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CONTRIBUTION OF WATER BIRDS TO NUTRIENT LOADING TO THE ECOSYSTEM OF MESOTROPHIC RESERVOIR

ABSTRACT: One gram of the faeces of the black-headed gull (*Larus ridibundus* L.) and of mallard (*Anas platyrhynchos* L.) contains 78.6 mg P and 72.4 mg N and 8.5 mg P and 53.1 mg N respectively. The gull and the mallard defecated 0.96 g P and 0.88 g of N and 0.42 and 2.62 g per day per individual respectively. The participation of waterfowl in the nutrient loading to the reservoir was small (less than 1% of only inorganic P and N). The mallard significantly affects phosphorus and nitrogen cycling in the reservoir, and the gulls increase the phosphorus resources there.

KEY WORDS: *Larus ridibundus*, *Anas platyrhynchos*, defecation, phosphorus, nitrogen, eutrophication.

1. INTRODUCTION

Nitrogen and phosphorus play a key role in water ecosystems because of their effect on algal growth and eutrophication (V o l l e n w e i d e r 1971, V o l l e n w e i d e r and K e r e k e s 1980). The water birds affect the nutrient cycling but their role in this process is not usually taken into account, mainly because of methodological difficulties (D o b r o w o l s k i et al. 1976). To estimate the role of water birds in nutrient cycling, the numbers and species composition of the community, the defecation rate, and the content of phosphorus and nitrogen per 1 g of faeces is necessary to estimate. The effects of bird droppings on water chemistry were studied by some researchers (L e e n t v a a r 1967, G a n n i n g and W u l f f 1969, M a n n y et al. 1994, M a r i o n et al.

1994). The birds increase the nutrient concentration in water, thus they can play a part in the process of cycling and recycling of nutrients (Linnman 1983, Gere and Andrikovics 1994). If they feed on land and rest on the water, they may increase the input of allochthonous matter (Linnman 1983, Marion et al. 1994).

The ecosystems of the reservoirs are exposed to eutrophication, therefore it is important to estimate the relative input of phosphorus and nitrogen from the water birds. Birds have been studied in the Dobczyce Reservoir since 1986 (Gwiazda 1989).

2. STUDY AREA

Dobczyce Reservoir (49°52'N, 20°02'E) is a mesotrophic dam reservoir, in Southern Poland. Its area is c. 1000 ha and its mean depth equals 11 m. Total input of inorganic P were estimated as 20.2 t year^{-1} and of inorganic N – 239.3 t year^{-1} respectively (Mazurkiewicz 1988). Average concentration of inorganic P in water was 47 mg m^{-3} in 1990 (Mazurkiewicz unpubl. data). Most of the shores are steep (50% of shoreline has a gradient of more than 35%) and covered with meadows and forest. The part of reservoir less than 1 m deep covers only 5% of the total area. There are no reed or rush beds in the littoral. *Salix sp.*, *Phragmites communis* and a small stand of *Polygonum amphibium* occur in a few places of reservoir.

3. MATERIALS AND METHODS

The observations and counting of birds were conducted from the shore in all parts of the reservoir in 1990 and 1991; binoculars (10 x 50) and telescopes (40 x 64) were used. The birds which only spent the night on the reservoir, flew outside of reservoir in the morning and came back to reservoir in the evening was counted from the one place characterized by the good sight of these flights. 20 days of continous (between dawn and dusk of each day) bird counts and 15 were made in 1990 and 1991 respectively. The birds were counted once or twice a month. The time spent on the reservoir by flocks of birds which only rested and slept here was determined.

The droppings of black-headed gull (*Larus ridibundus* L.) and mallard (*Anas platyrhynchos* L.) were studied. The frequency of gulls' defecation was counted both for birds which were observed in the time longer than 5 minutes resting (on the viaduct over the arm of the reservoir) and for birds in flight. 45 individuals were observed during a time of 15 hours 35 minutes in total.

In the breeding period the gulls' droppings were collected on the polyethylene sheets (about 1.5 m^2) spread out and fastened to the ground. The sheets were exposed near the gull breeding colony for 24 hours. The birds flying over the colony defecated on the ground and also on the sheets from which the samples of excrement were taken. After the breeding period the samples were taken from the viaduct where the gulls stayed in great numbers. The samples were taken in March, May, and November. They were dried at a temperature of 105° C to the constant weight and weighed. Altogether 163 droppings were weighed. Twenty faeces of every month were ground in a mortar. The daily quantity of excrements defecated by a gull was calculated as the product of the rate of defecation and the mean weight of the excrements.

Since it was impossible to determine the defecation rate of mallards, the quantity of excrements was calculated from their diel energetic demand. The diel energetic demand (metabolism) of the mallard was estimated from the regression equations of N a g y (1987) for energy budgets under natural conditions measured by the method based on doubly labelled water. Daily metabolism was calculated as:

$$y = 0.681 + 0.749 \log x,$$

where: y = metabolism (kJ d^{-1}), x = body weight (g).

The mean body weight of mallard (1080 g) was taken according to B r o u g h (1983).

The quantity of excrements was estimated as:

$$z = [y/(a \cdot k)] - [y/k],$$

where: z = quantity of excrements (g), y = energetic demand (kJ d^{-1}), a = food digestibility (%), k = food caloric value (kJ g^{-1}).

The caloric value of food was taken according to C u m m i n s and W u y c h e c k (1971). Feeding mallards were observed, and the main food types determined. The digestibility of food was assumed to be 50%. Mallard excrements were collected from the shores where they rested in flocks in January, August, September, October and December; 20 samples of feaces taken in every month were dried at 105° C to constant weight.

The nutrient content of one subsample per month was analysed. To estimate total phosphorus, 200 mg portions of dry mass of 20 faeces were weighed out and ashed for 5 hours at 550° C in a muffle furnace. Loss on ignition and hence the content of inorganic and organic matter were noted. The residue was mineralized in hydrochloric acid and nitric acid (3 : 1) and the PO_4–P was determined colorimetrically by the molybdate method (J a n u s z k i e w i c z 1978).

To determine faecal N content, 200 mg of dry mass of 20 faeces were mineralized in a mineralizer at 440° C using concentrated sulphuric acid and hydrogen peroxide (B r a y t o n 1990). After mineralization, the residue was placed in a beaker and distilled water was added to a value of 100 ml. This solution was used for further analyses according to H e r m a n o w i c z (1976). Nitrate nitrogen was determined colorimetrically with phenylodisulfonic acid. To estimate ammonia and nitrite nitrogen, 2 ml of solution was diluted to 100 ml by adding distilled water, leached using 3 drops of sodium hydroxide, and nesslerized to determine ammonia nitrogen. For nitrite nitrogen, colorimetric analysis with brucine was used. The total nitrogen was the sum of nitrate nitrogen, ammonia nitrogen, and nitrite nitrogen.

The amount of phosphorus and nitrogen defecated by the dominant species of bird population per day was calculated as the product of the number of defecations per species per day and the nutrient content of the faeces. The amount of phosphorus and nitrogen defecated per species per year was calculated as the sum of the products of the mean numbers of individuals per month, number of days per month, and amount of nutrients defecated by individuals per species per day. For flocks of gulls which rested and slept on the reservoir, number of hours per day at the reservoir, and the amount of nutrients per hour was used. Statistical differences in N and P content of faeces of gull versus mallard were determined using the t-test (H a y s 1988).

4. RESULTS

The black-headed gull *(L. ridibundus)* and mallard *(A. platyrhynchos)* were dominanting in the bird community. The highest gull numbers were recorded in spring and in autumn (maximum 1979 individuals in November 1990), while the mallard were most numerous in autumn and winter (maximum 1475 individuals in January 1991).

In March and April of 1990 and 1991, October 1991 and November 1990 the flocks of gulls flew out from the reservoir in the morning and returned in the evening, feeding outside the reservoir, but resting and sleeping here in March (from 16.30 to 6.30 h), April (from 17.30 to 5.30 h), October, and November (from 15.30 to 7.30 h). The gulls spent 14 hours per day on the reservoir in March, 12 hours per day in April, and 16 hours per day in October and November. The mean numbers of mallard and gull per month are shown in Fig. 1.

The defecation rate of the black-headed gull was estimated as 2.37 per hour and the mean weight of the excrements was determined as 214.7 (± 102.6) mg of dry mass. If the defecation rate were constant, the black-headed gull would defecate 12.2 g (dry mass) per day.

The mallard's daily energetic demand was estimated as 897.5 kJ. Observations of feeding birds indicated that they eat mainly plant food like *Polygonum amphibium*, with a caloric value of c. 18.1 kJ g^{-1} of dry mass. Mallard defecated about 49.4 g of dry mass of faeces per day.

The faeces of the black-headed gull in March, May and November contained c. 52.2% (range: 35.3–66.4) of inorganic material. One gram of the faeces of this species contained 78.6 mg (range: 53.3–99.4) of phosphorus and 72.4 mg (range: 39.9–116.4) of nitrogen. There were 40.4% (range: 29.9–50.1) of inorganic material in the mallard faeces in January, August, September, October and December. One

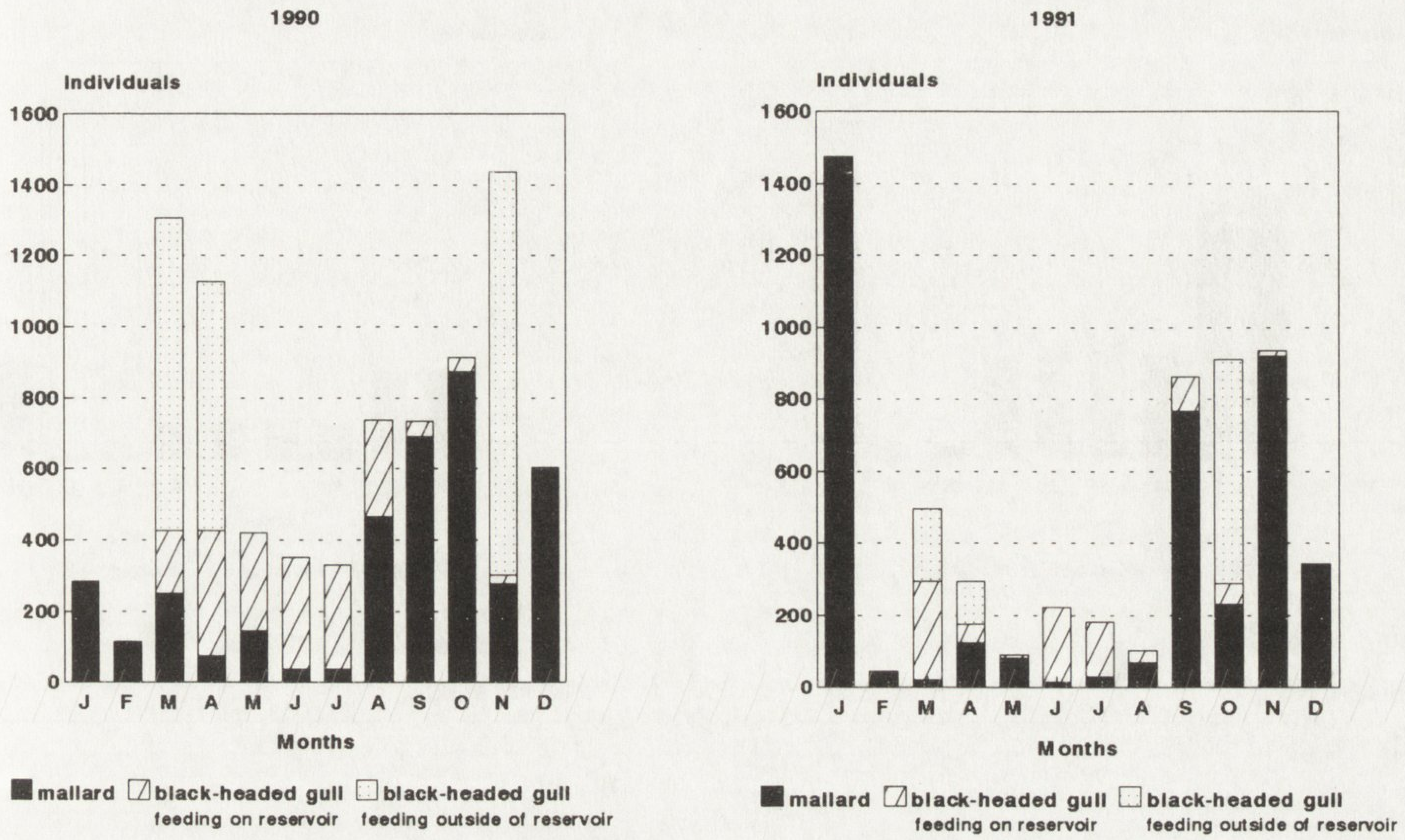

Fig. 1. Average numbers of mallards and black-headed gulls at the Dobczyce Reservoir in 1990 and 1991

gram of these faeces contained 8.5 mg (range: 4.1–12.4) of phosphorus and 53.1 mg (range: 29.3–88.9) of nitrogen. Significant differences in phosphorus content between gull and mallard were observed ($t = 6.97$, $df = 6$, $p < 0.05$).

It was estimated that gull defecated 0.96 g of phosphorus and 0.88 g of nitrogen per day, while mallard defecated about 0.42 g P and 2.62 g N. The two dominating bird species excreted about 149.6 kg of phosphorus and 400.1 kg of nitrogen into the Dobczyce Reservoir in 1990 but 32% of phosphorus and 11% of nitrogen originated from outside the reservoir; in this way the pools of nutrients were increased. In 1991 the values were lower – about 96.1 kg of phosphorus and 373.0 kg of nitrogen and 18% of phosphorus and 4%. of nitrogen was from the outside the water body. The amounts of phosphorus and nitrogen defecated by these two species into the Dobczyce Reservoir were estimated for 1990 and 1991 years (Fig 2, Fig 3). The excrements of black-headed gulls can influence mostly the phosphorus cycling and those of mallards the nitrogen cycling in reservoir. The greatest impacts of gulls was recorded during the migration periods (March, April, October, November) and of mallards in autumn (October, November).

5. DISCUSSION

The number of gulls was higher in 1990, as it was connected with a great breeding colony (which was absent in 1991), and great numbers of migrating birds.

The defecation rate of the herring gull (*Larus argentatus),* estimated by P o r t - n o y and S o u k u p (1990) as 3.12 per hour, was higher than the values for black-

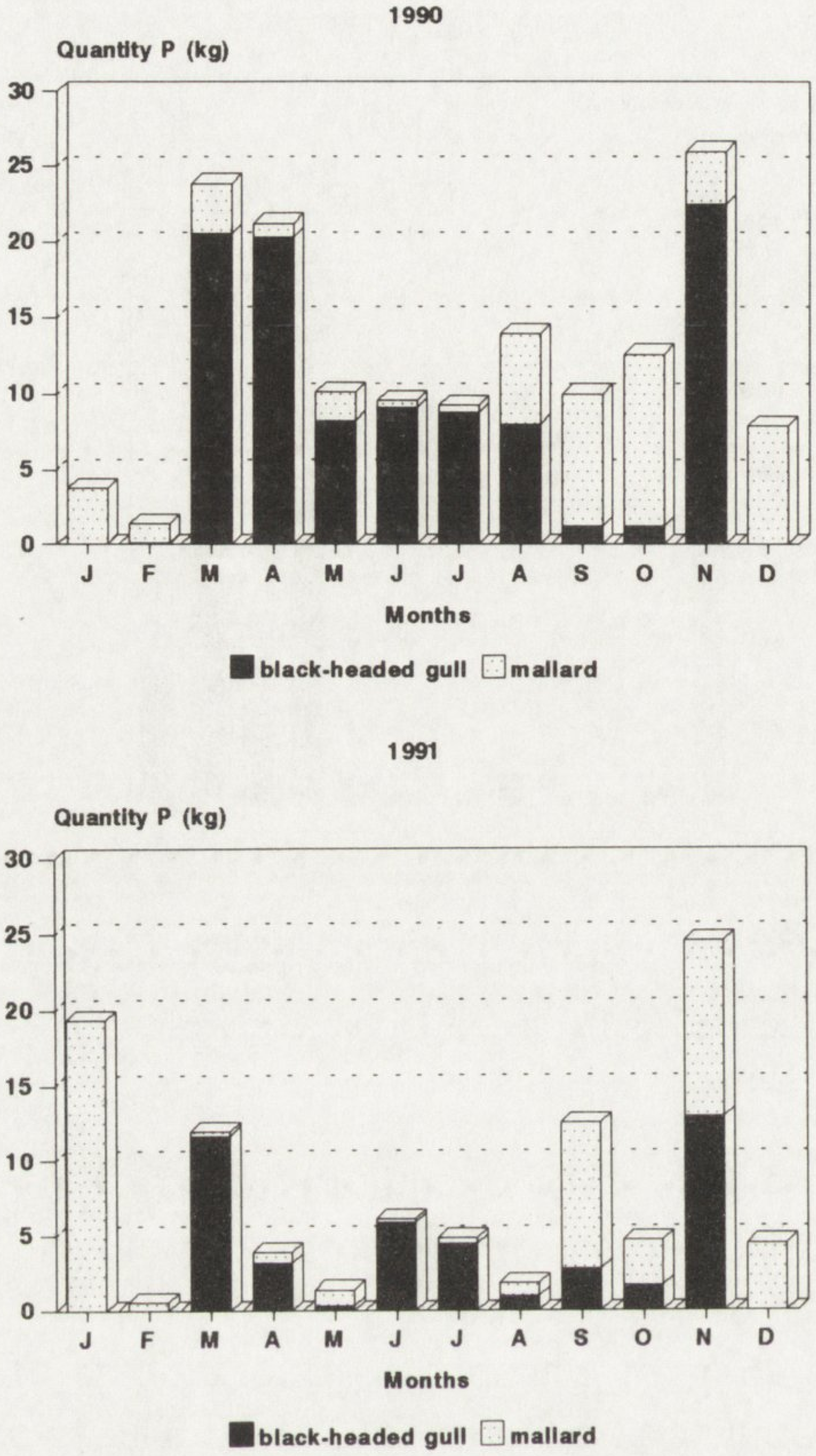

Fig. 2. Seasonal changes of amount of phosphorus defecated by mallards and black-headed gulls in 1990 and 1991 in the whole reservoir

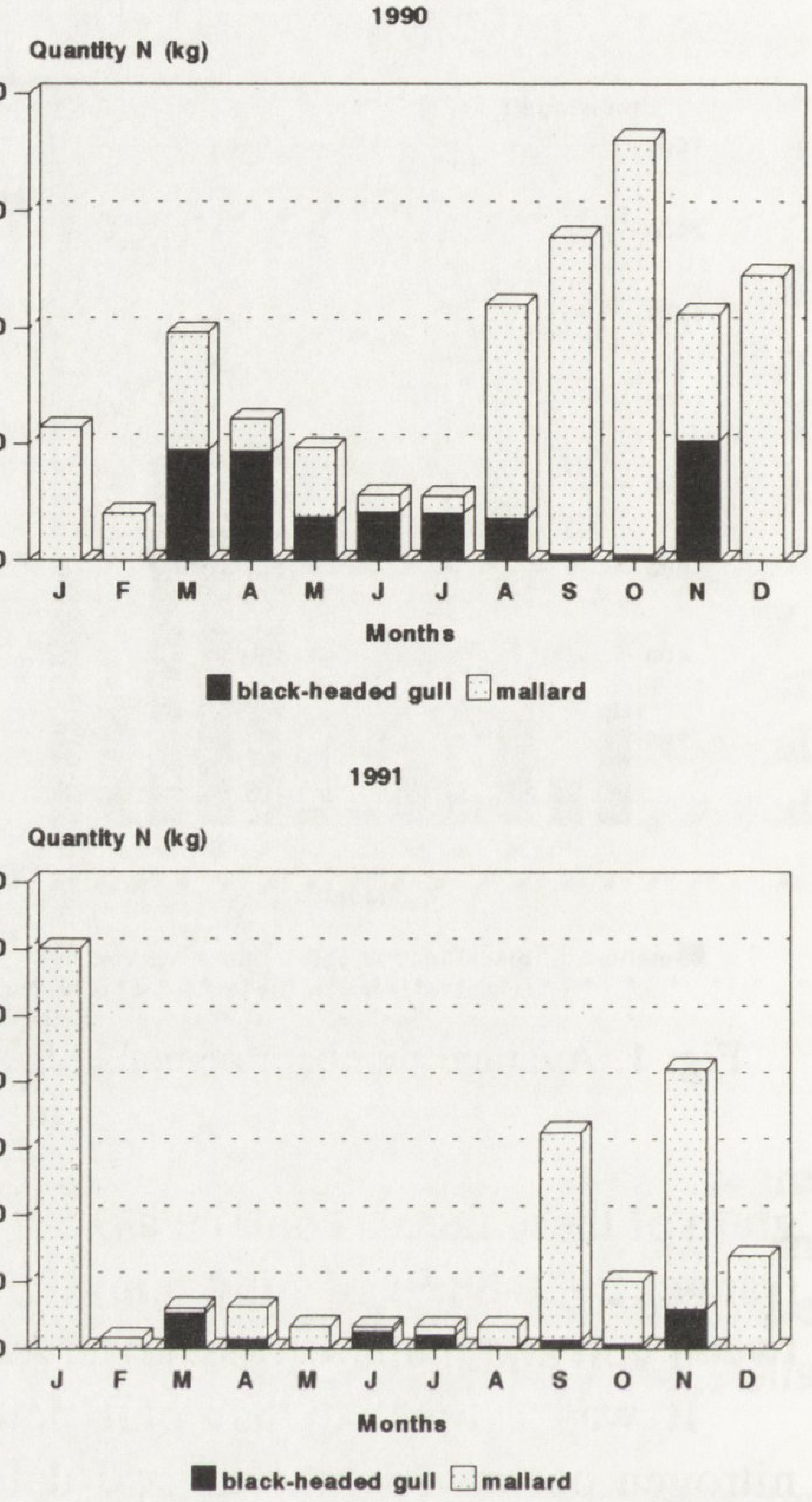

Fig. 3. Seasonal changes of the amount of nitrogen defecated by mallards and black-headed gulls in 1990 and 1991 in the whole reservoir

headed gull in this study. The average weight of herring gull faeces was also higher, about 529 mg of dry mass (Portnoy and Soukup 1990), because of its greater body size and food consumption. The average body mass of this species is about 1020 g and black-headed gull – 275 g (Brough 1983). The daily food consumtion of herring gull was estimated as 64.9 and black-headed gull as 25.8 g (Gwiazda 1990). According to Dobrowolski et al. (1993) caged black-headed gulls excreted 8.2 g of dry mass of faeces per day; this value is lower than obtained in this study. It could be connected with non-natural diet of caged birds.

The gull defecated less fecal mass per unit time than duck. The gull feed on insects and fish, while the mallard feed on aquatic plants and benthic animals (Dobrowolski 1969, 1973). Animal food has usually a higher caloric value than plant food (Cummins and Wuycheck 1971).

The great ranges of phosphorus and nitrogen content of faeces can be explain by the probably different diet of birds in the successive seasons. Significant differences in the phosphorus content of faeces between gull and mallard reflects the higher content of phosphorus in animal food than in plant food. The faeces of herbivorous birds (*Anas sp., Branta sp.)* contain more nitrogen than phosphorus (Table 1). Gould and Fletcher (1978) studied the nitrogen and phosphorous in feaces of black-headed gulls kept in captivity, and found lower values than in the present study. It was possibly connected with the fact that birds did not fly and were perhaps stressed. Portnoy and Soukup (1990) found herring gulls to defecate a similar quantity of phosphorus and nitrogen per indvidual per day as black-headed gulls. This is surprising, because the rate of defecation and the weight of faeces of the herring gull was greater than that of the black-headed gull (Portnoy and Soukup 1990). Brezonik (1972) found that generally waterfowl defecated 90–180 g of phosphorus and 480–950 g of nitrogen per individual per year.

Table 1. Comparison of daily defecation of nutrients in selected species of birds (TP – total phosphorus; TN – total nitrogen) in g per individual^{-1}day^{-1}

	TP	TN
Larus ridibundus		
Gould and Fletcher (1978)	0.038	0.608
This study	0.96	0.88
Larus argentatus		
Gould and Fletcher (1978)	> 0.115	1.819
Portnoy (1990)	0.61	0.67
Branta canadensis		
Manny et al. (1975)	2.1	6.8
Manny et al. (1994)	0.49	1.57
Anas platyrhynchos		
This study	0.42	2.62

The year-to-year difference in nutrient input was caused by a decreasing number of gulls in 1991. The participitation of waterfowl in the nutrient loading to the ecosystem of Dobczyce Reservoir was small and was determined as less than 1% of inorganic phosphorus and nitrogen loading from other sources (mainly surface water loading). Mazurkiewicz (1988) estimated that yearly input of nutrients into the Dobczyce Reservoir from the catchment basin and with the water of the River Raba would be about 20 t of inorganic phosphorus and 206 t of inorganic nitrogen. The relative input phosphorus and nitrogen by birds was also low (2.4 to 6.6% for P and 0.4 to 0.7% for N) in the hypereutrophic Lake Grand-Lieu (Marion et al. 1994). However, waterfowl can deteriorate the water quality. For example, in the small eutrophic Wintergreen Lake the waterfowl added 70% of phosphorus and 27% of nitrogen inputs from external sources (Manny et al. 1994).

Although the mallards did not add to the nutrient pools, they can significantly affect the recycling of phosphorus and nitrogen in the Dobczyce Reservoir. The gulls, however, were a very important factor in increasing the phosphorus resources there in spring and in autumn.

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6. SUMMARY

The black-headed gull (*Larus ridibundus* L.) and mallard (*Anas platyrhynchos* L.) are dominant species of birds at the Dobczyce Reservoir. In spring and autumn the gulls foraged outside of reservoir and resting and sleeping there (Fig. 1). It was estimated that the black-headed gull defecated 12.2 g and the mallard 49.4 g dry mass of faeces per day. One gram of the faeces of the black-headed gull contained 78.6 mg of phosphorus and 72.4 mg of nitrogen. One gram of mallard faeces contained 8.5 mg of phosphorus and 53.1 mg of nitrogen. It was estimated that the gull defecated 0.96 g of phosphorus and 0.88 g of nitrogen per day, and the mallard about 0.42 g and 2.62 g, respectively (Table 1). The two dominant bird species excreted about 149.6 kg of phosphorus and 400.1 kg of nitrogen into the Dobczyce Reservoir in 1990 (Fig. 2) and 96.1 kg of phosphorus and 373.0 kg of nitrogen in 1991 (Fig. 3). The mallards possibly affect significantly the phosphorus and nitrogen circulation in the Dobczyce Reservoir and the gulls mostly increase the phosphorus resources there.

7. POLISH SUMMARY

Mewa śmieszka (*Larus ridibundus* L.) i krzyżówka (*Anas platyrhynchos* L.) są dominującymi gatunkami ptaków na Zbiorniku Dobczyckim. Wiosną i latem część mew żerowała poza zbiornikiem, odpoczywając i śpiąc na nim (rys. 1). Oszacowano, że mewa śmieszka wydalała 12.2 g suchej masy odchodów na dobę, a krzyżówka 49.4 g (sucha masa). Jeden gram ekskrementów mewy śmieszki zawierał 78.6 mg fosforu i 72.4 mg azotu. Jeden gram ekskrementów krzyżówki zawierał 8.5 mg fosforu i 53.1 mg azotu. Oszacowano, że mewa wydalała 0.96 g fosforu i 0.88 g azotu na dobę, a krzyżówka odpowiednio ok. 0.42 i 2.62 g (tab. 1). Oba gatunki wydaliły ok. 149.6 kg fosforu i 400.1 kg azotu do zbiornika w 1990 roku (rys. 2) i 96.1 kg fosforu i 373.0 kg azotu w 1991 roku (rys. 3). Populacja krzyżówki silniej oddziaływała na krążenie fosforu i azotu w Zbiorniku Dobczyckim, zaś mewy na zasoby fosforu.

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