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SHORT COMMUNICATION

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Planktonic communities in a small post-peat reservoir (Ustka Forest District, Poland)

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Abstract

The aim of this study was to evaluate the present state of a small (area of 0.2 ha), shallow (mean depth of 2 m) and approximately 30-year-old post-peat reservoir located in Bruskowskie Bagno, a Baltic raised mire in northern Poland. The study was conducted during all seasons of the year (August 2019–July 2020). The reservoir was characterised by a yellow to brown water colour, low pH (5.4) and quite low conductivity (40.4 µS cm^{-1}), which are the main features of dystrophic water bodies. Similar to natural, dystrophic lakes and ponds, the phytoplankton was mainly composed of mixotrophic species like *Dinobryon* sp. and *Gonyostomum semen*. The only numerous non-flagellate group within the phytoplankton was desmids, which indicated that the water was influenced by the mire. The reservoir was characterised by a high abundance of ciliates (annual mean of 55.6 cells ml^{-1}) and a very high abundance of rotifers (annual mean of 3.72 ind. ml^{-1}). Among ciliates, the most important were prostomatids, accounting for 53% of the mean annual ciliate abundance. The results of our study indicate that artificial, approximately 30-year-old, post-peat reservoir resembled a natural dystrophic water body.

Key words

acidic waters, Baltic raised mire, phytoplankton, ciliates, rotifers, *Gonyostomum semen*

Introduction

Peat is used as fuel and for fertilisation, spa treatments and other purposes (Ilnicki 2002). Pits resulting from the extraction of peat are often filled with water from surrounding areas and form post-peat reservoirs. Because of the considerable allochthonous input of humic substances, these reservoirs are similar to dystrophic ponds or lakes in their brown water colour, low primary production and elevated bacterial secondary production (Mieczan 2007; Jasser et al. 2009; Kostrzewska-Szlakowska and Jasser 2011). As any other ponds distributed in landscapes or forests, they provide valuable habitats for many organisms and increase local biodiversity (Chomutowska and Krzyściak-Kosińska 2015). According to a literature review, the abundance and composition of plankton in post-peat reservoirs remain understudied (Mieczan 2007; Demetraki-Paleolog and Kolejko 2011). Similar studies in dystrophic lakes are more advanced and are concentrated on the impact of environmental parameters on phytoplankton or zooplankton distribution (Karpowicz and Ejsmont-Karabin 2018; Lebret et al. 2018; Kalinowska et al. 2021). Kalinowska et al. (2021) emphasised that majority of studies in dystrophic lakes are carried

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out during the growing season and the winter planktonic communities are less thoroughly studied.

A post-peat pond investigated in this study is situated in the Bruskowskie Bagno raised mire located in the Ustka Forest District in northern Poland. Presently, the area of the raised bog is considered as destroyed and drained. Due to draining of the area, the surface layers of peat became, to some extent, dried up too (Jasnowski 1990; Jasnowska and Markowski 1995). The mire deserves protection as rare bog-type species such as *Erica tetralix*, *Ledum palustre*, *Lycopodium annotinum*, *Drosera* spp., *Urticularia* spp., *Andromeda polifolia*, *Vaccinium oxycoccus* and *Vaccinium uliginosum* are located here (Pawlaczyk et al. 2005; Słupsk Community 2008/2010). The Bruskowskie Bagno raised mire is now protected as Nature-Landscape Complex under Resolution of the Słupsk Community Council (Official Journal of Law of the Pomeranian Voivodeship 2014).

According to Jasnowska and Markowski (1995), the post-peat pond located in the Bruskowskie Bagno raised mire appeared in about 1990, approximately 30 years before the present study was carried out. It contains brown water and resembles a dystrophic pond. The aim of this study was to evaluate its present state. The authors assumed that it developed plankton communities typical of dystrophic water bodies (hypothesis). The evaluation was conducted based on water characteristics (pH, conductivity, water colour) and planktonic communities (the abundance and composition of algae, ciliates and rotifers). Studies were carried out during all seasons of the year. All three groups of organisms studied occupy crucial positions within the food web. The algae are primary producers. The ciliates, which feed on bacteria, algae and protozoa, are the top predators within the microbial food web (Sherr and Sherr 2002). The rotifers are an important component of the zooplankton, especially in dystrophic waters (Klimaszyk and Kuczyńska-Kippen 2006), which feed on bacteria, algae, protozoa and detritus (Arndt 1993; Rybak 1994, 2000).

Material and methods

The study was conducted in a small (0.2 ha), shallow (about 2 m), rectangular (95 × 20 m) pond (54°29'55''N, 16°55'32''E) located in the Baltic (cupola) raised mire of Bruskowskie Bagno near the village of Bruskowo Wielkie in the Zębowo Forest Unit (division 527B) of the Ustka Forest District in northern Poland. The pond is surrounded by forest composed predominantly of pine and birch with an admixture of aspen, oak and other species (State Forest Information System 2019). In direct vicinity of the pond dominate birches (*Betula pendula*) with admixture of poplar (*Populus tremula*), pine (*Pinus sylvestris*) and various species of willow (*Salix* spp.). The pond is surrounded by *Juncus* sp., *Typha latifolia* and *Sphagnum* spp.

Surface water samples were collected about 6 m from the shore. Samples were collected monthly from August 2019 to July 2020. Approximately 200 ml of water was fixed with acidified Lugol's solution for subsequent analyses of algae, ciliates and rotifers. Organisms in the samples were analysed under an Olympus CKX41 inverted microscope with the Utermöhl method (Sournia 1978). Algae, ciliates and rotifers were identified on the basis of keys by Starmach (1989) and Hutorowicz et al. (2006), Foissner and Berger (1996) and Rybak (1995), and Rybak (1994, 2000), respectively. Species names, generic names and taxonomic affiliations were updated to recent taxonomic nomenclature. Water temperature, pH and conductivity were measured using a thermometer and an Elmetron CPC-401 pH/conductivity meter. Additionally, the water colour was evaluated visually.

Results

Physical and chemical characteristics

The water temperature ranged from 2.4°C in December 2019 to 20.2°C in June 2020. No ice cover was recorded. Water of the reservoir was acidic (pH 5.4 ± 0.3; mean ± standard deviation, 12 measurements). Mean water conductivity was 40.4 ± 4.6 $\mu S\ cm^{-1}$ (12 measurements). The water colour throughout the year was yellow, bright brown or brown. No seasonal trends were noted in changes of pH, conductivity and water colour.

Planktonic algae

Algal abundance in the pond ranged from 0.5 to 186 cells $10^3\ ml^{-1}$ (annual mean of 28.7 cells $10^3\ ml^{-1}$). The phytoplankton assemblage consisted of flagellates (Chrysophyceae, Cryptophyceae, Dinophyceae, Raphidophyceae, Euglenoidea and Chlorophyceae) and desmids belonging to Conjugatophyceae, which were the only numerous non-flagellate group in the phytoplankton. Flagellates dominated the phytoplankton assemblage throughout the year and constituted 89–100% of the total abundance in particular samples, except in July when a desmid bloom was observed and the flagellate contribution to the total phytoplankton abundance dropped to 13%.

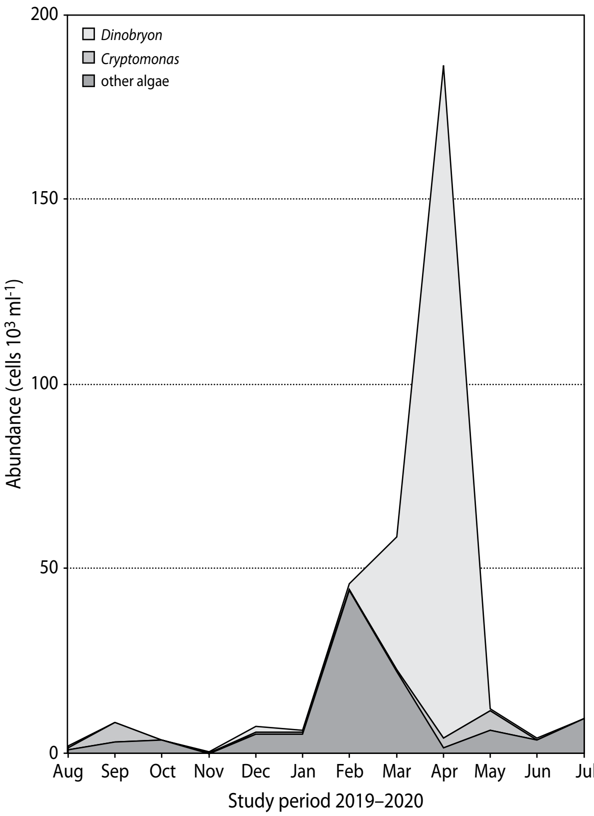

Figure 1. Seasonal changes in algal abundance in the post-peat reservoir in the Ustka Forest District. Shares of abundance contributed by flagellates from the genera *Dinobryon* (65% of mean annual abundance) and *Cryptomonas* (5% of mean annual abundance) are indicated

The single most important flagellate was the chrysophyte *Dinobryon* sp. During an intense bloom in March and April, its abundance reached 182 cells 10^3 ml^{-1} (Fig. 1). The mean annual contribution of *Dinobryon* sp. to the total algal abundance was 65%. *Cryptomonas* spp. were present throughout the year except in early summer (June and July, Fig. 1), and their mean annual contribution to the total algal abundance was 5%. Between May and July, *Gonyostomum semen* (Ehrenberg) Diesing (Raphidophyceae) was observed at an abundance that ranged from 1.09 to 2.76 cells 10^3 ml^{-1}. During all seasons of the year, some naked (e.g. genus *Gymnodinium*) and thecate (e.g. genus *Peridinium*) dinophytes were observed at an abundance of up to 0.86 cells 10^3 ml^{-1}. A few euglenoid specimens were observed in summer and autumn that belonged to the genera *Euglena* and *Trachelomonas* at abundances of up to 0.13 cells 10^3 ml^{-1}. Apart from the algae listed above, a considerable number of small flagellates (2–20 µm) were observed. They were not identified further because of the method applied for the analyses. These small flagellates dominated in February (Fig. 1).

Desmids (Conjugatophyceae) belonging to the genera *Cosmarium*, *Staurastrum*, *Xanthidium* and *Closterium* were observed during summer (June–September). The most frequent was *Cosmarium minimum* West & G.S. West at an abundance that ranged from 0.10 to 0.30 cells 10^3 ml^{-1}, except in July when a bloom was observed with an abundance reaching 7.5 cells 10^3 ml^{-1}. The second most important genus in terms of abundance was *Staurastrum* recorded in July. The abundance of the other desmids was low, and some of them were represented by single specimens. The mean annual desmid contribution to the total algal abundance was 9%.

Planktonic ciliates

Ciliate abundance ranged from 7.51 cells ml^{-1} in October to 343 cells ml^{-1} in September. The mean annual abundance was 55.6 cells ml^{-1}. Seasonal changes in abundance were irregular. The most important ciliates were those of the order Prostomatida. They contributed 11–85% of the abundance (annual mean of 53%), and among them, the most frequent were *Urotricha* spp. and *Balanion planctonicum* (Foissner, Oleksiv & Müller). Less frequent ciliates were those of the orders Oligotrichida and Choreotrichida at a range of 1–37% and an annual mean of 16%. The most important species were *Halteria grandinella* (Müller) Dujardin, *Rimostrombidium caudatum* (Kahl) Agatha & Riedel-Lorje and *Pelagostrombidium mirabile* (Penard) Krainer. No tintinnids were recorded. Specimens of the order Scuticociliatida (0–39%, mean of 11%, mainly *Cyclidium* spp.) were less important. Other orders were combined and included mostly hypotrichs and haptorids (0–20%, mean of 4%). Typically, about 16% of ciliates remained unidentified because of the damage caused by Lugol's solution. No clear seasonal succession within ciliate communities was observed.

Planktonic rotifers

Rotifer abundance ranged from 0.24 ind. ml^{-1} in November to 12.0 ind. ml^{-1} in June. The mean annual abundance was 3.72 ind. ml^{-1}. Five genera made up the majority of the numbers. These were *Ascomorpha* (observed between autumn and spring), *Colurella* (between spring and autumn), *Polyarthra* (from spring to autumn), *Trichocerca* (recorded in summer and autumn) and *Lecane* (noted in spring and autumn). During winter and spring, considerable numbers of *Keratella cochlearis* (Gosse) and *Keratella quadrata* (O. F. Müller) were also observed. Occasionally, species of the genus *Asplanchna* were recorded.

Discussion

Physical and chemical characteristics

Based on the water colour, low pH (5.4) and quite a low conductivity (40.4 µS cm^{-1}), the reservoir can be classified as dystrophic. Similar values of pH and conductivity were reported for a small, mid-forest, dystrophic lake located in Drawieński National Park (Poland) at a pH 5.2 and a conductivity of 38 µS cm^{-1} (Kuczyńska-Kippen 2008), 12 humic lakes in the Masurian Lakeland (Poland) at a pH range of 3.7–5.4 and a conductivity of 18–80 µS cm^{-1} (Kalinowska 2000) and peat bog pools in Argentina at a pH range of 4.5–6.3 and a conductivity ranging from 23 to 33 µS cm^{-1} (Quiroga et al. 2013).

Planktonic algae

Algal abundance in the reservoir studied (range 0.5–186 cells 10^3 ml^{-1}, mean 28.7 cells 10^3 ml^{-1}) was higher than in the small, shallow humic Lake Płotycze (eastern Poland) in which the range was 0.4–19.6 cells 10^3 ml^{-1} and was typically below 10.0 cells 10^3 ml^{-1} (Pęczuła 2013b) or in four dystrophic, humoeutrophic lakes in eastern Poland where summer algal abundance ranged from 2.0 to 8.5 cells 10^3 ml^{-1} (Poniewozik et al. 2011). Comparable algal abundances were observed in five dystrophic lakes in northeastern Poland in July 2016 – mean abundances were 15.5–33.0 cells 10^3 ml^{-1} and maximal abundances were 37.5–92.6 cells 10^3 ml^{-1} (Karpowicz and Ejsmont-Karabin 2018).

The phytoplankton of the reservoir studied was characterised by poor diversity with the distinct dominance of flagellates. Similar phytoplankton composition was reported in a dystrophic, humoeutrophic water body (e.g. Poniewozik et al. 2011) and in a dystrophic lake (Owsianny and Gąbka 2006). Some groups of algae, which are common in harmonic water bodies, like diatoms (class Bacillariophyceae) and cyanobacteria (class Cyanophyceae) were completely absent in the reservoir studied. Quiroga et al. (2013) reported the rarity or absence of cyanobacteria in acidic humic water bodies as typical. Cyanobacteria were absent and diatoms were found to be insignificant in oligohumic and polihumic lakes located in the Masurian Lakeland (northeastern Poland) (Jasser et al. 2009). However, Owsianny and Gąbka (2006) studied the dystrophic Lake Kuźniczek and observed considerable cyanobacterial abundance and low diatom abundance. Some diatoms were also reported in four dystrophic, humoeutrophic water bodies (Poniewozik et al. 2011).

In the present study, the most prominent were the flagellates *Dinobryon* sp. (Chrysophyceae) and *Cryptomonas* spp. (Cryptophyceae), the joint, mean annual contribution of which was 70% of the total algal abundance. These organisms are typical of dystrophic ponds and lakes (Klimaszyk and Kuczyńska-Kippen 2006; Kuczyńska-Kippen 2008; Quiroga et al. 2013), in which light and nutrient availability is limited. Cryptophyceae and Chrysophyceae include many mixotrophic organisms that are adapted to such unfavourable conditions (Bird and Kalff 1987; Urabe et al. 2000; Klimaszyk and Kuczyńska-Kippen 2006).

In May, June and July, the flagellate *Gonyostomum semen* (class Raphidophyceae) was observed in the reservoir studied. As reviewed by Hutorowicz et al. (2006) and Pęczuła (2013a, 2013b), it is an invasive species that prefers acidic waters. In Poland, its presence is recorded in an increasing number of dystrophic acidic lakes, especially in northern Poland (Kalinowska 2000; Hutorowicz et al. 2006; Jasser et al. 2009). However, Pęczuła (2013a) and Poniewozik et al. (2011) observed high abundances of *G. semen* in dystrophic, humoeutrophic lakes in central and eastern Poland. *G. semen* is also sometimes observed in lakes with neutral pH (Hutorowicz et al. 2006; Pęczuła 2013a). Compared to data reviewed by Hutorowicz et al. (2006), the occurrence of *G. semen* reported in this study was typical and its abundance (up to 2.76 cells 10^3 ml^{-1}) was high. A considerable number of *G. semen* specimens observed in this study were damaged after fixation. The sensitivity of *G. semen* to strong illumination or fixatives was reported in other studies (Kalinowska 2000; Hutorowicz et al. 2006).

Representatives of less abundant flagellates like dinophytes (genera *Gymnodinium* and *Peridinium*) or euglenoids (genera *Euglena* and *Trachelomonas*) were reported in dystrophic lakes (e.g. Owsianny and Gąbka 2006).

The most important non-flagellate algal group in the reservoir studied were desmids (Conjugatophyceae). They prefer acidic waters and are indicators of waters influenced by mire (Foissner and Berger 1996; Pęczuła 2013b). Their importance in algal communities was also reported in the dystrophic Lake Kuźniczek (Owsianny and Gąbka 2006). Genera recorded in this study (*Cosmarium*, *Staurastrum* and *Closterium*) were reported in other humic water bodies, including Lake Płotycze (Pęczuła 2013b) and Lake Kuźniczek (Owsianny and Gąbka 2006). These genera and *Xanthidium* were also observed in swamps in Western Siberia (Shakhmatov and Pavlovskiy 2019).

Planktonic ciliates

Spring and autumn peaks in ciliate abundance are usually observed in surface waters in the temperate climatic zone (reviewed by Rychert et al. 2016). In this study, no such distinct peaks were recorded and seasonal changes in ciliate abundance were irregular (not shown). The mean annual abundance of ciliates (55.6 cells ml^{-1}) was lower than the mean value reported from 10 peat-ponds in northern Germany (147 cells ml^{-1}; Pfister et al. 2002) and higher than the mean values calculated for the April–October period in six peat bog reservoirs located in the Łęczna-Włodawa Lakeland (eastern Poland) (5–27 ind. ml^{-1}; Mieczan 2007). Similarly, Kalinowska (2000) studied 12 mid-forest humic lakes in the Masurian Lakeland (Poland) and reported that spring and summer ciliate abundances did not exceed 25 ind. ml^{-1}. Comparable ciliate abundances were also reported in peat bog pools in the southern temperate zone (Rancho Hambre, Tierra del Fuego, Argentina; 13.8–43.6 ind. ml^{-1}; Quiroga et al. 2013).

The ciliates observed were common and their communities were typical of surface lacustrine waters (Foissner and Berger 1996). Pfister et al. (2002) described ciliate communities in 10 peat-ponds located in northern Germany and demonstrated that, except during spring, the most important orders were Prostomatida, Oligotrichida and Choreotrichida, which was similar to the findings of the present study. Pfister et al. (2002) applied a different taxonomic system that did not contain the order Choreotrichida, but species list permitted identification of its representatives. In the present study, the most important ciliates were prostomatids, the mean annual contribution of which to ciliate abundance was 53%. Thus, the ciliate communities differed from those observed by Mieczan (2007) in six small, acidic peat bog reservoirs located in the Łęczna-Włodawa Lakeland (eastern Poland), where oligotrichs and choreotrichs (according to the taxonomic system applied in this study) prevailed over prostomatids. Similarly, Kalinowska (2000) observed that oligotrichs and choreotrichs (according to the taxonomic system applied in this study) were more abundant than prostomatids in 12 mid-forest humic lakes situated in the Masurian Lakeland (Poland). *Balanion planctonicum*, an important component of the ciliate community, is rather an oligosaprobic organism (Foissner and Berger 1996). Less important *Cyclidium* spp. are typically observed in α-mezosaprobic waters (Rybak 1995).

Planktonic rotifers

The rotifer abundance in the reservoir studied was high (annual mean 3.72 ind. ml^{-1}, maximum value 12.0 ind. ml^{-1}). Demetraki-Paleolog et al. (2018) found that maximum rotifer abundance in dystrophic ponds in southeastern Poland only reached 0.78 ind. ml^{-1}, while rotifer abundance in seven other post-peat water bodies sampled during spring and autumn ranged from 0.02 to 0.41 ind. ml^{-1} (Demetraki-Paleolog and Kolejko 2011). Similarly, in a dystrophic lake that was similar to the reservoir studied with respect to pH and conductivity, rotifer abundance was also low (0.03 ind. ml^{-1}) in summer (Kuczyńska-Kippen 2008). Rotifer abundance in the present study can be compared to that reported from a polihumic peat bog pool situated in Wielkopolski National Park, where rotifer abundance was typically below 0.35 ind. ml^{-1}, but some peaks of abundance reached as high as 8.66 ind. ml^{-1} (Klimaszyk and Kuczyńska-Kippen 2006). Similar abundances were also reported for the peat bog pools situated in the southern temperate zone in Argentina, where the mean values for pools ranged from 0.095 to 2.31 ind. ml^{-1} and the maximum abundance was 6.76 ind. ml^{-1} (Quiroga et al. 2013).

The genera and species observed in the reservoir studied were common (Rybak 2000). Species of genera *Ascomorpha* and *Polyarthra* prefer acidic environments (Rybak 1994). Other studies performed in dystrophic water bodies reported occurrence of the same genera, for example, *Polyarthra*, *Lecane*, *Colurella* and *Trichocerca* (Demetraki-Paleolog and Kolejko 2011); *Polyarthra*, *Trichocerca* and *Keratella cochlearis* (Kuczyńska-Kippen 2008); *Asplanchna*, *Colurella*, *Lecane*, *Polyarthra* and *K. cochlearis* (Demetraki-Paleolog et al. 2018); *Polyarthra*, *Trichocerca*, *K. cochlearis* and *Asplanchna* (Karpowicz and Ejsmont-Karabin 2018); *Ascomorpha*, *Trichocerca*, *K. cochlearis* and *Asplanchna* (Kalinowska et al. 2021); and *Ascomorpha*, *Asplanchna*, *Colurella* and *Polyarthra* (Quiroga et al. 2013). These studies also reported other genera that were not noted in the reservoir studied.

Concluding remarks

The small, post-peat reservoir situated in the Ustka Forest District is an acidic, humic water body. It is similar to natural, dystrophic water bodies in that it hosts numerous mixotrophic algal species and the characteristic flagellate *Gonyostomum semen*. The only numerous, non-flagellate group in the phytoplankton are desmids. The ciliates and rotifers observed in the studied reservoir are common; however, the reservoir is characterised by a high ciliate abundance (annual mean of 55.6 cells ml^{-1}) and very high rotifer abundance (annual mean of 3.72 ind. ml^{-1}). In summary, this artificial, approximately 30-year-old reservoir resembles a natural, dystrophic pond.

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