r = 0.90$; $p = 0.005$). In the PD lake, the density of *Cricotopus sylvestris* negatively correlated with periphyton biomass ($r = -0.79$; $p = 0.03$); the abundance of *Psectrocladius sordidellus* was affected negatively by the total phosphorous concentration ($r = 0.80$; $p = 0.03$); the density of *Parachironomus varus* positively correlated with chlorophyll-a concentration ($r = 0.77$; $p = 0.04$); density of *Glyptotendipes* sp. showed positive relations with dissolved oxygen ($r = 0.82$; $p = 0.002$) and N-NO_3 ($r = 0.85$; $p = 0.001$) contents. The abundance of *Polypedilum sordens* negatively correlated with total phosphorous ($r = -0.77$; $p = 0.04$) and chlorophyll-*a* concentrations ($r = 0.87$; $p = 0.017$); the density of *Paratanytarsus austriacus* showed a negative relation with total phosphorous ($r = -0.82$; $r = 0.002$) and P-PO_4 ($r = -0.79$; $p = 0.03$).

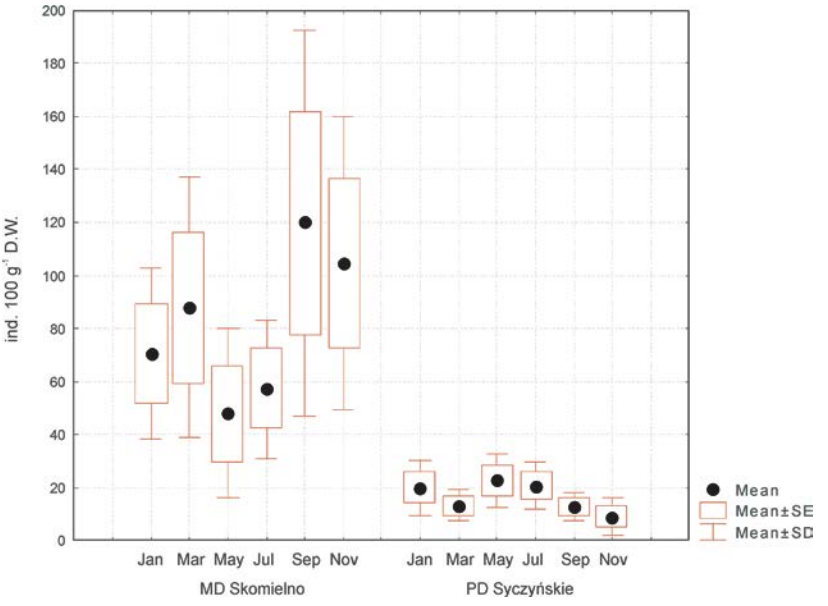

Fig. 1. Density of epiphytic midges on *C. demersum* in lakes Skomielno and Syczyńskie in studied months in 2007.

Canonical Correspondence Analysis illustrated that habitat conditions had a clear effect on the community structure of epiphytic midges (Fig. 2A, B). In the MD lake, the CCA explained 65.5% of the cumulative variability in the study, the first axis accounted for 43.8%, the second axis - 21.8%. The eigenvalue for axis 1 amounted to 0.582 and for axis 2 - 0.289. Axis 1 is most strongly positively correlated with periphytic chlorophyll-a concentration and water temperature (Table 6), and reflects the reaction of three midge taxa (*Ablabesmyia phatta*, *Paratanytarsus austriacus*, *Tanytarsus* sp.) to these factors. Axis 2 was most strongly positively correlated with P-PO_4 and total P (Table 6) and showed the highest influence on larvae of *Parachironomus varus*. In the PD lake, the CCA explained 77.4% of the cumulative variability, the first axis accounted for 56.4%, the second axis – 20.9%. The eigenvalue for axis 1 amounted to 0.440 and for axis 2 – 0.164. Axis 1 most strongly positively correlated with periphyton biomass, total suspension and N-NH_4 (Table 7), and influenced the density of *Endochironomus albipennis*, *Dicrotendipes* sp. and *Polypedilum sordens*. Axis 2 most positively correlated with total P and pH (Table 7), and affected the abundance of *Endochironomus albipennis* and *Cricotopus sylvestris*.

Table 4

Correlation coefficients between individual Chironomidae taxa and environmental variables in Lake Skomielno.

Taxon	SD	diss.oxygen	TP	$P\text{-}PO_4$	$N\text{-}NH_4$	$N\text{-}NO_3$	chl-*a*	periphyton biomass	*C.demersum* biomass
Ablabesmyia phatta	0.33 ns	-0.03 ns	0.59 ns	0.55 ns	-0.27 ns	-0.62 ns	-0.51 ns	-0.35 ns	0.02 ns
Cricotopus sp. (gr. *sylvestris*)	0.34 ns	0.41 ns	0.39 ns	0.60 ns	-0.68 ns	0.32 ns	-0.35 ns	-0.16 ns	-0.86*
Psectrocladius sp. (gr. *sordidellus*)	-0.56 ns	-0.53 ns	0.05 ns	-0.004 ns	0.57 ns	0.11 ns	0.007 ns	0.42 ns	-0.04 ns
Parachironomus sp. (gr. *varus*)	0.48 ns	0.69 ns	0.11 ns	0.31 ns	-0.84*	0.11 ns	-0.34 ns	-0.12 ns	-0.58 ns
Dicrotendipes sp.	0.07 ns	0.09 ns	-0.17 ns	-0.24 ns	-0.13 ns	-0.69 ns	0.88**	-0.61 ns	0.62 ns
Endochironomus albipennis	0.43 ns	0.35 ns	0.05 ns	0.10 ns	-0.67 ns	0.04 ns	-0.46 ns	0.32 ns	-0.68 ns
Glyptotendipes sp.	-0.34 ns	-0.54 ns	0.56 ns	0.57 ns	0.39 ns	0.37 ns	-0.32 ns	0.39 na	-0.57 ns
Microtendipes pedellus	0.39 ns	0.75 ns	0.28 ns	0.43 ns	-0.72 ns	0.16 ns	-0.02 ns	-0.55 ns	-0.09 ns
Phaenopsectra flavipes	-0.20 ns	-0.34ns	0.58 ns	0.54 ns	0.40 ns	0.36 ns	-0.47 ns	0.46 ns	-0.35 ns
Polypedilum sordens	0.18ns	0.15 ns	0.17 ns	-0.02 ns	0.17 ns	-0.58 ns	0.48 ns	-0.29 ns	0.90**
Paratanytarsus austriacus	0.41 ns	0.22 ns	0.59 ns	0.52 ns	-0.08 ns	0.008 ns	-0.58 ns	0.49 ns	-0.13 ns
Cladotanytarsus mancus	0.36 ns	0.62 ns	-0.14 ns	-0.16 ns	-0.38 ns	-0.18 ns	-0.25 ns	0.11 ns	0.22 ns
Tanytarsus sp.	0.55 ns	0.03 ns	0.63 ns	0.51 ns	-0.24 ns	-0.81 ns	0.48 ns	-0.16 ns	0.28 ns

n=54; ns p>0,05; * 0,05<p<0,01; ** 0,01<p<0,001

Table 5

Correlation coefficients between individual Chironomidae taxa and environmental variables in Lake Syczyńskie.

Taxon	SD	diss.oxygen	TP	P-PO_4	N-NH_4	N-NO_3	chl-*a*	periphyton biomass	*C.demersum* biomass
Cricotopus sp. (gr. *sylvestris*)	0.07 ns	-0.41 ns	0.31 ns	0.27 ns	0.04 ns	-0.39 ns	-0.28 ns	-0.79*	0.62 ns
Psectrocladius sp. (gr. *sordidellus*)	-0.52 ns	-0.58 ns	0.81*	0.72 ns	0.28 ns	-0.31 ns	-0.25 ns	0.08 ns	0.28 ns
Parachironomus sp. (gr. *varus*)	-0.43 ns	-0.21 ns	-0.21 ns	0.44 ns	0.35 ns	-0.27 ns	0.76*	-0.22 ns	-0.11 ns
Dicrotendipes sp.	0.53 ns	0.11 ns	-0.46 ns	-0.33 ns	-0.18 ns	-0.17 ns	-0.12 ns	-0.67 ns	0.02 ns
Endochironomus albipennis	-0.58 ns	-0.46 ns	-0.32 ns	-0.35 ns	-0.16 ns	-0.56 ns	0.61 ns	-0.07 ns	-0.54 ns
Glyptotendipes sp.	0.41 ns	0.83*	-0.26 ns	-0.28 ns	0.34 ns	0.84**	0.28 ns	0.56 ns	-0.13 ns
Polypedilum sordens	-0.25 ns	-0.02 ns	-0.77*	-0.63 ns	-0.24 ns	-0.16 ns	0.87**	0.20 ns	-0.66 ns
Paratanytarsus austriacus	0.37ns	0.55 ns	-0.82**	-0.79*	-0.30 ns	0.25 ns	0.45 ns	0.01 ns	-0.51 ns

n=54; ns p>0.05; * 0.05<p<0.01; ** 0.01<p<0.001

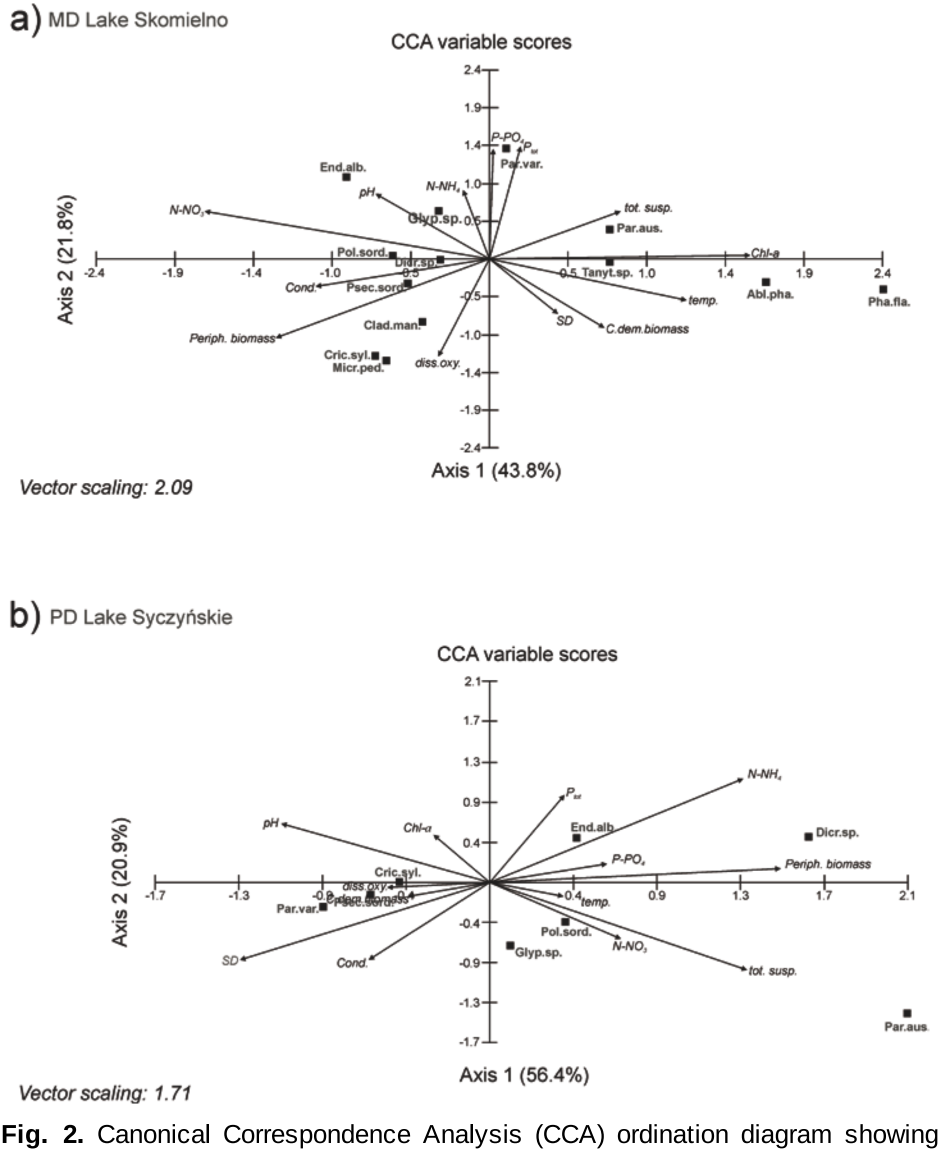

Fig. 2. Canonical Correspondence Analysis (CCA) ordination diagram showing the relation between abundance of midges taxa and environmental variables (temp. - water temperature, SD-Secchi disc depth, cond.-conductivity, tot.susp.-total suspension, $N\text{-}NH_4$- ammonium nitrogen, $N\text{-}NO_3$-nitrate nitrogen, Ptot.- total phosphorous, $P\text{-}PO_4$– orthophosphates, chl-a-epiphytic chlorophyll-a, diss.oxy.-dissolved oxygen, C.dem.biomass– biomass of *C. demersum*, periph. biomass-biomass of periphyton; Abl.pha.-*Ablabesmyia phatta*, Clad.man.-*Cladotanytarsus mancus*, Cric.syl.-*Cricotopus sylvestris*, Dicr.sp.-*Dicrotendipes* sp., End.alb.-*Endochironomus albipennis*, Glyp.sp.-*Glyptotendipes sp*., Micr.ped.-*Microtendipes pedellus*, Par.var.-*Parachironomus varus*, Par.aus.-*Paratanytarsus austriacus*, Pha.fla.-*Phaenopsectra flavipes*, Pol.sord.-*Polypedilum sordens*, Psec.sord.-*Psectrocladius sordidellus*, Tanyt.sp.-*Tanytarsus* sp.)

Table 6

Canonical correspondence analysis: inter-set correlation of environmental characteristics with first two axis of CCA for studied sites of *C. demersum* of MD Lake Skomielno. Explanations as in Fig. 2.

Characteristics	Correlations	
	Axis 1	Axis 2
water temperature	0.575	-0.251
Secchi disc depth	0.201	-0.338
pH	-0.333	0.392
conductivity	-0.509	-0.168
dissolved oxygen	-0.152	-0.595
total suspension	0.380	0.287
ammonium nitrogen	-0.076	0.415
nitrate nitrogen	-0.831	0.288
total phosphorous	0.091	0.681
orthophosphates	0.009	0.668
epiphytic chlorophyll-a	0.761	0.021
biomass of periphyton	-0.623	-0.481
biomass of *C. demersum*	0.333	-0.416

Table 7

Canonical correspondence analysis: inter-set correlation of environmental characteristics with first two axis of CCA for studied sites of *C. demersum* of PD Lake Syczyńskie. Explanations as in Fig. 2.

Characteristics	Correlations	
	Axis 1	Axis 2
water temperature	0.219	-0.084
Secchi disc depth	-0.747	-0.483
pH	-0.623	0.648
conductivity	-0.362	-0.486
dissolved oxygen	-0.306	-0.033
total suspension	0.768	-0.542
ammonium nitrogen	0.756	0.346
nitrate nitrogen	0.390	-0.351
total phosphorous	0.224	0.543
orthophosphates	0.350	0.118
epiphytic chlorophyll-a	-0.167	0.293
biomass of periphyton	0.868	0.087
biomass of *C. demersum*	-0.244	-0.090

DISCUSSION

Previous studies on the macroinvertebrate distribution in relation to environmental conditions stressed the role of a few variables. There were the biomass and the type of macrophytes (Biggs, Malthus 1982; van den Berg et al. 1997; Weatherhead, James 2001; Tolonen et al. 2003), the substrate type (James et al. 1998; Chaloner, Wotton 1996), the periphyton abundance and the slope (Brodersen 1995; James et al. 2000).

The results of the present study suggest that the abundance of epiphytic midges was related to macrophyte biomass and colonization surface. In the MD lake, where macrophytes form dense homogenous beds, the average biomass of *C. demersum* was almost 4 times higher (326.7-1197.7 g m^{-2} WW) than in the PD lake with sparse, patchy vegetation cover (82.5-285.6 g m^{-2} WW). In the studied months, the average densities of midges showed significantly higher values in the clear state lake (72 - 180 ind. 100 g^{-1} DW) than those of the turbid state lake (13-34 ind. 100 g^{-1} DW).

High densities of chironomids on rigid hornwort in the macrophyte dominated lake confirmed the role of the plant as a habitat for invertebrate fauna. Such an observation has been pointed by other studies (Kornijów 1989; Hann 1995; Lombardo 1995). *C. demersum* is preferred for colonization by macrofauna, in comparison to other submerged macrophyte species. Due to highly dissected leaves, the plant forms bowl-shaped whorls set tightly together, particularly next to the tip of its stem. Such a morphological structure enables firmer attachment and protection for epiphytic organisms (Cyr, Downing 1988; Lalonde, Downing 1991).

The taxonomic composition of chironomids was closely related to habitat conditions. In the MD lake, larvae of *Psectrocladius* sp. (gr. *sordidellus*), *Paratanytarsus austriacus* and *Glyptotendipes* sp. presented high abundance These taxa usually colonized diatoms-covered and detritus-rich substrata (Coffman, Ferrington 1996), and can be classified as typical for clear-water ecosystems with well developed submerged vegetation (Tarkowska-Kukuryk, Kornijów 2008). In the PD lake, due to deterioration of the water quality (decrease of water transparency, high concentrations of chlorophyll-a and total P) and colonization area (small patches of *C. demersum),* the community of midges was represented mostly by larvae of *Cricotopus sylvestris* and *Endochironomus albipennis*. Both species are usually associated with aquatic plants, including algal mats. *E. albipennis* belongs to herbivore-scrapers, which feeds on epiphytic diatoms and detritus (Cattaneo 1983; Pinder 1986). Larvae of the *C. sylvestris* group are one of the most productive chironomids (Menzie 1981), which utilize a particular part of food resources (pennate diatoms and extremely high share of particulate matter). These larvae are characterized as detritus-collectors/grazers (Moller-Pillot, Buskens 1990; Dvorak 1996; Tarkowska-Kukuryk, Mieczan 2008). The abundance of *C. sylvestris* in the MD lake was low and negatively correlated with *C. demersum* biomass. In that lake, the area of colonization is very large, but the ecosystem is low productive and not abundant in detrital material. In the PD lake, the density of *C. sylvestris* larvae negatively correlated with periphyton biomass. The highest densities of these larvae were observed in months with lower biomass of periphyton. It can suggest that larvae of *C. sylvestris* did not utilize epiphytic algae as food and the abundance of periphyton did not determine the distribution of these midges. Moreover, in the periphyton structure in the PD lake, usually filamentous blue-green algae have high abundance, and they are not used as food by midges' larvae.

This study has demonstrated that lake status clearly affected the structure of midges' community associated with *C. demersum*. The density, species richness and composition of epiphytic chironomids, as well the results of CCA ordination showed significant differences between the lake types. The key direct determinants of the midges composition in the MD lake were N-NO_3, chlorophyll-*a* and periphyton biomass. In the PD lake, the most important factors were periphyton biomass, total suspension, N-NH_4, Secchi disc visibility and pH. The obtained results confirmed that the lake status influences not only the macrophyte structure and biomass, but also reflects other physical and biological conditions of a habitat (oxygen content, periphyton structure and biomass, detritus content) important for colonization of macroinvertebrates.

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