Chironomidae of semiaquatic lake shore habitats in the Karelian Isthmus (northwestern Russia)

Andrey Przhiboro[1] and Lauri Paasivirta[2]

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Shores of lentic waters are poorly studied as habitats of Chironomidae. We investigated floating shore marsh surrounding the lakes Bol'shoe Rakovoe (Äyräpäänjärvi or Eteläjärvi) and Okhotnich'e (Muolaanlampi), shallow mesotrophic wetlands in the Karelian Isthmus. Our research aimed to identify species structure of immature chironomid assemblages in this peculiar habitat and to provide their quantitative assessment. Five sites of the water margin zone (a 20-m part of floating marsh adjoining the lake littoral) were studied using two techniques, quantitative samples taken with a grab-net and laboratory rearings of adults from substrata. Thirty-two samples were taken in July and October; 2970 emerging chironomid adults were identified. Nineteen species were found, 3 of Tanypodinae, 10 of Orthocladiinae and 6 of Chironominae. *Tavastia yggdrasilia*, *Thienemanniella minuscula* and *Polypedilum trigonus* are first recorded from Russia, and 8 more species, from NW Russia. Orthocladiinae accounted for over 99% emerging adults, with 3 species predominant and numerous on all sites, *Paraphaenocladius impensus*, *Limnophyes minimus* and *L. natalensis*. Species structure is discussed and compared with the data on similar habitats. Chironomid larvae were most numerous macroinvertebrates. Mean abundance of chironomid immatures varied from 1246 to 32060 ind./m^2, mean biomass, 0.104 to 3.591 g(wet weight)/m^2, depending on site and season. In July, Chironomidae comprised 3-15% of Diptera biomass and 1-5% of macroinvertebrates biomass; in October, 13-49% and 7-20%, respectively.

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1. Zoological Institute, Russian Academy of Sciences, Universitetskaya nab. 1, St Petersburg 199034, Russia
2. Ruuhikoskenkatu 17 B5, Salo 24240, Finland

Corresponding author: Andrey Przhiboro
E-mail: dipteran@mail.ru

INTRODUCTION

Lake shores and other semiaquatic ecotones of inland waterbodies are poorly studied as habitats of chironomids. In northern Europe, the emergence of Chironomidae from semiaquatic habitats was studied only by few researchers (Paasivirta et al. 1988; Paasivirta 2007; Przhiboro 2008; Lundström et al. 2009a, 2009b; Ekrem et al. 2010). Chironomid immatures were rarely sampled quantitatively in these habitats as well. In central and southern Europe, researchers seem to focus more on shorelines of running waters, like springs and streams. Only some papers considered chironomid assemblages in the shores of standing waterbodies and in similar semiaquatic habitats (e.g. Strenzke 1950; Pankratova 1954; Dowling & Murray 1981; Frouz & Matěna 2000; Delettre 2001).

The aims of our study were (1) to estimate species composition and structure of chironomid assemblages in a highly specific semiaquatic habitat (floating marsh at lake shores) based on the emergence of adults and (2) to provide quantitative assessment of chironomid immatures in these habitats and to estimate their proportion in the total abundance of macroinvertebrates.

Study lakes and habitats

Lakes Bol'shoe Rakovoe (=Äyräpäänjärvi or Eteläjärvi) and Okhotnich'e (=Muolaanlampi) are shallow mesotrophic wetlands situated in the Karelian Isthmus, ca. 80 km NW of St Petersburg (60°37'N 29°25'E and 60°37'N 29°20'E, respectively). For the detailed data on the conditions of the study lakes, see Drabkova and Prytkova (1999) and Iovchenko (2012).

Both lakes are surrounded by a swing moor (marsh floating shore) hundreds meters wide and more than 0.5 m thick, which is formed by herbaceous vegetation and mosses (some tens of species are common; sedges, grasses and mosses predominate) and gradually turn into a *Sphagnum* bog in the direction of the basic shore. In the swing moor, roots form a thick turf filled with detritus and covered by a litter layer consisting of remains of herbaceous plants and mosses. Many places abound in mounds and small 1-2 cm deep pools between them. We studied only the water margin zone (a 20-m part of swing moor along the lake littoral zone except for a 0.5-m stripe adjoining the littoral; Figure 1). The zone under study is remarkable for several traits, no wave influence observed, stable water regime (neither flooding nor distinct drought occurred, as swing moor floats at water surface, and its upper layers always remained wet) and incoming coarse organic matter (mostly plant remains without allochthonous components).

For this study, five model sites were chosen different in some characteristics (Figure 2; Table 1). Large pools were not sampled.

MATERIAL AND METHODS

Study sites were sampled in 2001 using two techniques:
1. Quantitative samples of substrata (turf and litter) were taken with a biocoenometer (1/20 m^2 grab-net sampler). The samples were washed in sieves (the smallest 0.25 mm mesh), then the macroinvertebrates were extracted by flotation in a strong solution of NaCl combined with hand-sorting of the coarse fraction. Wet weight of invertebrates fixated in 4%-formaldehyde was determined using a VT-500 torsion balances, after drying the material on filter paper for several tens of seconds.
2. Shore substrata were sampled to a depth of 5-10 cm from the surface and placed into plastic containers (surface area from 10x15 to 30x30 cm) covered with a tight lid supplied with a fine-meshed window for ventilation. Total area of the substratum taken from each site at a time was ca. 2500 cm^2. After sampling, the litter layer of substratum in each container was examined to remove adult dipterans as well as larger predatory arthropods taken with the substratum. The containers were kept in the laboratory at room temperature (15-25°C) and natural light regime. In winter, the substrata were placed in 5-10°C and darkness for two months, for a reactivation of hibernating dipterans. The emerging imagines were collected with an aspirator once ever 2-6 days and stored in 70% ethanol. The substrata were kept until May 2002, a period when no emerging adults were observed for some weeks. The Chironomidae adults were determined in temporary water slides or permanent Euparal slides.

A total of 36 quantitative samples were taken on 5-6 July and on 30-31 October 2001, four samples per site at a time (site 5 was sampled only in July); 2910 chironomid adults emerged from the substrata, which were collected on the same dates from sites 1-4. The material is kept at the Zoological Institute, St Petersburg, and in the collection of L. Paasivirta.

RESULTS

Based on the identifications of adult males and females emerged from the substrata, we recorded 19 chironomid species in 16 genera and 3 subfamilies (Table 2). Eleven species represent new regional records. *Tavastia yggdrasilia*, *Thienemanniella minuscula* and *Polypedilum trigonus* are new for Russia. *Pseudorthocladius curtistylus and Stenochironomus hibernicus* are new for European Russia. Six more species are for the first time recorded from NW Russia (Table 2).

The Orthocladiinae accounted for over 99% emerging adults (Figure 3), with three species of *Limnophyes* and *Paraphaenocladius impensus* predominant. The dominance structure varied considerably between the sites as well as the total emergence (ca. 3 times). Sites at the same lake were more similar in the structure of chironomid assemblages according to Czekanowski-Sørensen quantitative index: the index value was 29% for sites 1 and 2 and 30% for sites 3 and 4; in other pairs, it was lower, 14-25%.

The abundance and biomass of chironomid immatures and other macroinvertebrates on study sites in July and October 2001 are displayed in Figure 4. The mean abundance of chironomid immatures varied from 1246 to 32060 ind./m^2, the mean biomass, 0.104 to 3.591 g(wet weight)/m^2, depending on the site and season. At each site, the values of abundance and biomass in July were several times lower than in October. Chironomid larvae were predominant in the abundance of macroinvertebrates on all sites (Figure 4). The proportion of Chironomidae comprised over 50% of the total abundance at all sites and dates except the sites of Lake Okhotnich'e (1 and 2) in July. In July, Chironomidae comprised 3-15% of the biomass of Diptera (except for site 5, where they accounted for 41%), and 1-5% of the biomass of macroinvertebrates; in October, their contribution was generally higher, 13-49% and 7-20%, respectively.

DISCUSSION

All chironomid species recorded are widespread; none of them is confined only to Northern Europe or to the Boreal Region

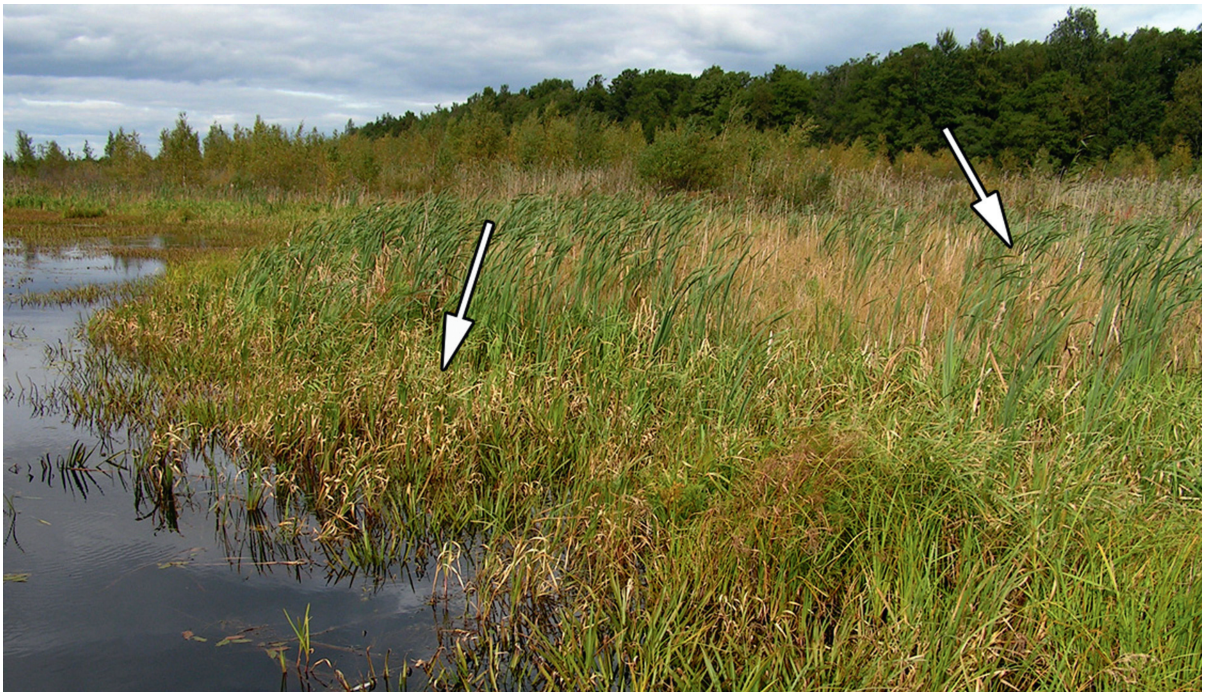

Figure 1. A typical landscape of the water margin zone at study lakes (Lake Bol'shoe Rakovoe, site 3). Arrows designate the borders of sampling zone. Photo: Andrey Przhiboro, 9 September 2004.

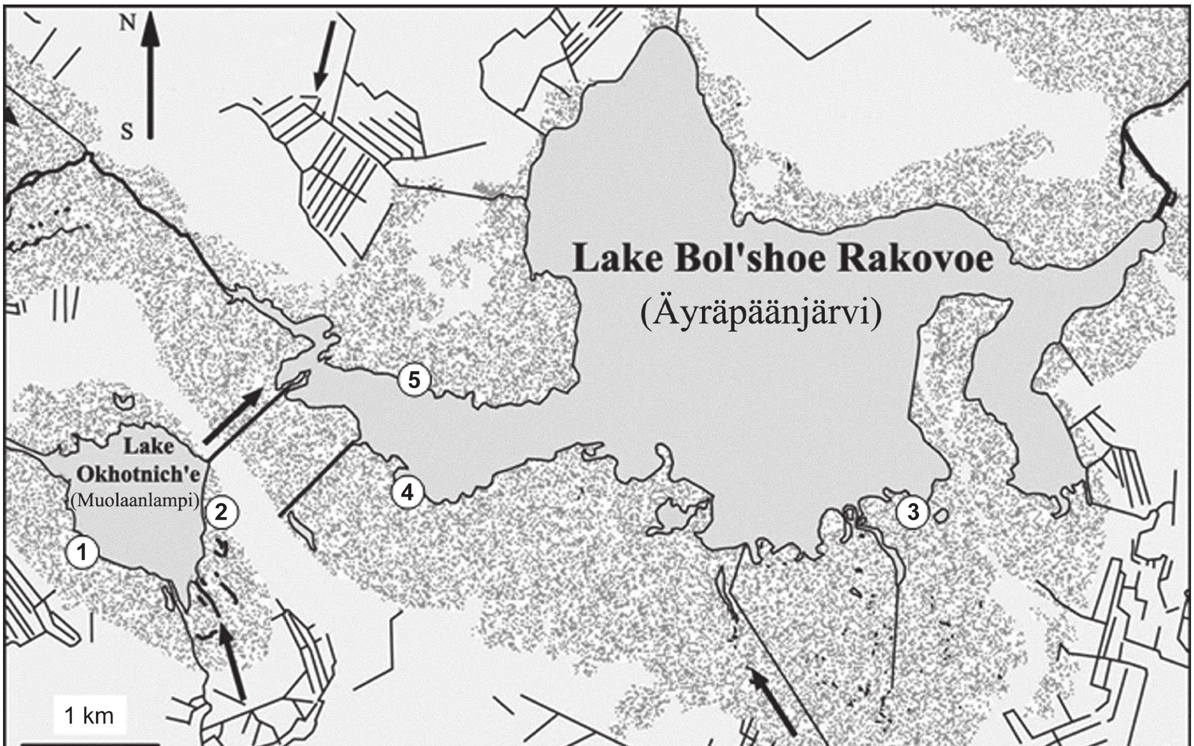

Figure 2. Map of the study lakes. Marshy shores (mostly, floating swing moor) are in grey colour. Position of model sites is designated by numbers in circles (1-5).

Table 1. Characteristics of the study sites.

Lake	Okhotnich'e (Muolaanlampi)		Bol'shoe Rakovoe (Äyräpäänjärvi)		
Site	1	2	3	4	5
Predominant phanerogams	*Comarum palustre, Carex diandra, Eriophorum polystachior*	*C. rostrata, C. diandra, Typha latifolia*	*C. palustre, Menyanthes trifoliata, Calamagrostis neglecta, C. rostrata, C. diandra*	Same as in site 3 + *Peucedanum palustre, Calla palustris, T. latifolia*	*Phragmites australis, C. diandra, C. palustre*
Vegetation height, cm	30-60	60-120	50-70	60-80	ca. 200
Total cover of phanerogams, %	15-40	30	50-80	80	70
Predominant mosses	*Sphagnum obtusum* *	mosses not abundant	*Calliergon cordifolium*	*C. cordifolium, S. squarrosum*	mosses not abundant
Litter layer	weak to well-developed	strongly developed	well-developed	strongly developed	weak
Mounds	weak (10-15 cm) or absent	numerous strong (20-30 cm)	numerous weak	numerous, weak to strong	numerous strong
Pools	small (less than 20x20 cm)	small	small to large	almost absent	small to large
Turf density	low to medium	medium to high	medium	medium to high	low

* As distinct from other sites, *Sphagnum* forms cushions on site 1 occupying ca. 60% of its area.

Table 2. Chironomidae adults emerging in the water margin zone of lakes Okhotnich'e (Muolaanlampi) and Bol'shoe Rakovoe (Äyräpäänjärvi) in 2001: species distribution by four sites.

LAKE	Okhotnich'e		Bol'shoe Rakovoe	
SITE	1	2	3	4
Tanypodinae				
Ablabesmyia monilis (Linnaeus, 1758)	1/0			
Monopelopia tenuicalcar (Kieffer, 1918)	0/1			
Natarsia sp.				0/1
Orthocladiinae				
Limnophyes asquamatus S. Andersen, 1937 +	**40/174**	**31/98**	0/13	**12/23**
Limnophyes minimus (Meigen, 1818)	**2/380**	**3/98**	**14/111**	**23/46**
Limnophyes natalensis (Kieffer, 1914) +	**78/42**	**19/13**	**109/90**	**175/90**
Metriocnemus eurynotus (Holmgren, 1883)	1/0		3/0	1/1
Paraphaenocladius impensus (Walker, 1856) +	**38/52**	**34/41**	**106/124**	**389/364**
Pseudorthocladius curtistylus (Goetghebuer, 1921) ●			3/2	2/1
Pseudosmittia forcipata (Goetghebuer, 1921) +			3/0	1/0
Smittia sp.			0/3	0/4
Tavastia yggdrasilia Brodin, Lundström & Paasivirta,2008 ●			12/2	8/5
Thienemanniella minuscula (Brundin, 1949) ●				0/1
Chironominae				
Chironomini				
Endochironomus albipennis (Meigen, 1830)	0/1			
Paratendipes nudisquama (Edwards, 1929) *		0/1	2/0	
Polypedilum (*Pentapedilum*) *tritum* (Walker, 1856) +	0/1		1/1	
Polypedilum (s. str.) *trigonus* Townes, 1945 ●	1/1	0/1	3/4	1/1
Stenochironomus hibernicus (Edwards, 1929) ●	1/0	0/1		
Tanytarsini				
Zavrelia pentatoma Kieffer & Bause, 1913 +			0/1	
SPECIES NUMBER	11	7	13	12
TOTAL NUMBER OF ADULTS EMERGED	814	340	607	1149

Designations. In cells, numbers of males/females emerged; those of species abundant on respective sites are **in bold.** New records: "●", species new for European Russia; "+", species new for NW European Russia.

* *Paratendipes nudisquama* (Edwards, 1929) is a possible junior synonym of *P. subaequalis* (Malloch, 1915) according to Hayford (2003).

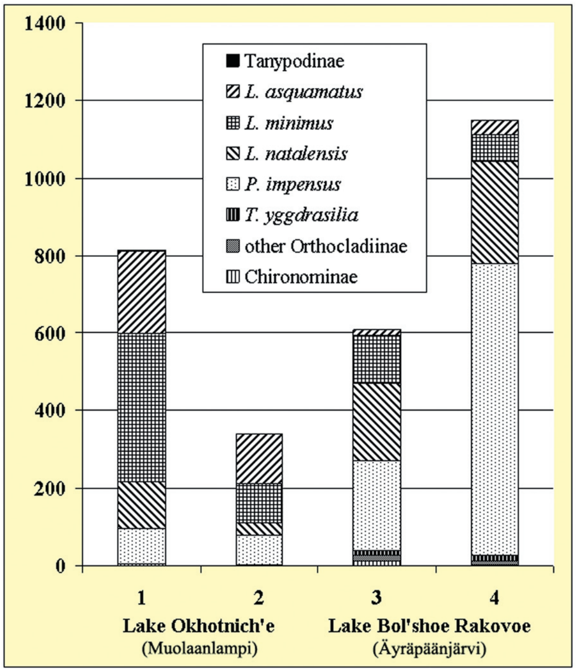

Figure 3. Species structure of chironomid assemblages in semiaquatic shore habitats of the study lakes based on the emergence of adults in 2001-2002. Abscissa: sites. Ordinate: numbers of adults emerged.

(Sæther & Spies 2011). Many new records above all indicate poor knowledge of the chironomid fauna in NW Russia. *Tavastia yggdrasilia* is a recently described species, which was recorded only from Sweden, Finland, the Netherlands and Belarus; this species is confined to wetlands (Brodin et al. 2008) and is abundant in temporary flooded floodplain wetlands in Central Sweden (Lundström et al. 2009a). It was recently collected also in NE European Russia (Krasheninnikov 2012). *Polypedilum trigonus* was only recently found in Europe (Lundström et al. 2009a; Paasivirta 2012).

The chironomid assemblages in the floating marsh habitat include mostly so-called "semiterrestrial" species, which always predominated in numbers. Immatures of the collected species of Orthocladiinae are known to prefer semiaquatic habitats (e.g. Fittkau & Reiss 1978; Moller Pillot 2005; Paasivirta 2012). Some of these species are able to develop in drier terrestrial habitats, like meadow and forest soil (e.g. Strenzke 1950; Frouz 2000); on the other hand, many of them were also recorded from aquatic habitats (e.g. Pankratova 1970; Sæther 1990). The recorded species of Tanypodinae and Chironominae live mostly in shallow aquatic habitats in standing waters (Pankratova 1977; Maschwitz & Cook 2000; Vallenduuk & Moller Pillot 2007; Moller Pillot 2009; Paasivirta 2012), except for *Natarsia*, which occur in semiaquatic conditions as well (Frouz & Matěna 2000; Vallenduuk & Moller Pillot 2007). No species restricted

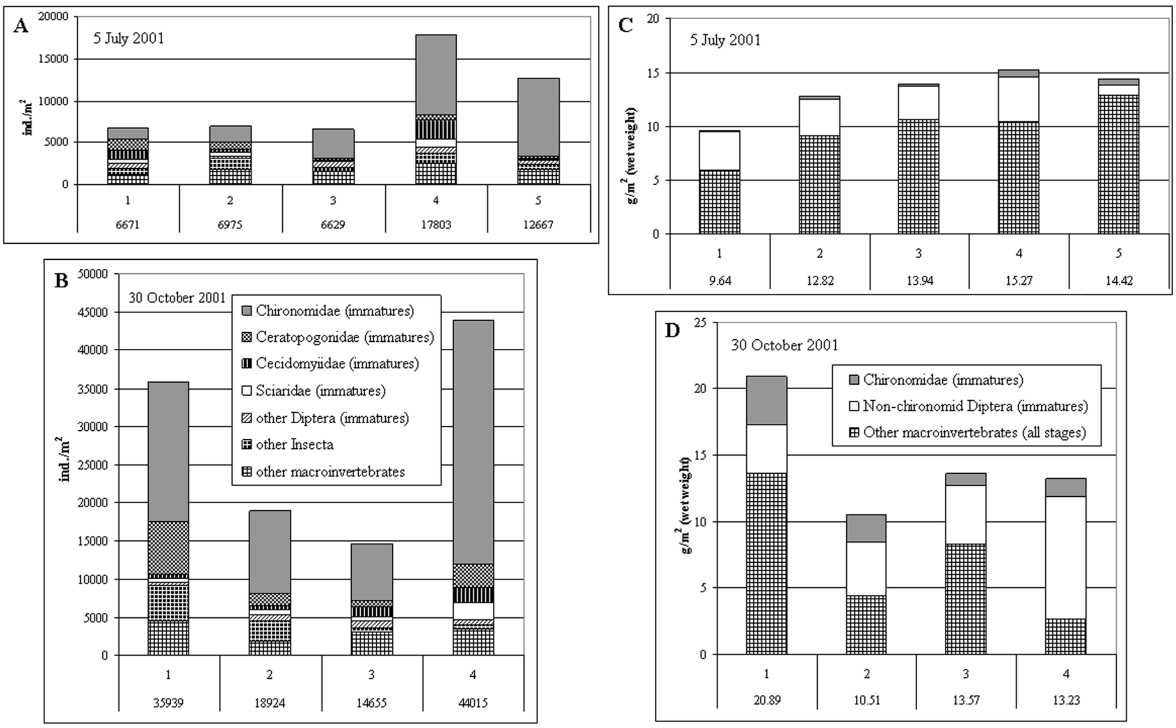

Figure 4. Abundance and biomass of chironomid immatures and other macroinvertebrates on study sites (A, B – abundance; C, D – biomass). Sampling dates are indicated. Abscissa: sites (in upper row) and values of total abundance or biomass (wet weight) per square meter (in lower row). Ordinate: values of abundance or biomass (wet weight), as designated. Legend is the same for charts on both dates. Averaged values (n = 4) are given for each site and date.

to marshes or bogs were found, although *T. yggdrasilia* and *P. trigonus* occurred mostly in these habitats.

At Lake Okhotnich'e, emerging females of *Limnophyes minimus* were abundant, whereas males were almost absent during all the period of emergence, supporting the earlier conclusion about facultative parthenogenesis in this species (Goetghebuer 1932; Sæther 1990).

Only small-sized chironomids colonized the study habitat (larvae and adults rarely exceed 3-4 mm in the body length; no species with larvae larger than 6 mm were found). Almost all chironomid species in our list feed on detritus or/and algae (mostly gatherers-collectors); some are facultative predators and only *Ablabesmyia monilis* feeds mostly as predator (Berg 1995; Berg et al. 1996; Monakov 2003; Vallenduuk & Moller Pillot 2007; Moller Pillot 2009). Both the latter tendencies were not observed in most other semiaquatic habitats in the temperate zone–marshes, fens, swamps, shores of springs and streams, etc. (e.g. Crisp & Lloyd 1954; Pankratova 1954; Hudson 1987; Wrubleski 1987; Lundström et al. 2009a, 2009b; Ekrem et al. 2010).

In the study habitat, only Orthocladiinae were abundant. Although high abundance of "semiterrestrial" orthoclads is quite typical of shoreline and moist terrestrial habitats (e.g. Strenzke 1950; Rosenberg et al. 1988; Lundström et al. 2009a; pers. obs.), species of Tanypodinae and Chironominae are often common or abundant in such situations as well (e.g. Erman & Erman 1975; Dowling & Murray 1981; Frouz & Matěna 2000; Lundström et al. 2009a; pers. obs.). Species structure in the study sites was similar to that described by Strenzke (1950) for "*Pseudorthocladius-curtistylus*-Synusie", which was described from lakeshores, wet meadows and alder swamps in Germany and Austria. In addition, the abundance values reported by Strenzke (3600-13000 ind./m^2; recalculated to m^2) are similar to those in our sites (Figure 4), suggesting that the habitat conditions were similar as well.

The species number of Chironomidae in all study sites is rather low, much lower than in most of shallow aquatic habitats of NW Europe. The species richness was several times as high in more unstable floodplain wetland (Lundström et al. 2009a) and in spring habitats on a fen (Ekrem et al. 2010), the habitats situated in the same geographical zone. At the same time, the total number of species found in our study (19) is compatible to that was found to develop in many other semiaquatic habitats of the temperate zone (5-35 spp. per habitat in the locality), if aquatic parts like pools or ditches on bogs are not included (e.g. Strenzke 1950; Wrubleski 1987 and references therein; Rosenberg et al. 1988; McLaughlin & Harris 1990; Delettre 2001).

Among the study sites (1-4), species richness was the lowest at site 2 (Table 2), which looked more uniform in relief and vegetation. Although we recorded a considerable variability between the sites in the abundance of chironomid immatures and in the total emergence of adults (Figures 3, 4), no trends were found on the site scale correlated to the variability in conditions (Table 1). The only possible tendency is that the highest abundance of chironomid larvae was observed in autumn on sites 1 and 4 with the most developed *Sphagnum* cover; the higher numbers of emerging adults characterized the same sites. Apparently, to conclude about factors it is necessary to take into account a higher number of environmental variables, model sites and variability on a smaller scale (e.g. microzonality and patchiness within site).

A comparison of our data with the results of a study of macrobenthos in the littoral zone of the same lakes conducted in the late 1980ies (Skvortsov & Belyakova 1999) has shown that the species lists of chironomids are very different. Of 35 chironomid species recorded in the littoral zone, only *Ablabesmyia monilis* and *Endochironomus albipennis* were found in the water margin, as single specimens. The abundance of chironomid larvae in the water margin as a rule was several times as high as in littoral habitats. Typically, the biomasses in the water margin in July (0.1-0.7 g/m^2) were lower than in the littoral (0.5-5.6 g/m^2); the biomasses in October (0.9-2.0 g/m^2) were level with those in the littoral. Skvortsov and Belyakova (1999) published only mean values without standard errors; hence, precise comparison is not possible. Similarly, mean abundance values recorded in our study look as rather high as compared to most semiaquatic and aquatic habitats. The mean biomasses are similar to the values typically recorded for shallow oligo- and mesotrophic aquatic habitats in NW Russia (e.g. Przhiboro 1999, 2004; Yakovlev 2005).

In addition to the "semiterrestrial" Chironomidae, immatures in many other families of Diptera develop in this habitat abundantly but are absent or not common in other lakeshore habitats of NW Russia (Przhiboro 1999, 2001, 2004). Among them are many species of Ceratopogonidae, Mycetophilidae, Cecidomyiidae and Phoridae (Przhiboro & Mamaev 2003; Przhiboro 2012).

Probably, two factors determine specific features of swing moor as a habitat for chironomids and other dipterans, stable water regime and the composition of incoming plant remains. Fluctuations of the water level were reported as a major limiting factor for the diversity of chironomids and other insects in wetland and semiaquatic habitats (e.g. Wrubleski 1987; Batzer & Wissinger 1996). In particular, immatures of many "semiterrestrial" Chironomidae require high moisture of substratum and do not tolerate drying or prolonged flooding (Moller Pillot 1994, 2005 and references therein; Frouz 2000). However, in our case, stable and rather diverse semiaquatic conditions of the lake shore marsh support high abundance but low species richness of Chironomidae.

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