Phenology of non-biting midges (Diptera: Chironomidae) in peatland ponds, Central Poland

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Płóciennik, M., Skonieczka, M., Antczak, O. & Siciński, J. 2018: Phenology of non-biting midges (Diptera: Chironomidae) in peatland ponds, Central Poland. — Entomol. Fennica 29: 61–74.

Non-biting midges are one of the most diverse and abundant aquatic insects in peatlands. The Rąbień mire is a raised bog located on the edge of the Lodz Agglomeration in Central Poland. After peat extraction, many ponds remained in the Rąbień area. During the growing season in 2012, adult chironomids were collected by a light trap and a hand net near one of the excavation ponds. The phenology of adult flight period was documented from April to November. Thirty-one species were recorded and assigned to one of five phenology groups. Three parameters reflecting duration of daytime and weather conditions, i.e. air temperature, air humidity, were found to covary significantly with the observed flight periods. Taxa emerging in the spring may be classified as cold-adapted and those collected in the summer only as preferring higher air temperature. Emergence in late summer was related to a shorter duration of daytime.

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Received 21 December 2016, accepted 27 September 2017

1. Introduction

Besides typically aquatic ecosystems, Chironomidae occur in various semiterrestrial and terrestrial habitats, and are present in natural and human-transformed peatlands. Wrubleski (1987), Walker *et al.* (1985) and Suren *et al.* (2008) have shown that Chironomidae are among the dominant groups of aquatic insects in diverse types of bogs and fens, including water bodies. The domination of Chironomidae increases considerably in degraded wetlands (Brady *et al.* 2002, Ramchunder *et al.* 2012).

In the last decades in Europe, there have been few comprehensive studies on Chironomidae phenology including springs, streams, ponds and dystrophic lakes (e.g. Cayrou & Céréghino 2005, Krasheninnikov 2012, Przhiboro & Paasivirta 2012, Ivković *et al.* 2015). Whereas Cayrou and Céréghino (2005) and Ivković *et al.* (2015) present records of the whole life cycles and emergence phenologies of various insects, including Chironomidae, from karst water bodies in the Mediterranean Region, Krasheninnikov (2012) and Przhiboro and Paasivirta (2012) investigated adult and immature stages of Chironomidae in

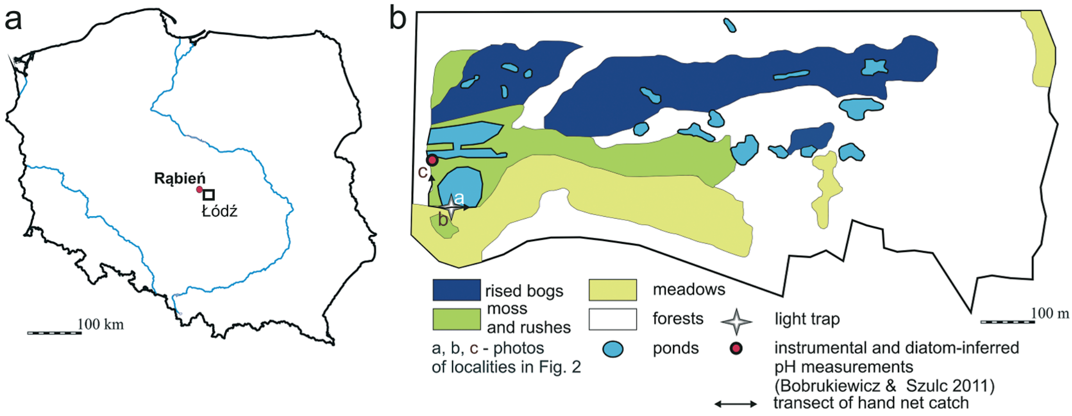

Fig. 1. The Rąbień Bog reserve in Central Poland. – a. Geographic location. – b. Habitat distribution map based on Kucharski *et al.* (2004).

North-Eastern European streams and lakes. Such a study, conducted on a broad scale, was provided earlier on wetlands and ponds in North America, for example, by Rosenberg *et al.* (1988) and Dendy (1971). Rosenberg *et al.* (1988) investigated the life cycle of semiterrestrial taxa (mostly Orthocladiinae) in truly peatland habitats. Dendy (1971) investigated emergence of adults from experimental ponds during studies of three years.

The most recent study of macrobenthos in peatland lakes is by Baars *et al.* (2014). As they collected pupal exuviae, their information strictly concerns species emergence, but samples were gathered only twice a year, in April and August.

A detailed review of the phenology of Europaen Tanypodinae, Chironomini and Orthocladiinae was made by Vallenduuk and Moller Pillot (2007) and Moller Pillot (2009, 2013). They gathered diverse data from intensive studies to more random observations from all types of habitats across Europe.

In Poland, wetlands cover only 1.9% of the Lodz region territory. They are mostly fens in river valleys and only few may be classified as raised bogs covering no more than 1% of the peatland area (Forysiak 2012, Żurek & Okupny 2015). Although these habitats are so rare, studies on bogs on watersheds constitute an important part of paleolimnological and ecological studies. One of the mires on watersheds is the Rąbień Bog, located at the edge of the Lodz Agglomeration. Some entomological studies at this site concerned Carabidae (Jaskuła 2003, Jaskuła & Stępień 2012) and moths (Zima 2014). The communities of higher plants and algae were investigated by Mamiński (1987), Kucharski *et al.* (2004) and Bobrukiewicz and Szulc (2011). More intensive studies have concerned past Chironomidae assemblages from the Late Weichselian (14,800 calibrated years before present (cal. BP)) to the beginning of the Subatlantic Period (2,100 cal. BP) (Płóciennik *et al.* 2015, Słowiński *et al.* 2016).

To complement subfossil data, research of the current Rąbień's midge fauna was conducted. Ponds left after former peat extraction are an important habitat for chironomids in the reserve. That is why studies were focused on midge appearance close to one of them. The main aim of this research was to recognise the flight periods of the chironomid taxa living at the pond area and their relation to local weather conditions.

2. Materials and methods

2.1. Study area

The Rąbień Bog (Fig. 1) is located in the Łask Upland, 11 km northwest of the Łódź city centre, in the village of Rąbień AB. The bog covers an area of about 42.5 ha and is located 189 m above the sea level. The south part of the peatbog is almost totally degraded to meadow-like open habitats and rushes. Peat excavations have been backfilled by construction debris. On the border of the peatbog, there is a first order watershed between the rivers of Bzura and Ner (Forysiak 2012). Currently, the Rąbień Bog is protected by law as a nature reserve. The main purpose of the reserve is to preserve a raised bog with *Shagnum-Eriophorum* peatland, unique in this region. A great part of the reserve is covered with peat pools, which are in various stages of secondary succession, with a total area of 0.4 ha. The youngest peat pools are in the form of small ponds or are filled with brown water and covered with swamp communities. In the oldest ones, there are floating *Sphagnum* mosses and rhizomes of semiaquatic plants, such as *Calla palustris*.

2.2. Sampling and taxonomic identifications

The site where the light trap was situated is in the west part of the Rąbień Bog (Fig. 1), directly at the largest pond of the reserve (Fig. 2a), with a large surface of exposed water table and a wide reed belt. The older peat pool, fully covered by cattail and reed on the *Sphagnum* carpet, was also near the light trap (Fig. 2b). The light trap was equipped variably with a 250 or a 500 W mercury vapour lamp and it was generally operated between 9 and 11 p.m. for at least 1.5 h after dusk (Table 1). Net catches were taken along the above-described shorelines of the pond (Fig. 1), as well as on the margins of the bog, approx. 100–200 m away from the light trap (Fig. 2c). Catches were made on the east side of the Rąbień Bog reserve, in Torfowa Street, near the large pond (Fig. 2). Net samples were taken between 6.30 and 8.00 p.m. during sunlight. From April to November 2012, catches of Chironomidae imagines were made during 20 days. Non-biting midges occurred in the period from 18 April to 15 September.

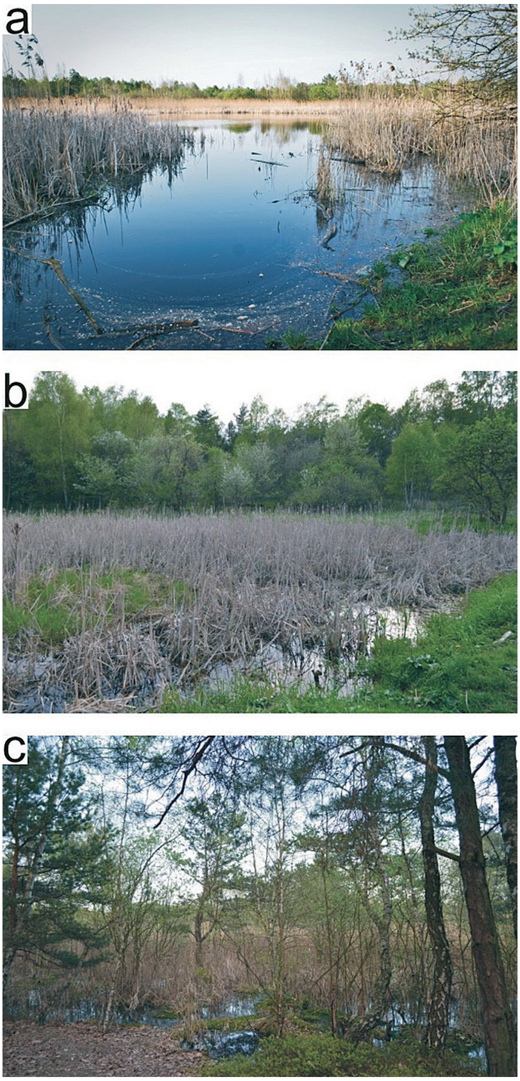

Fig. 2. Photographs of sampling sites. – a. Pond. – b. Swamp developed after peat extraction, overgrown by reed rushes. – c. Edge of peat bog.

Taxonomic identifications are based on male hypopygia following Langton and Pinder (2007), Giłka (2011) and Makarchenko (2006). Out of 240 caught specimens, 199 were identified to the species or species group level. Taxon names are reported as given in Sæther and Spies (2013), where applicable. Among male hypopygia in collected species of the genus *Chironomus* Meigen, 1803, *C.* cf. *pilicornis* (Fabricius, 1787), *C. longistylus* Goetghebuer, 1921, *C. anthracinus* Zetterstedt, 1860 and *C.* "pallidivittatus" sensu Edwards, 1929, as well as *C.* cf. *plumosus* (Linnaeus, 1758) are easier to distinguish. Besides these taxa, two morphotype groups were distinguished: *Chironomus piger* Strenzke, 1956 group, and *Chironomus annularius* Meigen, 1818 group. *Chironomus* gr. *piger* includes the morphologically similar species *C. piger*, *C. lugubris* Zetterstedt, 1850 and *C. riparius* Meigen, 1804. *Chironomus* gr. *annularius* includes *C. annularius* Meigen and *C. prasinus* Pinder, 1978.

The reference collection of permanent slides of hypopygia mounted in Euparal® is deposited and available at the Department of Invertebrate Zoology and Hydrobiology, University of Lodz.

Table 1. Meteorological data of the Łódź Lublinek station and times of days recorded on the dates of sample collection in 2012. – A. April–June. B. July–September.

A. April–June	April	May			June				
	18	3	15	20	5	17	18	19	30
Method*	HN	HN	LT	LT	HN&LT	LT	LT	LT	HN
Light trap collecting									
Duration (h)			2	2	2	2	2	2	2
Hours			21–23	22–24	21–23	22–24	22–24	22–24	
Hand net collecting									
Duration (h)	1.5	2			2				2
Hours	19–20.30	18.30–20.30			19–21				18–20
Air humidity									
Mean	67	65	73	65	84	66	67	68	65
Max	93	94	100	100	100	88	100	83	88
Min	47	41	51	30	63	50	43	46	43
Dew point (°C)	0	24	6	12	10	15	16	15	17
Precipitation (mm)	0	0	0	0	0	0	0	0	0
Air temperature (°C)									
Mean	5	18	12	19	12	22	22	20	24
Max	12	26	13	27	17	24	30	23	32
Min	–2	11	10	11	7	18	14	18	16
Air pressure (hPa)	1004.12	1008.42	1012.5	1013.77	1010.63	1020.52	1019.75	1019.35	1014.30
Wind speed (km/h)									
Mean	11	6	10	11	3	11	8	8	8
Max	28	18	24	26	17	20	22	17	17

B. July–September.	July				August			September		
	2	5	8	23	11	12	20	2	9	15
Method*	HN	LT	HN&LT	LT	HN	LT	HN	HN&LT	LT	LT
Light trap collecting										
Duration (h)		2	1	2		2		2	1	2
Hours		22–24	21–22	22–24		22–24		21–23	22–23	22–24
Hand net collecting										
Duration (h)	2.5		2		2		2	1.5		
Hours	17–19.30		18.30–20.30		18.30–20.30		19–21	19–20.30		
Air humidity										
Mean	78	70	79	62	89	67	52	78	78	79
Max	100	100	100	100	100	94	88	100	100	94
Min	57	49	54	31	77	43	26	53	49	67
Dew point (°C)	18	20	18	9	12	9	14	13	12	10
Precipitation (mm)	0	0	0	0	0	0	0	0	0	0
Air temperature (°C)										
Mean	22	25	22	16	14	15	26	17	17	14
Max	26	31	27	25	17	19	35	21	21	16
Min	19	19	17	8	12	10	16	13	13	11
Air pressure (hPa)	1019.77	1013.47	1011.49	1028.51	1019.09	1018.76	1017.43	1024.93	1020.37	1011.17
Wind speed (km/h)										
Mean	9	8	6	3	6	9	6	2	8	12
Max	17	15	15	11	15	17	28	7	15	28

* HN: Hand net, LT: Light trap.

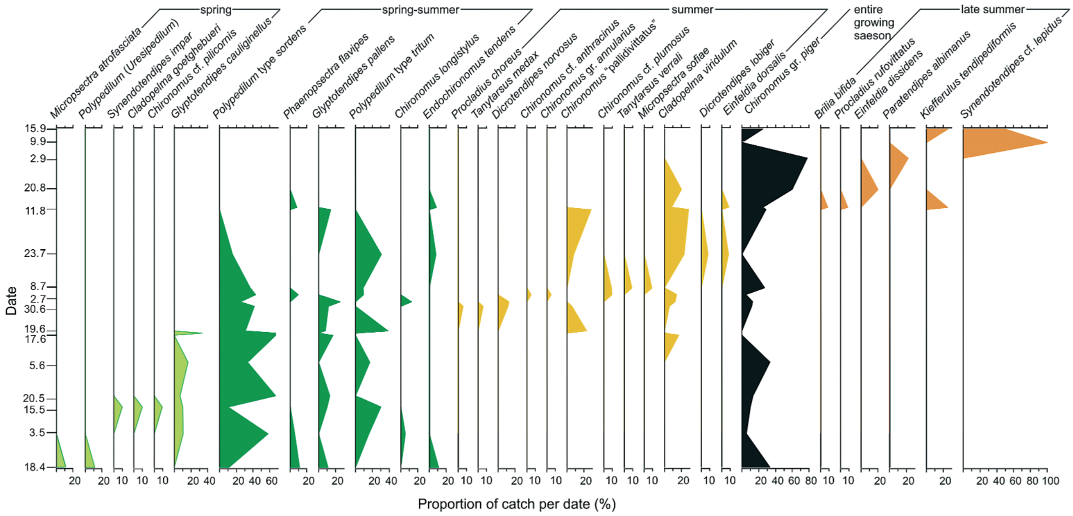

Fig. 3. Species-specific adult male phenologies of recorded chironomid taxa at the Rąbień Bog.

2.3. Meteorological data

Meteorological data of the Łódź Lublinek station (approx. 12 km southeast of the study area) were obtained from the www.wunderground.com website. Data on duration of daytime and weather variables (mean day temperature, min. day temperature, max. day temperature, mean day humidity, min. day humidity, max. day humidity, presence of rain, presence of storm, presence of fog) were gathered for all 151 days of the investigated growing season in 2012 (summarized Table 1).

2.4. Analyses

Based on the taxon records per sampling date, a phenological diagram was created with C2 software (Juggins 2007). The taxa were divided into five groups according to their flight seasons: collected in spring only, during spring and summer, in summer only, in late summer only, and throughout the season. Each of the seasons was delineated by the first and last appearances of males within the respective species group. The mean, standard deviation, as well as extreme values of air temperature and humidity were calculated for each swarming season for all the days (not only the sampling days). The mean, shortest and longest duration of daytime for each swarming season was also determined. Significance of the difference between mean values of air temperature, humidity and duration of daytime was tested by the Kruskal-Wallis test (Zar 1984) using STATISTICA software (StatSoft Inc. 2015).

To test for possible relations between the phenological groups of the chironomids and the weather conditions, a Canonical Variate Analysis (CVA) was performed with the use of Canoco 4.5 software (Ter Braak & Smilauer 2002). Due to autocorrelation, min. day temperature and max. day temperature were excluded from the analysis. An unrestricted full model Monte Carlo permutation using automatic selection was computed to test for significance of the relations between the environmental variables and the species occurrences.

3. Results

In the material collected, 31 Chironomidae taxa were identified (Table 2a, b, Fig. 3). The species of the tribe Chironomini were the most abundant. The highest species abundances in the samples were recorded for *Chironomus* gr. *piger* and *Polypedilum* cf. *sordens* (van der Wulp, 1875), with slightly lower values for *Cladopelma viridulum* (Linnaeus, 1767), *Glyptotendipes pallens* (Meigen, 1804) and *Polypedilum* cf. *tritum* (Walker, 1856). All other species were considerably less frequent in the samples.

Table 2. Numbers of collected Chironomidae specimens on the Rąbień Bog, Central Poland, in 2012. – A. April–June. B. July–September.

A. April–June	April	May			June				
	18	3	15	20	5	17	18	19	30
Chironomini									
Chironomus gr. *annularius* (*annularius* + *prasinus*)									
Chironomus cf. *anthracinus*									
Chironomus longistylus		1							
Chironomus “pallidivittatus”								3	1
Chironomus gr. *piger* (*piger, lugubris, riparius*)	3	1	1	2	2				2
Chironomus cf. *pilicornis*			1						
Chironomus cf. *plumosus*									
Cladopelma goetghebueri			1						
Cladopelma viridulum						1			1
Dicrotendipes logiber									
Dicrotendipes nervosus									2
Einfeldia dissidens									
Einfeldia dorsalis									
Endochironomus tendens	1								
Glyptotendipes cauliginellus			1	1	1		1		
Glyptotendipes pallens	1		1	2		1		1	2
Kiefferulus tendipediformis									
Paratendipes albimanus									
Phaenopsectra flavipes	1	1							
Polypedilum (*Uresipedilum*)	1								
Polypedilum cf. *sordens*	1	11	1	10	2	4	2	4	7
Polypedilum cf. *tritum*		3	3		1			5	
Synendotendipes impar			1						
Synendotendipes cf. *lepidus*									
Tanytarsini									
Micropsectra atrofasciata	1								
Micropsectra sofiae									
Tanytarsus mendax									1
Tanytarsus verrali									
Tanypodinae									
Procladius choreus									1
Procladius rufovittatus									
Orthocladiinae									
Brilia bifida									
Number of specimens	9	19	10	15	6	6	3	13	17

B. July–September	July				August			September		
	2	5	8	23	11	12	20	2	9	15
Chironomini										
Chironomus gr. *annularius* (*annularius* + *prasinus*)		1								
Chironomus cf. *anthracinus*		1								
Chironomus longistylus	1									
Chironomus “pallidivittatus”				1	2					
Chironomus gr. *piger* (*piger, lugubris, riparius*)	1	1	3		2	3	3	7		2

Table 2, continued

Chironomus cf. *pilicornis*										
Chironomus cf. *plumosus*		2	1							
Cladopelma goetghebueri										
Cladopelma viridulum	1	3		3	2	1	1			
Dicrotendipes logiber				1						
Dicrotendipes nervosus	1									
Einfeldia dissidens							1			
Einfeldia dorsalis				1		1				
Endochironomus tendens				1		1				
Glyptotendipes cauliginellus										
Glyptotendipes pallens	2				1					
Kiefferulus tendipediformis						3				2
Paratendipes albimanus								2		
Phaenopsectra flavipes		2				1				
Polypedilum (*Uresipedilum*)										
Polypedilum cf. *sordens*	2	9	4	2						
Polypedilum cf. *tritum*		2	1	4						
Synendotendipes impar										
Synendotendipes cf. *lepidus*									7	4
Tanytarsini										
Micropsectra atrofasciata										
Micropsectra sofiae			1							
Tanytarsus mendax										
Tanytarsus verrali			1							
Tanypodinae										
Procladius choreus										
Procladius rufovittatus						1				
Orthocladiinae										
Brilia bifida						1				
Number of specimens	8	21	11	13	7	12	5	9	7	8

In Fig. 3, each recorded species is assigned to one of the five phenological groups of Chironomidae, ordered according to their subsequent appearance during the growing season. Fig. 4 presents weather specification for the spring, spring–summer, summer and late summer seasons, excluding *C*. gr. *piger* emerging from spring to late summer. The *Chironomus* gr. *piger* flight occurs throughout almost the entire growing season.

Three out of the eight investigated variables were significantly associated with flight periods shown by the results of CVA: duration of daytime (*P*=0.002, explaining 34% of flight season variability) and the weather variables of mean day air temperature (*P*=0.002, 9.6%) and mean day humidity (*P*=0.002, 7.4%). Mean day humidity was correlated positively and duration of daytime was correlated negatively with the 1st axis; mean day temperature was negatively correlated with the 2nd axis. The first and second CVA axes explained 39.4% and 13%, respectively, of the variance of the species occurrences, as well as 75.2% and 24.7% of the variance of the species–environment relations.

4. Discussion

The phenology of most of the chironomid species reported from the Rąbień Bog was reviewed for other areas by Vallenduuk and Moller Pillot (2007) and by Moller Pillot (2009, 2013). Our results largely agreed with those reviews, with however some differences. In general, our study indicated that the spring–summer species fly during long daytimes, when air humidity remains relatively low. They are eurythermic. The flight periods of the late summer species are strongly related to a short and decreasing daytime and relatively high air humidity. Whereas the spring–

summer and the late summer taxa are more closely related to the duration of the daytime and humidity, the species that fly only in spring or only in summer are more related to air temperature. The spring species fly in low air temperature, the longest and the most increasing duration of daytime, as well as low humidity. The taxa, which fly during summer seem to be unrelated to the duration of day-time or humidity but clearly prefer higher mean air temperature for their emergence.

Spring taxa were the earliest flying ones at the study site and were not reported as adults after 15 May, besides *G. cauliginellus*, whose last males were collected on 19 June. It has usually two generations from June to September (Moller Pillot 2009). It seems that in Rąbień it appears much earlier, being one of the first species that was flying as early as on 3 May. It may be associated with a long and increasing duration of daytime. It is supposed that in Russia *S. impar* has two generations, the first one in April and the second one, possibly incomplete, in autumn (Moller Pillot 2009). In Rąbień, the second generation was not observed. *Chironomus pilicornis* is a cold stenotherm and has a mostly northern distribution (Moller Pillot 2009). It is considered to have only one generation in Europe and the adults emerge in spring from April to May. The present study confirm the early occurrence and at least cold adaptation of *C.* cf. *pilicornis*, as far as it can be compared with the true *C. pilicornis*. However, because the collected material is small, it cannot be excluded that some of spring taxa appear also later in summer or even in late summer.

Endochironomus tendens, *P. tritum*, *P. flavipes*, *G. pallens* and *P. sordens* are spring–summer species. Nearly all these species have 2–3 generations in Europe (Moller Pillot 2009). In the Rąbień Bog, they also emerge from pupae for a longer part of the growing season. *Polypedilum tritum* was present during almost the entire growing season. Despite significantly higher temperature in the spring–summer period than in spring, the CVA indicated that these species are rather eurythermic. Together with spring taxa, they are related to lower humidity and longer duration of daytime than the species that emerged as adults only in the late summer.

The group of summer species are *C.* gr. *annularius*, *C. anthracinus*, *C.* “pallidivittatus”, *C.* cf. *plumosus*, *C. viridulum*, *D. nervosus*, *D. lobiger*, *E. dorsalis* and *P. choreus*. Moller Pillot (2009) reviews these taxa as having usually two generations and the flight period from about May to about September. Nevertheless, some of them may have only one generation or emerge only once a year, such as *C. anthracinus*, *D. nervosus* and *P. choreus*. *Chironomus* gr. *annularius* may have a variable number of generations in Europe, from one to many. Its development is negatively correlated to the duration of daytime but together with *C.* cf. *plumosus* it is positively correlated to temperature (Moller Pillot 2009). *Dicrotendipes nervosus* occurs in Central Europe in a variable number of generations – from 2–3 to one generation in England. Another *Dicrotendipes* species, *D. tritomus* (Kieffer, 1916) have two generations in south-western France – the first, long, overwintering one, from September to May and the second one – short, lasting from July to August (Cayrou & Céréghino 2005). Moller Pillot (2009) suggests that if winter is hard with long-lasting ice cover, the first generation may be delayed or very small. Whereas in the present study the winter of 2011/12 was generally within the long-term average temperature, there were periods of quite severe conditions. December was mild (t_{mean} 2 °C, t_{min} –9 °C, t_{max} 10 °C) but January (t_{mean} –1 °C, t_{min} –14 °C, t_{max} 10 °C) and February (t_{mean} –6 °C, t_{min} –21 °C, t_{max} 9 °C) were quite severe with long periods of temperature below 0 °C. Even in March, temperature decreased to –9 °C. This might have had an influence on the number of generations and their abundance, and might have delayed flight period of the summer taxa. It is possible that the summer taxa were also present as imagines longer at the investigated site, but their populations were too small to be detected. Apart from that, it is clear from these studies and the data cited by Moller Pillot (2009) that they prefer higher air temperture than the taxa of the other phenological groups.

Kiefferulus tendipediformis, *P. albimanus, E.* cf. *lepidus*, *B. carbonaria*, *P. rufovittatus* and *B. bifida* can be classified as late summer species in the Rąbień pond. These taxa may be either bivoltine (*K. tendipediformis*, *E. lepidus*) or can have one generation (*B. carbonaria*, *P. nudisquama*, *P. rufovittatus*). Most of them emerge in

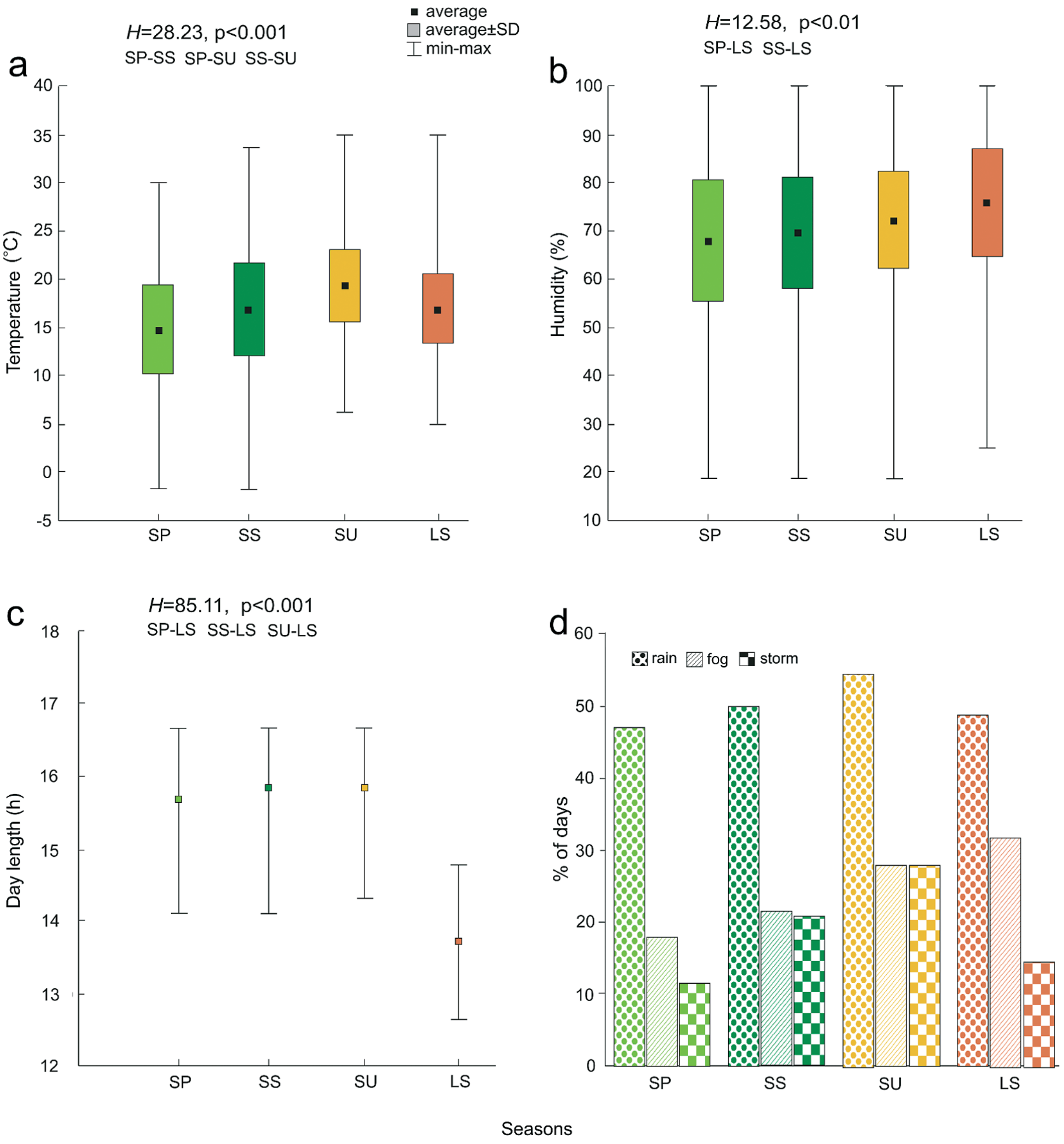

Fig. 4. Statistics for selected weather conditions during the phenological seasons. – a. Temperature. – b. Humidity. – c. Day length. – d. Percent of days with rain, fog or/and storm; as there were often days with both rain and storm, or both fog and rain, this does not amount to 100%. In connection of Kruskal-Wallice tests, significant differences between the seasons are shown as pairs (e.g. SP-LS). Spring (SP), spring-summer (SS), summer (SU), late summer (LS).

Europe from May to September. *Paratendipes albimanus* can have two generations in stagnant waters but low temperature and low trophy (i.e. low concentration of biogenic compounds in the water and bottom sediments) may prevent the appearance of the second generation. In South England, it has one generation with 4th larval instar appearing in July–August. *Brillia bifida* can emerge all the year round in Western Europe (Vallenduuk & Moller Pillot 2007, Moller Pillot 2009, 2013). Only single specimens of the late summer taxa were collected in the present study. Therefore, it cannot be excluded that some adults emerged earlier but were not collected. Our results showed that the late summer species emerged in a period with significantly shorter duration of daytime and relatively higher humidity than the taxa of the other phenological groups.

Chironomus piger often occurs in Europe even in 5–6 generations per year (Moller Pillot 2009), i.e. througout the growing season. Taxa of *C.* gr. *piger* have similar phenology in the Rąbień Bog. Csabai *et al.* (2015) recorded *C. piger* on peaty shores of water reservoirs and small, temporary ponds with a wide belt of rushes.

The present study does not concern winter activity of Chironomidae, but, for example, Baranov and Ferrington (2013) as well as Soszyńska-Maj *et al.* (2015) document winter activity of adult non-biting midges in Europe, even on the snow.

The species recorded in the Rąbień Bog come mainly from a nearby pond, whereas Rosenberg *et al.* (1988) studied the phenology of Chironomidae developing on peatlands in Canada. Peatlands surrounding lakes in the Experimental Lake Area are dominated by semiterrestrial Orthocladiinae (Rosenberg *et al.* 1988). In that study, the majority of the abundant species were univoltine with synchronous emergences. Their emergence started in May and ended in September, but 95% of the taxa emerged mainly in late spring and early summer. That timing allows larvae to develop to a sufficiently advanced instar to survive summer peat desiccation, and then grow large enough during moist autumn to survive freezing in winter (Rosenberg *et al.* 1988). Similarly, Krasheninnikov (2012) showed that most of Orthocladiinae taxa in Middle Ural river valleys emerge from May to August.

In Irish dystrophic lakes, most of invertebrate assemblages, mainly insects, did not show any significant differences of species composition in spring (April) and late summer (August). Nevertheless, Chironomidae significantly differed in species composition in the two sampling periods (especially in lakes with low pH) (Baars *et al.* 2014). Chironomini clearly dominated at the margin of the pond at the Rąbień Bog, whereas in Irish lakes within peatlands also many Orthocladiinae, Tanypodinae and Tanytarsini were recorded. In Ireland, imagines of *C. viridulum* and *P. flavipes* occur in late summer, whereas in the Rąbień pond *P. flavipes* emerged earlier, since April, which is the case also in Croatia (Ivković *et al.* 2015). In Ireland, adults of *C. anthracinus* and *P. choreus* occur already in April and August, whereas at the Rąbień pond both species were observed as single individuals from June to early July.

The abundances of the collected chironomids was surprisingly low in the present study. This may be associated with the sampling methods as not all midges are attracted to light, and the net sampling was conducted mostly in the late afternoon and early evening. Taxa active during different times of day might have been omitted. The light trap and the net sampling transect were also located directly at the pond, which might have excluded Orthocladiinae from the catch, typically dominating on peatlands (Rosenberg *et al.* 1988, Przhiboro & Paasivirta 2012). On the other hand, the pH of the nearby pond was also low (Bobrukiewicz & Szulc 2011), the diatom-inferred pH ranged between 3.75 and 5.6. The low pH is unfavourable for most Chironomidae and limits the number of taxa and the midge abundance in the water body (Brooks *et al.* 2007). The number of larval subfosssils in lakes undergoing paludification is also much lower than in other water bodies with the circumneutral or almost neutral pH, which was recorded at sites in Central Poland including Rąbień palaeolake (Płóciennik *et al.* 2011, Pawłowski *et al.* 2015, Płóciennik *et al.* 2015). At the light trap locality (Fig. 2a) of our present study, presence of pupal exuviae on the water was also surveyed. Their number was very low and often hardly observed. Przhiboro and Paasivirta (2012) used other, more precise methods of estimating abundance and species composition on moss carpets in Karelia. There, the abundances of collected chironomids were much higher at Bol'shoe Rakovoe and Okhotnich'e Lakes than reported here from the investigated light trap at Rąbień reserve.

In the present study, CVA demonstrated that mean day air temperature, mean day air humidity and day length may significantly influence the flight period of investigated Chironomidae species. This is consistent with the general findings that temperature is the most important factor influencing midge physiology, life cycle and community structure (Brooks 2006, Barley *et al.* 2006, Woodward & Shulmeister 2006, Brooks *et*

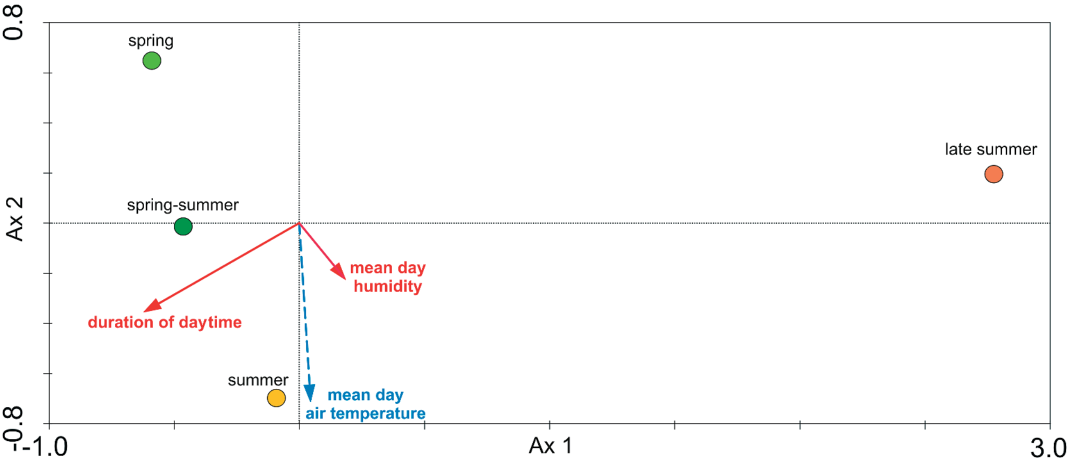

Fig. 5. Results of the Canonical Variate Analysis (CVA) of the flight periods of chironomids of different assemblages of the growing season at the Rąbień Bog in 2012. Solid arrows: factors correlated to 1st CVA axis, dashed arrow: factor correlated to 2nd CVA axis.

al. 2007, Bouchard 2007, Rees *et al*. 2008, Luoto *et al*. 2014, Nazarova *et al*. 2015). At Rąbień pond, the species emerging only in spring and only in summer seem to be most related to the mean temperature but in the opposite direction for these two groups (Fig. 5). The flight period of taxa emerging through the nearly whole growing season or in late summer is rather linked to other factors, like local habitat or duration of daytime.

Płóciennik *et al.* (2015) studied the history of Chironomidae assemblages in the Rąbień Bog from the formation of the paleolake in the late Weichselian to its disappearance in the late Holocene. The abundance and species richness of Chironomidae were the highest in the late Weichselian. The concentration of subfossils in the sediments and the number of recorded species sharply declined because of paludification and water level decrease in the Holocene. Since 3600 cal. BP, it has formed communities of semiterrestrial orthoclads typical of *Sphagnum* bogs (Słowiński *et al.* 2016). Taxa recorded in these studies inhabit mainly the pond developed after the peat extraction. In the Rąbień sequence, they were mainly observed from the Late Glacial to the Middle Holocene (up to 4,470 cal. BP). Płóciennik *et al.* (2015) distinguished five stages in Late Glacial–Holocene history of the Rąbień palaeolake: X_1, X_2, X_3, Y_1, Y_2. Some of the taxa recorded at the pond in 2012 may be easily assigned to the morphotypes reported from the Rąbień Late Glacial stages X_2, Y_2 (*Chironomus* type *anthracinus*, *Chironomus* type *plumosus*, *Tanytarsus* type *medax*), the Late Glacial–Early Holocene stage Y_1 (*Cladopelma* type *goetghebueri*), and the Middle Holocene stage X_3 (*Dicrotendipes*, *Glyptotendipes pallens*) (see Płóciennik *et al.* 2015). At that time, Rąbień was a shallow, meso- and later eutrophic overgrown lake (Płóciennik *et al.* 2015).

Effects of human activity before the establishment of the reserve, visible in the form of many small reservoirs in various stages of succession, have contributed to the re-appearance of typical limnetic taxa. They are mostly common, eurytopic species, present in many other anthropogenic reservoirs in Central Poland (Płóciennik & Klukowska 2010). Surprisingly, this research did not record any taxa typical to peatland habitats from the Orthocladiinae subfamily, such as *Limnophyes* or *Pseudorthocladius*, which are present in the subfossil material from Rąbień (Słowiński *et al.* 2016) and in the nearby Żabieniec bog (Lamentowicz *et al.* 2009). Most likely this is due to the location of the light trap close to the local pond, but not directly at the lobe of *Shagnum-Eriophorum* mire. Relatively high species richness of Chironominae compared to the other subfamilies at the pond habitats was also documented e.g. by Dendy (1971).

5. Conclusions

The present study was aimed to cast light on the flight periods of chironomids in a peatland pond area but not to reflect the entire life cycles of the recorded species. From the results of CVA (Fig. 5) and the analysis of weather conditions of flight seasons (Fig. 4), it is clear that the primary factor that determines, at least indirectly, the emergence of the investigated groups of species is air temperature. Air humidity divides taxa into ones emerging early and later in the growing season. The third factor that was statistically significant was duration of daytime, which was, as expected, shorter for the late emerging species.

The present study is based on a relatively small material, so it cannot be excluded that midges were present at the pond longer as imagines but their abundances were too small to be recorded. Local conditions (e.g. water chemical composition) and specific weather (e.g. in winter) of the 2012 season might have limited the length of the flight period of the multivoltine taxa. Chemical and physical conditions in Rąbień pond, where the light trap was situated, were not measured. It can be supposed that the pool developed after peat extraction and, surrounded by bog lobes, should have low pH. It means that the conditions in the ponds could be unfavourable for chironomids, and species, which elsewhere appear much longer as imagines, might have only low abundances in Rąbień pond.

Whereas it is difficult to assess the flight period of certain species recorded as few specimens, phenological stages of well-defined groups of taxa are clearer. The phenology of the midges of the ponds are different than in the peatlands investigated by Rosenberg *et al.* (1988). Their research reflects peat bog communities more strictly as they are based on emergence traps located directly on the bog surface. Midge composition even in strongly acidified lakes (Walker *et al.* 1985) may be much more similar to the investigated one than to peatlands *sensu stricto* (Rosenberg *et al.* 1988). Lake paludification and final terrestrialisation cause gradual pauperisation of midge communities (Płóciennik *et al.* 2015, Słowiński *et al.* 2016). Peat extraction may considerably contribute to the appearance of small water bodies, and thus the reappearance of limnetic species, which according to these studies are, nevertheless, mostly common generalists.

Acknowledgements. The research in the Rąbień Bog was co-financed by a grant from the Polish Ministry of Science and Higher Education (N N306 276735). We would like to thank professional translator Marta Koniarek for linguistic corrections.

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