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PREDICTING THE POLLUTION OF GREAT MASURIAN LAKES FROM POINT AND NONPOINT SOURCES

ABSTRACT: According to point and nonpoint sources for 1976 and 1990 Great Masurian Lakes are seriously endangered by nutrients. Out of twelve lakes examined seven has high external loading of nitrogen and phosphorus exceeding the unacceptable loading determined by Volenweider (1971). Point sources are responsible for phosphorus loading of Great Masurian Lakes and nonpoint sources – for nitrogen loading. Protection of these ecosystems is absolutely necessary.

KEY WORDS: Lakes, drainage area, pollution, predicting, point sources, nonpoint sources, phosphorus loading, nitrogen loading, unacceptable loading.

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1. INTRODUCTION

Great Masurian Lakes are the largest lake complex in Poland. They are joined (naturally or artificially) by waterways (Fig. 1) and the water level is almost constant 116 m a.s.l.

This region has a differentiated, beautiful landscape formed during the last glaciation, with rare specimens of flora and fauna and large natural water bodies (Lake Mamry – 2711 ha, Lake Śniardwy – 11340 ha). Agriculture and forestry are the main assets of the drainage area of Great Masurian Lakes (Table I).

Great Masurian Lakes are seriously endangered by tourism and economical development (industry, agriculture).

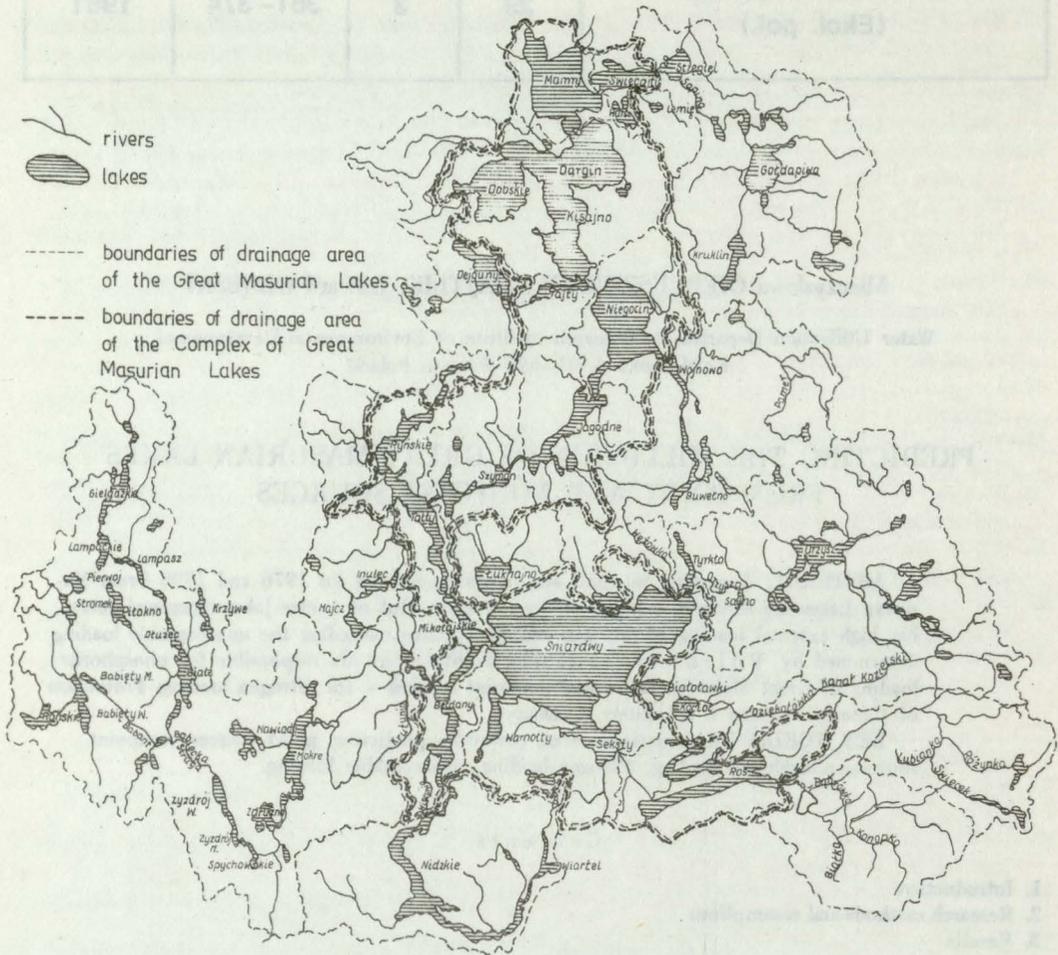


Fig. 1. Hydrographic map of Great Masurian Lakes (scale 1 : 600000)

Table I. Land use in the drainage area of Great Masurian Lakes

Drainage area of Great Masurian Lakes	Surface area						
	total*	arable land	meadows and pastures	forests	area with buildings	waste land	water
	km ²	%					
Direct	715.17	43.1	14.1	36.8	1.0	0.7	4.3
Whole	3603.30	37.7	9.2	37.9	0.4	0.4	14.4

*Determined after Stephan, Czarnecka and Stachy (in press).

Recent investigations of the purity of waters on this area (Soszka, Cydzik and Kudelska 1979) show that some water bodies are greatly polluted. Increased eutrophication in last years is a very disturbing fact. This is proved by results of investigations of Mikołajskie Lake (one of the most polluted lakes) in the years 1963–1977 (Spodniewska 1974, 1976, Pieczyńska 1976, Kajak 1978, Gliwicz et al. 1980). This is characterized by three-fold increase of phytoplankton biomass during summer stagnation in the last ten years. This is accompanied by higher oxygen deficits in the lake hypolimnion and longer periods of algal blooming (Spodniewska 1974, 1976).

This is a presentation of present and future pollution danger of Great Masurian Lakes due to increased anthropopressure. It indicates the urgency of protection of these ecosystems.

2. RESEARCH METHODS AND ASSUMPTIONS

Nutrient loading from point and nonpoint sources in 1976 is characterized for lakes: Dargin, Święcajty, Mamry, Tajty, Jagodne, Tałtowisko, Ryńskie-Tałty, Mikołajskie, Beldany, Śniardwy and Roś. Also total loading for Great Masurian Lakes is given.

Direct drainage areas and the drainage area of the complex of Great Masurian Lakes have been determined according to Stephan, Czarnecka and Stachy (in press) (see map in Figure 1 which is a cartographical illustration of the work). Surface area of direct and total drainage areas of complex of Great Masurian Lakes (Stephan, Czarnecka and Stachy – in press) are given in Table II.

Table II. Surface of drainage area (km²) of Great Masurian Lakes (acc. to Stephan, Czarnecka and Stachy – in press)

Lake	Drainage area	
	direct	whole
Dargin	87.1	169.4
Mamry	31.3	593.5
Święcajty	14.6	316.2
Niegocin	51.7	380.4
Tajty	26.2	89.3
Jagodne	89.5	497.7
Tałtowisko	72.1	579.2
Ryńskie-Tałty	53.4	782.8
Mikołajskie	14.1	1791.5
Beldany	46.1	966.9
Śniardwy	15.0	2425.3
Roś	78.9	2963.8

Nutrient load in sewage released directly into lakes and their tributaries has been calculated according to data from field services of environment protection. Nutrient concentration in sewage has been assumed after literature data (Stecher and Rupprecht 1940, Davidson 1950, Cywiński et al. 1972, Meinck, Stoff and Kohlschutter 1975) (Table III).

Reduction of nitrogen and phosphorus compounds in sewage treatment plants were de-

terminated according to purification method after Cywiński et al. (1972) and Huang and Hwang (1973) (Table IV).

In order to determine the load of Great Masurian Lakes with impurities from nonpoint sources, mean doses of mineral fertilizers used on the drainage area examined per surface area of fields ($70 \text{ kg N} \cdot \text{ha}^{-1}$ and $24 \text{ kg P} \cdot \text{ha}^{-1}$ on arable land and $86 \text{ kg N} \cdot \text{ha}^{-1}$ and $28 \text{ kg P} \cdot \text{ha}^{-1}$ on grassland) were taken into account giving the total of phosphorus and nitrogen fertilizers used in direct drainage areas of lakes and in drainage areas of their tributaries.

Table III. Concentration of nutrients in sewage ($\text{mg} \cdot \text{dm}^{-3}$)

Kind of sewage	N total	P total
Distillery wastes (potatoes)	410	88.0
Dairy wastes	30	2.5
Pork-butcher's wastes	145	7.6
Municipal wastes	40	11.4

Table IV. Reduction of nitrogen and phosphorus in sewage treatment (per cents)

Kind of treatment	N total	P total
Mechanical cleaning	20	20
Mechanical-biological cleaning	50	40
III degree of water purification	50	90

Table V. Fertilizers in direct drainage areas of Great Masurian Lakes in 1976 (thous. $\text{kg} \cdot \text{year}^{-1}$)

Drainage area of lake	Arable land			
	mineral fertilizers		organic fertilizers	
	N	P	N	P
Dargin	478	158	—	—
Mamry	145	49	—	—
Święcajty	80	27	—	—
Niegocin	302	100	62	11
Tajty	166	56	9	2
Jagodne	557	185	—	—
Tałtowisko	426	141	—	—
Ryńskie-Tałty	254	85	—	—
Mikołajskie	67	22	10	2
Beldany	58	19	—	—
Śniardwy	354	118	18	3
Roś	150	49	—	—

On the whole, in direct drainage areas of Great Masurian Lakes in 1976, 3037 thousand of kg of nitrogen fertilizers and 1009 thousand of kg of phosphorus fertilizers were used. In drainage areas with large scale farms the nutrient loading from the faeces should

be added (Table V). The calculations take into consideration the kind of animals being bred, their numbers and amount of nutrients in the faeces.

Data for 1990 as regards the amount of sewage, fertilization level of arable land in the drainage area of Great Masurian Lakes, have been based on indices for the development of industry, agriculture and human population and the canalization project for the future in this region.

The nutrient loading from nonpoint sources supplying Great Masurian Lakes has been calculated after Vollenweider (1971), who has determined the percentage of penetration of nitrogen and phosphorus compounds from fertilizers into water. The calculations assumed the bottom limit of flow from arable lands: 1% of phosphorus and 10% of nitrogen. The flow of nutrients from forests of the drainage area of lakes after Vollenweider (1971) has been assumed as constant, i.e., 1 kg of nitrogen and 0.1 kg of phosphorus from 1 ha of the forest.

Nutrient loading of Great Masurian Lakes by means of tributaries has been calculated by summing the nutrient flow from point and nonpoint sources of the drainage area.

In the case of tributaries with lakes on their way the nutrient loading of waters decreased by 80% assuming their retention in lakes.

Total nutrient loading of Great Masurian Lakes from point and nonpoint sources has been calculated using the equation:

$$L = \frac{\sum (I_{sj} \cdot C_{sj})}{A_o} + \frac{(N_j \cdot A_{rj}) V_r + (A_{Lj} \cdot V_L)}{A_o} +$$

$$\frac{[\sum (I_{sd} \cdot C_{sd}) + (N_d \cdot A_{rd}) V_r + (A_{Ld} \cdot V_L)] R}{A_o}$$

I_{sj} – amount of sewage inflowing to the lake, C_{sj} – concentration of nutrients released into the lake, A_o – lake surface area, N_j – present mean dose of fertilizers used on arable land in the direct drainage area of the lake, A_{rj} – surface area of arable land in the direct drainage area of the lake, V_r – coefficient of the flow of nutrients from arable lands of the drainage area after Vollenweider (1971) (0.1 of nitrogen and 0.01 of phosphorus), A_{Lj} – surface area of forests in the direct drainage area of the lake, V_L – coefficient of the nutrient flow from the forests of the drainage area after Vollenweider (1971) (0.01 of nitrogen and 0.001 of phosphorus from 1 ha of forest), I_{sd} – amount of sewage released to lake tributaries, C_{sd} – nutrient concentration in sewage released into lake tributaries, N_d – present, mean dose of fertilizers used on arable lands of the drainage area of lake tributaries, A_{rd} – surface area of arable land in the drainage area of lake tributaries, A_{Ld} – surface area of forests in the drainage area of lake tributaries, R – coefficient of nutrient retention in lakes of the drainage area of tributaries (0.2).

The calculations do not include the inflow of nitrogen and phosphorus with water from neighbouring lakes within the complex of Great Masurian Lakes and with underground waters and precipitation.

Table VI. Present and predicted nutrient loading of the complex of Great Masurian Lakes from point and nonpoint sources of the direct drainage area and tributaries

Year	Direct drainage area				Indirect drainage area (tributaries)				Total			
	point sources		nonpoint sources		N total	P total	%	N total	P total	%	N total	P total
	N total	P total	N total	P total								
	$g \cdot m^{-2} \cdot year^{-1}$	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	$g \cdot m^{-2} \cdot year^{-1}$				
1976	0.43	0.10	0.81	0.03	1.62	0.11	45.8	2.86	0.24		2.86	0.24
1990	1.03	0.29	1.67	0.05	2.88	0.20	37.0	5.58	0.54		5.58	0.54

The serious situation of Great Masurian Lakes is illustrated by comparing the calculated external phosphorus and nitrogen loading of these lakes with the determined after Vollenweider (1971) unacceptable loading of lakes of the same depth.

3. RESULTS

3.1. POLLUTION OF GREAT MASURIAN LAKES IN 1976

An analysis of pollution of Great Masurian Lakes for 1976 as a result of industry, agriculture and tourism illustrates the problem.

Nitrogen loading of sewage reaching the lake 126.7 thousand $kg \cdot year^{-1}$ and phosphorus loading 31.7 thousand $kg \cdot year^{-1}$ in an amount of about 10000 $m^3 \cdot day^{-1}$ increase in summer up to 12000 $m^3 \cdot day^{-1}$ due to intense tourism in this region. At low level of sewage treatment the crude sewage and industrial wastes decide considerably about the pollution of these ecosystems.

Large area of arable land (57%), high doses of fertilizers (about 210 $kg \text{ NPK} \cdot ha^{-1}$) and the use of faeces from maintenance of domestic animals (but without straw) in direct drainage areas of lakes Niegocin, Tajty, Mikołajskie, Śniardwy contribute greatly to the flow of impurities from fields into Great Masurian Lakes and the loading is 254 thousand $kg \text{ N} \cdot year^{-1}$ and 9.8 thousand $kg \text{ P} \cdot year^{-1}$.

Varied hydrographic net (Fig. 1) also favours the transport of loading to lakes from the indirect drainage area. Both nitrogen and phosphorus loadings reaching the lakes by means of tributaries are high (508 thous. $kg \text{ N} \cdot year^{-1}$ and 33.1 thous. $kg \text{ P} \cdot year^{-1}$).

Most of phosphorus comes from point sources of direct and indirect drainage area, and of nitrogen – from nonpoint sources (Table VI).

Nitrogen and phosphorus loadings for the entire complex of Great Masurian Lakes exceed already the level assumed by Vollenweider (1971) as unacceptable (Table VI, Figs. 2, 3).

When analysing the pollution of 12 Great Masu-

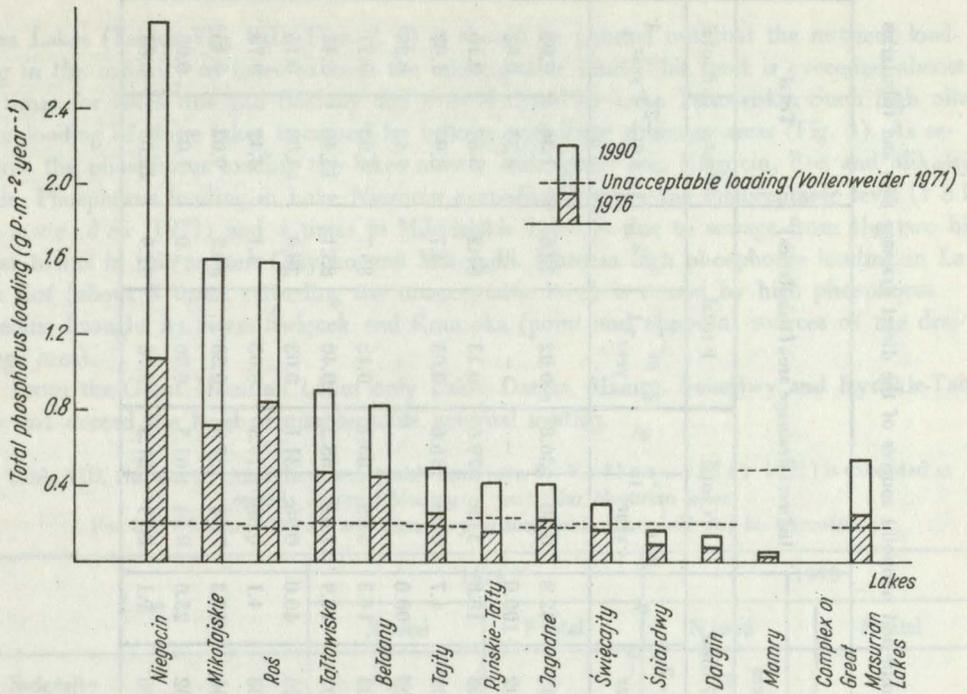


Fig. 2. Present (1976) and predicted (1990) phosphorus loading for Great Masurian Lakes

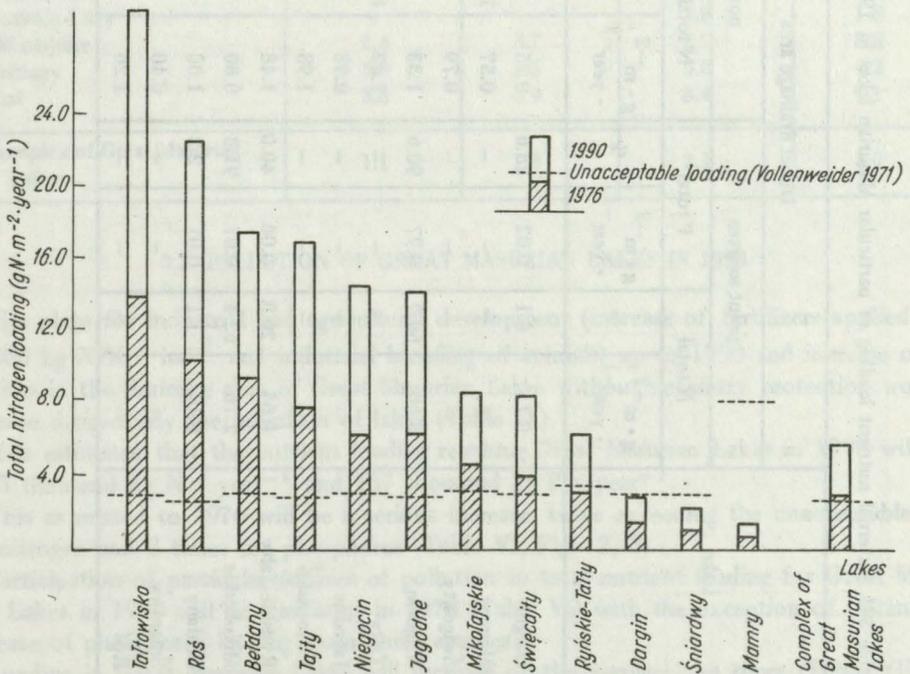


Fig. 3. Present (1976) and predicted (1990) nitrogen loading for Great Masurian Lakes

Table VII. External nutrient loading of particular Masurian lakes in 1976 from point and nonpoint sources of the direct drainage area and tributaries

Lake	Direct drainage area								Indirect drainage area (tributaries)				Total	
	point sources				nonpoint sources									
	N total		P total		N total		P total		N total		P total		N total	P total
	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	
Dargin	0.11	8.1	0.02	28.6	0.75	55.1	0.03	42.8	0.50	36.8	0.02	28.6	1.36	0.07
Mamry	—	—	—	—	0.57	100.0	0.02	100.0	—	—	—	—	0.57	0.02
Święcajty	—	—	—	—	0.79	20.4	0.03	18.8	3.08	79.6	0.13	81.2	3.87	0.16
Niegocin	3.60	60.9	0.97	90.6	1.33	22.5	0.05	4.7	0.98	16.6	0.05	4.7	5.91	1.07
Tajty	—	—	—	—	7.42	100.0	0.25	100.0	—	—	—	—	7.42	0.25
Jagodne	—	—	—	—	0.98	16.3	0.03	14.3	5.05	83.7	0.18	85.7	6.03	0.21
Tałtówisko	—	—	—	—	1.98	14.8	0.07	14.9	11.42	85.2	0.40	85.1	13.40	0.47
Ryńskie-Tałty	0.64	20.8	0.06	40.0	1.48	48.1	0.06	40.0	0.96	31.1	0.03	20.0	3.08	0.15
Mikołajskie	2.76	62.4	0.67	91.8	0.80	18.1	0.03	4.1	0.86	19.5	0.03	4.1	4.42	0.73
Bekdany	0.10	1.1	0.01	2.2	1.00	11.1	0.06	13.3	7.92	87.8	0.38	84.5	9.02	0.45
Śniardwy	—	—	—	—	0.40	38.5	0.02	25.0	0.64	61.5	0.06	75.0	1.04	0.08
Roś	—	—	—	—	1.26	12.5	0.06	7.1	8.79	87.5	0.78	92.9	10.05	0.84

rian Lakes (Tables VII, VIII, Figs. 2, 3) it should be pointed out that the nutrient loading in the majority of lakes exceeds the unacceptable limit. This limit is exceeded almost 3 times for lakes Roś and Będany and even 4 times for Lake Tałtowisko. Such high nitrogen loading of these lakes is caused by inflows with large drainage areas (Fig. 1). As regards the phosphorus loading the lakes mostly endangered are: Niegocin, Roś and Mikołajskie. Phosphorus loading in Lake Niegocin exceeding 5 times the unacceptable level (Vollenweider 1971) and 4 times in Mikołajskie Lake, is due to sewage from the two biggest towns in this region: Giżycko and Mikołajki. Whereas high phosphorus loading in Lake Roś (about 5 times exceeding the unacceptable level) is caused by high phosphorus loading brought by rivers Świąćek and Konopka (point and nonpoint sources of the drainage area).

From the Great Masurian Lakes only Lakes Dargin, Mamry, Śniardwy and Ryńskie-Tały do not exceed the level of unacceptable external loading.

Table VIII. Number of times the unacceptable limit (acc. to Vollenweider 1971) is exceeded as regards external loading of particular Masurian lakes
For lakes Mamry, Dargin and Śniardwy unacceptable limit will not be exceeded

Lake	1976		1990	
	N total	P total	N total	P total
Świąćajty	1.3	—	2.7	1.5
Niegocin	2.0	5.4	4.7	14.5
Tajty	2.6	1.3	5.7	2.5
Jagodne	2.2	1.2	4.9	2.2
Tałowisko	4.6	2.4	10.4	4.6
Ryńskie-Tały	—	—	1.8	1.8
Mikołajskie	1.4	3.7	2.7	8.0
Będany	3.0	2.3	5.6	4.2
Roś	3.8	4.9	8.4	9.1
Complex of Great Masurian Lakes	1.1	1.3	2.1	3.0

3.2. POLLUTION OF GREAT MASURIAN LAKES IN 1990

The plans for industrial and agricultural development (increase of fertilizers applied up to 360 kg NPK · ha⁻¹ and industrial breeding of animals) up to 1990 and increase of tourism in the drainage area of Great Masurian Lakes without necessary protection would increase dangerously the pollution of lakes (Table IX).

It is estimated that the nutrient loading reaching Great Masurian Lakes in 1990 will be 1755 thousand kg N · year⁻¹ and 167 thousand kg P · year⁻¹.

This as related to 1976 will be a serious increase, twice exceeding the unacceptable limit for nitrogen and 3 times for phosphorus (Table VI, Figs. 2, 3).

Participation of particular sources of pollution in total nutrient loading for Great Masurian Lakes in 1990 will be similar as in 1976 (Table VI) with the exception of distinct increase of phosphorus loading from point sources.

Loading in Great Masurian Lakes will increase on the average 2–3 times (Table VIII)

Table IX. External nutrient loading of particular Masurian lakes in 1990 from point and nonpoint sources of the direct drainage area and tributaries

Lake	Direct drainage area								Indirect drainage area (tributaries)				Total	
	point sources				nonpoint sources				N total		P total		N total	P total
	N total		P total		N total		P total		N total		P total			
	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	%	$g \cdot m^{-2} \cdot year^{-1}$	
Dargin	0.19	6.6	0.04	30.8	1.46	51.2	0.05	38.4	1.21	42.2	0.04	30.8	2.86	0.13
Mamry	—	—	—	—	1.29	100.0	0.04	100.0	—	—	—	—	1.29	0.04
Święcajty	—	—	—	—	1.97	14.0	0.06	20.7	6.17	86.0	0.23	79.3	8.14	0.29
Niegocin	9.59	68.3	2.73	94.5	2.39	17.0	0.07	3.3	2.06	14.7	0.09	3.1	14.04	2.89
Tajty	—	—	—	—	16.16	100.0	0.48	100.0	—	—	—	—	16.16	0.48
Jagodne	—	—	—	—	2.21	16.2	0.06	15.0	11.42	83.8	0.34	85.0	13.63	0.40
Tałowisko	—	—	—	—	4.47	14.7	0.13	14.3	25.88	85.3	0.78	85.7	30.35	0.91
Ryńskie-Tałty	0.87	14.4	0.25	61.0	3.33	55.0	0.10	24.4	1.85	30.6	0.06	14.6	6.05	0.41
Mikołajskie	5.27	63.7	1.50	94.3	1.54	18.6	0.05	3.1	1.46	17.7	0.04	2.6	8.27	1.59
Bekłany	0.11	0.7	0.01	1.2	1.97	11.7	0.09	10.8	14.70	87.6	0.73	88.0	16.78	0.83
Śniardwy	—	—	—	—	0.82	35.8	0.03	20.0	1.47	64.2	0.12	80.0	2.29	0.15
Roś	—	—	—	—	2.57	11.7	0.09	5.8	19.48	88.3	1.45	94.2	22.05	1.54

and in many cases this will be disastrous. Lake Tałtowisko will exceed the unacceptable nitrogen loading over 10 times and Lake Roś 8 times. Phosphorus loading of Lake Niegocin will exceed over 14 times the level considered by Vollenweider (1971) as unacceptable, Lake Roś – 9 times and Mikołajskie Lake – 8 times.

Only lakes Dargin, Mamry and Świącjayty will not exceed the limit of unacceptable loading in 1990 for all Great Masurian Lakes.

4. DISCUSSION

The drainage area of Great Masurian Lakes because of its natural value and future use of waters should be under special protection. This is why thorough investigations are being conducted on this area. This is the first estimation of loading of phosphorus and nitrogen of the whole complex of Great Masurian Lakes.

Górski and Rybak (1974) have calculated the phosphorus loading of Mikołajskie Lake ($0.34 \text{ g} \cdot \text{m}^{-2} \cdot \text{year}^{-1}$) which is one of the most polluted lakes in the complex of lakes. Phosphorus loading in Mikołajskie Lake in 1976 is almost twice higher (Table VII) in present paper due to other assumptions and to real increase of loading.

Schaffner and Oglesby (1976 after Schaffner and Oglesby 1978), when estimating phosphorus loading in eight Finger Lakes of New York have also observed that estimations for one lake conducted by different authors are not consistent. In their opinion methods of estimation are more at fault than natural variability.

Lake Owasco polluted by industrial and crude sewage has phosphorus loading $0.97 \text{ g} \cdot \text{m}^{-2} \cdot \text{year}^{-1}$ (Oglesby, Schaffner and Mills 1975 after Schaffner and Oglesby 1978), i.e., less than Lake Niegocin which has the highest load of phosphorus of all Masurian lakes (Table VII). Phosphorus loading of the other seven Finger Lakes of New York has been determined within the range $0.23\text{--}0.64 \text{ g} \cdot \text{m}^{-2} \cdot \text{year}^{-1}$.

Patalas (1972) has calculated phosphorus loading in Lake Superior – $0.03 \text{ g} \cdot \text{m}^{-2} \cdot \text{year}^{-1}$ and in Lake Huron – $0.15 \text{ g} \cdot \text{m}^{-2} \cdot \text{year}^{-1}$. According to Vollenweider (1971) the surface area of Lake Aegersee has $0.16 \text{ g} \cdot \text{m}^{-2} \cdot \text{year}^{-1}$ of phosphorus load, whereas that for lakes Sempacher, Ontario, Melar, Erie, Zurich Lake and Boden Lake as given by Vollenweider (1971), Patalas (1972), Ahl (1975), Snodgrass and O'Melia (1975) remained within $0.7\text{--}1.3 \text{ g} \cdot \text{m}^{-2} \cdot \text{year}^{-1}$. Nitrogen loading was determined only for Lake Melar ($11.2 \text{ g} \cdot \text{m}^{-2} \cdot \text{year}^{-1}$). Phosphorus loadings of lakes vary greatly.

Phosphorus and nitrogen loadings of Great Masurian Lakes, such as Niegocin, Tajty, Jagodne, Tałtowisko, Mikołajskie, Beldany and Roś exceed the unacceptable loading as determined by Vollenweider (1971) (Table VIII, Figs. 2, 3).

In the case of phosphorus loading in the complex of Great Masurian Lakes point sources are mainly responsible and nonpoint sources – for nitrogen (Table VI). Similar are the proportions for Lake Malaren and the Swedish and California lakes (75–90% P point sources) as shown by Landner (1976), for Lubuskie Lakes (60% P – point sources) according to Solski after Kajak (1979), for Mikołajskie Lake (86% P point sources), Górski and Rybak (1974). Whereas Lee (1970) has analysed in detail sources of nutrient export from drainage area to Lake Mendota proving that only 53% of phosphorus loading in the lake is from point sources. This, undoubtedly, depends on the size of drainage area, its management, the presence and kind of point sources.

Considerable increase of loading of Great Masurian Lakes predicted for 1990, the high eutrophy and pollution of these lakes already, will cause gradual deterioration of water quality.

Thus it is absolutely necessary to reduce the pollution (Table X). This required in 1976 a 37.5–90.7% phosphorus loading reduction and 61.2–85.1% of nitrogen loading reduction (counting from the acceptable level) in lakes Niegocin, Mikołajskie, Tałtowisko, Beldany, Roś, Tajty, Jagodne and Świącayty.

Table X. Necessary reduction of nutrient loading (per cents related to acceptable level determined by Vollenweider 1971) in particular Masurian lakes

The low nitrogen and phosphorus loading in Lake Mamry does not require reduction

Lake	1976		1990	
	N total	P total	N total	P total
Dargin	—	—	47.6	23.1
Świącayty	61.2	37.5	81.6	65.5
Niegocin	74.6	90.7	89.3	96.5
Tajty	79.8	60.0	90.7	79.2
Jagodne	75.1	52.4	89.0	75.0
Tałtowisko	70.2	46.8	86.8	72.5
Ryńskie-Tałty	—	—	33.9	39.0
Mikołajskie	66.1	86.3	81.9	93.7
Beldany	83.4	77.8	91.1	87.9
Śniardwy	—	—	34.5	33.3
Roś	85.1	88.1	93.2	93.5

The loading in Great Masurian Lakes will increase in 1990 and the required reduction of phosphorus loading is 23.1–96.5% and of nitrogen 33.9–93.2%.

Reduction of the inflow of impurities from the drainage area to Great Masurian Lakes requires radical protection of these ecosystems. Most important seems proper management of sewage treatment plants on the drainage area. Complete cutting of sewage from Great Masurian Lakes can only reduce the external phosphorus loading for lakes Niegocin and Mikołajskie. Lakes Świącayty, Tajty, Ryńskie-Tałty, Beldany and Roś will remain under the influence of nonpoint sources and tributaries (Table IX) and phosphorus and nitrogen loading will exceed the unacceptable limit as determined by Vollenweider (1971). Therefore, apart from dealing with the discharge of impurities from point sources their flow from nonpoint sources should be limited by lowering the doses of fertilizers, a ban on fertilizing aircraft and the use of faeces in direct drainage areas of lakes and their tributaries.

Great Masurian Lakes are a group of joined lakes with inflow and outflow (Fig. 1). As the majority of these lakes are considerably polluted the loading can be transported from one lake to another. And so, Lake Jagodne is distinctly affected by polluted water from highly eutrophic Lake Niegocin, and polluted Mikołajskie Lake pollutes Lake Śniardwy.

The real danger of pollution of Great Masurian Lakes is greater than described here because the pollution due to erosion, underground water, precipitation and internal loading has not been taken into consideration.

5. SUMMARY

According to analysis of pollution from point and nonpoint sources and by tributaries the present nutrient load and that for 1990 in 12 lakes and the entire complex of Great Masurian Lakes have been estimated (Table VI). Serious external nitrogen and phosphorus loadings exceeding the unacceptable level as determined by Vollenweider (1971) have been found in lakes: Niegocin, Tajty, Tałtowski, Mikołajskie, Bełdany and Roś (Figs. 2, 3). Lakes Dargin, Mamry, Śniardwy and Ryńskie-Tały do not exceed the level of unacceptable external loading.

Point sources are responsible for external phosphorus loading of Great Masurian Lakes, whereas non-point sources – for nitrogen (Table VI).

Intense nitrogen transport by means of tributaries – 56.6% of nitrogen loading and 45.8% of phosphorus loading in the complex of Great Masurian Lakes – has been pointed out (Table VI). For lakes Święcajty, Jagodne, Tałtowski, Bełdany and Roś the nutrient loading by means of tributaries exceeded 80% (Table VII).

In 1990 as compared to 1976 external nutrient loading in the complex of Great Masurian Lakes will increase two times (Table VI) resulting in further deterioration of the quality of water.

Thus it is absolutely necessary to reduce pollution as quick as possible (Table X). This requires first of all a radical programme for protection of these ecosystems.

6. POLISH SUMMARY

Na podstawie szacunkowej analizy dopływających do jezior zanieczyszczeń ze źródeł punktowych i przestrzennych oraz z wodami dopływów, określono aktualne i przewidywane na rok 1990 obciążenie substancjami biofilnymi 12 jezior oraz całego kompleksu Wielkich Jezior Mazurskich (tab. VI). Wykazano poważne obciążenie zewnętrzne azotem i fosforem przekraczające poziom niebezpieczny, określony przez Vollenweidera (1971) dla jezior: Niegocin, Tajty, Tałtowski, Mikołajskie, Bełdany i Roś (rys. 2, 3). Jeziora Dargin, Mamry, Śniardwy oraz Ryńskie-Tały nie przekraczają poziomu niebezpiecznego obciążeń zewnętrznych.

Oceniono, że o obciążeniu zewnętrznym fosforem Wielkich Jezior Mazurskich decydują źródła punktowe, zaś azotem źródła przestrzenne (tab. VI).

Zwrócono uwagę na intensywny transport do jezior, zarówno azotu jak i fosforu wodami dopływających rzek, który w skali kompleksu Wielkich Jezior Mazurskich stanowi 56,6% dopływającego ładunku azotu oraz 45,8% ładunku fosforu (tab. VI). Dla jezior Święcajty, Jagodne, Tałtowski, Bełdany i Roś ładunek związków biofilnych wnoszony dopływami przekracza 80% (tab. VII).

W 1990 r. obciążenie zewnętrzne związkami biofilnymi kompleksu Wielkich Jezior Mazurskich w stosunku do 1976 r. 2-krotnie wzrośnie (tab. VI), co wpłynie niewątpliwie na dalsze pogarszanie się jakości ich wód.

Aktualny i prognozowany stan zagrożenia Wielkich Jezior Mazurskich wskazują na pilną konieczność redukcji dostających się do nich zanieczyszczeń (tab. X). Można to osiągnąć przede wszystkim drogą realizacji radykalnych przedsięwzięć ochronnych tych ekosystemów.

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