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Impact of waterbirds on chemical and biological features of water and sediments of a large, shallow dam reservoir

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Key words: bird assemblages, water chemistry, nutrient concentration, chlorophyll-*a*, bacteria coli

Abstract

Large numbers of Mallard *Anas platyrhynchos* (max. 10,490 ind.), Black-headed Gull *Chroicocephalus ridibundus* (max. 3,430 ind.) and Great Cormorant *Phalacrocorax carbo* (max. 1,449 ind.) were recorded on the Goczałkowice Reservoir, Poland (2,754 ha). Most of the waterbirds occurred in the backwater of this reservoir. The amount of phosphorus and nitrogen loaded by the most numerous waterbirds into Goczalkowice Reservoir was estimated at 958 kg and 2,621 kg, respectively in 2011 and 1,043 kg and 2,793 kg, respectively in 2012. In 2011 and 2012, the waterbirds introduced a considerable amount of phosphorus, nitrogen and a large number of coliforms into the backwater of the reservoir. The concentration of different forms of phosphorus and nitrogen, chlorophyll-*a* and bacteria coli in the water was not greater at the site of birds' concentration (except dissolved organic nitrogen). The concentration of nitrates in the water at the site near the breeding colony of gulls in comparison with the reference site was not different. The amounts of P-tot and N-tot in the sediment were similar at the site affected by waterbirds and at the reference site. The dynamics of water masses was not the reason for the lack of differences between the studied sites.

INTRODUCTION

Birds have quick metabolism and produce large amounts of feces in the areas of their concentration. Loading of nitrogen and phosphorus to ecosystems by bird feces can be an important source of nutrients. Higher concentrations of this excrement would occur in places where birds are concentrated (breeding colonies or resting sites). The load of phosphorus and nitrogen contributed by birds to the environment was studied mainly in lakes (Dobrowolski et al. 1976, Gere & Andrikovics 1992, Manny et al. 1994, Marion et al. 1994, Rönicke et al. 2008). The influence of bird nutrient enrichment in other water bodies has not been extensively studied (Ganning & Wolff 1969, Portnoy 1990, Post et al. 1998) and it has been very rarely studied in dam reservoirs (Gwiazda 1996).

Amounts of nutrients introduced by waterbirds into large lakes and reservoirs were usually small (Marion et al. 1994, Gwiazda 1996). Waterbirds significantly increased the resources of phosphorus and nitrogen in small water bodies (Kitchell et al. 1999, Manny et al. 1994, Scherer et al. 1995, Post et al. 1998) but also in some large lakes (Dobrowolski et al. 1976, Rönicke et al. 2008).

Many studies showed the impact of birds on the concentrations of nutrients (Leentvaar 1967, Ganning & Wolff 1969, Manny et al. 1994, Marion et al. 1994, Kitchell et al. 1999) or fecal bacteria (Benton et al. 1983, Levesque et al. 2000) in the habitat. However, the impact of waterbirds on the deterioration of water quality was not observed in

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any water bodies (Brierley et al. 1975, Pettigrew et al. 1998).

The waterbird excrement is a source of pathogenic microorganisms (Wiśniewska et al. 2007, Klimaszyk & Rzymski 2013). However, the risk of contamination depends also on the abundance of birds (Meerburg et al. 2011).

The impact of waterbirds on the ecosystem of dam reservoirs needs further study. The purpose of the study was to determine: (1) the loading of nutrients to a reservoir by waterbirds, (2) the effect of large numbers of waterbirds on the concentration of nutrients, fecal bacteria and chlorophyll-*a* in the water, and (3) the impact of a gull breeding colony on the nutrients in the sediment of a lowland reservoir.

STUDY AREA

The study was conducted in the Goczałkowice dam reservoir (49°52' N, 18°52' E) located on the Vistula River in southern Poland (Fig. 1). This is a lowland reservoir with an area of 2,754 ha, a volume of 118 GL, and a shoreline of c. 50–60 km (depending on the water level), and a mean depth of 5.2 m (max. c. 14 m). The length of the reservoir is c. 10 km and the width c. 3 km. The most abundant aquatic macrophytes are *Glyceria maxima* (Hartm.) Holmb., and *Phragmites australis* Cav. Trin. ex Steud. The largest areas covered by macrophytes are located in the backwater of the reservoir and on the southern shores. Submerged vegetation was very rare. In the western part of the reservoir, there are some islands, wet meadows and fields.

The reservoir is eutrophic and polymictic. Circulation of the whole water volume occurs throughout the year. The retention period is c. 190 days. The total input from the Vistula River of inorganic P was estimated at 97 t yr^{-1} and inorganic N as 596 t yr^{-1}. The Goczałkowice Reservoir catchment is 532 km^2 in area.

The reservoir supplies water to the Silesian agglomeration and is used for recreational fishing. The Goczałkowice Reservoir is one of the most important refugia of water birds in Poland and the Natura 2000 network site (PLB area code 240001). This reservoir is the most important breeding area of two threatened species in Poland: the Purple Heron

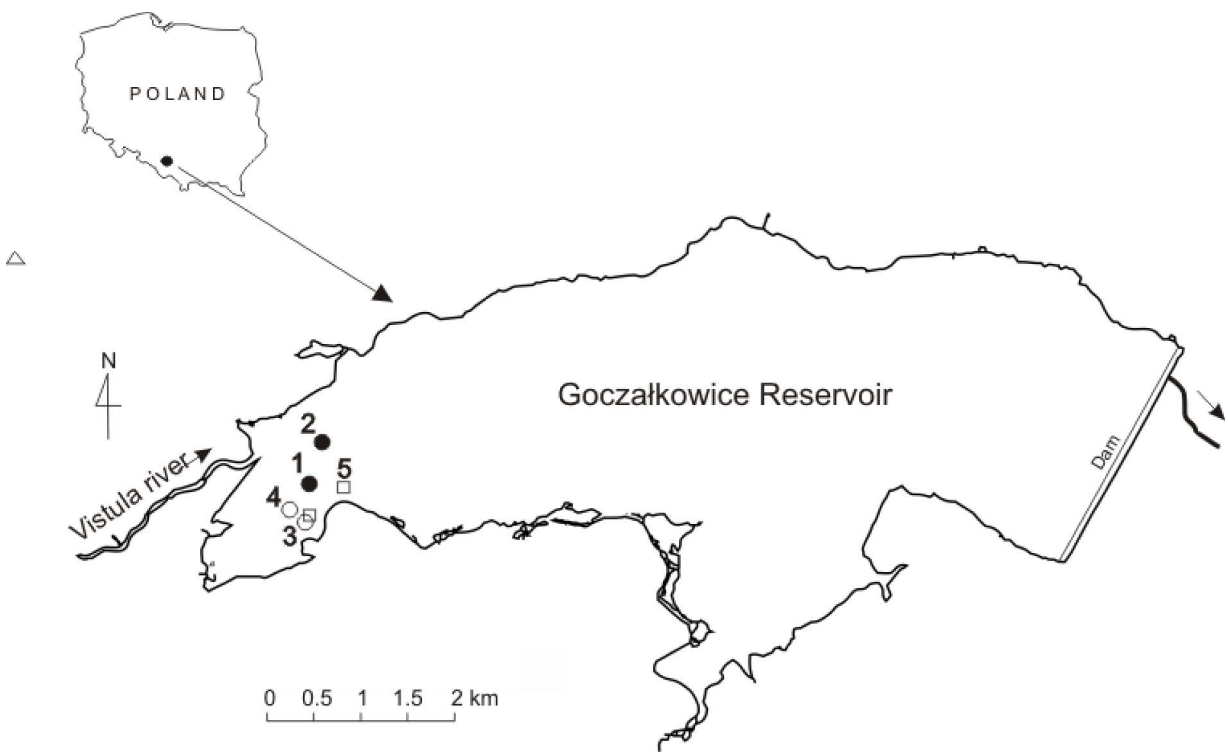

Fig. 1. Goczałkowice Reservoir. Sampling stations: 1 – water sampling station in the waterbird area; 2 – reference water sampling station; 3 – water and sediment sampling station near the gull colony; 4 – water sampling station outside the gull colony; 5 – sediment sampling station outside the gull colony

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Ardea purpurea and the Whiskered Tern *Chlidonias hybrida*. Sixteen bird species from the Birds Directive and 36 others were identified as breeding on Goczałkowice Reservoir (Betleja et al. 2006). The maximum number of breeding pairs of Black-headed Gulls reached 9,000. The Goczałkowice Reservoir also plays an important role in migration of birds. The most numerous species were the Mallard *Anas platyrhynchos*, the Great Cormorant *Phalacrocorax carbo*, and the Black-headed Gull *Chroicocephalus ridibundus*. In the autumn, the number of waterbirds reaches 20,000 individuals, mostly mallards (Betleja 2005).

MATERIALS AND METHODS

The dominant species of waterbirds over the reservoir area were counted from the shore for two to six days every month from January to December 2011–2012.

The nutrients deposited by the Great Cormorant, the Mallard, and the Black-headed Gull into the reservoir were calculated as a product of the mean number of different bird species per month, the number of days in a given month, and the amount of N-tot and P-tot in feces excreted by individuals per day. The amount of nutrients in the feces of different species was taken from the literature. The Mallard excretes daily 0.4 g P-tot and 2.6 g N-tot (Gwiazda 1996), the Black-headed Gull 1.0 g P-tot and 0.9 g N-tot (Gwiazda 1996), and the Great Cormorant 2.5 g of P-tot and 3.3 g of N-tot (Gwiazda et al. 2010). The amount of nutrients derived from the Black-headed Gull colony was estimated as a total for adults and chicks. The amount of nutrients produced by adults was determined based on the double number of nests, breeding period (75 days) and the amount of N-tot and P-tot excreted by individuals per day. The amount of nutrients produced by chicks was determined based on the number of young per nest (estimated at two chicks), the period they spent in their nest (30 days), and half of the amount of N-tot and P-tot excreted by adult individuals per day.

The site affected by waterbirds was situated in the backwater of the reservoir, while the reference site was located near the mouth of the Vistula into the reservoir (Fig. 1). A hydrodynamic model of the Goczałkowice Reservoir was prepared by the Institute of Ecology of Industrial Areas in Katowice based on the ELCOM model to determine the water flow in the reservoir (Laval & Hodges 2000). It showed that water was stirred very slowly at the site affected by waterbirds despite the considerable velocity of the water mass throughout the reservoir. The dynamics of water masses did not have an impact on the values of the studied parameters at the site affected by waterbirds.

Water samples were collected with a 5 l sampler in the shallow (depth < 1 m) zone of the reservoir at two studied sites at monthly intervals from April to November in 2011 and from May to November 2012. Specific forms of nutrients (N-tot, NO_3^-, NH_4^+, organic N, P-tot, PO_4^-, organic P) and chlorophyll-*a* concentrations were determined in water samples according to Standard Methods (2006). Total and organic nitrogen were determined using the distillation method (BUCHI Distillation UNIT K-314). Nitrogen NO_3^-, NH_4^+, chlorophyll-*a*, and phosphorus forms were determined using the spectrophotometric method (Spectrophotometer UV–Visible, Cary 50 Scan, Varian). Concentrations of fecal bacteria (Coliforms, *Escherichia coli*, Enterococcus) were also monitored. The number of bacteria coli, *Escherichia coli* and Enterococcus in 100 ml of water were determined using the membrane filtration method. Nitrate concentrations were measured near the Black-headed Gull colony (which was also a resting site of water birds during migrating passages) and c. 150 m further on July 3 and October 2, 2012 using an automatic multiprobe Hydrolab MS5 (Fig. 1).

Sediment samples were collected from the site near the colony of gulls and the reference site unaffected by birds (Fig. 1). The sediment samples were collected with a polythene corer (diameter 5 cm). Two sub-samples of sediment were collected at these two sites once in October 2012. N-tot and P-tot were determined in these samples. Total nitrogen and total phosphorus were determined using the X-ray photoelectron spectroscopy method.

The fecal bacteria introduced into the reservoir by the Great Cormorant, the Mallard, and the Black-headed Gull were calculated in the same way as the nutrients' deposition. The amount of the excreted feces and *Escherichia coli* in feces was taken from the literature. The daily amount of feces excreted by the Great Cormorant, the Mallard, and the Black-headed Gull was estimated at 27 g d. m. (Marion et al. 1994), 16.6 g d. m. (Marion et al. 1994), and 12.2 g d. m (Gwiazda 1996), respectively. The value of the colony forming unit (CFU) of *Escherichia coli* for a gull (1.2×10^8) was used for the Great Cormorant and the Black-headed Gull, and value for the Eurasian Coot *Fulica atra* (1.0×10^7) was used for the Mallard (Meerburg et al. 2011).

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The differences in the nutrient, chlorophyll-*a* and bacteria coli concentrations in the water at the two sites were tested using the U Mann-Whitney test (Sokal & Rohlf 1987). Relationships between the average waterbird density and water parameters in months of the observations were determined based on the Spearman coefficient. All calculations were made using StatSoft, Inc. STATISTICA (data analysis software system), version 10. www.statsoft.com.

RESULTS

Bird numbers and nutrients loading by waterbirds

Large numbers of the Great Cormorant, the Mallard, and the Black-headed Gull were recorded on the Goczałkowice Reservoir. The median numbers of the Mallard, the Great Cormorant, and the Black-headed Gull were 975 ind., 652 ind., and 293 ind., respectively in 2011 (N=40) and 1,026 ind., 543 ind., 630 ind., respectively in 2012 (N=50). The number of birds varied throughout a year, with a peak during migratory passages with a maximum of 10,490 ind. for the Mallard (December 2011), 1,449 ind. for the Great Cormorant (September 2012), and 3,430 ind. for the Black-headed Gull (November 2012). Most of the studied waterbirds (median of share: 78.9% in 2011 and 58.5% in 2012) occurred in the shallow backwater of this reservoir (c. 280 ha).

The excrement of the Mallard, the Great Cormorant and the Black-headed Gull affected the phosphorus and nitrogen loading into the ecosystem. The amount of phosphorus excreted by the Mallard, the Cormorant, and the Black-headed Gull into the Goczałkowice Reservoir in 2011 and 2012 was estimated at 958 kg and 1,043 kg, respectively. The load of nitrogen excreted by waterbirds into this reservoir in 2011 and 2012 was 2,621 kg and 2,793 kg, respectively. The largest amount of phosphorus and nitrogen was loaded in autumn (Fig. 2). Nutrient loading by waterbirds was approximately 1.0% of total P and 0.5% of total N flowing into the reservoir. In 2011 and 2012, the waterbirds introduced a considerable amount of phosphorus (641 kg yr^{-1}; 2.3 kg ha^{-1} yr^{-1} and 547 kg yr^{-1}; 2.0 kg ha^{-1} yr^{-1}, respectively) and nitrogen (1,346 kg yr^{-1}; 4.8 kg ha^{-1} yr^{-1} and 1,181 kg yr^{-1}; 4.2 kg ha^{-1} yr^{-1}, respectively) into the backwater of the Goczałkowice Reservoir.

Table 1

Mean, median, range of values and statistical differences (U Mann-Whitney test – Z and *p* value) of analyzed nitrogen and phosphorus forms (mg dm^{-3}), chlorophyll-*a* (µg dm^{-3}), and bacteria coli (CFU 100 ml^{-1}) in the water of the Goczałkowice Reservoir at the site under the influence of waterbirds (W) (N=15) and at the reference (R) (N=15) site near the mouth of the Vistula River into the reservoir

Parameter	Site	Mean	Median	Range	Z	*p*
NO^{3-}	W	2.198	1.927	0.04–5.98	**3.38**	**< 0.001**
	R	7.697	7.455	2.30–17.50		
NH_4^+	W	0.515	0.489	0.31–0.87	0.02	0.983
	R	0.529	0.433	0.05–1.07		
N-tot dissolved	W	1.806	1.733	1.02–3.02	**3.09**	**0.002**
	R	2.875	2.766	1.31–4.89		
N org. dissolved	W	0.891	0.850	0.62–1.30	**2.10**	**0.036**
	R	0.698	0.660	0.28–1.35		
N org. suspended	W	0.378	0.325	0.14–1.10	0.16	0.870
	R	0.355	0.355	0.09–0.84		
PO_4^-	W	0.0138	0.0100	0.001–0.046	1.55	0.110
	R	0.0284	0.0135	0.001–0.084		
P tot. dissolved	W	0.2770	0.2130	0.046–1.083	0.23	0.818
	R	0.2564	0.1670	0.120–0.691		
P org. dissolved	W	0.2125	0.1170	0.010–1.000	0.37	0.711
	R	0.1774	0.1425	0.061–0.600		
P org. suspended	W	0.2213	0.1470	0.010–0.672	0.22	0.828
	R	0.2042	0.1395	0.047–0.764		
Bacteria coli (Coliforms)	W	4478.7	1700.0	200–19000	1.29	0.198
	R	2657.0	610.0	68–19000		
Escherichia coli	W	406.7	100.0	50–3000	1.13	0.214
	R	383.3	100.0	3–2700		
Chlorophyll-*a*	W	37.20	28.25	8.3–85.0	1.81	0.070
	R	23.87	13.98	3.2–107.8		

Nutrients in water – the macroscale of the reservoir

No higher level of different forms of phosphorus and nitrogen was found in the water at the site affected by waterbirds in comparison with the reference site, except dissolved organic nitrogen. The concentration of chlorophyll-*a* was not different at this site as compared to the reference site (Table 1).

No relationships were found between the density of waterbirds in the backwater and water parameters (nutrients, chlorophyll-*a*) (Table 2).

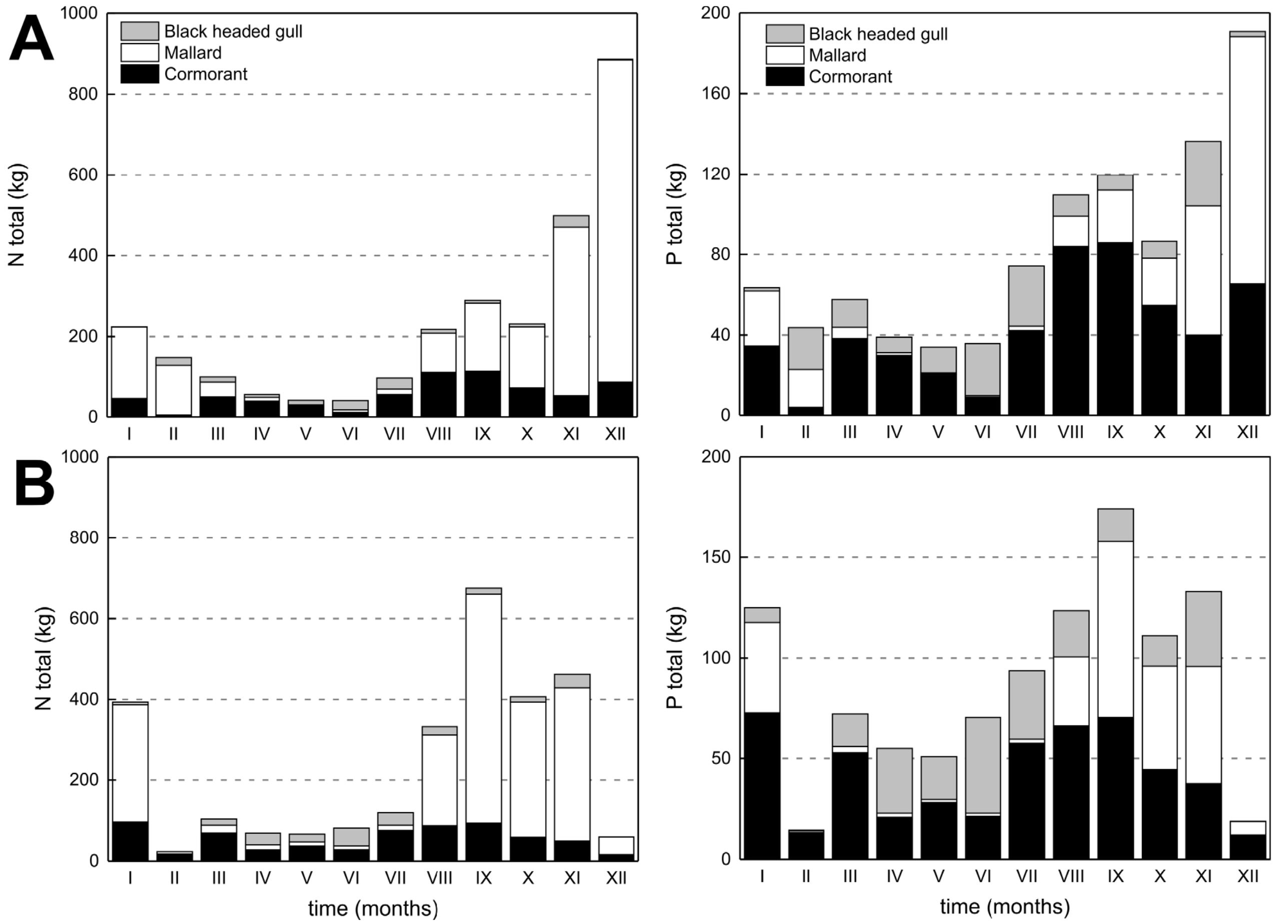

Fig. 2. Mean seasonal load of nitrogen (N-tot) and phosphorus (P-tot) excreted by waterbirds into the Goczałkowice Reservoir (2,754 ha) in 2011 (A) and 2012 (B)

Nutrients in the water and in the sediment – the microscale of the reservoir

The nutrient load of the Black-headed Gulls in the breeding colony (220 pairs) was estimated at 41.6 kg of nitrogen and 46.2 kg of phosphorus during a breeding season. The concentration of nitrates in the water at the site nearby the breeding colony of the Black-headed Gull was not different in comparison with the site c. 150 m from the colony in July and October 2012 (Z=0.400, p=0.89, N=14; Z=0.548, p=0.58, N=11, respectively). The amounts of P-tot in the sediment were similar at the site affected by waterbirds (0.04 and 0.08 mg kg^{-1}) and at the reference site (0.03 and 0.06 mg kg^{-1}). The amounts of N-tot in the sediment were not different at the site affected by waterbirds (1.7 and 1.8 mg kg^{-1}) and at the reference site (1.5 and 2.1 mg kg^{-1}), as well.

Table 2

Values of Spearman coefficients (r) and significance (p) between the density of waterbirds and some water parameters in backwaters of the Goczałkowice reservoir in 2011-2012 (N=15)

Parameter	r	p
NO_3^-	0.109	0.70
NH_4^+	-0.186	0.51
N-tot dissolved	0.064	0.82
N org. dissolved	0.268	0.33
N org. suspended	-0.105	0.73
PO_4^-	0.219	0.43
P-tot dissolved	-0.057	0.84
P org. dissolved	-0.036	0.90
P org. suspended	0.077	0.80
Bacteria coli	0.147	0.60
Escherichia coli	-0.060	0.83
Chlorophyll-*a*	-0.164	0.56

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Fecal bacteria in the water – the macroscale of the reservoir

No higher level of bacteria coli (a possible effect of birds' droppings) was found at the site with a large concentration of waterbirds (Table 1). No relationship was found between the waterbird density in the backwater and bacteria coli (Table 2). The highest CFU value was recorded in autumn at the site of large concentration of birds (1.9×10^4) (Fig. 3). Coliforms (CFU) ranged from 68 to 1.9×10^4 (median for the waterbird area – 1,700, and for the reference site – 610), and *Escherichia coli* (CFU) ranged from 3 to 3.0×10^3 (median for the waterbird area and for the reference site is 100) (Table 1).

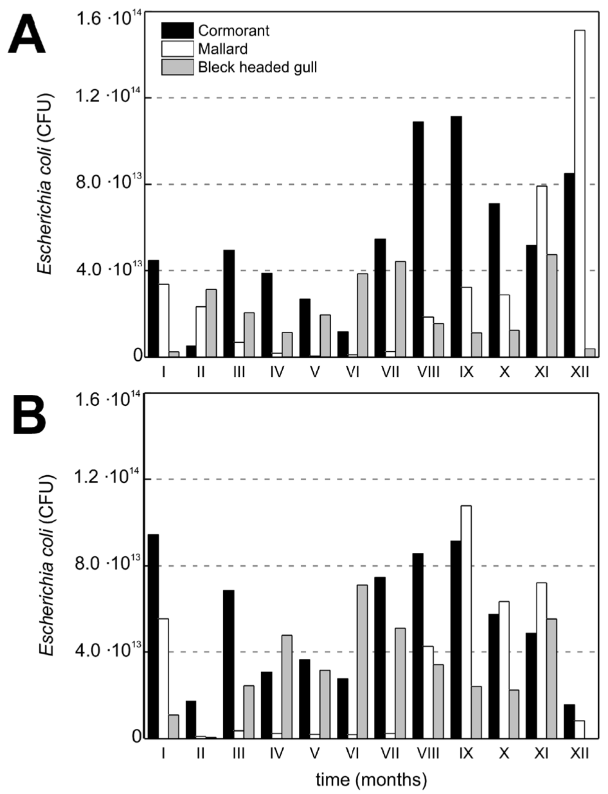

Fig. 3. CFU value of *Escherichia coli* excreted by waterbirds into the Goczałkowice Reservoir (2,754 ha) in 2011 (A) and 2012 (B)

DISCUSSION

Birds in high densities have been associated with introducing large amounts of nutrients into aquatic habitats. Leentvaar (1967) suggested that the accumulation of phosphate is a characteristic of a guanotrophic environment, but we did not find this kind of environment in our study.

Many authors (Dobrowolski et al. 1976, Portnoy 1990, Marion et al. 1994, Post et al. 1998, Rönicke et al. 2008) have indicated that the amount of N and P introduced by birds to ecosystems may be large. The total N and P concentrations attributed to bird droppings were respectively in Lake Łuknajno (60 and 30 kg ha^{-1} yr^{-1}), Lake Warniak (18 and 11 kg ha^{-1} yr^{-1}), and Lake Mikołajskie (30 and 20 kg ha^{-1} yr^{-1}) (Dobrowolski et al. 1976). Similarly, dense aggregations of migrating or wintering geese contributed large amounts of nutrients to the Bosque del Apache National Wildlife Refuge, New Mexico (USA) (Post et al. 1998) and Lake Arendsee (Germany) (Rönicke et al. 2008). Gulls (*Larus argentatus, L. marinus*) have been associated with the increased P and N concentrations (in Gull Pond, Wellfleet, Canada) (Portnoy 1990), and also the Canada Goose (*Branta canadensis*) and the Mallard in Lake Wintergreen, Michigan (USA) (Manny et al. 1994). Lesser Snow Geese (*Anser caerulescens caerulescens*) and Ross's Geese (*Chen rossii*) excreted in total more than 15 t N and nearly 1.8 t P during the period from November to March into the Wildlife Refuge area in New Mexico (USA) (Post et al. 1998). Waterbirds introduced lower amounts of N and P into the Goczałkowice Reservoir. Gwiazda (1996) indicated that Mallards and Black-headed Gulls produced only 100-150 kg of P and 370-400 kg of N in the Dobczyce Reservoir (980 ha) in Poland. Kitchell et al. (1999) showed that birds (mostly Lesser Snow Geese) increased P and N levels (40% and 75%, respectively) in wetlands of New Mexico (USA). Canada Geese and ducks (mostly Mallards) added 280 kg of N (27% of the total), and 88 kg of P (70% of the total) into a small lake (15 ha) in Michigan (USA) (Manny et al. 1994). Total P and N loading from gulls into the Gull Pond (USA) (44 ha) was estimated at 52 kg yr^{-1} and 14 kg yr^{-1} (Portnoy 1990). Waterbirds loaded 160 kg of the total P (27% of the total) in 1992, 159 kg (25% of the total) in 1993, 167 kg (34% of the total) in 1994 into a shallow urban lake (150 ha) (Scherer et al. 1995). Geese (*Anser fabalis* and *Anser albifrons*) produced a phosphorus load of 2.8 t in 1996 and 1.7 t in 1997 in Lake Arendsee (Saxony, Germany) (514 ha) during their wintering. The contribution of phosphorus by birds was 88% in 1996 and 92% in 1997 compared with the annual phosphorus import from different sources (Rönicke et al. 2008). About 40,000 waterbirds during 1981-1982 and 1990-1991 contributed relatively low amounts of nitrogen (0.7 and 0.4%, respectively) and phosphorus (2.4 and 6.6%, respectively) to a large lake (6,300 ha) in France (Marion et al. 1994). Gere and Andrikovics (1992) estimated that Cormorants loaded only 3.1 t of P and 12.5 t of N (2% of the total) into Lake Balaton (Hungary). The amounts of nitrogen and phosphorus introduced by waterbirds into the Goczałkowice Reservoir were relatively low in comparison with the total input from the Vistula River.

Small rock pools in the Baltic Sea (Sweden) affected by breeding colonies of birds had very high $N\text{-}NH_4^+$(Ganning & Wulff 1969). An effect of bird feces on the water chemistry is not always observed. An experimental study of the impact of different quantities of Canada Goose feces on the water chemistry showed no significant changes in the water column of total phosphorus, total nitrogen, nitrate, or chlorophyll-*a*, and the associated nutrients from bird feces settled quickly into the sediment (Unckless & Makarewicz 2007). No differences were found in the concentrations of NO_3^-, NO_2^-, NH_4^+, PO_4^-, and P-tot in the water between the area associated with the Cormorants and the reference site of the Dobczyce Reservoir (Poland) (Gwiazda et al. 2010). Similarly, the amount of nutrients in the water of the area associated with the waterbirds and the reference site was not different in the Goczałkowice Reservoir (except dissolved organic nitrogen). This can probably be explained by the water exchange, nutrient dilution in the reservoir, and intensive nitrification processes in relatively good oxygen conditions.

Nutrients from bird populations have the potential to contribute to the process of eutrophication in smaller water bodies. Water birds caused deterioration of the water quality and intensive eutrophication in Lake Hilversumse Wasmeer (The Netherlands) (Leentvaar 1967) and Lake Wintergreen, Michigan (USA) (Manny et al. 1994). Phosphorus load during the winter appears as a significant eutrophication factor for the trophic level of Lake Arendsee (Germany) (Rönicke et al. 2008). However, birds played a generally minor role in the eutrophication of a large lake in France (Marion et al. 1994). Significant changes in the water quality of the shallow soft-water lobelia lake (Dołgie Wielkie Lake, Poland) were observed in terms of reduced water transparency, and increased conductivity, nitrogen, phosphorus and chlorophyll-*a* content (Klimaszyk et al. 2014). The research of Kitchell et al. (1999) showed that the concentration of chlorophyll-*a* increases with an increasing density of birds in the wetland system at the Bosque del apache National Wildlife Refuge, New Mexico (USA). However, Unckless and Makarewicz (2007) found that different doses of geese feces added to water samples caused no differences in the concentration of phosphorus, nitrogen, nitrate, or chlorophyll-*a* in the water. Gwiazda et al. (2010) described the impact of the Great Cormorant roost on the green algae in the Dobczyce Reservoir (Poland). On the other hand, Ganning and Wulff (1969) showed that bird feces provided nutrients well beyond the needs of the algal biomass, hence the development of algae close to bird colonies can be restricted by the toxic impact of ammonia. According to Scherer et al. (1995), phosphorus from droppings did not remain in the water column or stimulate algae production in the short term but was deposited in sediments. We did not confirm this finding in our study. Pettigrew et al. (1998) suggested that migratory birds excreting in a marsh significantly affected the water quality.

Nutrient concentrations in the sediment of the Dobczyce Reservoir (Poland) affected by the Great Cormorant were higher (Gwiazda et al. 2010). Higher concentrations of nutrients in the water sediment can show a long-term process of nutrient enrichment and accumulation of phosphorus and nitrogen in the habitat. Marion et al. (1994) found greater differences in nutrients between bird habitats and areas not affected by birds in Lake Grand-Lieu (France) (nitrogen 8 times higher and phosphorus 42 times higher than in bird habitats). The soils of an island associated with birds were characterized by higher concentrations of NO_3^-, NH_4^+ and N-tot compared to soils of the island not affected by these birds (Wait et al. 2005). Similarly, the soil samples from the site of Great Cormorant colonies had a content many times higher for all investigated chemical elements compared with control samples (Ligęza & Smal 2003, Klimaszyk et al. 2014).

Water birds occurring in large numbers may affect the water quality by excreting large numbers of fecal coliforms. The high correlation between the density of birds and the amount of *Escherichia coli* confirmed that bird droppings are scattered sources of fecal contamination in the inland water bodies (Kirschner et al. 2004; Meerburg et al. 2011). Meerburg et al. (2011) showed that gull feces contain a higher average concentration of *E. coli* per gram than geese or coot feces. Chemical and microbial pollution

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(together with *E. coli*) of groundwater was recorded in the area of the Great Cormorant colony located on Lake Chrzypskie (Poland) (Klimaszyk 2012). Most of the intestinal tracts of Canada Geese and Bewick's Swans *Cygnus columbianus bewickii* contained *E. coli* (Damare et al. 1979). Hussong et al. (1979) concluded that fecal coliform densities vary in different species of waterfowl, and depends on the pond size, diets and feeding habits. Benton et al. (1983) observed a significant relationship between the number of roosting gulls and the number of *E. coli* in the water from two lakes north of Glasgow in Scotland (UK). Levesque et al. (2000) reported that feces of the Ring-billed Gull *Larus delawarensis* contained large quantities of bacteria and affected the water quality in a lake in Quebec (Canada). We did not find a relationship between the density of waterbirds and bacteria coli concentration in the studied reservoir. However, the microbial contamination can be significantly changed by a fluctuating number of birds. On the other hand, Brierley et al. (1975) found that the presence of large numbers of migratory birds did not affect the water quality in New Mexico (USA).

The water dynamics and the chemical processes caused that a relationship between the number of waterbids and the content of nutrients in the water of the Goczałkowice Reservoir was not found. The movement of water masses, the varied inflow and the input of large amounts of inorganic and organic suspension has a considerable effect on the nutrient concentration and the eutrophication process. A large number of *E. coli* bacteria in the water of the reservoir does not affect the quality of the produced water for human consumption if the relevant technology is used. However, the recreational use of areas with higher concentrations of *E coli* bacteria can be limited, especially in the period of low water levels (associated with lesser dilution of birds' feces). This could generate a conflict between the reservoir functions and a problem for the management. Contamination of the recreational water by bird feces is the main concern of water managers. These are important aspects for effective water bird management (Meerburg et al. 2011). We conclude that even a large number of waterbirds cannot exert an impact on a large, shallow reservoir.

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