Oceanological and Hydrobiological Studies

International Journal of Oceanography and Hydrobiology

Volume 44, Issue 4, December 2015
pages (480-486)

ISSN 1730-413X
eISSN 1897-3191

Small water ponds as reservoirs of algae biodiversity

by

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DOI: **10.1515/ohs-2015-0045**
Category: **Original research paper**
Received: **July 21, 2015**
Accepted: **September 11, 2015**

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Abstract

The areas of northern Poland are typical examples of recently formed post-glacial landscapes with a very large number of small ponds. Phycology of these ponds has been seldom studied, especially when compared to data collected from lager post-glacial lakes. The aim of our study was to determine the importance of small ponds to the biodiversity of algae.

In 1996-2002 and 2012-13, we carried out phycological studies in 20 small ponds located in fields and forests. During the study period, we recorded the presence of 503 taxa of algae. The flora of algae was unique in each pond. Another important and frequent observation was the total and rapid "rebuilding" of algal flora.

Statistical analyses revealed some other important facts, including the importance of small ponds to algal biodiversity. The average number of taxa recorded during the studies of individual water reservoirs was 56, thus much less than usually recorded in typical large lakes. But when we take the large number of small ponds into consideration, it appears that they represent more than 97% of the populations of algae and for this reason they are important to the biodiversity of algae.

Key words: algae, biodiversity, astatic ponds, small ponds

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Introduction

Small astatic water ecosystems are typical elements of the environment in many parts of the world. Despite the climatic differences, they share some common features including: the small total mass of the water, lack of thermal stratification, large fluctuations in the water level, frequent and radical changes in physicochemical parameters of the water (Paczuska et al. 2002). This type of astatic reservoirs could possibly be further divided into some subgroups, significantly different from each other and including: field reservoirs, cattle holes, forest reservoirs, short-lived reservoirs formed in small depressions of the ground in spring or a rainy season. Areas of northern Poland are typical examples of a recently formed post-glacial landscape, with a very large number of small ponds. Ecology of these ponds has been seldom studied, especially when compared with data collected from lager post-glacial lakes (Celewicz-Gołdyn 2009; Chmielewski 1992; Gołdyn et al. 2015; Jurkowska 1987; Kuczyńska-Kippen et al. 2013; Kurzątkowska 2008; Paczuska et al. 2002, 2006; Paczuska 2007).

In the eastern and southern part of the Świecie Plateau (in Polish: *Wysoczyzna Świecka*, Europe, Poland), the inventory (1995-2000) and phycological studies (1996-2002 and 2012-13) were conducted in natural water reservoirs which have characteristics of considerable astatism (Paczuska et al. 1997, 2002, 2006). This area represents the type of landscape formed during the last glacial period. The surface was originally covered with forests but since the beginning of the Neolithic period (4500 B.C.), the introduction of agriculture caused systematic deforestation and currently most of the land is used for agriculture, with the exception of infertile sandy soils which still remain covered with forests. On the basis of several years of observations, astatic ponds on the Świecie Plateau were divided into: stable ponds characterized by considerable water-level fluctuations (e.g. from 1 m to 0.2 m) and periodic ponds – drying up in the annual cycle or in the long-term cycle.

The inventory studies of field and forest ponds in the south-eastern part of the Świecie Plateau showed that during the last 100 years, the number of ponds of this type have considerably decreased. About 30% of them disappeared and this process still continues (Paczuska et al. 1997, 2002).

Dynamic changes occurring in the ecosystems of the above-mentioned type involve specific, local geological and climatic conditions such as temperature, rainfall, evaporation, but are also strongly influenced by both biotic factors (flora) and human activity (land improvement, deepening and filling of ponds).

Large-scale projects implemented in the course of land adaptation for agriculture, especially deep drainage induced irreversible changes in the water circulation. This process has been observed in large areas of northern Poland, causing disappearance of more than 8000 small ponds during the last 60 years (Kaniecki et al. 1996). According to the Convention on Biological Diversity signed by the Polish government in 1996, the Ramsar Convention (1971) and the Habitats Directive (1992), ecosystems of small natural water reservoirs should be protected. The Nature 2000 project and local agricultural-environmental projects involve implementation of this purpose. The European results of the research on the biodiversity of microinvertebrates indicate that small water reservoirs represent their main habitats (Céréghino et al. 2008; Bazzanti et al. 2009). In Poland and adjacent countries, the importance of these habitats to the biodiversity may be even higher than expected, because the hydrological conditions of the landscape result in the isolation of most small water reservoirs from other reservoirs, including those located in the close proximity. The aim of our study was to determine the importance of natural, small water reservoirs to the biodiversity of algae in this type of landscape.

Materials and Methods

In 1996-97, 2001-2002 and 2012-13, we were carrying out phycological studies in 20 small ponds located in fields and forests in the eastern part of the Świecie Plateau (Fig. 1). The collected samples were qualitatively and quantitatively analyzed. Benthic algae, algae on the surface of higher plants were sampled, and whenever possible, considering the small depth of the water reservoirs, heleoplankton was collected from the water column. Samples for phycological analysis were collected once a month in the case of minor changes in the water level, whereas in July 2001, 2002 and 2013, additional

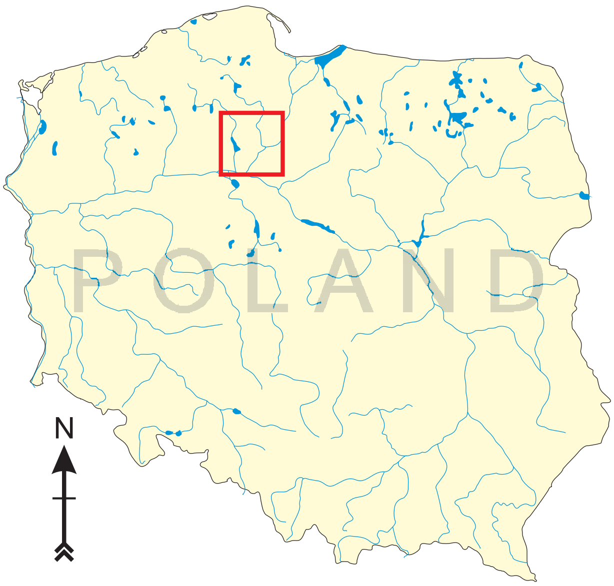

Figure 1

Location of Świecie Plateau

samples were collected once a week when the water level was falling very quickly. Samples intended for qualitative analysis were collected from the water using a 0.5 l bottle without using any plankton net in order to get all specific features of the reservoir, then they were preserved in 4% alkalized formalin. Live samples were collected and stored in 0.25 l receptacles, 1 l receptacles were used to store samples for quantitative analysis, which were preserved in Lugol's solution. Benthos algae were collected from a 10 cm^2 area of the bottom surface –balls of filamentous algae. Epiphytic algae were collected by pulling the submerged higher plants. Samples of benthos and periphyton were preserved in 4% formalin. Water samples for chemical analysis were also collected. The following measurements were taken into consideration in the study area: the water pH, water temperature, air temperature, water electric conductivity, the water level. The analysis of physicochemical characteristics of water was carried out according to the valid standards (Hermanowicz et al. 1976). Taxa found in only one reservoir were defined as characteristic. Statistical relations were analyzed using Pearson's correlation method. General characteristics of field and forest ponds studied in the area of Świecie Plateau, including the number of reservoirs, permanence, location, area, depth, the total number of taxa, and the number of characteristic taxa, were presented in Table 1.

Table 1

General characteristics of field and forest ponds studied in the area of Świecie Plateau

Number of reservoir	permanence: C – permanent, P – periodical	Location	Location	Area (m^2)	Depth (m)	General number of taxa	Number of characteristic taxa
1	C	Mariampol	53.1179049 N; 18.153744 E	290	1.0	52	11
2	P	Mariampol	53.168047 N; 18.146298 E	272	0.4	57	12
3	C	Las Jastrzębie	53.173331 N; 18.115993 E	4000	0.4	58	11
4	P	Las Jastrzębie	53.201626 N; 18.109323 E	203	0.2	25	4
5	C	Niwy	53.199687 N; 18.101606 E	267	0.5	70	25
6	C	Osielsko	53.175006 N; 18.088377 E	92	1.0	54	13
7	P	Osielsko	53.1744295 N; 18.094904 E	697	0.2	51	17
8	C	Osielsko	53.177693 N; 18.098392 E	733	1.8	44	14
9	C	Pruszcz	53.337968 N; 18.186220 E	370	1.5	47	16
10	C	Borówno	53.234340 N; 18.136778 E	275	1.7	91	53
11	P	Strzelce	53.191357 N; 18.178413 E	5100	0.25	69	22
12	P	Jasiniec	53.338831 N; 18.034081 E	320	0.5	89	27
13	P	Jarużyn	53.190284 N; 18.151996 E	762	1.2	40	20
14	P	Dobrcz forest	53.246807 N; 18.128589 E	2617	1.0	55	18
15	P	Mariampol	53.178928 N; 18.154003 E	919	0.7	65	40
16	C	Osielsko	53.177188 N; 18.097515 E	2280	1.0	88	64
17	P	Jasiniec	53°19'57.3" N; 18°02'00.4" E	340	0.25	28	5
18	P	Jasiniec	53°19'56.6" N; 18°01'58.6" E	560	0.5	33	10
19	P	Wudzyn	53°19'55.0" N; 18°02'00.5" E	420	0.3	48	15
20	P	Wudzyn	53°19'54.1" N; 18°02'11.2" E	328	0.7	61	18

Results

During the study period, we recorded the presence of 503 algal taxa, specific to different microenvironments: heleoplankton, benthos, and epiphyton. The most frequent were taxa of Chlorophyta – 212, Bacillariophyceae – 124, Cyanoprocaryota – 89 and Euglenophyta – 78.

Algal communities of astatic water ecosystems on the Świecie Plateau are varied. Each reservoir has a unique set of different species at a random point in time (Fig. 2, Table 1). The recurrence of respective species throughout the year and two years of the research is inconsiderable. Depending on environmental conditions during a few or several days, the complete reconstruction of a reservoir can occur, which points to a high biodiversity of these ecosystems.

During the whole study period, i.e. in 1996-97, 2001-02, 2012-2013, we observed rapid changes in the water levels and physicochemical properties of the water (Paczuska et al. 2002; Paczuska et al. 2006). Blooms and dominance of algae were observed only occasionally and included the following taxa: Chlorophyta: *Volvox aureus* Ehr., (biomass: 3.2 mg dm^{-3}, reservoir 1 Mariampol Aug. 1996; 53.1179049 N; 18.153744 E), Euglenophyta: *Trachelomonas volvocina* Ehr., (biomass: 4.8 mg dm^{-3}, Aug. 1996, Jastrzębie Forest 3 53.173331 N, 18.115993 E and 2.8 mg dm^{-3}, Aug. 1997, reservoir 6 Osielsko 53.175006 N, 18.088377 E); Cyanoprocaryota: *Snowella lacustris* (Chod.) Komarek et Hindák, (biomass: 52.2 mg dm^{-3}, July. 2001; 8.1 mg dm^{-3}, July 2012 and 14.1 mg dm^{-3}, Aug. 2013, reservoir 10 Borówno field 53.234340 N, 18.136778 E) and *Microcystis aeruginosa* (Kütz.) Kütz. (biomass: 8.6 mg dm^{-3}, Aug. 2001; 5.8 mg dm^{-3} Aug. 2002, reservoir 14 Dobrcz forest 53.246807 N, 18.128589 E). Two taxa considered as endangered species in Poland (Wołowski 2003) were observed: *Drapanaldia glomerata* (Vaucher) Ag. in ponds Mariampol and 5 Niwy (53.199687 N; 18.101606 E), *Cladophora fracta* in pond 13 Jarużyn (53.190284 N; 18.151996 E). Another rare taxon in Poland, i.e. *Hormidiella parvula* Iyen. Et. Kanth (Chlorophyta) growing epiphytically on strands of *Vaucheria* sp., was observed in reservoir 10 Borówno field (2001, 2012 yr.).

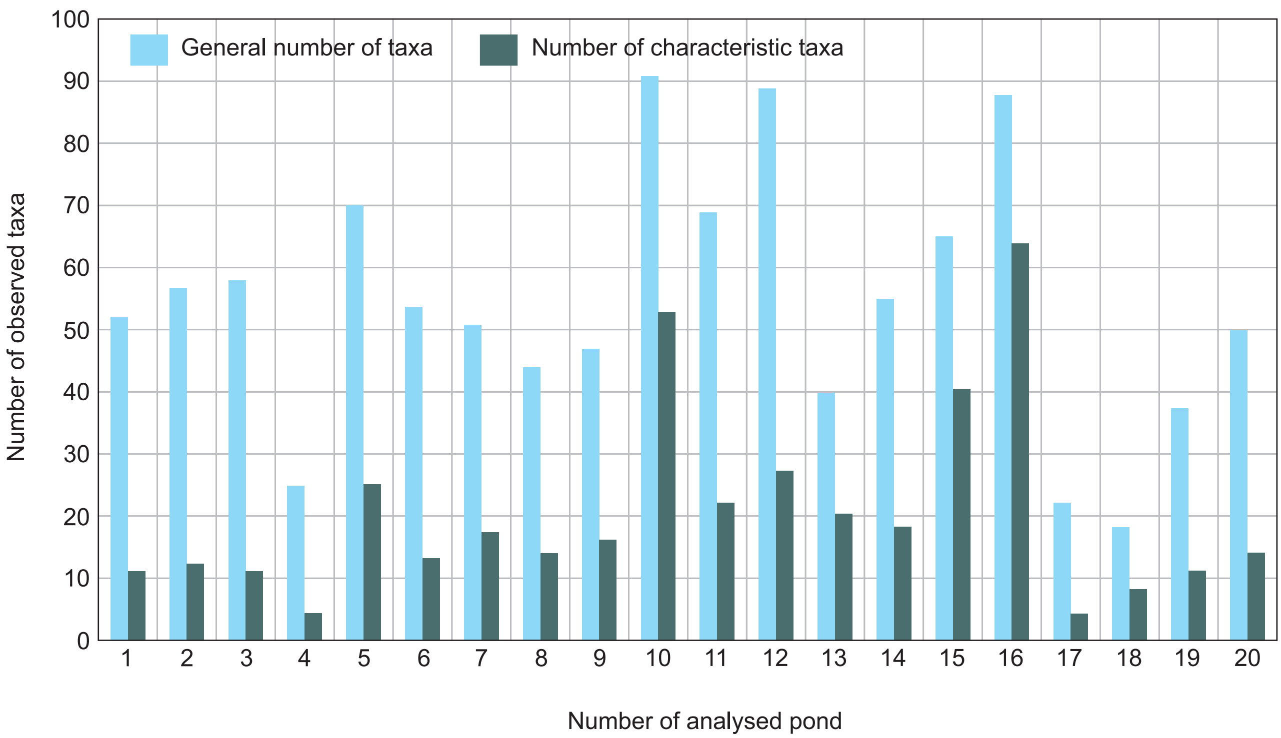

Figure 2

Total number of taxa and the number of characteristic taxa (with occur only in a given reservoir) in the astatic ponds of the Świecie Plateau researched in 1996-97, 2001-02 and 2012-13

Statistical analyses revealed some other important facts including the importance of small ponds to the biodiversity of algae. The average number of taxa recorded for a single reservoir was 56.2 SD 20.8. The number of characteristic taxa varied from 4 to 64 (16%-72% of all taxa, respectively), reaching the average value of 21 taxa per reservoir (Fig. 2).

The average number of new taxa recorded in each pond was 25.2, SD 17.6. The increase in the number of new species significantly correlated with the number of the studied ponds at r=0.99 and p<0.001 (according to Pearson's correlation test). The details are presented in Figure 3.

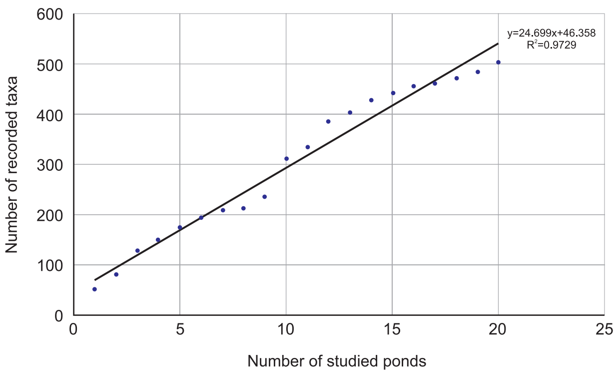

Figure 3

The relation between the number of the studied ponds and the number of observed taxa. The graph represents a linear regression calculated from the data.

Discussion

The comparison of the calculated mean number of 56 species per reservoir with the total number of 503 algal taxa observed in 20 small ponds indicates the existence of large differences between these ecosystems. The flora of algae occurring in each pond was unique compared to other ponds. According to the results of statistical analyses, the average number of taxa recorded in one reservoir was 56, but 25% of taxa were characteristic of one reservoir only. Another important and frequent observation was the complete and rapid "rebuilding" of the algal flora. Very quick changes in the physicochemical properties of the water are responsible for this phenomenon. The dynamics of changes in the algal communities reflect changes in the environment and are observed in all microenvironments, including heleoplanktonic, benthic, and epiphytic ones (Paczuska et al. 2002). That is why the flora of algae in each reservoir differed not only from other reservoirs but also from its own flora observed at the same time of the year during previous studies. For this reason, the number of characteristic taxa varies from 4 to 64. Green algae Chlorophyta dominate both taxonomically and quantitatively, but they are represented by different taxa in each pond. Most taxa are cosmopolitan with the "r" type of life strategy suitable for adaptation to rapid environmental changes. A similar structure of algal communities was observed in the region of Wielkopolska (Chmielewski 1992; Celewicz-Gołdyn et al. 2015; Jurkowska 1987).

Both variability of algal communities and their changes were much higher than observed in typical large lakes. Algal blooms – another phenomena typical of large lakes in this area – were observed only occasionally in small ponds. For this reason, their ecology should be considered as more related to natural conditions than in large lakes.

The average number of taxa for an individual pond was 56.2 SD 20.8, thus much smaller than usually recorded in typical large lakes in this area, i.e. 120-230 (Wiśniewska 1996; Wiśniewska et al. 1998, 2009, 2013). On the other hand, when we take into consideration the large number of small ponds, it appears that they represent more than 97% of algal populations and therefore, they are of major importance to the biodiversity of algae.

When we compare the number of taxa observed in the 20 studied ponds with the number of taxa observed in large lakes from the same area (Wiśniewska et al. 1998), it appears that they are represented by many more species. The difference is even more obvious when we compare it with the results of previous studies (Paczuska et al. 2002). In total, 281 small ponds were found in the area of 300 square kilometers of the Świecie Plateau. Only two large lakes are located in the same area. The number of the studied ponds represents 7.1% of all reservoirs in this area. For this reason, the statistical algorithm of taxa recorded in small ponds may be different than the calculated one (Fig. 3) but it is clear that this type of reservoirs is crucial for the taxonomic biodiversity of algae.

Statistical analyses revealed some other important facts reflecting the importance of small ponds to the biodiversity of algae. The average number of taxa calculated for a single reservoir was 56, thus much fewer than usually recorded in typical large lakes. But when we take into account the large number of small ponds and compare it to the number of larger reservoirs, it appears that they represent more than 97% of algal populations. The hydrological conditions in the study area and their landscape consequences are similar to other parts of northern Poland and neighboring countries. Therefore, they are of major importance to all aspects of the biodiversity of small ponds, including taxonomy, population biology and genetic variability.

The observed 30% decrease in the number of small ponds reflects the loss of algae biodiversity during the last hundred years caused by drainage. Although the study area was only 300 square kilometers large, similar environmental conditions and their changes are characteristic of large areas in central and northern Poland, Germany, Russia, Lithuania, Byelorussia, Estonia and Latvia.

Acknowledgements

The studies were funded by the Polish Ministry of Education and Science, research grants: 6PO4G04711 and 6PO4G00519.

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