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Impact of a small cormorant (*Phalacrocorax carbo sinensis*) roost on nutrients and phytoplankton assemblages in the littoral regions of a submontane reservoir

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Abstract: Cormorants (median numbers of 54.5 ind.) excreted ca. 102.7 kg yr^{-1} of nitrogen and ca. 80.5 kg yr^{-1} of phosphorus in the area of the Dobczyce Reservoir (ca. 980 ha). Concentrations of N-tot and P-tot were 3 times higher in soil from the roosting area of the cormorants than outside this area. Nutrient concentrations in the littoral sediment of the reservoir were also higher in the area frequented by these birds. Differences in concentrations of pH, NO_3^-, NO_2^-, NH_4^+, PO_4^-, and P-tot in water between the area associated with the cormorants and the reference site were not found. Differences in the planktonic algal communities from around the roost and the reference site were not found, with the exception of the chlorophytes which were more abundant in the area occupied by the cormorants. Water movement and mixing in the reservoir can influence the effect of the nutrient load on the water chemistry and planktonic algae.

Key words: Cormorants; water birds; reservoir; nutrients; algae

Introduction

Birds produce considerable amounts of excrement that may influence the geochemical cycling of nutrients both on land and in water ecosystems. Higher concentrations of these excrements would occur in places of breeding colonies or roosts. However, the influence of bird nutrient enrichment in water bodies has rarely been studied, with most studies about nutrients added to the environment by water birds (Dobrowolski et al. 1976; Gilmore et al. 1984; Portnoy 1990; Gere & Andrikovics 1992; Manny et al. 1994; Post et al. 1998; Kitchell et al. 1999; Ligęza & Misztal 1999; Ligęza et al. 2000; Goc et al. 2005; Rönicke et al. 2008). The impact of water birds on the water chemistry has been studied in lakes (Leentvaar 1967; Manny et al. 1994; Marion et al. 1994), salt pools (Ganning & Wulff 1969), and in laboratory conditions (Unckless & Makarewicz 2007). However, there have few studies on the impact to algae in water bodies affected by bird excrements (Leentvaar 1967; Ganning & Wulff 1969; Kitchell et al. 1999).

Piscivorous birds, including the cormorants, are an important link in some food webs and a factor, which facilitates the dislocation of matter between aquatic and terrestrial ecosystems (Gere & Andrikovics 1992; Marion et al. 1994; Ligęza & Smal 2003). The impact of the rapidly increasing number of cormorants in Europe on the biogeochemical cycle in various aquatic habitats needs further study. For instance, what are the effects of small colonies or roosts of birds on nutrient sources in aquatic habitats? The purpose of this study was to determine: 1) the amount of nutrients added to a reservoir by a small cormorant population, 2) the concentration of selected N and P forms in soil, sediment and water in an area of roosting, or resting cormorants, and 3) what is the impact of these nutrients on the phytoplankton community.

Study area

The study was conducted in the Dobczyce Reservoir (49°52′ N, 20°02′ E) located on the Raba River in southern Poland and constructed in 1986. This is a submontane reservoir with an area of 985 ha, a volume of 108 GL, with a shoreline of ca. 42 km and a mean depth of 11 m (max. ca. 27 m) (Fig. 1). In general, the littoral zone is narrow with shallow water (< 2 m) forming about 10% of the total area because of the steep slopes of the inundated valley. The reservoir is eutrophic and dimictic (Mazurkiewicz-Boroń 2000). The reservoir is stratifying between May and September (Amirowicz 2000). The Secchi depth ranged between 0.3 and 5.7 m. Average concentrations of nutrients in influx of the river are: PO_4^+ 0.072–0.548 mg L^{-1}, NH_4^+ 0.558–1.23 mg L^{-1}, and NO_3^- 0.983–1.579 mg L^{-1} (Mazurkiewcz-Boroń 2000). Circulation of the whole water volume occurs during spring and autumn, and is changed on average 3.6 times a year. The Raba River is the main tributary of the reservoir supplying 89% of its total inflow. The remainder of the water is supplied by streams (6.7%), precipitation on the surface (2.6%) and direct flows (2.1%) (Mazurkiewicz-Boroń 2000). Total input of inorganic P was estimated as 20.2 t yr^{-1} and inorganic N as 239.3 t yr^{-1} (Mazurkiewicz-Boroń 2000).

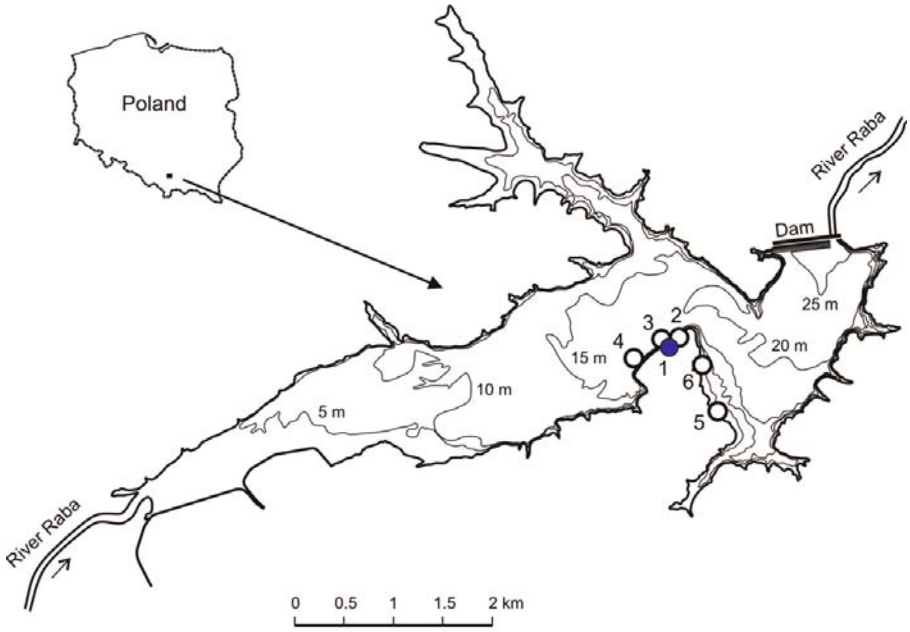

Fig. 1. Dobczyce Reservoir and sampling stations 1–6. Localization of the cormorant roost was marked with the black circle.

Aquatic macrophytes most abundant are *Phragmites australis* Cav. Trin. ex Steud. and *Polygonum amphibium* L. and these are restricted to the long shallow bay in the northern part of the reservoir and few other small areas.

The different phytoplankton groups had inter-annual variability. In the spring (April–June) the diatoms (Bacillariophycae) were dominant in abundance, in summer (July–September) the cyanobacteria (Cyanoprokaryota) and chlorophytes (Chlorophyceae), were most abundant, and in autumn (October–December) again the diatoms were dominant (Wilk-Woźniak 2000).

Eighty two water bird species were recorded on the Dobczyce Reservoir (including 21 breeding species). A greater number of species occurred during the spring and autumn migration with highest numbers (to 4000 ind.) in October–November. Among these birds the most abundant were the great crested grebe *Podiceps cristatus* (L., 1758), mallard *Anas platyrhynchos* L., 1758, black-headed gull *Larus ridibundus* L., 1766, and the grey heron *Ardea cinerea* L., 1758 (Gwiazda 2000). In the late 1990s the cormorant (*Phalacrocorax carbo* (L., 1758)) increased in number and was an abundant species as well, but it did not breed on the reservoir.

Material and methods

Cormorants were counted over the reservoir area, from the shore, monthly from March to December during 2000–2002. Cormorant faeces samples were collected from large stones below the roosting area (station 1) in October 2007. Soil samples (0–15 cm layer) were collected from stations 1 and 2. Station 1 was situated directly below the roost, while station 2 (reference site) was on a control plot unaffected by birds, ca. 100 m from the roost. From these stations two sub samples of soil were taken in October 2006. Both the cormorant faeces and soil samples were analyzed for N-tot and P-tot, and for pH in the soil samples.

Water samples were taken with a Patalas sampler from stations 3 and 4 situated in the shallow (depth < 1 m) zone of the reservoir monthly from April 2006 to March 2007. Station 3 was situated below the roost, while station 4 (reference site) was located ca. 500 m away. Specific nutrient (NO_3^-, NO_2^-, NH_4^+, PO_4^-, P-tot) concentrations were determined in these water samples.

Sediment samples were also taken from two other stations, e.g., one from a small bay (station 5, and depth of ca. 2 m) where birds (cormorants, herons, ducks) rested and from a reference site (station 6) without birds, ca. 700 m away. Collecting sediment samples was not possible at stations 3 and 4 with respect to bottom character. The samples of sediment (0–3 cm layer) were collected with a polythene corer (diameter 4 cm) in May and December 2006. In these sediment samples pH, N-tot, and P-tot were determined.

The water analysis of anions NO_3^-, NO_2^-, and PO_4^- was conducted using ion chromatography (DIONEX, IC25 Ion Chromatograph). Ammonia was analyzed with the nesslerization method, while P-tot (after mineralization) was measured using the molybdenum blue method (APHA 1992). Total nitrogen concentrations from the reservoir samples and cormorant faeces were determined by the Kjeldahl method, and total phosphorus using spectrophotometry with ammonium molybdate and ascorbic acid as a reducing agent (APHA 1992). The wet soil pH and wet sediment pH was measured *in situ* with Elmetron pH meter (CX-742).

The nutrients deposited by cormorants to the reservoir were calculated as the product of the mean number of cormorants per month, the number of days in a particular month, and the amount of N and P in faeces defecated by individuals per day. The amount of nutrients was estimated based on daily excretion (32 g dry mass per day; Marion et al. 1994) and obtained nitrogen and phosphorus content in cormorant faeces from this study.

Samples for phytoplankton analysis were collected with a 5 dm^3 sampler from the upper layer of the epilimnion (1 m). Samples were concentrated with a plankton net (# 10 µm). Qualitative analyses were done with non-preserved samples with a light microscope (Zeiss Jenaval) under 250× magnification, immediately after return to the laboratory. Composition of the phytoplankton indicated eight systematical groups: cyanobacteria, chrysophytes, diatoms, euglenophytes, dinophytes, cryptophytes, chlorophytes, and conju-

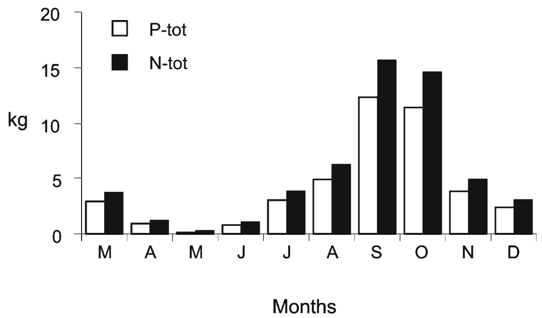

Fig. 2. Mean seasonal load of nitrogen (N-tot) and phosphorus (P-tot) given by cormorants to the Dobczyce Reservoir (985 ha) in 2000–2002.

Table 1. Mean and range of analyzed nitrogen and phosphorus forms (mg L^{-1}) in water of the Dobczyce Reservoir in two sites.

Parameter		Mean	Range
NO_3	Cormorant roost	5.008	2.936–8.018
	Reference site	5.007	2.828–8.128
NO_2	Cormorant roost	0.052	0–0.126
	Reference site	0.052	0.002–0.134
NH_4	Cormorant roost	0.250	0.170–0.350
	Reference site	0.261	0.210–0.340
PO_4	Cormorant roost	0.020	0–0.165
	Reference site	0.020	0–0.165
P-tot	Cormorant roost	0.039	0.024–0.066
	Reference site	0.033	0.020–0.059

gatophytes (Bucka & Wilk-Woźniak 2007). Algal concentrations were counted as 1 cell = 1, 1 colony = 1, 1 coenobium = 1 and 100 μm trichome = 1. Quantitative analyses were done on Lugol's fixed samples. These were counted as the percentage share of the particular groups in the total phytoplankton. The algae were counted in 30 fields in each fixed sub sample.

The differences in the nutrient concentrations in the water at the two sites, and the differences in the percentage share of the planktonic algae were tested using the Wilcoxon signed-ranks test (Sokal & Rohlf 1987).

Results

N and P in cormorant faeces introduced to the reservoir

A cormorant roost located on the sloped shore of the Dobczyce reservoir has been used from 1998. Cormorants occupied several beech trees (*Fagus sylvatica*). Cormorants occurred on the Dobczyce Reservoir from March to December, with maximum numbers present during September–October. They spent the night and sometimes during the day on a roost. Median of numbers in 2000–2002 was 54.5 ind. (quartile 1 = 10.5; quartile 3 = 128.2; $N = 30$).

Cormorant faeces contained 10.2% of N-tot and 7.9% of P-tot. The number of cormorants and their estimated daily excretion indicated that cormorants introduce a considerable amount of N (102.7 kg N $year^{-1}$, 1.0 kg ha^{-1} yr^{-1}) and P (80.5 kg yr^{-1}; 0.8 kg ha^{-1} yr^{-1}) to the water of the Dobczyce Reservoir. Because a great part of time cormorants spent on roost, a considerable portion of N and P were introduced to the soil and water environment in this area. Maximum amounts of nutrients occurred in autumn (September and October; Fig. 2), e.g., cormorants excreted 15.7 kg of N and 12.3 kg of P in September.

Soil pH, N-tot, and P-tot concentrations in the reservoir

Soils were acidic in both the area affected (station 1) and not affected (station 2) by the cormorants. The soil pH at station 1 (pH 4.0) was slightly lower than the control (pH 4.3). Differences in the amounts of N-tot and P-tot in the soils between studied stations in the bank of the reservoir were found. The amounts of N-tot and P-tot were higher in soils at station 1 compared to station 2, e.g., in an area of cormorant roost these values were ca. 0.59% and 18%, respectively, compared to those at station 2 at ca. 0.21% and 0.06%, respectively.

The reservoir sediments had a similar pH of 7.5 at both stations in May, when cormorants numbers were very small. In December, a higher sediment pH was at station 5 (pH 7.8), where cormorant number was high, compared to those at station 6 (pH 7.1). In the bottom sediment the N-tot and P-tot concentrations were higher at station 5, being impacted by the cormorants, compared to station 6, not affected by these birds. The amount of N-tot at stations 5 and 6 were 0.18 and 0.06%, respectively in May, and 0.34 and 0.11%, respectively, in December. Those differences at these stations for P-tot were greater in May (0.10 and 0.08%, respectively) than in December (0.06 and 0.01%, respectively).

Nutrients in the water of the reservoir

Nitrates in the water of the reservoir at stations 3 (roosted site) and 4 (reference) ranged from 2.94 to 8.02 and 2.83 to 8.13 mg L^{-1}, respectively (Table 1). The pattern of NO_3^- occurrence at both stations was similar. Their amounts decreased from April to September and then increased into February and March.

The range of NO_2^- (0.0–0.134 mg L^{-1}) was also similar at both stations (Table 1). Inversely to NO_3^-, NO_2^- increased from April to September, when a sharp drop was determined. The NO_2^- water concentrations were lowest from October to March. Similarly to the above inorganic N compounds, NH_4^+ concentrations (0.17–0.35 mg L^{-1}) in the water at both stations were also similar (Table 1), and characterized low variability in the water. The lowest NH_4^+ concentrations occurred in July and increased to March, with its highest values at both stations.

The amount of PO_4^- in the water was low (0.0–0.16 mg L^{-1}) at both stations (Table 1). Concentrations were less than 0.025 mg L^{-1} during the studied period (except April 2003). In April 2003 the highest and similar results for PO_4^- (0.16 mg L^{-1}) occurred at both stations.

The amount of P-tot in the water ranged from 0.02–0.07 mg L^{-1} (Table 1). The highest P-tot amounts

Table 2. Statistical differences in concentration of the studied parameters between cormorant roost and the reference site (Wilcoxon's signed-ranks test).

Parameter	T	*P*
NO_3^-	38	0.94
NO_2^-	34	0.70
NH_4^+	13	0.14
PO_4^-	32	0.93
P-tot	23	0.21

(0.07 mg L^{-1}) were at station 3 in August and November, and at station 4 (0.06 mg L^{-1}) in October and November. During most of the study period the P-tot concentrations at both stations were similar. The greatest differences in P-tot between the stations occurred in June and August. Then, P-tot was ca. 2.5 times higher in an area of the roosts (station 3) compared to reference station 4.

Statistical calculation show the lack of differences in the amount of NO_3^-, NO_2^-, NH_4^+, PO_4^-, and P-tot between an area of cormorant roost (station 3) and the reference site (station 4) were not found (Table 2).

Phytoplankton community in the reservoir

Dominant taxa of the particular group in phytoplankton of the Dobczyce Reservoir was represented by: *Woronichinia naegeliana*, *Microcystis aeruginosa*, *Aphanothecee* sp. (cyanobacteria); *Asterionella formosa*, *Cyclotella meneghiniana*, *Stephanodiscus neoastrea*, *Fragilaria crotonensis* (diatoms); *Pediastrum* spp., *Scenedesmus* spp., *Desmodesmus* spp., *Oocystis* spp. (chlorophytes); *Trachelomonas volvocina*, *Phacus longicauda* (euglenophytes); *Dinobryon divergens* (chrysophytes), *Ceratium hirundinella*, *Peridinium* sp., *Gymnodinium helveticum* (dinophytes); *Cryptomonas erosa*, *C. rostratiformis* (cryptophytes); *Cosmarium phaseolus*, *Closterium* sp., *Staurastrum planctonicum* (conjugatopytes). Cyanobacteria and diatoms had the greatest share of the phytoplankton community at both sites (Table 3). The chlorophytes had statistically significant differences between the site affected by cormorants and the reference site (T = 11, $P = 0.05$, $N = 12$). No other algal group had significant differences between these sites (Table 4).

The highest share of the cyanobacteria was at the site closest to the cormorant roost in September (66.0%) and at the reference site in October (73.9%). The greatest share of diatoms was during low temperatures (December–March) at both sites and reached 57.2% of the community near the cormorant roost and 81.7% in the reference site. In contrast, the highest share of chlorophytes were recorded close to the cormorant roost was in August (32.5%) and at the reference site in July (26%). The euglenophytes and dinophytes had distinct peaks the cormorant roost than at the reference site (54% vs. 8.5% and 50.4% vs. 25.3%, respectively). Another pattern showed chrysophytes were more abundant near the cormorant roost in

Table 3. Shares (mean and range in %) of particular planktonic algae groups in two sites of the Dobczyce Reservoir.

Group		Mean	Range
Cyanbacteria	Cormorant roost	40.4	19.5–66.0
	Reference site	41.4	13.8–73.9
Diatoms	Cormorant roost	29.3	0–57.2
	Reference site	35.0	0–81.7
Chlorophytes	Cormorant roost	10.9	0–32.5
	Reference site	7.7	0–26.0
Dinophytes	Cormorant roost	7.0	0–50.4
	Reference site	7.4	0–25.3
Euglenophytes	Cormorant roost	7.2	0–54.0
	Reference site	3.2	0–8.5
Chrysophytes	Cormorant roost	2.8	0–15.1
	Reference site	5.1	0–29.8
Cryptophytes	Cormorant roost	1.0	0–10.5
	Reference site	0.4	0–4.3
Conjugatophytes	Cormorant roost	0.6	0–3.9
	Reference site	0.8	0–5.4

Table 4. Statistical differences in the share of planktonic algae groups between cormorant roost and the reference site (Wilcoxon's signed-ranks test).

Group	T	*P*
Cyanobacteria	30	0.48
Diatoms	29	0.43
Chlorophytes	11	0.05
Dinophytes	11	0.33
Euglenophytes	20	0.77
Chrysophytes	5	0.13
Cryptophytes	1	0.28
Conjugatophytes	4	0.72

May (15.1%) and at the reference site in April (29.8%). The shares of other groups (cryptophytes and conjugatophytes) were small at either site (Table 3).

Discussion

Roosting birds may influence the eutrophication of an aquatic area due to the deposit of their faeces which may enter the water directly or by surface flow. For example concentration of seagulls in the Chafarinas Islands (North African islets) induced changes in soil properties including eutrophication, salinization, acidification and nutrient balance (Garcia et al. 2002). Water birds caused decreasing water quality and intensive eutrophication in Lake Hilversumse Wasmeer (The Netherlands) (Leentvaar 1967) and Lake Wintergreen (Michigan, USA) (Manny et al. 1994).

The amount of N-tot in the cormorant faeces in our study was similar to those obtained earlier in dropping's of dry mass (13.6%) in the Vistula Split (Goc et al. 2005). The amount of P-tot found in faeces was much greater than for example in seabirds guano (Smith & Jonson 1995) where value of 1.5% was given but similar to presented by Andrikovics et al. (2006) in cormorants faeces from Balaton Lake (Hungary) where varied between 4.5 and 5.5%.

The nutrient load introduced to the Dobczyce Reservoir by cormorants was relatively low, and is associated with the low numbers of these birds inhabiting the reservoir. An earlier study by Gwiazda (1996) indicated that other bird species, e.g., mallards and black-headed gulls produced more nutrients (100–150 kg of P and 370–400 kg of N) than cormorant in the Dobczyce Reservoir. However, considerable amounts of nutrients were introduced to the Bhanderaj Reservoir and Pandlodi Reservoir (India) by cormorants (Mukherjee & Borad 2001) and to the Kis-Balaton Reservoir (Hungary) (Gere & Andrikovics 1992) (11.8 t of N and 3.9 t of P; 12.5 t of N and 3.1 t of P, respectively). 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 a reservoir may be considerable. Similar findings were reported for the Mazurian Lakes, Poland by Dobrowolski et al. (1976). 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}). Great populations of cormorants (11,500 pairs) breeding at Kąty Rybackie (northern Poland) produced from 540 to 1,009 kg ha^{-1} of pure N during a single season (Goc et al. 2005). 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 to Lake Arendsee, Germany (Rönicke et al. 2008). Gulls (*Larus argentatus* Pont., 1763*, L. marinus* L., 1758) have been associated with increased P and N concentrations in Gull Pond, Wellfleet, Canada (Portnoy 1990), and also the Canada goose (*Branta canadensis* (L., 1758)) and mallard in Lake Wintergreen, Michigan, USA (Manny et al. 1994).

Higher concentrations of nutrients in soil and water sediment can show a long-term process of nutrient enrichment and accumulation of phosphorus and nitrogen in habitat. Marion et al. (1994) found greater differences in nutrients between bird habitats and areas not affected by birds in the Lake Grand-Lieu (western France) (nitrogen 8 times greater and phosphorus 42 times greater at the bird habitats). Despite the low nutrients introduced to the Dobczyce Reservoir by cormorants we found a greater concentration of nutrients in the soil and sediment of the bird resting area. In another study soils of an island associated with birds were characterized by having higher concentrations of NO_3^-, NH_4^+ and N-tot than soils of the island non-affected by these birds (Wait et al. 2005). Similarly soil samples in an area of cormorant colonies had many times higher content of all investigated chemical elements in comparison to control samples (Ligęza et al. 2001). The NO_3^- amount in the soil of the great cormorant colony in Kąty Rybackie (northern Poland) was in 94–216 times greater in the surface layer and 7–12 higher in deeper layer than at the reference sites (Ligęza et al. 2001). Ligęza & Misztal (1999) reported an impact of cormorant faeces on surface layers of soil in the breeding colony on Dobskie Lake (northern Poland), as a result of the dissolution of ammonia acid to ammonia. High concentration of NO_3^- showed that nitrification is a very important and intensive process in the soil exposed to bird colonies (Ligęza et al. 2001).

Bird excrements cause alkalization of the soil surface as a long term effect of faeces decomposition and change of ammonia acid to ammonia (Ligęza & Misztal 1999). However, the sloping structure of the bank at the roosting area of Dobczyce Reservoir caused surface flow to be more intensive and reduced this effect.

Cormorants not only contributed to the soil phosphorus concentrations but also to the water quality in nearby open waters (Breuning-Madsen et al. 2008). For instance N-NH_4^+ was very high with a maximum of 325 μg L^{-1} in small rock pools in the Baltic Sea (Sweden) that were affected by breeding colonies of birds (Ganning & Wulff 1969). It showed increased nutrients coming from near by bird colonies. The amount of NH_4^+ in the water was similar in both sites in the Dobczyce Reservoir. This can be explained by the exchange and mixing of water in reservoirs, and the intensive nitrification processes in relatively good oxygen conditions. Characteristic of a guanotrophic environment is the accumulation of phosphate (Leentvaar 1967). The total phosphorus concentration varied monthly in Dobczyce Reservoir. This may be due to the changing oxygen concentrations and mixing in the near bottom waters of the reservoir. An effect of bird faeces on the water chemistry is not always observed. In a laboratory experiment to study impact of different quantity of Canada goose (*Branta canadensis*) faeces on water chemistry it showed no significant changes in water column total phosphorus, total nitrogen, nitrate, N:P ratios, or chlorophyll-*a*, with the bird faeces and associated nutrients settling quickly to the sediment (Unckless & Makarewicz 2007).

It was noted that at all sampling sites the dominant groups were cyanobacteria and diatoms. Wilk-Woźniak (2000) showed that dominant groups of planktonic algae were diatoms, chlorophytes, and cyanobacteria in the Dobczyce Reservoir, however sometimes other groups played a greater role in this ecosystem. Moreover the share of chlorophytes, euglenophytes and dinophytes in autumn was greater in site affected by cormorants compared to the reference location. Euglenophytes often exist in water containing organic pollution (Bucka & Wilk-Woźniak 2007). Chlorophytes were present in large quantities during summer and indicated an increased fertility in the reservoir (Wilk-Woźniak 1996), and were associated with increased temperatures in these waters. Other results obtained by Leentvaar (1967) reported that diatoms, cyanobacteria and desmids were very scarce in guanotrophic environments (oligotrophic Hilversumse Wasmeer and the eutrophic Bakkerskooi, The Netherlands). Chlorophyll-*a* concentrations from sites where bird densities were high vs. low in the wetland system at the Bosque del apache National Wildlife Refuge, New Mexico, USA, indicated that geese faeces increased local algal production (Kitchell et al. 1999). Ganning & Wulff (1969) showed the bird faeces provided nutrients well beyond the needs of the algal biomass, but the development of algae close to the bird colonies can be restricted by the toxic impact of nitrogen compounds (e.g., ammonia).

Birds in high density have been associated with introducing large amounts of nutrients to soil and water habitats, but birds in smaller numbers can also increase the nutrient load in areas and impact phytoplankton on a local scale.

Conclusions

1. The occurrence of the small cormorant roost in the Dobczyce Reservoir increased nitrogen and phosphorus contents in the soil and water sediment near the roosting area.

2. Cormorant faeces did not change the pH in the soil and water sediment of the roosting area.

3. Cormorants did not affect changes in nutrient concentrations (nitrogen and phosphorus) in water near the roost which is attributed to the physical and chemical properties of the reservoir.

4. Concentration differences were noted only for the chlorophytes among the algal groups that were associated with the roosting area of the cormorants.

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