J. Elementol. 2010, 15(4): 705–712

CHANGES IN THE QUALITY OF WATER IN BRDOWSKIE LAKE IN 1997-2006

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Abstract

Most lakes in Poland are shallow and vulnerable to degradation mostly due to lake morphology and landscape structure. Other factors, like discharged sewage, internal loading and human activities in the watershed are also important. During studies on Brdowskie Lake, water samples were taken twice a year (spring and summer season) from the surface layer and analyses of soluble reactive phosphates, total phosphorus, nitrates, conductivity, five-day biochemical oxygen demand, chlorophyll a, dry mass of seston and Secchi depth were undertaken.

Brdowskie Lake is situated in Kujawskie Lakeland and its catchment basin covers about 155.3 km^2. The littoral vegetation is dominated by reed bed with a minor presence of other taxa. The lake is very susceptible to degradation (morphology, agricultural lands, housing) and has several potential sources of pollution, e.g. Noteć River, a nameless stream and summer houses. In general, water quality of the lake was better during the spring season, especially in terms of chlorophyll a and dry mass of seston concentrations. In 1997--2006, the level of conductivity was very changeable with the maximum values observed in 1999-2001.

Significant correlations between some parameters in certain seasons of the year were found, e.g. between chlorophyll *a* and Secchi depth during spring and total phosphorus and phosphates in summer. The impact of water level fluctuations on water quality parameters, like total phosphorus and chlorophyll a was observed.

According to the results, the quality water in Brdowskie Lake is improving. After a biological wastewater treatment plant in the catchment had opened, the rate of salts flowing into the lake with sewage was reduced.

Key words: water quality indicators, phosphorus, Brdowskie Lake, Kujawskie Lakeland, Province of Wielkopolska, water level fluctuations.

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ZMIANY JAKOŚCI WÓD JEZIORA BRDOWSKIEGO W LATACH 1997-2006

Abstrakt

Większość jezior w Polsce to jeziora płytkie i podatne na degradację. Jej głównym powodem są na ogół morfologia zbiorników oraz niekorzystna struktura użytkowania zlewni. Inne czynniki, takie jak dopływ ścieków, ładunek wewnętrzny i działalność gospodarcza, mają również istotne znaczenie. Podczas badań Jez. Brdowskiego próby wody pobierano 2 razy w roku (wiosną i jesienią) z warstwy powierzchniowej i wykonywano oznaczenia takich wskaźników, jak: fosfor reaktywny, fosfor ogólny, azot azotanowy, przewodność elektrolityczna właściwa, pięciodobowe zapotrzebowanie tlenu, chlorofil *a*, sucha masa sestonu i widzialność krążka Secchi'ego.

Jezioro Brdowskie usytuowane na Pojezierzu Kujawskim ma zlewnię o pow. ok. 155,3 km^2. Litoral zdominowała trzcina, a udział innych taksonów roślin jest mały. Akwen bardzo podatny na degradację (warunki morfologiczne, duży udział terenów wykorzystywanych rolniczo, zabudowania wiejskie) ma wiele potencjalnych źródeł zanieczyszczenia wody, jak np. rzeka Noteć, ciek bez nazwy, domki letniskowe z nieuregulowaną gospodarką wodno-ściekową oraz pobliskie zabudowania wiejskie. Zazwyczaj jakość wody była wyższa na wiosnę, szczególnie odnośnie do stężeń chlorofilu *a* oraz suchej masy sestonu. W latach 1997-2006 poziom przewodności elektrolitycznej był bardzo zmienny, a maksimum przypadało na lata 1999-2001.

Stwierdzono istotne korelacje między niektórymi wskaźnikami w zależności od pory roku, jak w przypadku chlorofilu *a* i widzialności krążka Secchi'ego wiosną i fosforu ogólnego i fosforanów rozpuszczonych latem. Zaobserwowano wpływ wahań poziomu lustra wody na niektóre wskaźniki jakości (fosfor ogólny, chlorofil *a*).

Uzyskane wyniki świadczą o poprawie jakości wód Jez. Brdowskiego. Po uruchomieniu oczyszczalni ścieków w Poloniszu obniżył się np. poziom przewodności elektrolitycznej, co świadczy o ograniczeniu dopływu różnych soli do wód akwenu.

Słowa kluczowe: wskaźniki jakości wody, fosfor, Jezioro Brdowskie, Pojezierze Kujawskie, Wielkopolska, wahania poziomu lustra wody.

INTRODUCTION

Most lakes in Poland (about 60%) are shallow. They often lie in lowlands and are susceptible to degradation mostly due to lake morphology and landscape structure (CHOIŃSKI 1995). In shallow lakes, both depth and volume of water can strongly affect trophic conditions (HAKANSON 2005, STANISZEWSKI et al. 2009). Other factors that influence water quality are discharged sewage, internal loading, agricultural activities, industry, climatic conditions, vegetation structure, soil conditions, elevation and even longitude (HEATHWAITE 1995, SAPEK 1998, SŘNDERGAARD et al. 1999, NŐGES et al. 2003, HAKANSON 2005 and others). The influence of some other factors on Brdowskie Lake, such as inflow of wastewater from houses (the western shore), wastewater after rainfall (the eastern shore) and from summer houses is difficult to assess.

MATERIAL AND METHODS

Water samples were taken from surface layer of the lake twice a year (spring and summer 1997-2006).

The following analyses were undertaken:

– soluble reactive phosphates – samples filtered using 0.45 µm pore size, Ascorbic Acid Method;
– total phosphorus – Acid Persulfate Digestion Method;
– nitrates – samples filtered using 0.45 µm pore size, Cadmium Reaction Method;
– conductivity – electrometrically;
– five-day biochemical oxygen demand (BOD 5) – Winkler method, summer only;
– chlorophyll *a*;
– dry mass of seston;
– Secchi depth.

Water quality was evaluated in accordance with the regulations imposed by the Ministry for the Environment (*Rozporządzenie Ministra Środowiska* 2008). Statistical evaluation was made using the programme Statistica (Statsoft Inc. 2004).

RESULTS AND DISCUSSION

Brdowskie Lake is a shallow lake (maximum depth of 5 m, average depth of 2.2 m and the catchment basin area of 155.3 km^2) situated in Kujawskie Lakeland (the Noteć River watershed) and covers an area of 198.2 ha; its catchment basin covers about 155.3 km^2 (*Raport o stanie środowiska…* 2005). Due to its morphology and landscape structure of the catchment basin (agricultural lands 74%, housing 10%) as well as prevalence of arable lands in the vicinity of the lake shores, Brdowskie Lake is very susceptible to degradation. Potential sources of pollution are tributaries (eg. the Noteć River in the northern part of lake, a nameless stream flowing from the south-western direction) and summer houses on the western and eastern lake shore.

Littoral vegetation is dominated by reed bed (class *Phragmitetea*, Tx. et Preisg. 1942) with a minor presence of perfoliate pondweed (*Potamogeton perfoliatus* L.) and other plant species from the class of *Potametea* (Tx. et Preisg. 1942). Phytoplankton is sometimes strongly dominated by blue-green algae, especially during summer, when they cause algal blooms (Staniszewski, Szoszkiewicz 2000, *Raport o stanie środowiska…* 2005, Staniszewski et al. 2005). It is a lake with good conditions for carp bream, whose the potential

fish yield is about 35 kg per 1 ha, but other species like common bleak, roach and perch are also present.

In general, water quality was better during spring season (Tables 1a, b). The highest concentrations of total phosphorus in Brdowskie Lake were ob-

Table 1a

Characteristics of selected water quality parameters of Brdowskie Lake in 1997-2006, spring measurements

Parameter	Mean values	Standard deviation
Total phosphorus (mg P dm^{-3})	0.08	0.04
Chlorophyll *a* (µg Chl *a* dm^{-3})	24.69	12.42
Secchi depth (m)	0.97	0.40
Dry mass of seston (mg DMS dm^{-3})	10.40	5.31
Soluble reactive phosphates (mg PO_4 dm^{-3})	0.11	0.06
Nitrates (mg N-NO_3 dm^{-3})	0.09	0.07
Conductivity (mS cm^{-1})	0.714	0.227

Table 1b

Characteristics of selected water quality parameters of Brdowskie Lake in 1997-2006, summer measurements

Parameter	Mean values	Standard deviation
Total phosphorus (mg P dm^{-3})	0.10	0.05
Chlorophyll *a* (µg Chl *a* dm^{-3})	39.83	15.79
Secchi depth (m)	0.79	0.16
Dry mass of seston (mg DMS dm^{-3})	17.85	7.73
Soluble reactive phosphates (mg PO_4 dm^{-3})	0.17	0.10
Nitrates (mg N-NO_3 dm^{-3})	0.08	0.11
Conductivity (mS cm^{-1})	0.685	0.267
BOD 5 (mg O_2 dm^{-3})	5.0	2.0

Table 1c

Water quality categories of Brdowskie Lake in 1997-2006 evaluated on the basis of average results (spring and summer surveys) of total phosphorus, chlorophyll *a*, Secchi depth and conductivity in the surface layer of water (five categories according to *Rozporządzenie Ministra Środowiska* 2008)

Year	Total phosphorus	Chlorophyll *a*	Secchi depth	Conductivity	The worst category assigned
1997	I-II	III	III-V	III-V	III-V
1998	I-II	III	III-V	III-V	III-V
1999	I-II	III	III-V	III-V	III-V
2000	I-II	II	III-V	III-V	III-V
2001	I-II	III	III-V	III-V	III-V
2002	I-II	IV	III-V	I-II	III-V
2003	I-II	III	III-V	I-II	III-V
2004	I-II	III	I-II	I-II	III
2005	III-V	IV	III-V	I-II	III-V
2006	I-II	II	I-II	I-II	II

served in summer 2005 but in spring they were lower (Tables 1a, b). Chlorophyll *a* and dry mass of seston behaved similarily. During the tests, Secchi depth was sometimes lower than 60 cm (spring 1998, summer 2003 and 2005) and once was over 180 cm (182 cm, spring 2006), which was attrobutable to an unusually low concentration of chlorophyll in water (4.28 µg Chl *a* dm^{-3}).

Concentration of soluble reactive phosphates in lake water ranged from 0.01 to 0.36 mg PO_4 dm^{-3} and showed slightly increasing tendency with maximum in summer 2006. It was partially related to water level fluctuations but it was not statistically significant.

The results showed, that presence of nitrates in surface layer was generally higher in spring before part of nitrogen was incorporated in biomass of phytoplankton and macrophytes. The highest concentrations of nitrates were observed in the year 2003 during spring (about 0.20 mg $N\text{-}NO_3$ dm^{-3}) and summer (0.40 mg $N\text{-}NO_3$ dm^{-3}) measurements were concentration of seston was also very high. Results obtained in summer surveys were very diverse and it gave high value of standard deviation for nitrates (Table 1b).

In the years 1997-2006 the conductivity of lake waters was very changeable. During spring the highest values (> 1.000 mS cm^{-1}) were observed in the years 1999-2001 and the lowest in the year 2006 (< 0.500 mS cm^{-1}). According to summer surveys the highest value (> 1.000 mS cm^{-1}) was measured in the year 1999 and very low in the years 2002-2006, one year

after sewage treatment plant in Polonisz had started-up (31st of March 2001). Conductivity showed positive but not statistically significant correlation with water level fluctuations.

Analyses of biochemical oxygen demand were made during summer period and results ranged from 2.0 mg O_2 dm^{-3} to 8.0 mg O_2 dm^{-3}.

According to physico-chemical parameters from the year 2006 the Brdowskie Lake waters can potentially fit standards of second category of water quality. Taking into account actual criteria, during at least eight years of surveys the situation was far from this. Main problem was low values of Secchi depth and high conductivity (Table 1c).

Presence of significant correlations between some trophic parameters in certain year season were found (Tables 2, 3). During spring season strong correspondence between concentration of chlorophyll *a* and Secchi depth was

Table 2

Brdowskie Lake – linear correlation among trophic parameters for the years 1997-2006, spring measurements ($p < 0.05$, $N = 10$)

Parameter	Total phosphorus	Soluble reactive phosphates	Chlorophyll *a*	Secchi depth	Dry mass of seston
Total phosphorus	1.00	0.58	-0.47	0.54	-0.51
Soluble reactive phosphates		1.00	-0.43	0.38	-0.61
Chlorophyll *a*			1.00	-0.84*	0.62
Secchi depth				1.00	-0.50
Dry mass of seston					1.00

* statistically significant

Table 3

Brdowskie Lake – linear correlation among trophic parameters for the years 1997-2006, summer measurements ($p < 0.05$, $N = 10$)

Parameter	Total phosphorus	Soluble reactive phosphates	Chlorophyll *a*	Secchi depth	Dry mass of seston
Total phosphorus	1.00	0.70 *	0.61	-0.64*	0.52
Soluble reactive phosphates		1.00	0.05	-0.34	0.08
Chlorophyll *a*			1.00	-0.61	0.58
Secchi depth				1.00	-0.65*
Dry mass of seston					1.00

* statistically significant

found. In summer time relations between total phosphorus and phosphates, total phosphorus and water clarity and also between Secchi depth and dry mass of seston. Strong correlations between water clarity and trophic parameters were found by other authors in earlier studies (CARLSON 1977, MANDAVILLE 2000 and others).

In surface waters of Brdowskie Lake the impact of water level fluctuations on water quality parameters was not strong and only in case of trophic parameters significant correlations were found. Especially in case of chlorophyll a concentration in spring (positive correlation) and total phosphorus concentration in summer (negative correlation) – Table 4.

Table 4

Linear correlation between water table level and trophic parameters, spring ($p < 0.05$, $N = 8$) and summer measurements ($p < 0.065$, $N = 8$), Brdowskie Lake in the years 1999-2006

Parameter	Total phosphorus	Soluble reactive phosphates	Chlorophyll *a*	Secchi depth	Dry mass of seston
Water table level – spring	-0.57	-0.34	0.71 *	-0.53	0.32
Water table level – summer	-0.72*	-0.70	-0.09	0.44	-0.63

* statistically significant

CONCLUSIONS

1. Brdowskie Lake waters studied in the period 1997-2006 have had rather poor quality but results from years 2004 and 2006 proved, that according to physico-chemical parameters the lake has a potential to achieve second category of water quality.

2. Since the year 2002 the decrease of water conductivity has been found and it was one year after start-up of biological waste water treatment plant in lake catchment, which probably limited the rate of salts inflowing to lake with sewages.

3. Influence of water level fluctuations on water quality parameters was observed but only in case of total phosphorus concentration and water clarity it was significant.

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