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IMPACT OF TROUT FARMS ON WATER QUALITY IN THE MARÓZKA RIVER (MAZURIAN LAKELAND, POLAND)

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ABSTRACT. In 2004, measurements of the chemical properties of the waters of the Marózka River in the Mazurian Lakeland (northern Poland) were taken eight times in order to determine the impact two trout farms located in Szwaderki (farm A) and Kurki (farm B) had on this river. The negative impact was manifested mainly through the increased nutrient content in the river waters. The annual total phosphorus (P) load increased downstream from farm A by 19.0% and from farm B by 26.1%, while the total nitrogen (N) load was higher by 22.6% and 10.3%, respectively. In the summer, water oxygen saturation downstream from the trout farms dropped considerably whereas other physicochemical parameters did not change notably. Lake Święte received effluents from farm A, while Lake Łańskie received those from farm B. The contribution of farm B to the total external load received by the mesotrophic Lake Łańskie, which is a highly valuable ecosystem, was 12.9% total P and 5.0% total N.

Key words: PHOSPHORUS, NITROGEN, TROUT FARMS, EUTROPHICATION

INTRODUCTION

It is generally known that the fattening of salmonid fishes has a negative impact on the aquatic environment (Bureau and Cho 1999, True et al. 2004, Papatryphon et al. 2005). Most of the research on farms that have such a negative impact is done at various fish breeding facilities, including those which employ recirculation technologies of different intensities and farms without water recirculation (Alabaster and Lloyd 1982). The pollution of receiving water is caused mainly by fish metabolic products (ammonia N, urea) (Kajimura et al. 2004), excreta, and unused feed. The amount of pollutants depends on the chemical composition of the feed and its stability in the water but also on the feeding method. The composition and amounts of nutrients disposed of into waters from individual farms can vary widely. The determinants are fish production, feed conversion ratio (FCR), and P and N content in the feed. Therefore, the nutrient

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load in the water is the difference between the input of the feed and the consumption by fish (growth and energetic demand).

Rainbow trout production in Poland is growing rapidly (Goryczko 2001), which is why methods should be developed to reduce nutrient loads to waters. Current attempts focus on new water treatment technologies (Teleżyński 2004) and the development of feeds (Bureau and Cho 1999, Bergheim and Brinker 2003). Research that is currently being conducted worldwide aims at determining the actual impact fish farms have on supply waters. Changes in the chemical composition and manufacture technology of feeds necessitate updating research results regularly. Most surveys conducted address the nutritive element loads, mainly phosphorus, imported to waters from fish farms of different production intensities (Coloso et al. 2003). The reason for this is the role of phosphorus in water eutrophication (True et al. 2004). Sugiura et al. (2006) contend that the best way to solve the eutrophication problem is to use better feeds rather than reduce fish production. Lellis et al. (2004) share the opinion that the P content in the feeds currently available can be lowered considerably; however, the higher P demand of smaller fish should be taken into account.

The negative impact of fish farms is considerably larger if the receiving water (directly or indirectly) is a lake, as is the case with the two farms in the current study. Pollutants from the farms are carried by the Marózka and the Łyna rivers into lakes. As one of the largest and most highly valued lakes in the Mazurian Lakeland (northern Poland), Lake Łańskie is deserving of special attention.

The goal of this study was to determine the impact the trout farms in Szwaderki (farm A) and Kurki (farm B) had on the water quality in the Marózka and upper Łyna rivers and the threat posed by the inflow of pollutants into Lake Łańskie.

MATERIAL AND METHODS

Trout farms A and B are located on the lower Marózka River (Fig. 1). Like many other rivers in the Mazurian Lakeland, the Marózka flows through numerous lakes. Downstream from the farms studied, this river connects with the Łyna River, which discharges into Lake Łańskie. The analysis of the nutritive element migration in the studied watershed and the characteristics of the waters are reported in the work by Lossow et al. (2006).

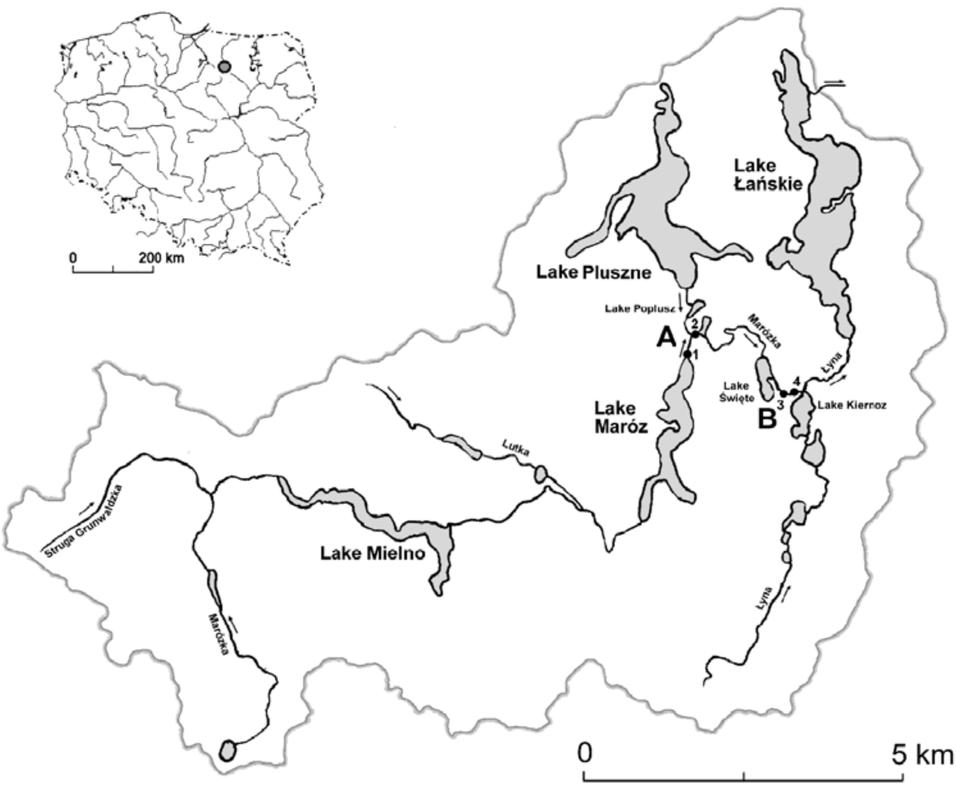


Fig. 1. Location of the trout farms and the distribution of the water sampling sites. A – farm A (1 – upstream from farm, 2 – downstream from farm); B – farm B (3 – upstream from farm, 4 – downstream from farm).

The trout breeding technologies at farms A and B are similar, and the two farms are supplied with water from lakes Maróz and Święte, respectively. The farms consist of the following elements: concrete grow-out ponds (1); a hatchery and rearing building (2); earth grow-out ponds with fish other than salmonids (3); barriers in the river (4) (Fig. 2). Farm B also has a settling pond (6) located downstream from the barrier, so that all the used water flows through this pond before it returns to the river.

In 2004, the physicochemical parameters of the water and the flow rate were measured eight times in the Marózka River. The sampling and measurement sites were located just upstream and 100-200 m downstream from the farms (Fig. 1). Water

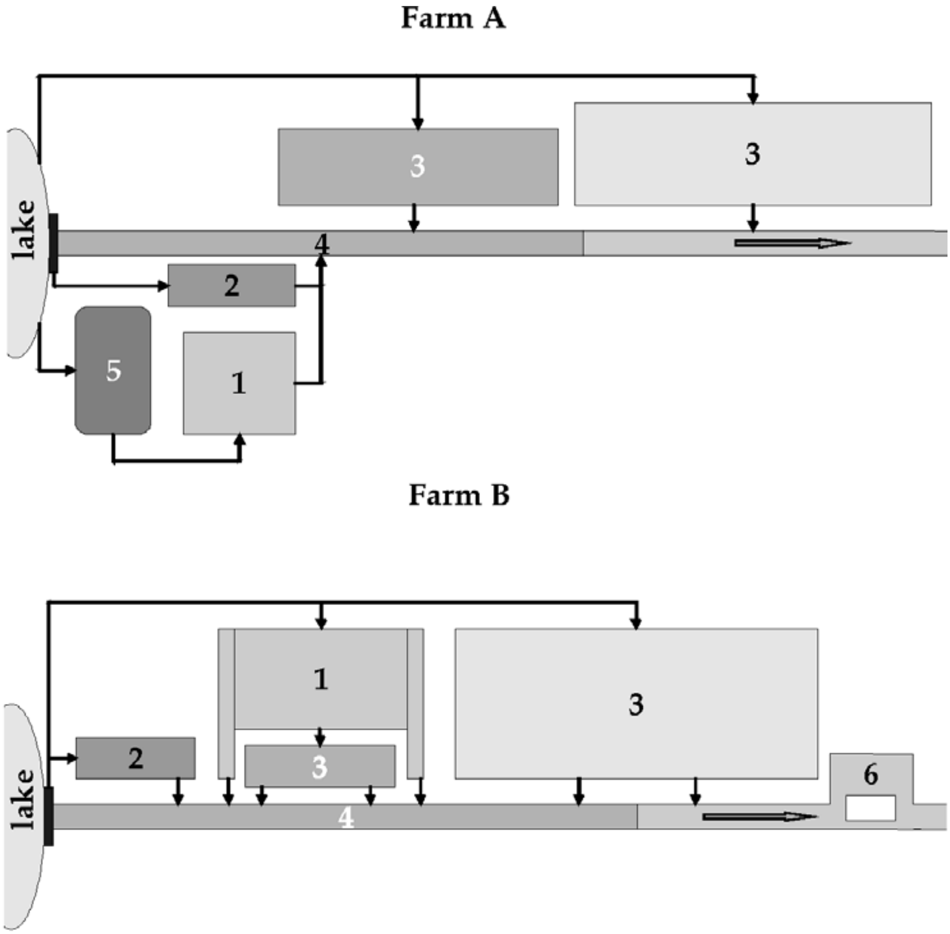


Fig. 2. Technological scheme of trout farms A and B: 1 – grow-out trout ponds, 2 – hatchery, 3 – earth grow-out ponds, 4 – production barriers in the river, 5 – water mixing zone, 6 – settling pond.

velocity in the river was measured with an electromagnetic meter model 801 manufactured by Valeport Limited, UK. Water flow was determined using Harlacher's method. Analyses of the physicochemical composition of the water were done according to the methods described in Hermanowicz et al. (1999) and Standard Methods (1998).

Nutrient loads were calculated by multiplying total N and total P concentrations by water flow for the interim periods between the subsequent measurements. The theoretical loads of N and P in the used waters were determined in reference to the quantity and quality of the feed applied.

RESULTS AND DISCUSSION

The main indicators of the environmental impact of intensive trout farming are the type and amount of fish feed, fish production, and water flows in supply rivers. All of these are listed in Table 1. Attention should be paid to the higher water flow values in the Marózka River near farm A than those near farm B which are due to the possibility of controlling the water table in the lakes that supply water to the farms.

TABLE 1

List of basic parameters that characterize trout farms A and B

Farm	Trout production (t)	Quantity of feed applied (t)	Feed conversion ratio (FCR)	Annual water flow (thousands m^3)
Farm A	67.41	87.99	1.31	50858.2
Farm B	11.38	116.68	0.99	38598.5

The effectiveness of feed consumption depends largely on the content of dissolved oxygen (DO) in the water. It is assumed that a decrease in saturation to below 60% (measured at the outflow from the farm radically reduces feed consumption and deteriorates water quality at the outflow. McDaniel et al. (2005) report that high oxygen concentration (approx. 10 mg O_2 l^{-1}) improves feed consumption while simultaneously negatively influencing the P content in the outflow from grow-out ponds. In the current study, oxygen saturation at farm A never dropped below 73% (9.4 mg O_2 l^{-1}), whereas in farm B at the end of August a value of 50.4% (4.6 mg O_2 l^{-1}) was recorded (Table 2).

Dissolved oxygen concentration in Marózka waters and variations in it downstream from the trout farms depended on temperature and the production cycle. At low temperatures in the winter, early spring, and late fall, the water was always well oxygenated (usually > 10 mg O_2 l^{-1}) or even, as in the case of farm A, the oxygen content at the outflow increased slightly. At higher temperatures during the summer when fish biomass increased, oxygenation dropped by 1.8-2.9 mg O_2 l^{-1} at farm A and by 1.0-6.9 mg O_2 l^{-1} at farm B. This phenomenon is typical for trout farms and has been discussed by, among others, Rosentahl et al. (1981) and Boaventura et al. (1997). During a two-year study at farm B, Teodorowicz (2002) reported repeated oxygenation decreases in the waters used for trout breeding, including in the winter.

TABLE 2

List of water parameters at fish farms A and B (range and mean values)

Parameter	Farm A upstream	Farm A downstream	Farm B upstream	Farm B downstream
Temperature (°C)	1.3 – 20.7	1.5 – 20.3	1.0 – 21.2	1.1 – 20.4
	9.6	9.6	9.5	9.4
Oxygen concentration (mg l^{-1})	8.80 – 12.00	7.20 – 12.64	6.88 – 13.60	4.64 – 13.76
	10.44	9.66	10.62	8.84
BOD_5 (mg l^{-1})	0.80 – 4.68	0.96 – 3.18	1.92 – 4.30	1.76 – 4.30
	2.17	1.98	2.64	2.60
pH	7.84 – 8.68	7.80 – 8.36	7.86 – 8.50	7.63 – 8.24
	8.18	7.96	8.14	7.91
P_{min} (mg l^{-1})	0.01 – 0.08	0.01 – 0.09	0.01 – 0.10	0.04 – 0.11
	0.05	0.06	0.05	0.07
P_{org} (mg l^{-1})	0.04 – 0.08	0.04 – 0.10	0.05 – 0.09	0.05 – 0.16
	0.06	0.07	0.07	0.08
P_{total} (mg l^{-1})	0.05 – 0.15	0.08 – 0.18	0.08 – 0.17	0.11 – 0.22
	0.10	0.12	0.12	0.15
N_{NH4} (mg l^{-1})	*nf* – 0.10	0.01 – 0.15	*nf* – 0.15	0.03 – 0.18
	0.03	0.08	0.05	0.10
N_{NO2} (mg l^{-1})	*nf* – 0.007	0.002 – 0.011	0.001 – 0.011	0.002 – 0.025
	0.002	0.005	0.006	0.011
N_{NO3} (mg l^{-1})	0.08 – 0.25	0.09 – 0.23	0.10 – 0.32	0.09 – 0.25
	0.14	0.16	0.19	0.17
N_{org} (mg l^{-1})	0.24 – 1.46	0.43 – 1.66	0.56 – 1.68	0.61 – 2.11
	0.79	0.92	1.00	1.09
N_{total} (mg l^{-1})	0.45 – 1.72	0.66 – 1.94	0.77 – 2.01	0.89 – 2.43
	0.96	1.17	1.24	1.37

nf – not found

Rosentahl et al. (1981) revealed that the maximum DO reduction (as high as 50%) occurs within a few minutes after feeding. This is due to the increased respiration rate of the fish that is accompanied by a free CO_2 rise and a reduction in pH. This phenomenon was observed at farm B; at a water temperature of 21.2°C, DO decreased rapidly from 11.5 to 4.6 mg O_2 l^{-1}.

The nutrients N and P play key roles in the eutrophication of waters. This and the fact that the two fish farms are located upstream from Lake Łańskie, a highly valued natural ecosystem, are the impetus behind studying the enrichment of Marózka waters with nutrients. These two elements occurred in the river waters in average amounts and predominantly in organic forms, especially with regard to nitrogen (Table 2). As indicated by the results of the study, trout breeding increased concentrations of these nutri-

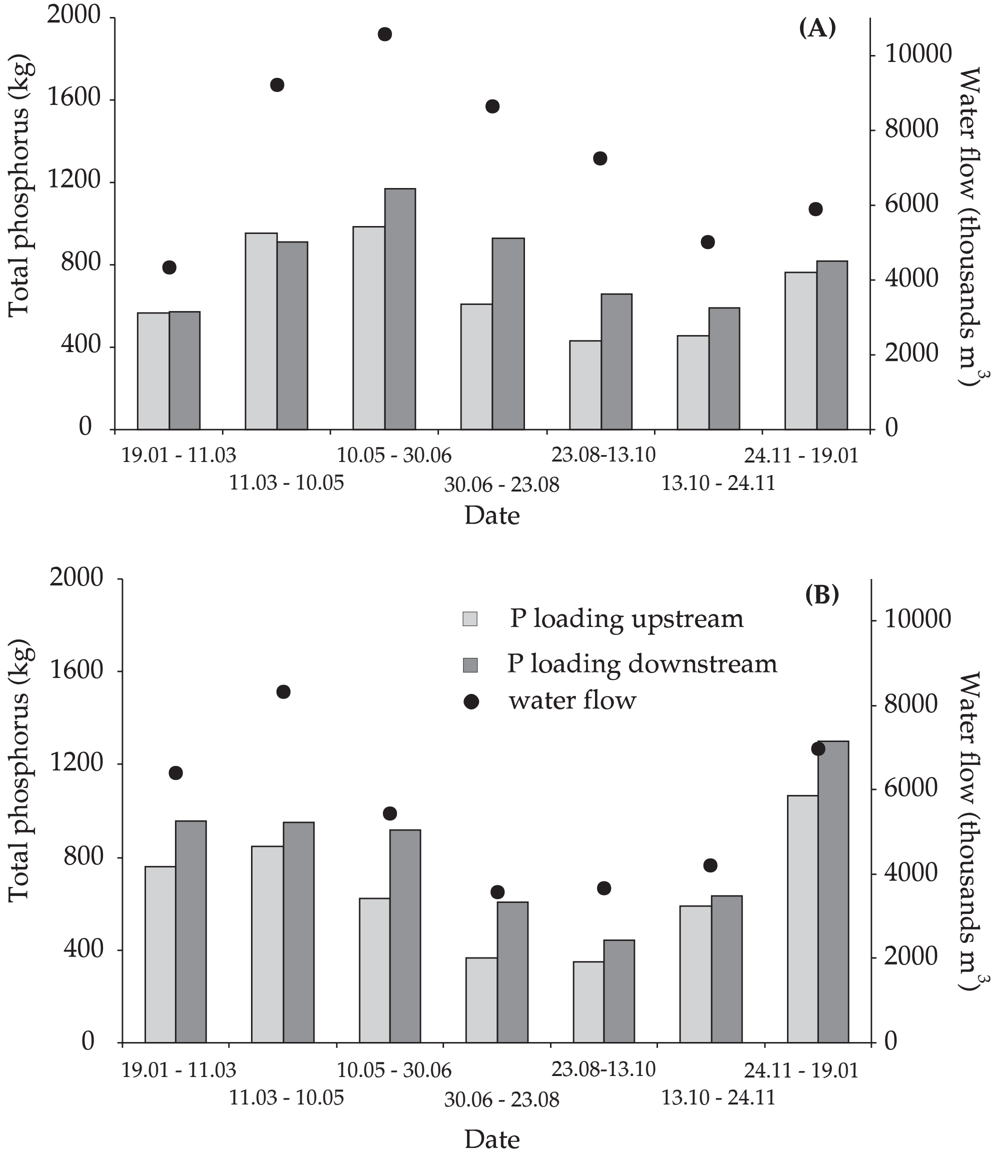


Fig. 3. Changes in Marózka water loading with P, upstream and downstream from trout farms A – (A) and B – (B), in an annual cycle.

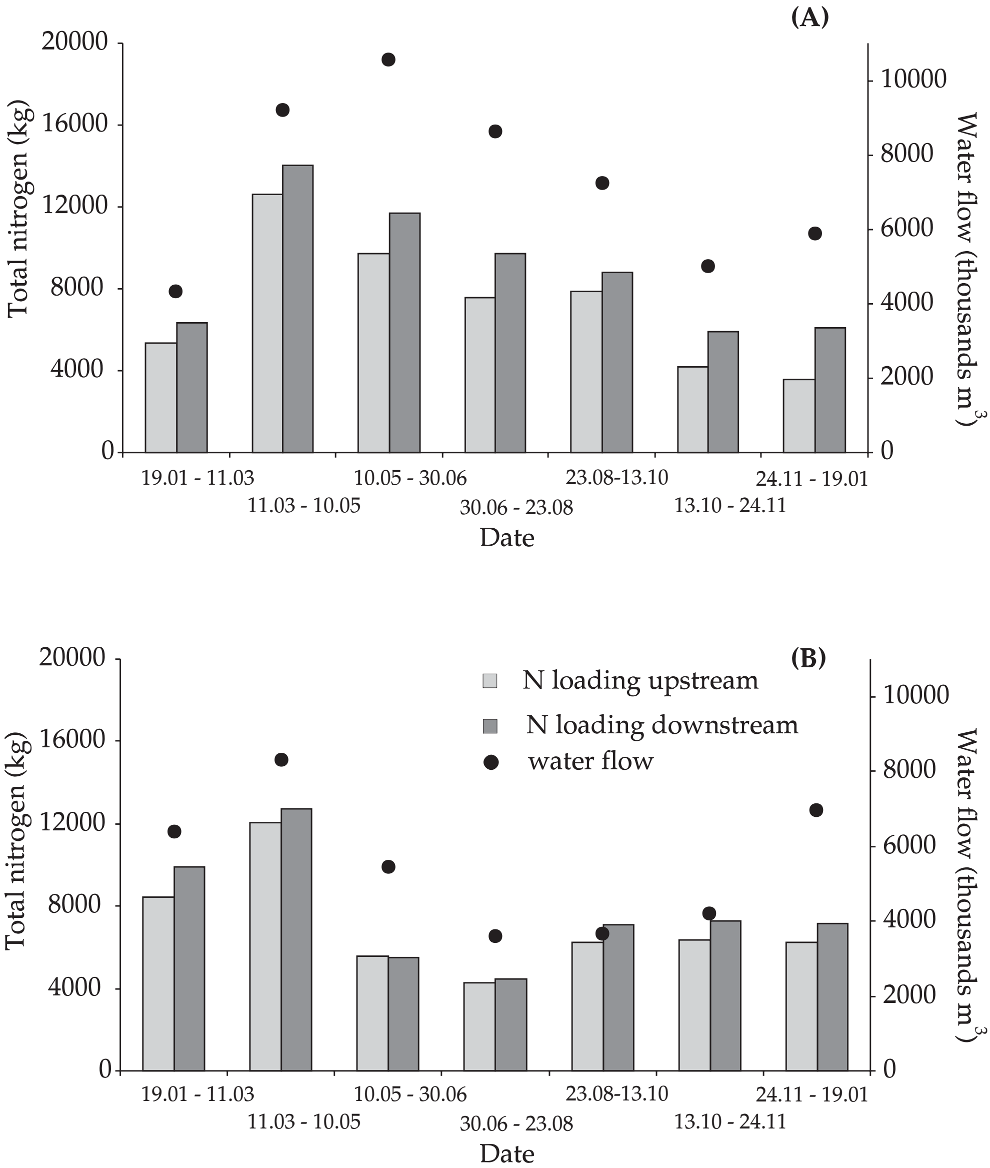


Fig. 4. Changes in Marózka water loading with N, upstream and downstream from trout farms A – (A) and B – (B), in an annual cycle.

ents in the river water downstream from both farms. The average annual concentration of total P increased by 0.02 mg l^{-1} at farm A and by 0.03 mg l^{-1} at farm B, while concentrations of N increased by 0.21 mg l^{-1} and 0.13 mg l^{-1}, respectively (Table 2). Similar increases in levels of N and P concentrations in the effluents from salmonid fish farms in Norway were reported by Bergheim and Brinker (2003). Despite the relatively low increase in concentrations, the loads of both elementary nutrients in the used water were considerable (Figs. 3 and 4, Table 3). However, P revealed distinct seasonal variability with regard to the Marózka River loading from both farms. Downstream from farm A, the highest load increase was observed from May to October whereas at farm B it was more stable throughout the year and only in early fall did it decline considerably (Fig. 3). As for N, the load was much higher downstream from farm A than from farm B where it was practically negligible in the summer (Fig. 4).

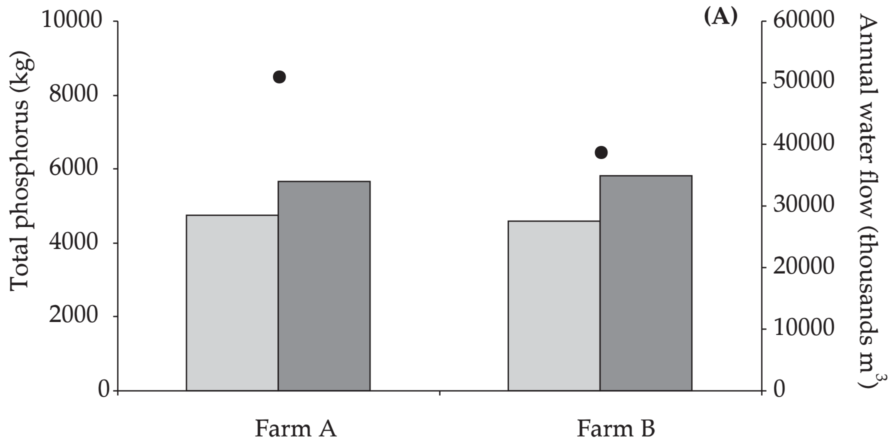
The loads of both elementary nutrients to receiving water depends mostly on the type of fish feed applied (Coloso et al. 2003, McDaniel et al. 2005, Sugiura et al. 2006). During the study both farms used BioMar (Norway) feed. According to the manufacturer's declaration, feeding the product (presented in Table 1) at the FCRs calculated for farms should result in water enrichment levels of 615.9 kg P and 5279.1 kg N at farm A and 816.8 kg P and 7000.8 kg N at farm B.

TABLE 3

Variation in mean loadings of P and N in Marózka River upstream and downstream from fish farms A and B (t statistic, n = 7) in 2004 (mean ± SD)

Parameter	Farm A		Farm B		Significance of the differences between upstream and downstream	
	upstream	downstream	upstream	downstream	Farm A	Farm B
P_{min} (kg)	273.49 ± 126.34	342.51 ± 88.88	322.24 ± 163.99	358.86 ± 208.25	t = -2.85 P = 0.029	t = -1.24 P = 0.260
P_{total} (kg)	680.09 ± 224.15	809.35 ± 216.48	657.70 ± 257.17	829.56 ± 288.59	t = -2.67 P = 0.038	t = -4.83 P = 0.003
N_{NH4} (kg)	123.56 ± 120.10	553.25 ± 345.97	194.50 ± 190.74	489.94 ± 192.06	t = -3.08 P = 0.021	t = -13.15 P < 0.001
N_{total} (kg)	7306.29 ± 3238.18	8957.63 ± 3123.71	7020.16 ± 2538.74	7741.28 ± 2758.08	t = -7.08 P < 0.001	t = -3.72 P = 0.010

However, the actual nutrient loads to the Marózka River were higher at 904.8 kg P and 11538.4 kg N from farm A and 1203.1 kg P and 5047.8 kg N from farm B (Fig. 5). The increase in P concentration was quite proportional to the amount of the feed dose



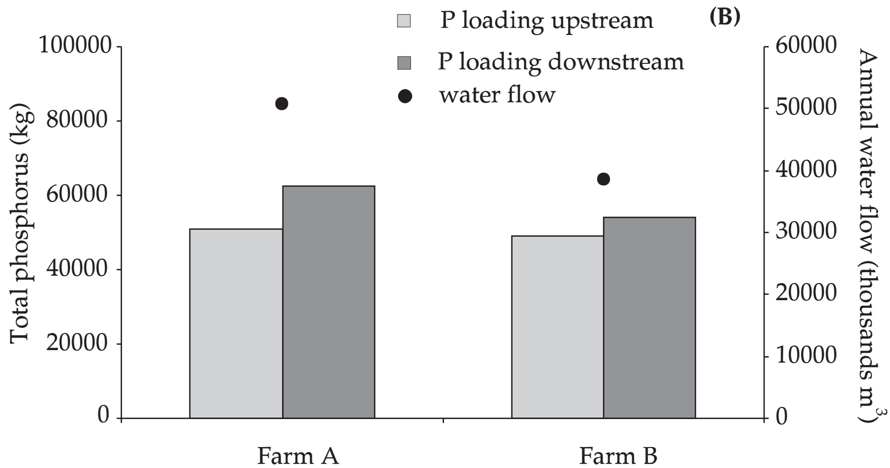


Fig. 5. Annual P (a) and N (b) loads to the Marózka River waters upstream and downstream from trout farms A – (A) and B – (B).

(*i.e.*, 10.71 and 10.39 kg P t^{-1}, respectively). Similar results were obtained by Kim et al. (1998) in their studies of nutrient utilization with various types of feed. In comparison with the load the in the Marózka River upstream from the farms, the increase in P was 19.0% in the case of farm A and 26.1% for farm B. The same parameters for N were 22.6 and 10.3%, respectively. A similarly low increase in the N load was observed at farm B by Teodorowicz (2002). This may have been caused by partial N removal through the settlement of suspensions and denitrification when the water flowed through the settling pond (Fig. 2).

The influence of the farms on the other physicochemical parameters of the Marózka waters was negligible. Only a constant but small decrease in water pH was noted downstream from the farms, as was a moderate increase in electrolytic conductivity. Increased contents of degradable organic compounds (BOD_5), which had been observed by other authors (Boaventura et al. 1997, Goryczko 2001), were not detected; this may have been associated with the lake water supply to the farms.

The results of the present study indicate that the influence of the analyzed farms is moderately negative (measured as the difference between pollutant concentrations in the supply and effluent waters). However, the situation changes radically if used waters are discharged into the lakes. Under such circumstances, it is necessary to calculate the nutrient loads discharged into lakes and to determine their contribution to overall loading from external sources. The annual load discharged from fish farm A of approximately 900 kg P and 11500 kg N has little effect on Lake Pawlik but a much larger impact on Lake Święte, which supplies water to farm B (Fig. 1). The main receiving water for the pollutants from the farms is Lake Łańskie. Taking into account only the P and N loads generated by fish farm B, which is in the closest proximity, the contribution to the overall loading to this large (1042 ha), yet mesotrophic lake is 12.9% P and 5.0% N. These values should be regarded as considerable and, as reported by Lossow et al. (2006), they exceed the loads from two sewage treatment plants located in the watershed (Zybułtowo and Waplewo). Therefore, it is necessary to reduce the discharge of nutrients from the trout farms.

CONCLUSIONS

1. The two trout farms affected the physicochemical parameters of the Marózka River waters, especially through DO reduction, a decrease in pH, increases in P and N concentrations, and a low increase in electrolytic conductivity.
2. Small changes in the nutritive compound concentrations in the water downstream from both farms caused a considerable increase in the loads of them carried by the river.

3. Nutrient loads generated by trout farms A and B significantly exceeded the theoretical loads calculated from the feed manufacturer's declarations and comprised the major portion in the external loading to Lake Łańskie.
4. Due to the hazard of accelerated eutrophication in Lake Święte, and especially due to that in the mesotrophic Lake Łańskie, reducing the nutrient loads from both farms to the Marózka River is a necessity.

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STRESZCZENIE

WPŁYW OŚRODKÓW HODOWLI PSTRĄGA NA JAKOŚĆ WODY RZEKI MARÓZKA (POJEZIERZE MAZURSKIE, POLSKA)

Określono wpływ ośrodków pstrągowych usytuowanych w Szwaderkach (A) i Kurkach (B) na chemizm wód rzeki Marózki oraz zagrożeń wynikających z prowadzenia intensywnej hodowli ryb w kontekście ochrony Jeziora Łańskiego (rys. 1) przed nadmierną eutrofizacją. W 2004 roku przeprowadzono ośmiokrotne badania chemizmu oraz przepływów wód rzeki Marózki. Na podstawie stężeń fosforu i azotu oraz natężenia przepływu wyliczono ładunki związków biogennych wprowadzane do rzeki. Oba ośrodki hodowlane stosowały podobną technologię produkcji (rys. 2, tab. 1).

Uzyskane wyniki badań wykazały negatywny wpływ gospodarstw pstrągowych na jakość wód odbiornika. Stwierdzono spadek natlenienia wód w rzece poniżej obu ośrodków (tab. 2), najbardziej widoczny latem, przy wysokich temperaturach wody i rosnącej biomasie ryb. Wynosił on 1,8-2,9 mg O_2 l^{-1} w Szwaderkach i 1,0-6,9 mg O_2 l^{-1} w Kurkach. Wody poprodukcyjne z badanych obiektów hodowlanych charakteryzowały się stosunkowo niewielkim podwyższeniem stężeń obu biogenów (dla fosforu o 0,02 mg l^{-1} w Szwaderkach i 0,03 mg l^{-1} w Kurkach, azotu zaś odpowiednio o 0,21 mg l^{-1} i 0,13 mg l^{-1}). Nieznaczny wzrost stężeń powodował jednak wyraźny wzrost ładunków tych pierwiastków przenoszonych rzeką Marózką (rys. 3-5). Rzeczywiste obciążenie odbiornika znacznie przekraczało ładunki teoretyczne, wyliczone na podstawie danych z deklaracji producenta paszy i stanowiło istotną część całkowitego ładunku obciążającego Jezioro Łańskie (12,9% dla fosforu i 5,0% dla azotu ogólnego).