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ASSESSMENT OF WATERSHED IMPACT AND SENSITIVITY OF LAKES TO DEGRADATION IN SUWAŁKI LANDSCAPE PARK (NORTH-EASTERN POLAND)

ABSTRACT: For 19 lakes of Suwałki Landscape Park (north-eastern Poland) the watershed sensitivity to matter inflow for the group of lakes was assessed as well as the category of lake resistance to eutrophication. The principles of this assessment are given. On the basis of morphometric characters of lake and its watershed, four groups of ecological systems "watershed – lake" of a differentiated rate of natural eutrophication, were distinguished. The lakes of Suwałki Landscape Park are presented according to these groups.

KEY WORDS: watershed, lake, eutrophication, Suwałki Landscape Park.

1. INTRODUCTION

The eutrophication rate of lakes is amongst others selected to the physico-geographical structure of the watershed, enhancing or not enhancing the supply of nutrients to the lake, and the natural features of the lake. The system suggested by B a j k i e w i c z - G r a b o w s k a (1985, 1987), consists of four groups of an watershed impact on lakes and four categories of lake sensitivity (as a receiver of watershed matter) to degradation, and roughly assesses the effect of these factors.

2. METHOD AND RESULTS

The impact of watershed on the lake is estimated on the basis of characteristic features both the total lake watershed and its direct watershed. The features are as

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follows: Ohle coefficient (quotient of total lake watershed and water body surface area), type of lake balance (flow, outflow, within outflow) providing information about including the water body into the surface runoff system. In the case of direct watershed (from where the matter load reaches the lake) it is the size of watershed affectively participating in matter inflow (the degree of its lack of outflow). Also the average watershed slope, the degree of which conditions the non point sources, density of channel network (as means of direct and fast matter transport), permeability of ground (deciding about transport to underground waters) and way of area utilization, affecting the amount and form of bioelements in the surface runoff (Tables 1, 2).

The impact of watershed on the rate of matter inflow to the lake is estimated by quality classification of each of the mentioned parameters from 0 to 3 points, where 0 means a very little impact on the inflow of matter and practically no possibility of reaching the lake, whereas 3 is a great impact and fast matter inflow to the lake. The final estimation is an arithmetical mean of points obtained when estimating particular parameters, and it qualifies the given watershed to one of the four sensitivity groups.

Group 1 – the mean value is smaller or equals 1; the watershed limits greatly the surface runoff, indicating practically no possibility of matter inflow to the lake; this group is not found amongst lakes of Suwałki Landscape Park.

Group 2 – mean value 1.1–1.4; the watershed is characterized by low susceptibility to mobilize the load deposited on its area and the low possibility of reaching the lake; this groups consists of watersheds of lakes: Jegliniszki, Hańcza, Szurpiły, Jeglówek and Perty (Table 3).

Group 3 – mean value 1.5–1.9; the watershed has an average impact, i.e., moderate possibilities of matter supply; to this group belong the watersheds of lakes: Szelment Wielki, Szelment Mały, Kopane, Jaczno and Kamenduł (Table 3).

Group 4 – mean value equals or exceeds 2.0; the watershed provides great possibilities of supplying matter to the lake. To this group belong watersheds of the majority of lakes of Suwałki Landscape Park (Table 3).

In estimating the natural resistance of lakes to eutrophication, the modified by B a j k i e w i c z - G r a b o w s k a (1978) part of the so-called System of Estimating Lake Quality (K u d e l s k a et al. 1983) can be applied. The characters conditioning the resistance of lakes to the impact of watershed, estimated from 0 to 3 points, are: mean lake depth, quatient of lake volume and its shoreline length, per cent of water stratification (i.e., percentage of meta- and hypolimnion layers in whole water mass), quatient of bottom surface within the epilimnion and epilimnion volume, mean annual intensity of water exchange in the lake (i.e., quotient of annual outflow and lake volume) and also Schindler's coefficient, i.e., quotient of lake surface (as pollution receiver) lake volume (as the water masses diluting) (Table 4).

The final estimation is an arithmetical mean of the impact estimations of particular resistance features of the lake (Table 5). The mean value, lower or equal 0.8, indicates that the lake belongs to I category (greatly resistant to external

Table 1. Selected physico-geographical characters of total and direct lake watersheds in Suwałki Landscape Park

Lake	Total lake watershed surface (km^2)	Ohle coefficient*	Water balance of lake	Surface of direct lake watershed** (km^2)	Areas without surface outflow in the direct watershed (%)	Drainage density of in the watershed (km · km^{-2})	Average slope of direct watershed (‰)
Jegliniszki	7.59	47	outflow	7.59	63	0.61	21
Hańcza	41.36	13	flow through	33.77	35	0.49	12
Szelment Wielki	54.08	15	flow through	54.08	4	0.81	9
Szelment Mały	80.27	48	flow through	26.19	1	1.00	13
Iłgieł	84.15	492	flow through	3.53	0	0.99	37
Kupowo	96.64	295	flow through	12.49	0	0.91	20
Szurpiły	11.14	14	outflow	11.14	56	0.07	21
Kopane	12.39	82	outflow	0.67	0	0.00	95
Jeglówek	1.80	9	outflow	1.80	3	0.50	43
Udziejek	16.08	264	flow through	0.97	10	0.00	85
Jaczno	13.88	35	flow through	13.88	33	0.15	32
Kamenduł	18.42	72	flow through	1.06	0	0.00	57
Gulbin	53.37	721	flow through	2.99	3	1.49	62
Okrągłe	55.17	317	flow through	1.80	0	1.56	38
Krajwelek	57.15	572	flow through	1.98	0	1.06	65
Przechodnie	64.37	227	flow through	4.74	0	1.44	43
Perty	2.48	13	outflow	2.48	10	0.18	55
Postawelek	66.51	2217	flow through	2.14	0	1.59	54
Pobondzie	92.88	175	flow through	14.10	24	0.38	31

*See text for explanation. ** Direct watershed of all lakes are of loam-sandy type.

Table 2. Land use in the direct watershed of lakes of Suwałki Landscape Park (% of area)

Lake	Forest	Arable land	Meadows and pastures	Wasteland	Buildings	Waters	Types of direct utilization of lakes wateshed
Jegliniszki	1.0	75.0	24.0	–	–	–	pasture-agricultural
Hańcza	15.8	69.3	14.6	–	–	0.3	pasture-forest-agricultural
Szelment Wielki	5.6	75.2	16.7	1.5	–	0.8	pasture-agricultural
Szelment Mały	20.6	58.5	20.0	0.5	0.3	0.1	pasture-forest-agricultural
Iłgieł	46.5	43.7	9.8	–	–	–	pasture-agricultural
Kupowo	13.2	68.0	17.2	1.6	–	–	pasture-agricultural
Szurpiły	9.9	79.6	6.9	3.0	0.6	–	agricultural
Kopane	27.7	54.9	16.8	0.6	–	–	pasture-forest-agricultural
Jeglówek	30.7	60.1	9.2	–	–	–	forest-agricultural
Udziejek	8.4	81.6	10.0	–	–	–	agricultural
Jaczno	20.0	74.7	5.3	–	–	–	forest-agricultural
Kamenduł	80.0	18.0	2.0	–	–	–	forest
Gulbin	18.8	75.2	4.0	2.0	–	–	agricultural
Okrągłe	21.8	65.6	12.6	–	–	–	pasture-forest-agricultural
Krajwelek	7.4	86.6	6.0	–	–	–	agricultural
Przechodnie	24.6	54.9	20.5	–	–	–	pasture-forest-agricultural
Perty	50.0	39.0	11.0	–	–	–	pasture-forest-agricultural
Postawelek	23.0	48.7	28.3	–	–	–	pasture-forest-agricultural
Pobondzie	30.9	62.8	6.3	–	–	–	forest-agricultural

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Table 3. Presentation of lake watersheds of Suwałki Landscape Park acc. to groups of watershed impact on the lake

Lake	Point estimation of particular physico-geographical characters of the watershed							
	Ohle coefficient*	water balance	areas without surface runoff	average slope of watershed	drainage density	geological substrate	land use	result of scoring ($\bar{x}$)
Group 2 – low impact (1.1 ≤ x ≤ 1.4)								
Jegliniszki	2	1	0	3	1	2	1	1.43
Hańcza	1	3	2	2	0	2	0	1.43
Szurpiły	1	1	3	1	0	2	2	1.43
Jeglówek	0	1	3	3	0	2	1	1.43
Perty	1	1	3	3	0	2	0	1.43
Group 3 – moderate impact (1.5 ≤ x ≤ 1.9)								
Szelment Wielki	1	3	3	1	1	2	1	1.71
Szelment Mały	2	3	3	1	1	2	0	1.71
Kopane	2	1	3	3	0	2	0	1.57
Jaczno	1	3	2	3	0	2	1	1.71
Kamenduł	2	3	3	3	0	2	0	1.86
Group 4 – high impact (x ≥ 2.0)								
Iłgieł	3	3	3	3	1	2	1	2.29
Kupowo	3	3	3	2	1	2	1	2.14
Udziejek	3	3	3	3	0	2	2	2.29
Gulbin	3	3	3	3	2	2	2	2.57
Okrągłe	3	3	3	3	3	2	0	2.43
Krajwelek	3	3	3	3	2	2	2	2.57
Przechodnie	3	3	3	3	2	2	0	2.29
Postawelek	3	3	3	3	3	2	0	2.43
Pobondzie	3	3	2	3	0	2	1	2.00

*See text for explanation.

Table 4. Parameters of natural resistance of Suwałki Landscape Park lakes to the influence of watershed

Lake	Mean depth of lake (m)	Ratio of lake volume to the length of shoreline	Percent of water stratification	Ratio of surface of active bottom to epilimnion volume	Water exchange*	Schindler's coefficient**
Jegliniszki	1.2	0.09	0	0.27	7.8	38
Hańcza	38.7	10.2	77	0.03	0.07	0.3
Szelment Wielki	15.0	2.8	70	0.05	0.09	1
Szelment Mały	7.4	1.3	46	0.10	2.5	6
Iłgieł	4.0	0.35	15	0.18	50	120
Kupowo	5.0	0.44	26	0.14	22	60
Szurpiły	10.0	1.23	59	0.08	0.27	1
Kopane	5.6	0.44	34	0.13	3.1	14
Jeglówek	9.6	0.79	55	0.07	0.18	1
Udziejek	3.8	0.23	7	0.24	13.4	70
Jaczno	10.0	0.79	39	0.06	0.63	4
Kamendul	6.8	0.75	42	0.10	2.2	11
Gulbin	5.6	0.24	12	0.23	40	201
Okrągłe	4.7	0.47	44	0.09	15	68
Przechodnie	3.3	0.43	13	0.21	16	68
Perty	6.0	0.46	47	0.15	0.4	2
Pobondzie	3.6	0.40	12	0.25	30	48

*Outflow from lakes was calculated on the basis of mean outflows in the years 1980–1984 **See text for explanation.

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Table 5. Presentation of Suwałki Landscape Park lakes acc. to category of their natural resistance to the influence of watershed

Lake	Estimation of score of particular resistance characters of the lake						
	mean lake depth	lake volume to shoreline length	percent of stratification	surface of active bottom to epilimnion capacity	intensity of water exchange	Schinder's coefficient*	scoring result
Category I – high resistance ($x \leq 0.8$)							
Hańcza	0	0	0	0	3	0	0.5
Szelment Wielki	0	2	0	0	3	0	0.8
Szelment Mały	1	2	0	0	2	0	0.8
Szurpiły	0	2	0	0	3	0	0.8
Category II – moderate resistance ($0.9 \leq x \leq 1.6$)							
Kupowo	1	3	1	1	0	2	1.3
Kopane	1	3	1	1	2	1	1.5
Jeglówek	1	3	0	0	3	0	1.2
Jaczno	0	3	0	0	3	0	1.0
Kamenduł	1	3	0	0	2	1	1.2
Perty	1	3	0	0	3	0	1.2
Okrągłe	2	3	0	0	0	2	1.2
Category III – low resistance ($1.7 \leq x \leq 2.4$)							
Jegliniszki	3	3	3	2	1	2	2.3
Iłgieł	2	3	2	2	0	3	2.0
Udziejek	2	3	3	2	0	2	2.0
Przechodnie	2	3	2	2	0	2	1.8
Gulbin	1	3	2	2	0	3	1.8
Pobondzie	2	3	2	2	0	2	1.8

*See text for explanation.

POLAND

L.Pobondzie

L.Kupowo

L.Jegliniszki

L.Białe

L.Czarne

L.Kojle

L.Przechodnie

L.Jaczno

L.Perty

L.Krajwelek

L.Jałowo

L.Itgiet

L.Okrągłe

L.Hańcza

L.Kamendut

L.Gulbin

L.Sumowo

L.Szelment Mały

L.Boczniel

L.Kopane

L.Jeglówek

L.Szelment Wielki

Szeszupa r.

Szeszupa r.

Szelmentka r.

Czarna Hańcza r.

L.Szurpiły

Resistance category

I
II
III

Susceptibility group

II
III
IV

0 1 2 km
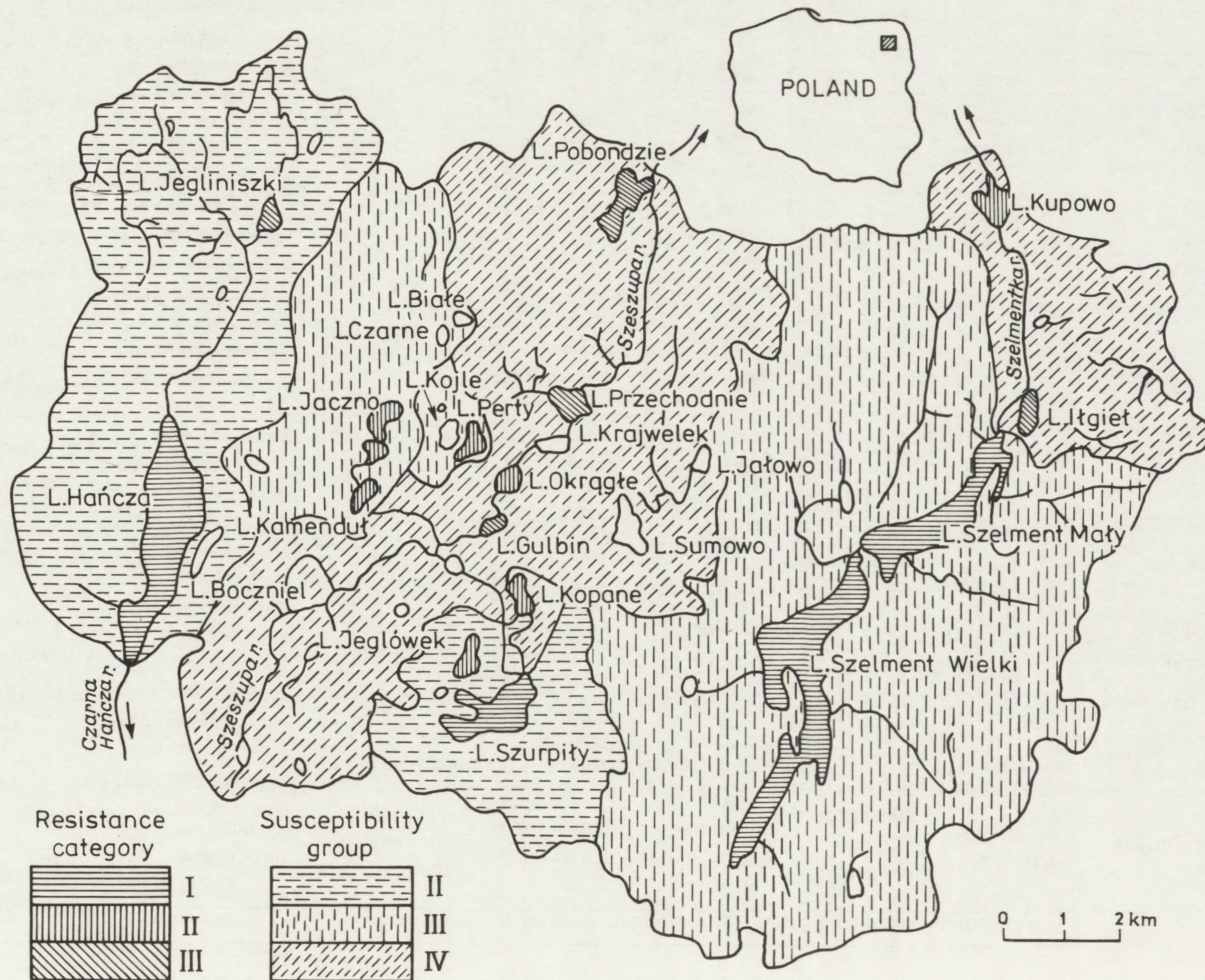
Fig. 1. Distribution in the Suwałki Landscape Park of water basins with different impact of matter supply to lakes and lakes of different resistance to natural eutrophication

influence), 0.9–1.6 is for II category (moderately resistant), 1.7–2.4 is for III category (weakly resistant), and over 2.4 is for IV category (not resistant, i.e. greatly exposed to external factors). Only four lakes of Suwałki Landscape Park belong to the most resistant ones: Hańcza, Szelment Wielki, Szelment Mały and Szurpiły (Table 5). Seven lakes show an moderate resistance, whereas six – a low one. Amongst the lakes examined, there are not any non-resistant water bodies (IV category).

Combination of groups of watershed impact and categories of lake resistance, allows to distinguish four groups of ecological watershed-lake systems of a differentiated rate of natural eutrophication. The first group represents such an ecological watershed-lake system, where both natural characters of water body (I or II category of resistance) and of watershed (1 or 2 group of impact) do not favour the eutrophication of lake waters; lake is resistant to external influence and its watershed does not provide actively the surface load to the water body. Thus, such a system may maintain the trophy at a low level. Among these groups are: Hańcza, Szurpiły, Jeglówek and Perty (Fig. 1). The second group is a system, where unfavourable for the lake watershed conditions (great possibility of mobilizing the surface load – 3rd or 4th group of impact) are balanced by the high resistance of the lake itself to external factors (I or II category of resistance). Therefore, the natural eutrophication rate is moderate. To this group belong the lakes: Szelment Wielki, Szelment Mały, Kopane, Jaczno, Kamenduł, Kupowo and Okrągłe (Fig. 1). The third group consists of the ecological watershed-lake system with favourable watershed conditions (watershed is not very active in mobilizing the surface load – 1 or 2 group of sensitivity), but the lake itself is sensitive to external factors (III or IV category of resistance). Eutrophication of lakes in this group is moderate, but interference in watershed structure (e.g., development of tourism, changes in land utilization, land reclamation treatments) may produce a fast increase in eutrophication of lake waters. In the Suwałki Landscape Park this group is represented only by lake Jegliniszki (Fig. 1). The fourth group is represented by an ecological system with natural conditions unfavourable for the state of purity of lake waters. Water bodies are characterized by the III or IV category of resistance, and 3 or 4 group of watershed impact. Natural watershed characters favour the surface runoff, whereas the lake is largely sensitive to external factors. Thus the eutrophication of lake waters can be intensive. This group is represented by lakes: Iłgieł, Udziejek, Gulbin, Przechodnie and Pobondzie (Fig. 1).

3. SUMMARY

For nineteen lakes within Suwałki Landscape Park the group of watershed impact on the lakes was assessed (Tables 1, 2) and also the category of resistance of lakes to eutrophication (Tables 3, 4). Four lakes: Hańcza, Szurpiły, Jeglówek and Perty are characterized by a group and category allowing to maintain the trophy on a low level (Fig. 1). Eight lakes and their watsheds are characterized by a system of conditions maintaining eutrophication at a relatively moderate level. Other five lakes display a system favouring high eutrophication (Fig. 1).

4. POLISH SUMMARY

Dla dziewiętnastu jezior z obszaru Suwalskiego Parku Krajobrazowego wyceniono grupę podatności zlewni na dostawę materii do jezior (tab. 1 i 2) oraz kategorię odporności jezior na eutrofizację (tab. 3 i 4). Cztery jeziora: Hańcza, Szurpiły, Jeglówek i Perty charakteryzują się grupą i kategorią pozwalającą na utrzymanie trofii na niskim poziomie (rys. 1). Osiem jezior i ich zlewnie cechuje układ warunków utrzymujący eutrofizację na względnie umiarkowanym poziomie. Pozostałe pięć jezior wykazuje układ sprzyjający silnej eutrofizacji (rys. 1).

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