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Small water bodies formed after peat digging in Dobrzyńskie Lakeland

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Abstract

Post-peat water bodies formed as a result of peat digging for fuel in the 19th and the first half of the 20th century are common in the middle part of Dobrzyńskie Lakeland. In many cases peat was dug almost completely to form small water bodies. In the studied part of the lakeland 56.24 ha or 10.20% of peatland area have been exploited. The share of peatlands in the surface area of particular regions varied from 3.79% to 9.81%. The degree of peat exploitation also varied. Peat coverage of 7.06% was larger than the mean for Poland (3.80%) but close to that in young glacial areas. A group of water bodies formed after peat digging differed in terms of water quality. Physical and chemical properties of waters in studied water bodies are typical of surface and shallow ground waters in young glacial areas. They are fresh waters of a slightly higher content of mineral ions and of neutral to alkaline pH. Their electrolytic conductivity ranged between 300 and 500 $\mu S \cdot cm^{-1}$. Bicarbonates and calcium dominated their ionic composition. Post-peat water bodies were colonised by pleustonic and rush plant communities. Their species composition indicates eutrophic habitat conditions. Despite the fact that post-peat water bodies were formed as a result of intense environmental disturbance, now they increase landscape diversity of the middle part of Dobrzyńskie Lakeland and are habitats of many rare and endangered plant species.

Key words: *geological documentation of peat deposits, peat digging, plant communities, small water reservoirs, water properties*

INTRODUCTION

Peat has been used as fuel for centuries [MITSCH, GOSSELINK 2000; TOBOLSKI 2000]. Already in the 10th century peat was used for heating in Holland and in the 12th century peatlands were drained for agricultural use. Particularly intensive exploitation of peat was carried out in Europe in the 18th, 19th and the first half of the 20th century [ŁAJCZAK 2006]. In Poland this activity developed intensively in the second half of the 19th and the first half of the 20th century [TAYTSCH 1955]. Apart from manual digging, the industrial methods of peat excavation were applied, which enabled its use in power and thermal power plants [ILNICKI 2002]. Now, most of peat excavated in the world is used to generate electricity [MITSCH, GOSSELINK 2000]. Apart from peat, underlying deposits were also excavated [ILNICKI 2002].

Peat exploitation intensified during wars and economic crisises. Post-peat water bodies sometimes called post-exploitation holes are the effect of peat digging. In old days the excavation was named "karier" [TAYTSCH 1955] or locally „torfniak" in Polish. A great number of post-peat water bodies and numerous historical sources evidence common peat exploitation in the past in Poland. In 1968 peat exploitation in Poland covered 3502 km^2. It was found that post-exploitation excavations covered 1751 km^2 and constituted 14.5% of peatland area [KACZAN 1968]. Small water bodies formed in peat excavations occupy ca. 500 km^2 in Poland [ILNICKI 2002].

Post-peat water bodies have different shape and depth, usually 1–2 m. Their status is quite differentiated from water-filled reservoirs to shallow depression covered by peat-forming but also by segetal and ruderal vegetation [PODBIELKOWSKI 1960]. Small water bodies have often shrubbery shores, open water table and a belt of rushes around. Post-peat water bodies may be covered by sedge and rush communities. They are usually displaced randomly. This is a result of the location of approach roads leading to the excavation and of a need for leaving fields (dykes) for drying peat. In many cases, peat was dug out almost completely from small peatlands thus forming small water bodies. Post-peat water bodies and peatlands devastated by unplanned exploitation was dealt with in a system of land classification as barren lands [Rozporządzenie... 1956]

Post-peat water bodies are important habitats for aquatic and wetland organisms and affect ecosystem stability and biodiversity. Many water bodies have high natural values and deserve protection, especially in agricultural lands devoid of natural wetlands [KUCHARSKI 1996; ŁACHACZ 1997]. Present law enables protecting marginal habitats (formerly described as barren lands) including habitats transformed by human activity. Many barren lands have been classified as "lands of ecological use". Nature Protection Act [Ustawa… 2004] defines lands of ecological use as "deserving protection remnants of ecosystems important for preservation of biodiversity – natural water bodies, mid-field and mid-forest water holes, clumps of trees and shrubs, bogs, peatlands, dunes, patches of unused vegetation, oxbow lakes, rock outcrops, escarps, gravel-banks, habitats and sites of rare and protected species of plants, animals and fungi, their refuges, reproduction grounds and sites of seasonal stay". Also Act on the protection of agricultural and forest grounds [Ustawa… 1995] obliges the users of agricultural space to preserve peatlands and water reservoirs. The act introduces also limits on changes in the natural landscape. OLACZEK [1990] rated 300 000 ha out of 500 000 ha of evidenced barren lands as areas having values of lands of ecological use. Substantial part among these areas constitute small water bodies, peatlands and other wetlands and post-peat water bodies.

The aim of this study was to assess present status of small water bodies formed after peat digging in the middle part of Dobrzyńskie Lakeland. Historical extent of peat exploitation, properties of waters in post-peat water bodies and their plant cover were considered [KOPROWSKI, ŁACHACZ 2012].

STUDY METHODS AND SCOPE

Study site is situated in the middle part of Dobrzyńskie Lakeland and covers an area located in the Ruziec River catchment basin from the Drwęca River valley to Urszulewska Plain [KONDRACKI 2001]. This is an historical part of Dobrzyń District situated among the Vistula, Drwęca, Skrwa Prawa and Brynica rivers. In the administration divisions the area belongs to Kujawsko-Pomorskie Province and covers parts of the Rypin Lipno and Golub-Dobrzyń counties.

Based on 4 peat documentations [Prezydium WRN… 1972a; Wojewódzki... 1971; Prezydium WRN… 1972b; Prezydium WRN… 1972c] covering southern part of the study area (Fig. 1), the areas of peatlands and post-peat water bodies were set up in Table 1.

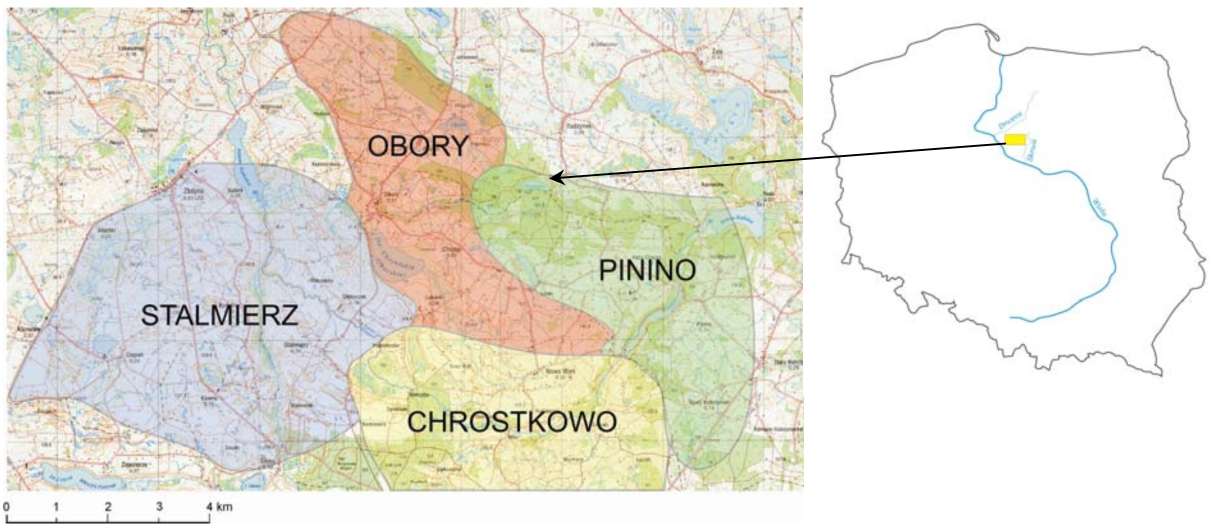

Fig. 1. Range of selected peat documentations in the study area; source: own elaboration with the use of topographic maps as a topographic base

Table 1. Peat exploitation in the study area according to peat documentations

Documented region	Surface area ha	Surface area of peatlands ha	Percent of peatlands in the region	Surface area of post-peat water bodies ha	Percent of water bodies in the peatland area
Chrostkowo	1 200	83.54	6.96	12.53	15.00
Obory	1 440	54.61	3.79	0.01	0.02
Pinino	1 970	193.22	9.81	24.00	12.42
Stalmierz	3 200	220.00	6.88	19.70	8.95
Total	**7 810**	**551.37**	**7.06**	**56.24**	**10.20**

Source: own elaboration.

Physical and chemical properties of waters of the studied water bodies were determined. Analyses were made in agreement with procedures of the Provincial Inspectorate of Environmental Protection in Bydgoszcz, Włocławek Branch according to Polish Norms and analytical procedures and modern applications of absorption spectrophotometry. Applied methods were described e.g. in RAND *et al*. [1975] and HERMANOWICZ *et al*. [1976].

Phytosociological relevés according to the Braun-Blanquet method [MATUSZKIWICZ 2001] were made to characterise plant communities in studied water bodies. Nomenclature of vascular plant species was adopted after MIREK *et al.* [2002].

PEAT EXCAVATION IN DOBRZYŃSKIE LAKELAND

Dobrzyńskie Lakeland occupies 2 993 km^2 and is situated in the middle part of the Lower Vistula River catchment basin. In northern part it reaches the Drwęca River Valley, in the north-east the lakeland neighbours morainic upland of Garb Lubawski. Western and south-western border of Dobrzyńskie Lakeland is delineated by the Vistula Valley and eastern and south-eastern range is determined by frontal moraines and other marginal forms of North-Poland glaciation [KONDRACKI 2001].

Peatlands are best recognised among wetlands in the study area (seven peatland documentations made in the years 1958–1972 were used in this study). Lowland peatlands which occupy 98.74% of peatland area dominate there (acc. to four peat documentations) (Fig. 1). Their occurrence is associated with eutrophic character of surface waters. Peatlands in Dobrzyńskie Lakeland have been transformed by humans at least since the Middle Ages. Along with the development of settlement and agriculture, the area was being drained and managed by agriculture [KOPROWSKI *et al.* 2012]. In the 19th and the first half of the 20th century due to the liquidation of forests, peat was excavated mainly for fuel.

In the middle part of Dobrzyńskie Lakeland excavated peat was used mainly for heating [CHEŁMICKI 2005] since there was no tradition among local population to use it as fertiliser or cattle litter [Dokumentacja... Pinino 1972]. This type of peat utilisation was often associated with a lack of forests and timber in land estates. POŁUJAŃSKI [1854] remarked that in the first half of the 19th century in most areas of the Płock Province due to "... timber abundance peat was of minor importance". DZIEWULSKI [1881] underlined, however, that in areas devoid of forests, peat was used as fuel. In deforested parts of the study area peat was used by both landowners and peasants already in 1826. Notes in land registries of the Dobre estate indicate sufficient amounts of good quality peat [GAŁKOWSKI 2002].

Geographic dictionary of the Kingdom of Poland and other Slavic countries [1880–1902] underlined the extent of "prehistoric aquatic communities" in the then Rypin County and substantial peat deposits covering 16 000 acres with a thickness of 3 to 5 feet. There was also a remark that "... excavation takes place on only one tenth of the area". Analysed historical sources contain information on operating peat workings not earlier than in the 19th century e.g. in Klonowo [Topograficzna Karta... 1839], Charszew [Słownik... 1880–1902] and in Ostrowite [GAŁKOWSKI 2002]. On a sketch of Zbójno estate there is a note of the peat excavation operating there [Odrys pomiaru Folwarku Zbójno 1860/1861].

Historical descriptions present indirect information about the acquisition and disposal of peat. The description of an inn in Ostrowite in 1850 reveals that innkeper and fisherman obtained two four-horse carts of peat or timber each for heating [GAŁKOWSKI 2002]. Peat remained fossil fuel also after World War the II. It was also used for industrial purposes for example as a sole source of fuel in the brick making factory near Rypin, where the annual peat consumption was 3 000 tons [Ministerstwo… 1958; Ministerstwo... 1960].

First documentations of peat deposits in the study area were made in the late 1950s. From these documentations one may extract information about the spatial distribution of peatlands and on the intensity of peat exploitation. Numerous and almost completely exploited mid-field peatlands due to their small areas were not covered by peat documentation which resulted in the underestimation of total (primary) peatland area.

In areas selected for this study (Fig. 1) out of the total area of 7810 ha, there were 551.37 ha of peatlands which constituted 7.06% of the total area. 56.24 ha or 10.20% of peatland area were exploited (Tab. 1). The share of peatlands in the surface area of particular regions varied from 3.79% (Obory) to 9.81% (Pinino). The degree of exploitation also varied. In the region of Obory only a few small post-peat water bodies of an area of several dozen square metres (0.02%) were noted while 15% of deposits were exploited near Chrostowo. The percent of peat cover (7.06%) was higher than the country mean (3.80%) but close to peat cover of young glacial areas [GIS Mokradła].

Lowland peat dominated in the study area but in the documented region of Obory (11 peatlands in total) there were two raised peatlands of an area of 1.88 and 5.06 ha. These peatlands were subject to intensive exploitation often not planned and chaotic. Whole peatland was cut by excavations, most often rectangular, dealt with as barren land devoid of any agricultural value. Part of peatlands was exploited in 80%, only narrow edges of primary area and open water table were left. The exception was peatlands in the Obory region, where new excavations (in time of making peat documentations) were practically absent and post-peat water bodies formed long ago were already overgrown.

Peat documentations contain also information on transformations of peatlands in river valleys – important sites of peat occurrence. An intensive, unplanned and sometimes devastating peat exploitation was carried out in these valleys. Peat exploitation under supervision was recommended in the documentation which would later enable management of resulting post-peat water bodies [Ministerstwo… 1960]. In the documentation of peatlands in Ruda Żalska and in the valley of Lake Czarownica one may find remarks on peat acquisition by local populations yet in 1966 [Wojewódzki… 1966]. Due to the destruction of grasslands it was found necessary to stop digging peat and use mineral fertilisation. Undersowing with a mixture of valuable grasses and reconstruction of reclamation ditches was recommended to increase yields. According to other recommendations, post-peat water bodies should be managed by agriculture or fishery. Documentations made in other regions later do not contain information on past and present exploitation of peatlands [Wojewódzki... 1971; Prezydium WRN... 1972b; Prezydium WRN... 1972c].

The approach to peat exploitation changed in the content of peat documentations. At the break of 1950s and 1960s the documentations focussed on the regulation of water conditions and agricultural management of exploited peatlands. Ten years later the need of peatland protection was the dominating view.

PRESENT STATUS OF POST-PEAT WATER BODIES – PHYSICAL AND CHEMICAL WATER PROPERTIES

Noteworthy, water bodies formed after peat digging were quite diverse in water properties. This was often a result of a complex origin of their basins. The water bodies were usually dug in earlier land depressions filled with deposits rich in organic matter (peat, mud, deluvial formations). As a result of digging, bottom formations were mixed. Part of peat often remained in the surrounding of a water body thus affecting its water quality but there were also such places, from which peat was completely removed and their origin is evidenced only by archive data.

Physical and chemical water properties of studied post-peat water bodies is typical of surface and shallow ground waters in young glacial areas [GAŁCZYŃSKA, GAMRAT 2007; KOC *et al.* 2001; PIEŃKOWSKI 2003]. These are fresh waters of slightly increased content of ions and of neutral to alkaline pH (Tab. 2). Their electrolytic conductivity varied from 210 to 654 $\mu S \cdot cm^{-1}$, most often from 300 to 500 $\mu S \cdot cm^{-1}$. Ionic composition was dominated by bicarbonates and calcium, which indicates that the main mechanism of water enrichment in these elements was the dissolution of calcium rocks (calcite) present in soils and parent rocks of the catchment basin. In many cases calcium and magnesium concentrations exceeded 70 $mg \cdot dm^{-3}$ and 10 $mg \cdot dm^{-3}$, respectively, which classifies these sites to the category of lowland alkalitrophic peatlands [WAUGHMAN, BELLAMY 1984; WOŁEJKO 2000]. Usually, there was more sodium than potassium and the concentration of chlorides and sulphates was very differentiated. BOD_5 and the concentration of total nitrogen, inorganic nitrogen and phosphorus indicate that the studied waters were eutrophic, enriched in nutrients.

Oxygen saturation of analysed waters was very differentiated (15.3–125.2%) and averaged 37.6% (Tab. 2), which resulted from a high content of decomposing organic matter. The latter may be judged from BOD_5 which was high (mean 5.4 mg $O_2 \cdot dm^{-3}$) in analysed waters. Inorganic forms of nitrogen were dominated by nitrates. Analysed waters contained substantial amounts of total phosphorus (mean 0.556 $mg \cdot dm^{-3}$). Noteworthy, phosphates constituted a large part of total phosphorus pool. This pertained particularly to "boggy" water bodies rich in dissolved organic matter.

The nitrogen to phosphorus ratio assumed to be one of measures of the trophic status of water bodies varied widely from 0.37 to 34.44 with a mean of 12.13 (Tab. 2). A high N:P is known to indicate phosphorus deficit and the source of nitrogen "excess" is decomposing plant remains, for example peat that decomposes at the edge of a water body. A low N:P ratio may point to denitrification i.e. biochemical reduction of nitrates to ammonium ions or to free nitrogen. This process removes nitrogen from water (hence promotes its self-purification) and proceeds at oxygen deficit in water. Low N:P ratio was found in some post-peat water bodies with low concentrations of dissolved oxygen.

PLANT COVER OF POST-PEAT WATER BODIES

Phytosociological relevés made in studied water bodies allowed for identifying the following communities of the class *Lemnetea minoris* R. Tx. 1955:

– *Wolffietum arrhizae* Miyaw. et J. Tx. 1960 (Tab. 3, relevés 1–3),
– *Lemnetum minoris* Soó 1927 (Tab. 3, relevés 4–6),
– *Spirodeletum polyrhizae* (Kelhofer 1915) W. Koch 1954 em. R. Tx. et A. Schwabe 1974 in R. Tx. 1974 (Tab. 3, relevés 7–8).

These are phytocoenoses of relatively simple composition built up by a few species (4–9), one of which is usually the dominant [MATUSZKIEWICZ 2001]. Their composition is similar to that described from other regions of the country [BOSIACKA, PIEŃKOWSKI 2003; OLACZEK, KRZYWAŃSKI 1970; SAMOSIEJ, KUCHARSKI 1986; URBAN, WÓJCIAK 2006; WÓJCIAK, URBAN 2009]. In the study area, communities of the class *Lemnetea minoris* are frequent as they are in other regions of Poland [WOŁEK 1997].

Wolffia arrhiza dominated in the *Wolffietum arrhizae* community and was always accompanied by *Lemna minor*. Other species of duckweeds: *Spirodela polyrhiza* and *Lemna trisulca* were also frequent. In two relevés the presence of a rare species – *Lemna gibba* was noted. Species of the class *Potametea* and *Phragmitetea* prevailed among the accompanying species. The presence of rush species was associated with a small depth of studied water bodies (mean 0.58 m). It seems that the contribution of rush species resulted also from astatic character of some water bodies (large fluctuations of water table until periodical drying). As it was in Kujawy [SAMOSIEJ, KUCHARSKI 1986], there was a clear relationship between the occurrence of *Wolffietum arrhizae* and habitats transformed by human activity (post-peat water bodies, ponds, dug and deepened reservoirs). *Lemna minor* dominated in the *Lemnetum minoris* community, other duckweed species covered much smaller areas. As the former community, this was a phytocoenosis poor in species (5–6) that occupied shallow water bodies. The third described community – *Spirodeletum polyrhizae* was built by *Spirodela polyrhiza* always accompanied by *Lemna minor*. In some water bodies a marked contribution of *Lemna trisulca,* which built lower, submerged plant layer, was noted.

Duckweed species in studied phytocoenoses occurred in various combinations (Tab. 3). Similar co-occurrence of duckweed species was found by Wójciak and Urban [2009] in oxbow lakes of the Bug River. This may indicate that the observed combinations of pleustophyte species were formed as a result of random dispersion of the plants [WOŁEK 1997; 2006].

We attempted to document communities with *Wolffia arrhiza* – relatively rare species in Poland. Performed studies confirmed that the species was quite frequent in Dobrzynskie Lakeland, which was also noted in the 1960s by KĘPCZYŃSKI [1972]. In the studied water bodies, *Lemna gibba* was less frequent than *Wolffia arrhiza*. The coverage of water table by the former species did not exceed 20%, therefore, the community *Lemnetum gibbae* Miy. et J. Tx. 1960 was not distinguished.

Pleustonic communities in post-peat water bodies of the middle part of Dobrzyńskie Lakeland were very differentiated. This was a result of abiotic factors (water depth, thermal conditions, chemical composition of water) overlapped by modifying human activity (digging and deepening of water bodies, nutrient input from surrounding area). In some cases, duckweed populations may be affected by waterfowl and domestic birds feeding on them [OLACZEK, KRZYWAŃSKI 1970].

No significant differences were found in the quality of water taken from three patches of distinguished pleustonic communities (Tab. 2). It seems, that water properties and nutrient content were not the factors limiting growth of duckweeds in studied water bodies. From recent studies [WOŁEK 2006] it appears that the duckweed species require waters rich in nitrogen and phosphorus. Recorded pH (6.64–7.85) was also adequate for the growth of duckweeds. Measured electrolytic conductivities (EC_{20} 453–654 $\mu S \cdot cm^{-1}$) also fell within the range typical of these species [WOŁEK 2006]. Water from pleustonic communities showed quite differentiated N:P ratio (5.48–34.44). Water saturation with oxygen was low there ranging from 15.3 to 41.8% with a mean of 25.7%. Obtained results seem to confirm Wołek's [1997; 2006] findings that combination of pleustonic species forms due to random dispersion of these species and water properties in studied water bodies were not the limiting factors.

Rush communities developed in studied post-peat water bodies were differentiated depending on local habitat conditions. The association *Oenantho-Rorippetum* (Tab. 4) was often found in eutrophic water bodies being recipients of waste waters or liquid manure. Observations showed that these water bodies were characterised by large fluctuations of water level and sometimes dried up. *Oenanthe aquatica* dominated in this community and the second characteristic species – *Rorippa amphibia* was noted sporadically.

Table 2. Physical and chemical properties of water in water bodies formed after peat excavation

Specification	No. of object						
	41	43	2	3	5	8	22
Sampling date	18.08.2005	18.08.2005	01.08.2007	18.08.2005	26.07.2007	24.08.2005	26.07.2007
Water temperature, °C	15.2	18.0	17.2	20.5	18.0	18.6	19.6
Dissolved oxygen, mg $O_2 \cdot dm^{-3}$	1.53	3.28	7.85	11.26	2.98	3.42	3.80
Oxygen saturation, %	15.3	35.0	82.6	125.2	31.8	37.0	41.8
pH	7.85	7.68	7.99	8.45	6.97	7.70	7.47
EC_{20}, $\mu S \cdot cm^{-1}$	544	453	392	210	386	289	513
BOD_5, mg $O_2 \cdot dm^{-3}$	n.o.	n.o.	5.9	n.o.	3.7	n.o.	2.7
Total nitrogen	2.631	1.713	1.668	2.433	5.140	1.461	1.963
Kjeldahl nitrogen	2.282	1.494	1.521	2.130	4.941	1.231	1.759
$N\text{-}NH_4$	0.587	0.033	n.o.	0.035	n.o.	0.034	n.o.
$N\text{-}NO_3$	0.349	0.219	0.136	0.303	0.192	0.230	0.198
$N\text{-}NO_2$	n.o.	n.o.	0.0109	n.o.	0.0069	n.o.	0.0063
Total phosphorus	0.227	0.179	0.178	0.200	0.678	3.905	0.057
$P\text{-}PO_4$	0.122	0.125	0.021	<0.016[1)]	0.379	0.050	0.034
Ca^{2+}	91.12	69.25	72.02	21.37	67.59	45.26	86.89
Mg^{2+}	15.02	10.86	9.63	4.38	6.55	5.85	10.18
K^+	2.46	10.11	2.20	18.58	13.08	3.63	5.27
Na^+	13.30	14.06	8.32	12.82	5.56	10.18	15.72
HCO_3^-	296	242	202	82	197	168	264
SiO_2	17.7	8.0	12.8	6.7	6.4	5.4	9.3
Cl^-	20.5	21.6	22.0	18.0	15.1	18.1	16.0
$S\text{-}SO_4$	25.7	11.4	25.0	19.3	16.3	<10.0[1)]	27.8
Total Fe	0.056	<0.05[1)]	<0.05[1)]	0.051	0.132	0.489	<0.05[1)]
N:P	11.59	9.57	9.37	12.16	7.58	0.37	34.44

Explanations: EC_{20} – electrolytic conductivity corrected to 20ºC; n.o. – not determined.
[1)] Below detection limit.
Concentrations of all components are given in mg·dm^{-3} if not stated otherwise.

The community *Sparganietum erecti* was found in some post-peat water bodies. The community was dominated by *Sparganium erectum* accompanied by species of the class *Lemnetea minoris* and *Phragmitetea*. Very common in the study area was the community *Typhetum latifoliae*. Sometimes *Ranunculus lingua* – a species considered endangered in Poland (category V) could be found there. Relevé no 6 represents a transitory facies of the broad-leaved cattail community, where this species showed smaller coverage (40%) and was accompanied by *Menyanthes trifoliata*, a species characteristic for the class *Scheuchzerio-Caricetea nigrae*.

The presence of the buckbean points to habitat properties associated with transitory peatlands and hence – to a decreasing effect of running waters. Three next relevés (Tab. 4, relevés 7–9) illustrate communities with the domination of *Menyanthes trifoliata* but at the same time with a great contribution of *Lysimachia thyrsiflora*, a species characteristic for the alliance *Magnocaricion* accompanied by *Ranunculus lingua* and in relevé no. 9 also by *Equisetum fluviatile*. Next relevé (Tab. 4, relevé 10) documents the association *Caricetum rostratae*. Dominating species there was *Carex rostrata* and accompanying species included e.g. *Lysimachia thyrsiflora* and *Menyanthes trifoliata*. In the study area this association was relatively rare as was *Caricetum vesicariae* (Tab. 4, relevé 11). *Hottonia palustris* was numerous in this association apart from *Carex vesicaria* which is the dominating and characteristic species. The association *Acoretum calami* (Tab. 4, relevés 12–13) was often found in the study area. It occurred usually at the edge of eutrophic water bodies, particularly those used as watering holes. The association was floristically poor being composed of 6–7 plant species. The association *Eleocharitetum palustris* is represented by relevé no 14. It developed at the shores of water bodies of variable water level.

SUMMARY

As a result of peat excavation for fuel in the 19th and the first half of the 20th century there are many post-peat water bodies in the middle part of Dobrzyńskie Lakeland. In many cases peat was removed almost completely forming thus small water bodies. These water bodies were colonised by plant species which formed pleustonic and rush communities. Their species composition indicates eutrophic habitat conditions. Species typical for raised bogs were relatively rare.

Despite being formed as a result of habitat disturbance, post-peat water bodies from the middle part of Dobrzyńskie Lakeland now increase landscape diversity and become habitats for many rare and endangered plant species.

No. of object								
34	35	51	45	347	226	222	223	219
24.08.2005	26.07.2006	27.07.2006	26.07.2007	26.07.2007	01.08.2007	01.08.2007	01.08.2007	01.08.2007
18.6	24.6	18.8	17.4	16.0	16.4	14.4	14.4	14.2
2.13	3.59	1.76	3.16	2.25	3.63	1.94	1.68	1.85
22.9	43.2	18.9	33.3	22.9	37.4	18.9	16.5	18.1
7.52	7.13	6.78	7.03	7.07	7.17	6.64	7.08	7.04
593	546	620	332	581	463	654	585	475
n.o.	6.1	5.9	3.9	3.4	8.2	7.7	8.8	3.3
3.383	2.460	5.280	1.756	3.020	3.440	4.659	4.863	3.318
2.974	2.180	4.918	1.535	2.624	3.210	4.397	4.606	3.127
0.178	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
0.409	0.281	0.360	0.216	0.327	0.221	0.251	0.245	0.184
n.o.	<0.005[1)]	<0.005[1)]	0.0053	0.0686	0.0089	0.0111	0.0122	0.0070
0.467	0.158	0.584	0.138	0.131	0.390	0.851	0.579	0.178
0.321	<0.016[1)]	0.398	0.058	0.068	0.096	0.779	0.363	0.088
78.72	86.08	86.13	54.18	91.43	78.52	124.90	102.60	83.66
16.13	12.88	15.98	6.85	15.65	11.94	12.40	12.98	9.88
18.36	11.68	10.10	2.75	5.78	3.90	3.98	8.54	2.84
18.84	14.24	22.13	7.85	14.10	9.71	10.96	14.98	7.17
267	287	309	182	289	260	375	298	270
22.2	11.9	18.5	4.6	12.2	17.2	28.8	21.0	17.0
42.7	22.3	186.3	10.5	20.0	23.7	20.9	31.6	22.0
13.7	43.9	25.7	17.4	43.8	11.0	15.8	36.0	12.0
0.101	<0.05[1)]	<0.05[1)]	<0.05[1)]	<0.05[1)]	0.05	0.120	0.150	0.106
7.24	15.57	9.04	12.72	23.05	8.82	5.48	8.40	18.64

Table 3. Floristic composition of pleustonic communities in studied post-peat water bodies

No. of the relevé	1	2	3	4	5	6	7	8
No. of the object	34	22	226	43	222	223	219	41
Date: day	09	08	20	09	20	20	20	09
month	07	08	07	07	07	07	07	07
year	05	05	06	05	06	06	06	05
Surface area of the relevé, m^2	4	4	6	4	4	4	4	4
Coverage, %	100	100	100	100	100	100	100	100
Water depth, m	0.7	0.5	1.0	0.4	0.3	0.5	0.8	0.4
Number of species in the relevé	9	7	4	6	5	5	5	6
ChCl., ChO.: *Lemnetea minoris*, *Lemnetalia minoris*								
Wolffia arrhiza	5	4	5	2	1	1	·	1
Lemna minor	2	2	2	5	5	5	2	1
Spirodela polyrhiza	2	2	2	2	·	·	4	4
Lemna trisulca	2	3	3	1	·	3	2	1
Lemna gibba	1	2	·	·	·	·	·	·
Accompanying:								
Hydrocharis morsus-ranae	·	·	·	·	·	·	2	·
Typha latifolia	+	+	·	+	+	+	·	·
Oenanthe aquatica	·	·	·	+	·	·	+	·
Carex pseudocyperus	·	+	·	·	+	·	·	·
Carex acutiformis	·	·	·	·	·	+	·	+
Rumex hydrolapathum	+	·	·	·	+	·	·	·
Phragmites australis	·	·	·	·	·	·	·	+
Sparganium erectum	+	·	·	·	·	·	·	·
Chara fragilis	+	·	·	·	·	·	·	·

Table 4. Floristic composition of rush communities developed in the studied post-peat water bodies

No. of the relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of the object	501	502	45	507	221	7	7	236	7	235	7	510	517	507
Date: day	07	07	05	08	20	05	05	21	05	21	05	08	08	08
month	08	08	08	08	07	08	08	07	08	07	08	08	08	08
year	2009	2009	2005	2009	2006	2005	2005	2006	2005	2006	2005	2009	2009	2009
Surface area of the relevé, m^2	4	4	4	2	25	30	40	25	40	20	25	2	3	1
Coverage, %	90	60	50	95	90	90	95	100	95	100	95	80	90	80
Water level, m	+0.4	+0.5	+0.3	+0.5	+0,4	0.0	–0.05	0.0	0.0	+0.05	0.0	+0.2	+0.2	+0.3
Number of species in the relevé	14	10	6	11	10	6	9	7	10	12	12	7	6	7
ChCl., ChO: *Phragmitetea, Phragmitetalia*														
Typha latifolia	+	·	·	5	4	3	1	+	+	+	1	+	·	·
Equisetum fluviatile	·	·	·	+	·	1	+	1	2	+	·	·	·	1
Rumex hydrolapathum	·	·	·	1	+	+	+	·	·	+	+	·	·	·
Sium latifolium	·	·	·	·	·	·	1	+	+	+	1	·	·	·
Alisma plantago-aquatica	+	·	1	1	·	·	·	·	·	·	·	·	·	·
Eleocharis palustris	·	·	·	·	·	·	·	·	·	·	·	·	·	4
Glyceria maxima	·	·	+	·	·	·	·	·	·	·	·	·	·	·
ChAll.: *Phragmition*														
Oenanthe aquatica	4	+	+	+	·	·	·	·	·	·	·	+	+	+
Acorus calamus	·	·	·	·	·	·	·	·	·	·	·	5	5	·
Sparganium erectum	·	4	3	+	·	·	·	·	·	·	·	·	·	·
Rorippa amphibia	·	·	·	·	·	·	·	·	·	·	·	1	·	·
ChAll.: *Magnocaricion*														
Lysimachia thyrsiflora	·	·	·	·	+	·	3	3	2	1	+	·	·	·
Ranunculus lingua	·	·	·	·	2	1	2	2	1	·	·	·	·	·
Carex rostrata	·	·	·	·	·	·	+	1	+	5	·	·	·	·
Carex vesicaria	·	·	·	·	1	·	·	·	·	·	4	·	·	·
Phalaris arundinacea	1	·	·	·	·	·	·	·	·	·	·	·	·	·
Galium palustre	·	+	·	·	·	·	·	·	+	+	+	·	·	·
Carex pseudocyperus	+	·	·	·	·	+	·	·	·	·	·	·	·	·
Carex gracilis	·	·	·	·	1	·	·	·	·	·	·	·	·	·
Iris pseudacorus	·	·	·	·	·	·	·	·	·	·	+	·	·	·
Poa palustris	·	·	·	·	·	·	·	·	·	·	+	·	·	·
ChCl. *Scheuchzerio-Caricetea nigrae*, ChAll. *Caricion lasiocarpae*														
Menyanthes trifoliata	·	·	·	·	·	4	3	4	4	1	·	·	·	·
ChCl., ChO.: *Lemnetea minoris, Lemnetalia minoris*														
Lemna minor	3	3	1	+	·	·	+	·	1	1	·	+	·	·
Spirodela polyrhiza	+	3	3	1	·	·	·	·	·	·	·	·	·	+
Lemna trisulca	1	1	·	2	·	·	·	·	·	·	·	·	·	·
Wolffia arrhiza	+	1	·	·	·	·	·	·	·	·	·	·	·	·
Lemna gibba	+	·	·	·	·	·	·	·	·	·	·	·	·	·
ChCl., ChO.: *Potametea, Potametalia*														
Hottonia palustris	·	·	·	·	1	·	·	·	·	1	2	·	·	·
Potamogeton natans	·	·	·	1	·	·	·	·	·	·	·	·	+	+
Elodea canadensis	·	·	·	·	·	·	·	·	·	·	·	·	2	+
Hydrocharis morsus-ranae	·	·	·	·	·	·	·	·	·	1	1	·	·	·
Polygonum amphibium	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Ceratophyllum demersum	·	2	·	·	·	·	·	·	·	·	·	·	·	·
Myriophyllum verticillatum	·	·	·	·	·	·	·	·	+	·	·	·	·	·
Accompanying:														
Lycopus europaeus	1	1	·	+	+	·	·	·	·	·	·	+	·	·
Polygonum persicaria	+	·	·	·	·	·	·	·	·	·	1	·	·	·
Cardamine dentata	·	·	·	·	·	·	·	·	·	+	+	·	·	·
Bidens connata	+	·	·	·	·	·	·	·	·	·	·	·	+	·

Sporadical species: 1 – *Bidens tripartita* (+); 2 – *Agrostis stolonifera* (+); 5 – *Lithrum salicaria* (+), *Caltha palustris* (+); 13 – *Epilobium parviflorum* (+); 14 – *Myosotis palustris* (+).

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Małe zbiorniki wodne powstałe po wydobyciu torfu na Pojezierzu Dobrzyńskim

STRESZCZENIE

Słowa kluczowe: *geologiczne dokumentacje złóż torfowych, małe zbiorniki wodne, właściwości wód, wydobywanie torfu, zbiorowiska roślinne*

W środkowej części Pojezierza Dobrzyńskiego często występują potorfia jako wynik wydobywania torfu na opał w XIX i pierwszej połowie XX wieku. W wielu przypadkach torf wybrano niemal zupełnie, tworząc małe zbiorniki wodne. W badanej części Pojezierza Dobrzyńskiego wyeksploatowano 56,24 ha, czyli 10,20% powierzchni torfowisk. Udział torfowisk w powierzchni poszczególnych rejonów wynosił od 3,79 do 9,81%. Zróżnicowany był również ilość eksploatacji torfów. Zatorfienie, wynoszące 7,06%, było większe niż średnio w całej Polsce (3,80%), a zbliżone do zatorfienia obszarów młodoglacjalnych. Właściwości wody grupy

zbiorników powstałych po wydobyciu torfu są bardzo zróżnicowane. Właściwości fizykochemiczne wód badanych potorfii są typowe dla wód powierzchniowych i płytkich wód gruntowych na obszarach młodoglacjalnych. Są to wody słodkie, z nieznacznie większą niż średnia mineralizacją (ogólna zawartość jonów) oraz odczynem od obojętnego do zasadowego. Ich przewodnictwo elektrolityczne najczęściej wynosiło 300–500 $\mu S \cdot cm^{-1}$. W składzie jonowym dominowały wodorowęglany oraz wapń. Powstałe po wydobyciu torfu zbiorniki wodne były kolonizowane przez gatunki roślin. W wyniku tego wykształciły się zbiorowiska pleustonowe, a także szuwarowe. Ich skład gatunkowy wskazuje na eutroficzne warunki siedliskowe. Mimo że powstały w wyniku znacznego przekształcenia środowiska, obecnie potorfia występujące w środkowej części Pojezierza Dobrzyńskiego zwiększają różnorodność krajobrazową i stanowią siedlisko wielu rzadkich i zagrożonych gatunków roślin.