Hydrobiologia **251**: 73–79, 1993.
A. Hillbricht-Ilkowska & E. Pieczyńska (eds),
Nutrient Dynamics and Retention in Land/Water Ecotones of Lowland, Temperate Lakes and Rivers.

Effect of filtering activity of *Dreissena polymorpha* (Pall.) on the nutrient budget of the littoral of Lake Mikołajskie

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Key words: lake, littoral, Dreissena polymorpha, nutrient budget

Abstract

The effect of filtering activity of *D. polymorpha* on nutrient dynamics in Lake Mikołajskie depended mostly on population density: *D. polymorpha* was important in N and P cycling in periods when its population density was medium or high. The amounts of N and P accumulated in mussel populations at medium density may be similar to those in emergent and submerged macrophytes. However, mussels remove nutrients from cycling matter for a much longer time than do macrophytes. The amounts of nutrients accumulated in a mussel population are several times lower than the quantities which flow through it.

Introduction

Dreissena polymorpha (Pall.) is one of the most abundant mussel species in lakes, and certainly the most important one as regards biomass. *D. polymorpha* forms a belt around the shore, usually in the littoral and upper sublittoral (Stańczykowska, 1964, 1977; Walz, 1973). Depending on the width of the littoral and its slope, the areas occupied vary and they are not constant in time either.

The role played by *D. polymorpha* in water ecosystems has long been considered important. In recent years, special attention has been paid to the effect of its filtration activity.

During filtration, *D. polymorpha* consumes seston from the water; while its pseudofaeces and faeces drop to the lake bottom. The filtration activity of whole *D. polymorpha* populations may be so intensive that they are even able to filtrate all the lake water in few days (Stańczykowska, 1968). The amounts of faeces which deliver P and N to the sediment, are also enormous.

D. polymorpha lives in the ecotone between the shore (eulittoral) and the sublittoral; it takes food (seston) from the pelagial. Its faeces are sedimented to the bottom in the littoral. We may expect abundant *D. polymorpha* populations to act as a natural biofilter in horizontal and vertical direction: they prevent nutrients from penetrating to the lake, and from the water to the sediments. This may be important in protecting lakes from eutrophication.

Previous studies in the Mazurian lakes have shown that *D. polymorpha*, which are present abundantly here, plays an important role in N and P cycles (Stańczykowska, 1983, 1984a, 1984b). Mussels remove considerable amounts of N and P from the water and accumulate them in their bodies and shells for several years. We (Stańczykowska, 1984b) compared N and P contents in *D. polymorpha* in lakes of different trophy. We

found that N and P accumulation in *D. polymorpha* populations in different lakes differed, and depended on *D. polymorpha* abundance, biomass and age structure.

Our 30 year studies on various Mazurian lakes also showed that the abundance of *D. polymorpha* greatly varies in time and so does its significance in a given ecosystem. The aim of the present work was to examine how the role played by *D. polymorpha* in nutrient cycling varies as a function of population abundance in the Lake Mikołajskie.

Description of the area

Lake Mikołajskie is situated in the central region of the Great Mazurian Lakes. It is a tunnel-valley lake, medium sized (460 ha) with mean depth 11 m and maximum depth 27.8 m. It is a eutrophic, dimictic water-body. Lake Mikołajskie is naturally connected with the Tałty, Sniardwy and Bełdany lakes. The average annual water exchange is three times the lake volume. Its surroundings include forests, field, meadows and Mikołajki town. The lake is exposed to strong eutrophication factors, of which the strongest is the disposal of municipal sewage from the town (Fig. 1).

Many years of limnological studies conducted in this lake showed various environmental and biocenotic changes.

The eutrophication of the lake is seen in a decrease in Secchi disc visibility from 3.0 m in 1954 (Szczepański, 1968) to 1.1 m in 1977 (Gliwicz *et al.*, 1980), and an increase in maximum phytoplankton biomass (from 18.7 mg l^{-1} in 1963 to 55.0 mg l^{-1} in 1972) (Spodniewska, 1976). The most pronounced change in the littoral concerns the occurrence of emergent and submerged macrophytes (Pieczyńska *et al.*, 1988). In the northwestern part of the lake the area covered by *Phragmites australis* (Cav.) Trin. ex Steudel, decreased from 10 ha to 5.2 ha; in 1984 the density and biomass were almost half that measured in 1963. In the south-eastern part of the lake these changes were small. A reduction in biomass of submerged macrophytes from 2.1 t ha^{-1} in 1963 to 0.2 t ha^{-1} in 1980 was observed (Ozimek & Kowalczewski, 1984). In contrast to the macrophytes, an increase in maximum algal biomass in the littoral (from 0.7 g l^{-1} in 1966 to 894.0 g l^{-1} in 1982) was significant (Pieczyńska *et al.*, 1988). During the 15 years, the number of littoral benthic animals and their biomass decreased. For example, a reduction of the zone of occurrence of the family Unionidae was observed (Lewandowski & Stańczykowska, 1975; Lewandowski, 1991).

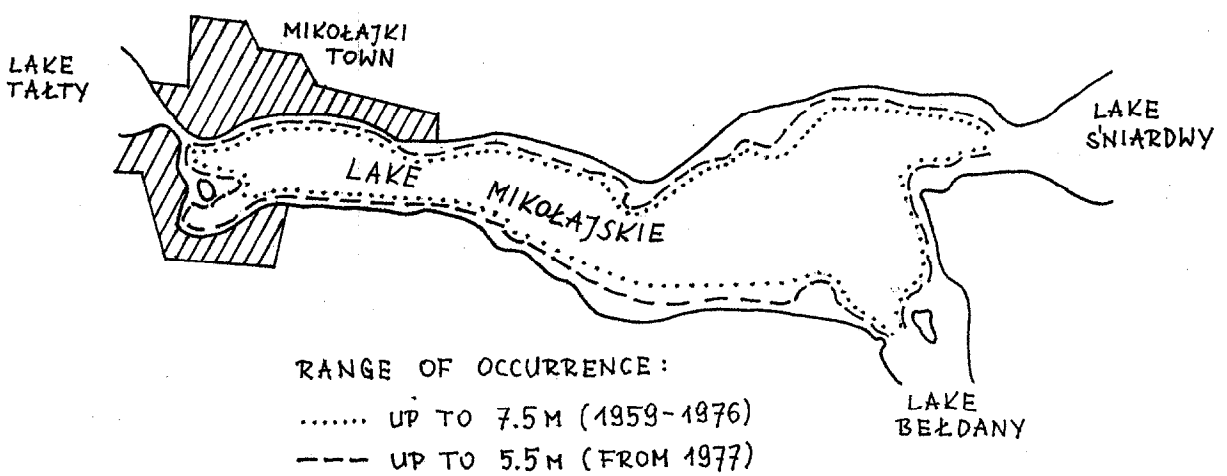

Fig. 1. Lake Mikołajskie – zone of *D. polymorpha* occurrence.

Table 1. Occurrence of *D. polymorpha* at different depth of Lake Mikołajskie in 1987

Depth (m)	0.5	1.5	2.5	3.5	4.5	5.5
Average density (indiv. m^{-2})	0.3	3.0	5.2	3.1	0.1	0.7
Range (indiv. m^{-2})	0–3	0–15	0–26	0–18	0–1	0–3

Material and methods

We used abundance and biomass data obtained at various stations and depths in Lake Mikołajskie in the years 1959–1990 (Stańczykowska, 1961, 1964, 1966, 1975, 1976, 1977, 1978; Stańczykowska *et al.*, 1975b; Lewandowski, 1982a).

Using this information, we analysed variation of *D. polymorpha* density across time. The number of individuals of *D. polymorpha* living in the lake was calculated. Based on results obtained from a field experiment on water filtration by mussels, seston consumption and faeces production (Stańczykowska *et al.*, 1975a), and the specific rate of these processes were determined.

In order to describe the role of *D. polymorpha* in the P and N budgets of the lake (Stańczykowska & Planter, 1985), using available data on the P and N content in *D. polymorpha* bodies, mussels, in seston and faeces, we estimated: the standing crop of P and N in bodies for the whole population; amounts of P and N contained in the filtered seston, and P and N amounts in the faeces. These values were estimated for different periods of time, corresponding to different *D. polymorpha* abundances.

Results

D. polymorpha in Lake Mikołajskie occupies a belt around the shores, and fringes the littoral and upper sublittoral zones. In 1959–1976, this mollusk occurred at depths ranging from 0.2 to 7.5 m, and in 1977–1990 not deeper than 5.5 m (Fig. 1, Table 1).

In the period of studies (1959–1990), great changes in density and biomass were observed (Fig. 2). In 1959, mollusk density was very high.

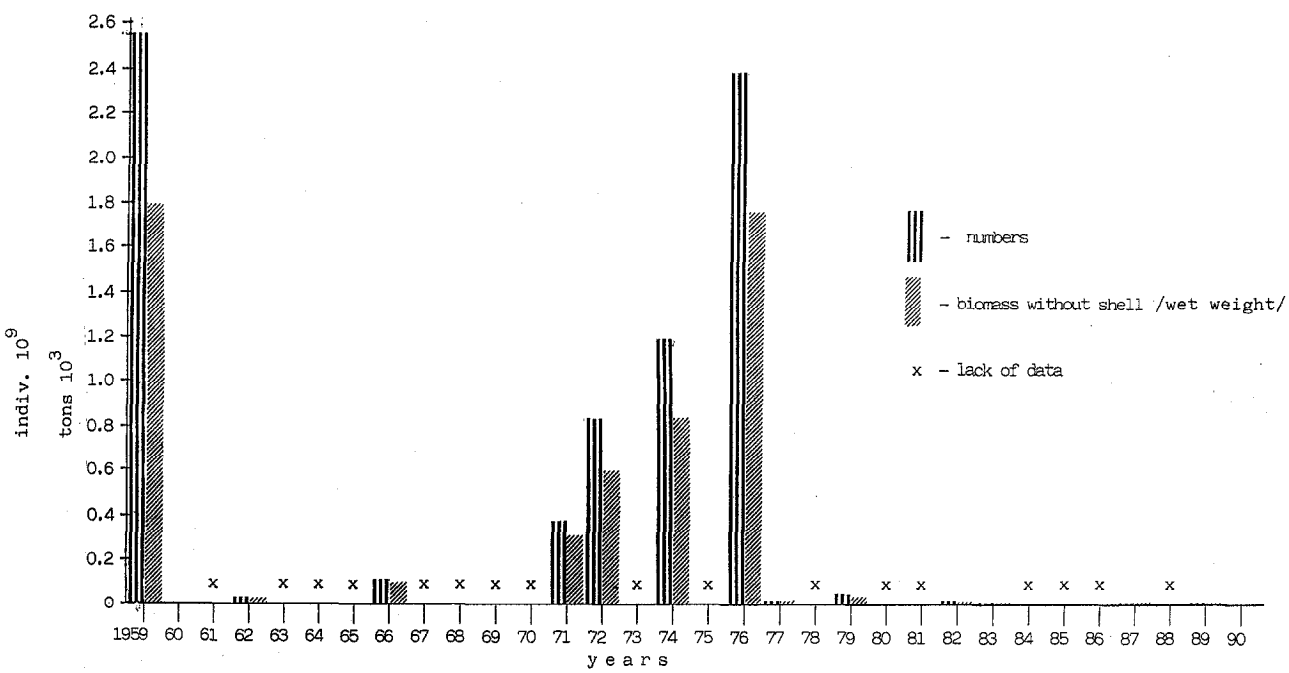

Fig. 2. Number and biomass changes of the *D. polymorpha* population in the whole Lake Mikołajskie.

In 1960, it was subject to a substantial reduction in numbers, followed by a gradual restoration of the population in the period 1961–1974; in 1976, it again reached the value of 1959. In the 80s the density decreased. During the last few years *D. polymorpha* disappeared from some parts of the lake, and in others parts their number was very low (Fig. 3). We attribute this fact to increased eutrophication.

The numbers of *D. polymorpha* also depend on a suitable macrophyte substrate available for postveliger colonization (Lewandowski, 1982b, 1982c). In constantly polluted sectors of Lake Mikołajskie, the amount of suitable substrate has decreased considerably (Pieczyńska *et al.*, 1988).

Based on population density the period of study was divided into 1) years with low numbers of molluscs: (up to 50 indiv. per 1 m^2), 2) medium numbers (from 300–1000 indiv. per 1 m^2) and 3) maximum numbers (over 2000 indiv. per 1 m^2).

The significance of *D. polymorpha* in the lake differed in years with different densities. In years when the population was very abundant, it was able to filtrate $388 \cdot 10^6$ m^3 of water during the season; in the years with medium density this was $123 \cdot 10^6$ m^3, and at minimum density, $27 \cdot 10^6$ m^3 (Table 2). Consumption of seston at maximum density was 3 and 46 times higher than at medium, and minimum densities, respectively, and production of faeces at maximum density was 3 and 4.4 times higher than at medium and minimum density.

In 1972, the density of *D. polymorpha* in Lake Mikołajskie was not exceptionally high (according to the above classification it was medium density), but its consumption of seston amounted to almost 9% of annual primary production in the pelagial, while production of faeces reached 13% of annual deposition of seston (Stańczykowska *et al.*, 1975a).

D. polymorpha, when abundant, also plays an important role in nutrient cycles. P and N content (dry weight) in *D. polymorpha* body ranges from 0.85% to 0.93% and from 11% to 12.8%, respectively. In shells, P and N content is 0.015%

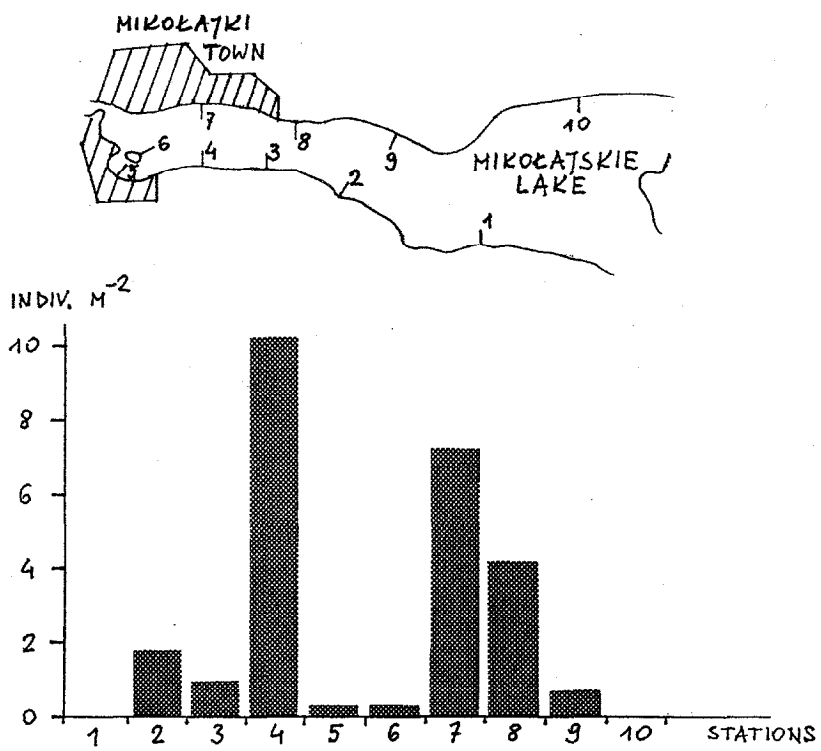

Fig. 3. Numbers of *D. polymorpha* at different stations of Lake Mikołajskie in 1987.

Table 2. Values of filtration, seston consumption and faeces production (per season = 6 months) for the whole population of *D. polymorpha* in Lake Mikołajskie

Periods of different densities		Filtration (10^6 m^3)	Consumption (t) dw	Faeces production (t) dw
Years	Indiv. m^{-2} in the area of occurrence			
1959 and 1976	2000–2200 (maximum)	388	1209	720
1971–1974	300–1000 (medium)	123	385	229
1960–1962 and 1977–1990	5–50 (minimum)	27	84	51

and 0.33% respectively. Nutrients in body fluids were not taken into consideration; according to Kuenzler (1961) they are about 3% of total P in mussel.

The amount of P accumulated in mussel population at high density was 470 kg, in years of medium density it was 164 kg, and at minimum density, 3 kg (Table 3). These values may be compared with the whole P-stock (including bottom deposits, water, macrophytes, seston, fish), which is about 56 t (Kajak, 1978). In periods of high density, P content of the whole population was about 0.9% of the P stock in the lake, but in periods of low density, it was only 0.007%.

The amounts of N and P accumulated in mussels during the 1970s were similar to the amounts stored in emergent and submerged macrophytes (0.7 t) and in fish (0.8 t) (Kajak, 1978).

The role of *D. polymorpha* in nutrient cycling is not restricted to accumulation in the mussel bodies; the accumulated N and P is several times lower than the quantities flowing through an actively filtering population. (Tables 3 and 4).

Of the seston consumed, about 70% reaches the alimentary tract and about 30% is expelled into the environment in the form of pseudofaeces (Stańczykowska, 1984b). The output of P and N from a mussel population is given by defaecation, individual death and egg production. As indicated by our analysis, the excretion of faeces is the most significant of these processes. According to experiments carried out previously, the average food assimilation ratio of *D. polymorpha* in Mazurian lakes is about 40%. The content of P and N in its faeces is 0.1% and 3.53% of dry weight. Nutrient output by dead mussels and sex products formed only about 10% of the whole P and N pool of the population.

Table 3. Role of *D. polymorpha* population in P budget in Lake Mikołajskie (periods of various population density)
a – in kg, b – in % of total amount of P in lake (including bottom deposits, water, macrophytes, seston, fish) (Kajak, 1978)

Population density	Standing crop of P in whole population		P flux through the population (per season = 6 months)			
			in seston consumed		in faeces produced	
	a	b	a	b	a	b
Maximum	470	0.9	3470	6.7	510	1.0
Medium	164	0.3	1210	2.3	180	0.34
Minimum	3	0.007	30	0.006	4	0.008

Table 4. Role of *D. polymorpha* population in the N budget of Lake Mikołajskie (periods of various population density)

Population density	Standing crop of N in whole population (kg)	N flux through the population (per season = 6 months) in	
		Food consumed (kg)	Faeces produced (kg)
Maximum	6670	48730	6800
Medium	2340	17050	2380
Minimum	50	370	50

From an estimation of food consumption and faeces production by *D. polymorpha* at various densities (Table 2), we found that at the highest density, *ca* 3500 kg of P passes through the population in the seston consumed, whereas its faeces contains *ca* 500 kg of P (Table 3). This is more than 6.5% and 1%, respectively, of total P in the lake (Kajak, 1978). At the lowest *D. polymorpha* density, these percentage are insignificantly (Table 3).

The amount of N in the *D. polymorpha* population, and flowing through it, is much greater than that of P; it evidently also depends on population density (Table 4). Yet, the lack of reliable data about the amount of N in individual components of Lake Mikołajskie does not permit us to estimate the percentage N in *D. polymorpha* relative to the total amount in the lake.

Conclusions

D. polymorpha, one of the most abundant filtrators in the littoral zone, may be important to nutrient cycling in the whole lake.

At high and medium densities, it accumulates about 0.3 to 0.9% of the phosphorus contained in all components (water with seston, sediments, macrophytes, fishes; Kajak, 1978) of Lake Mikołajskie. The amounts of P and N accumulated in the mussel population are similar to those accumulated in emergent and submerged macrophytes. Moreover, the mussels remove nutrients from material cycling in the late for a much longer time than do the macrophytes.

The amount of nutrients accumulated in mollusk bodies is several times lower than the quantities that flow through the *D. polymorpha* population. Phosphorus flux through a dense population is about 7% of the total amount of P in the lake, whereas P in its faeces is about 1% of total lake-P.

Populations at low density play only a minor role in the nutrient cycling, with the amount of P accumulated in the molluscs and flowing through the population reduced to 0.007% of the P contained in other components of the ecosystem.

Low *D. polymorpha* densities were often observed in the lake during periods when lake trophy was strongly increasing. Thus, in periods when a strong filtration ability by large littoral filtrators would be desirable to prevent a further increase in lake trophy, this was not available.

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