EKOLOGIA POLSKA (Ekol. pol.)	35	1	209–217	1987

Joanna KRÓLIKOWSKA

Hydrobiological Station, Institute of Ecology, Polish Academy of Sciences,
11 – 730 Mikołajki, Poland

REED (*PHRAGMITES AUSTRALIS* (CAV.) TRIN. EX STEUD.) GROWTH UNDER CONDITIONS OF INCREASING EUTROPHICATION OF LAKE MIKOŁAJSKIE *

ABSTRACT: Seasonal changes of reed production indices with special consideration to plant density, length of shoots and biomass of aboveground parts, were analysed in 1985 in the reed-belt of Lake Mikołajskie. In comparison with 1967, the reed-belt area, density and biomass decreased mainly as a result of mechanical damage of shoots by filamentous algae abundantly accumulating in the littoral of emergent plants.

KEY WORDS: Lake littoral, *Phragmites australis*, density, biomass.

1. INTRODUCTION

Advancing lake eutrophication causes many unfavourable changes in ecosystems. An increase of primary production as a result of mineral salts' load, especially of nitrogen and phopshorus, is the cause of permanently increasing changes. The water transparency decreases and there are oxygen deficits in the hypolimnion as a result of lack of balance between the quantity of oxygen there and the rate of using it in decomposition processes. An excess of mineral salts causes a strong development of filamentous algae, phytoplankton blooms. A decrease of water transparency changes the range of macrophyte occurrence. There are disturbances in the functioning of the trophic net (K a j a k 1979).

The eutrophic Lake Mikołajskie is a water body constantly supplied with municipal sewage – almost 84% of annual pollution from the drainage area (P i e c z y ń s k a 1972). The inflowing pollution causes the increasing lake

* This study was financially supported under project MR II/15.

eutrophication (P i e c z y ń s k a 1976, K a j a k 1978, 1979). Water transparency decreased to about 0.5 m of Secchi disc visibility (S z c z e p a ń s k i 1958, R y b a k 1972, 1975). Transformation of submerged macrophytes was observed in the lake littoral (P i e c z y ń s k a et al. 1975, O z i m e k and S i k o r s k a 1976, O z i m e k 1978). The number of filamentous algae increased considerably in the zone of emergent macrophytes (P i e c z y ń s k a 1976, S p o d n i e w s k a 1976, K a j a k 1978).

The present investigations were conducted in order to find, whether the advancing eutrophication of Lake Mikołajskie affected *Phragmites australis* dominant among helophytes.

2. AREA AND METHODS

Lake Mikołajskie (Masurian Lakeland) has a surface area 460 ha, its littoral being moderately covered by macrophytes (19% of lake surface); among helophytes common reed dominates distinctly – 84% of surface overgrown by helophytes (K o w a l c z e w s k i and W a s i l e w s k i 1966).

The studies were conducted in a reed-belt near the Hydrobiological Station (Fig. 1), where plant material was collected in 1967. The chosen part of littoral is typical of the

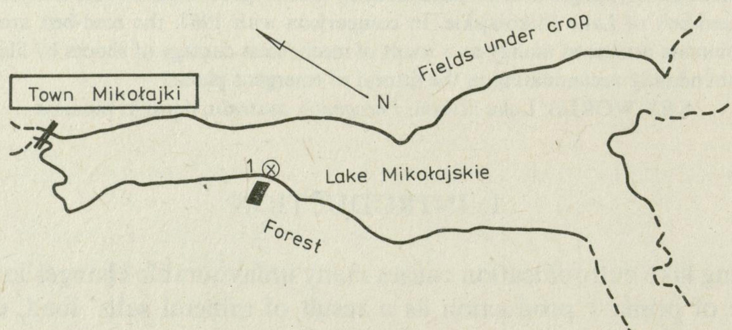

Fig. 1. Location of sampling site (1) in the littoral of Lake Mikołajskie

littoral of Lake Mikołajskie overgrown by reed. The reed-belts are along the forested shore, forming bigger or smaller monocenoses of *Phragmites australis*, and along shores with meadows and arable land also as monospecific patches. Only along the shoreline, directly neighbouring with buildings of Mikołajki town, there are no reed-belts.

In the chosen reed-belt, on an observation area, dynamics of reed growth and phenomena occurring during the vegetation season of 1985 were recorded. When sampling plant material and elaborating it the same method as in 1967 was used. Between May and October, every 10 days, a reed-belt surface area determined using a $0.25\,m^2$ frame (10 repeats), was cut after estimating the density. In thus sampled material the following were determined: length (from the bottom), near-bottom diameter of shoots, number of leaves on each shoot. In order to determine the assimilation area, the length and maximal width of each leaf were measured. Samples, after being dried to constant weight at 105°C, were weighed, obtaining thus the biomass of aboveground plants expressed in dry weight. Leaf surface was estimated using Ondok's (1968) equation and coefficient 0.57 calculated for reed in the reed-belt examined by A. Szczepański (Królikowska 1971, Szajnowski 1973).

Thus obtained results were compared with data from 1967 (Szczepański 1978, J. Królikowska – unpublished data) or with parameters calculated accordingly.

3. RESULTS

3.1. CHARACTERISTICS OF THE REED-BELT IN 1985

With the passing time the number of normally developing reed shoots (i.e., with one growth apex) decreased in the part of reed-belt observed during the whole vegetation season. Of the initial number of 64 shoots $\cdot$ m^{-2} in May, only 29 survived till October (Fig. 2). Already in June the increasing abundance of filamentous algae was observed in

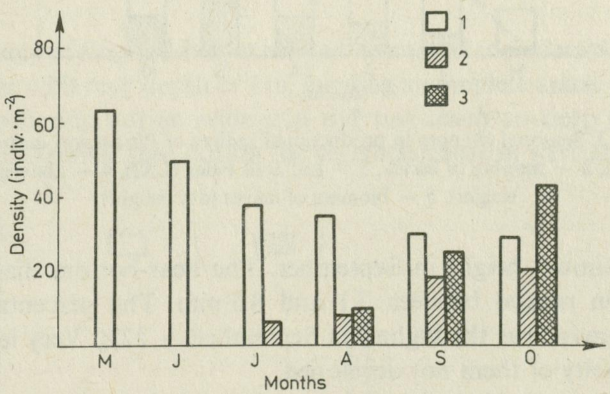

Fig. 2. Seasonal changes in the density of *Phragmites australis*
1 – normally developing shoots, 2 – collateral shoots, 3 – autumn buds

the reed-belt. The algae settled on tips of reed shoots under the water surface and moved upwards as the plants grew. When they got out of the water the reed shoots started to break, because of the weight of algae and wave action. Some plants had the growth apices damaged as a result of rotting processes under the algae covering the plant tips.

From the damaged nodes collateral shoots started, which at the end of July had 50% less leaves than the normally growing reed. Also the surface of these leaves was smaller. Morphometric differences between these two kinds of shoots were fading with the passing time. At the end of September and in October, the collateral shoots were only smaller and had a slightly smaller diameter of the bottom part. In August autumn reed seedlings began to appear, increasing in numbers, attaining in October almost 70% of the spring number of shoots (Fig. 2).

The density of shoots in the reed-belt was the highest in spring, changing very little between June and September. Maximal biomass of aboveground parts, assimilation surface of leaves and their number were recorded in September (Fig. 3). Also the plants

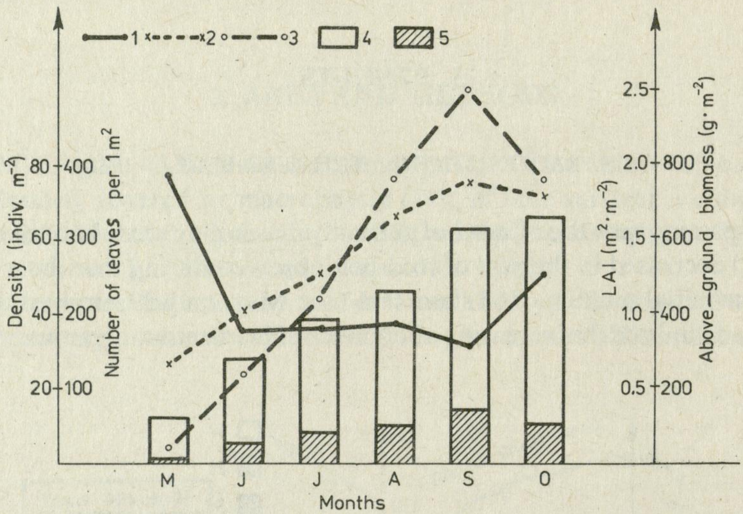

Fig. 3. Seasonal changes in productional indices of *Phragmites australis*
1 – density of plants, 2 – number of leaves, 3 – leaf area index (LAI), 4 – aboveground biomass (dry weight), 5 – biomass of leaves (dry weight)

attained the maximum height in September. The near-bottom diameter of shoots during the season ranged between 7.1 and 8.5 mm. The percentage of leaves in aboveground biomass was the highest in September – 22%. Very few panicles were noticed, the majority of them not developed.

3.2. CHANGES IN THE REED-BELT BETWEEN 1967 AND 1985

Great differences were observed in the seasonal density of plants in the reed-belt. In 1967, the number of shoots increased from spring, attaining the maximum in August during the biomass maximum (Szczepański 1978, J. Królikowska – unpublished data). In 1985, the highest density was recorded in May – almost 80 shoots · m^{-2}, then it decreased to 30 – 35 plants between June and September (Fig. 4). The density of reed shoots in 1985, in spring, was over 100% higher than in 1967, but almost identical in October (Fig. 4).

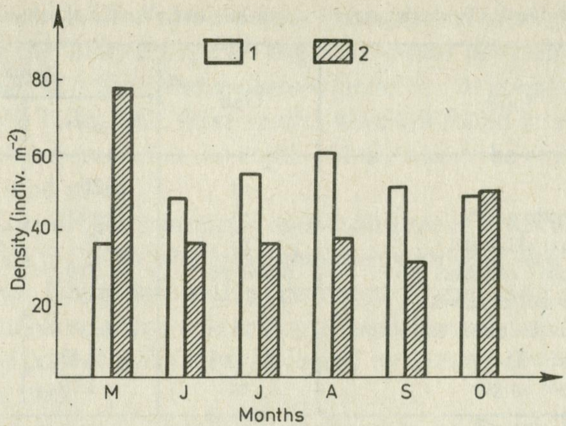

Fig. 4. Changes in reed density during the vegetation seasons of 1967 and 1985
1 – 1967, 2 – 1985

The length of reed shoots was also different in both years. In 1967, 32.5% of reed shoots attained the height of 201 – 250 cm, whereas in 1985, 21% of shoots were below 50 cm (Fig. 5). In 1967, up to the height of 100 cm there was 50% less shoots, whereas there was twice as much plants 201 – 300 cm high. In 1985, reed shoots were less differentiated in height, but single specimens attained a greater height – over 350 cm (Fig. 5).

The surface area of the reed-belt examined decreased considerably. In 1967, it had the width of 20 m with reed depth of 2 m, forming a complete stand from the land. In 1985, the reed-belt was not so wide and did not reach so deep (Table 1). Mean production parameters for reed during the vegetation season were also lower in 1985.

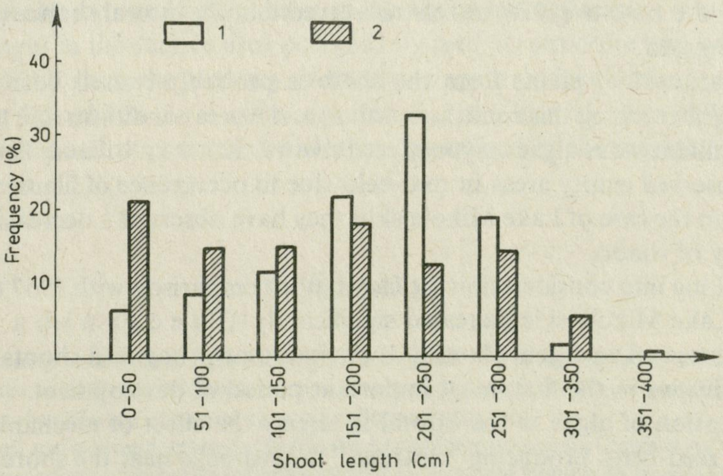

Fig. 5. Frequency distribution of *Phragmites australis* shoot length
1 – 1967, 2 – 1985

Table 1. Characteristics of a reed-belt in Lake Mikołajskie

Index	Unit	Value	
		1967 *	1985
Width	m	20	7
Range of depth	m	0 – 2.0	0.4 – 1.6
Distance from shoreline	m	0	2.5
Average density of plants	indiv. · m^{-2}	50.9	44.5
Average number of leaves	indiv. · m^{-2}	339	275
Aboveground biomass (dry weight)	$g \cdot m^{-2}$	477	420
Leaf area index (LAI)	$m^2 \cdot m^{-2}$	1.43	1.35
Average shoot length	m	1.79	1.51

* Data and recalculated data from Szczepański (1978), J. Królikowska (unpublished data).

4. DISCUSSION

The character, seasonal variability and degree of littoral development are significant for the functioning of the whole lake ecosystem (Pieczyńska 1972). The littoral vegetation is a natural barrier for the substances inflowing from the drainage area to the lake. An increased nutrient load from the drainage area (Górski and Rybak 1974) advancing the eutrophication of Lake Mikołajskie (Kajak 1979) results in changes in sumberged plants (Ozimek 1978) and as shown here – in reed, the dominant helophyte.

Smaller depth range and withdrawal of reed from land decreases considerably the width of reed-belt. This confirms the results obtained by Rejewski (1981) and Szajnowski (1983) for other lakes – nowadays reed does not utilize fully the littoral. Anderson (1976) has also observed that the littoral surface occupied by reed has decreased.

The withdrawal of plants from the shore is probably caused both by smaller amount of light reaching this zone (forestation) and worse conditions due to settling of detritus and filamentous algae on young reed shoots. Klötzli and Züst (1973) have also observed empty areas in reed-belts due to occurrence of filamentous algae. Similarly as in the case of Lake Mikołajskie, they have observed a decreasing over the years density of shoots.

When taking into consideration the fact that in comparison with 1967 the biomass of algae in Lake Mikołajskie increased significantly (Pieczyńska et al. 1984) also in the littoral of emergent plants, it is obvious that young reed shoots have worse growth conditions in the first, most important period of development.

Accumulation of algae in the littoral is largely the effect of mechanical damage (tourism) of reed-belts, producing "clearings" in reed-belts near the shore. The waves bring there great amounts of filamentous algae. It is quite possible that decomposing algae may have a toxic effect on young shoots.

Places, from which the reed withdraws, are occupied by other plant species. In the reed-belt examined the following species began to appear between land and the reed-belt: *Nuphar luteum* (L.) Sm., *Potamogeton lucens* L., *Myriophyllum spicatum* L., *Sagittaria sagittifolia* L. In 1967, these species were not found in a given place of the reed-belt. *M. spicatum* occurred at the depth of 2 m, where the reed-belt ended, other species were not found at all.

The greater density of shoots in spring than in autumn of 1985 confirmed the results of Szczepański (1978), who found that the majority of reed shoots grew out of rhizomes in autumn. Under favourable conditions (warm, long autumn) new reed shoots appear still in November and in spring of the following year. This is perhaps due to the not used food pool of reed rhizomes caused by damage of reed parts during the season as it was in 1985.

In both years the seasonal density of reed shoots was different, because in 1985, in place of normally growing shoots, the collateral ones appeared and thus the average density of reed shoots was smaller. Pieczyńska et al. (1984) observed a similar situation in reed-belts of Lake Mikołajskie. The growing out collateral shoots also reduced the average height of plants in the reed-belt.

Because of the disturbed normal seasonal growth of reed-belt, mainly due to damage of shoots by filamentous algae, the maximum reed production shifted from August, in 1967 (Szczepański 1978, J. Królikowska – unpublished data), to September, in 1985. The decreasing reed production indices reflect the changes in waters of Lake Mikołajskie, which affect the reed-belt, although it is not in the zone of direct and strong pollution impact.

With consideration to the effect of increasing lake eutrophication on the hydrochemistry of pelagial (Górski and Rybak 1974), submerged macrophytes (Ozimek 1978), abundance of filamentous algae (Pieczyńska 1976, Kajak 1978), and according to the above presented results, it can be assumed that the reed may also be one of the indices of increasing eutrophication of water bodies.

The changes in the surface area occupied by reed, its structure and production in Lake Mikołajskie show the necessity to determine again the lake surface area occupied by emergent helophytes. It is quite possible that the littoral covered by emergent vegetation decreased as compared with that determined in the nineteen-fifties.

5. SUMMARY

Investigations of a reed-belt in Lake Mikołajskie were conducted in the vegetation season of 1985. The material collected in 1967, partly elaborated by Szczepański (1978), allowed to grasp changes occurring under the influence of increasing water pollution in the reed.

The reed-belt surface area decreased as well as the depth of reed occurrence (Table 1). As compared with 1967, the density of shoots, their height and production of aboveground biomass decreased (Figs. 2 – 4). Also the frequency distribution of reed shoots' height changed (Fig. 5). A negative influence of filamentous algae accumulating in the littoral on reed was observed (mechanical damage of shoots).

6. POLISH SUMMARY

W sezonie wegetacyjnym 1985 r. przeprowadzono badania sezonowe trzcinowiska w Jeziorze Mikołajskim. Zbierane przez autorkę materiały w 1967 r., częściowo opracowane przez Szczepańskiego (1978), pozwoliły na uchwycenie zmian, jakim pod wpływem pogłębiającego się zanieczyszczenia wody uległa trzcina.

Stwierdzono zmniejszenie się powierzchni trzcinowiska oraz głębokości występowania trzciny (tab. 1). W porównaniu z 1967 r. zmniejszyło się zagęszczenie pędów, ich wysokość oraz produkcja biomasy nadziemnej (rys. 2–4). Zmianie uległ również rozkład częstości występowania wysokości pędów trzciny (rys. 5). Stwierdzono negatywny wpływ glonów nitkowatych nagromadzających się w litoralu na trzcinę (uszkodzenia mechaniczne pędów).

7. REFERENCES

1. Anderson F. O. 1976 – Primary production in a shallow water lake with special reference to reed swamp – Oikos, 27: 243–250.
2. Górski T., Rybak J. I. 1974 – Phosphorus runoff from the drainage basin to Mikołajskie Lake – Ekol. pol. A, 22: 275–286.
3. Kajak Z. 1978 – The characteristics of a temperate eutrophic, dimictic lake (Lake Mikołajskie, Northern Poland) – Int. Revue ges. Hydrobiol. 63: 451–480.
4. Kajak Z. 1979 – Eutrofizacja jezior [Eutrophication of lakes] – Państwowe Wydawnictwo Naukowe, Warszawa, 233 pp.
5. Klötzli F., Züst S. 1973 – Conservation of reed-beds in Switzerland – Pol. Arch. Hydrobiol. 20: 229–235.
6. Kowalczewski A., Wasilewski L. 1966 – Differentiation of biomass of *Phragmites communis* Trin. and its production in Mikołajskie Lake – Bull. Acad. pol. Sci. Cl. II. Sér. Sci. biol. 14: 219–223.
7. Królikowska J. 1971 – Transpiration of reed (*Phragmites communis* Trin.) – Pol. Arch. Hydrobiol. 18: 347–358.
8. Ondok P. 1968 – Measurement of leaf area in *Phragmites communis* Trin. – Photosynthetica, Prague, 2: 25–30.
9. Ozimek T. 1978 – Effect of municipal sewage on the submerged macrophytes of a lake littoral – Ekol. pol. A, 26: 3–39.
10. Ozimek T., Sikorska U. 1976 – Influence of municipal sewage on littoral biocenosis (In: Selected problems of lake littoral ecology, Ed. E. Pieczyńska) – Wydawnictwa Uniwersytetu Warszawskiego. Warszawa, 181–193.
11. Pieczyńska E. 1972 – Ecology of eulittoral zone of lakes – Ekol. pol. 20: 637–732.
12. Pieczyńska E. (Ed.) 1976 – Selected problems of lake littoral ecology – Wydawnictwa Uniwersytetu Warszawskiego, Warszawa, 238 pp.
13. Pieczyńska E., Balcerzak D., Kołodziejczyk A., Olszewski Z., Rybak J. I. 1984 – Detritus in the littoral of several Masurian lakes (sources and fates) – Ekol. pol. 32: 387–440.
14. Pieczyńska E., Sikorska U., Ozimek T. 1975 – The influence of domestic sewage on the littoral zone of lakes – Pol. Arch. Hydrobiol. 22: 141–156.
15. Rejewski M. 1981 – Roślinność jezior rejonu Laski w Borach Tucholskich [Lake vegetation of Laski region in Bory Tucholskie] – Rozprawy Uniwersytetu Mikołaja Kopernika, Toruń, 178 pp.
16. Rybak J. I. 1972 – Spatial and time changes of some environmental factors in the pelagial of Mikołajskie Lake – Ekol. pol. A, 20: 541–560.
17. Rybak J. I. 1975 – Ecosystem of the Mikołajskie Lake. Physico-chemical characteristics – Pol. Arch. Hydrobiol. 22: 9–16.

18. S p o d n i e w s k a I. 1976 – Changes in the structure and production of phytoplankton in Mikołajskie Lake, 1963–1972 – Limnologica (Berlin), 10: 299–306.
19. S z a j n o w s k i F. 1973 – Relationship between leaf area index and shoot production of *Phragmites communis* Trin. – Pol. Arch. Hydrobiol. 20: 257–268.
20. S z a j n o w s k i F. 1983 – Biotic structure and processes in the lake system of r. Jorka watershed (Masurian Lakeland, Poland). XI. Biomass and distribution of emergent macrophytes – Ekol. pol. 31: 793–800.
21. S z c z e p a ń s k i A. 1958 – Das Streuungsvermogen des Naturalwassers der masurischen Seenplatte – Pol. Arch. Hydrobiol. 5: 25–43.
22. S z c z e p a ń s k i A. 1978 – Ecology of macrophytes in wetlands – Pol. ecol. Stud. 4: 45–94.