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LANDSCAPE STRUCTURE AND ECOLOGICAL STATE OF LAKES – RESULTS OF RESEARCH IN SUWAŁKI LANDSCAPE PARK (NORTH-EASTERN POLAND) INCLUDING SUGGESTIONS FOR ITS PROTECTION

ABSTRACT: The main characters of landscape structure in the area of Suwałki Landscape Park (north-eastern Poland) were pointed out in terms of patch and ecotone pattern as well as its exposure to air pollution and acidification. The antierosional and anti- eutrophication properties of different patches were discussed as well as their proper arrangement in direct watersheds of lakes. The trophic and biotic properties of lakes were listed. The reasons for current slow eutrophication rate of majority of lakes were given and their hazard to further progress of this process was analysed. The requirements for new natural reserves and for enlargement of the existing ones were formulated.
KEY WORDS: lakes, landscape, ecological state, Suwałki Landscape Park.

1. INTRODUCTION

Suwałki Landscape Park (SLP) and its direct neighbourhood (ca 150 km^2 – Fig. 1) in north-eastern Poland (22°45' – 22°55' E, 54°13' – 54°18' N) is a fragment of young glacial hilly landscape of the subboreal zone belonging to Baltic lakelands. The greatly differentiated relief (irregular frontal and ground moraines, eskers, drumlins, deep troughs and river-lake valleys), numerous lakes and natural ponds, swamps, peat bogs, and streams are the basic landscape components deciding about its spatial structure.

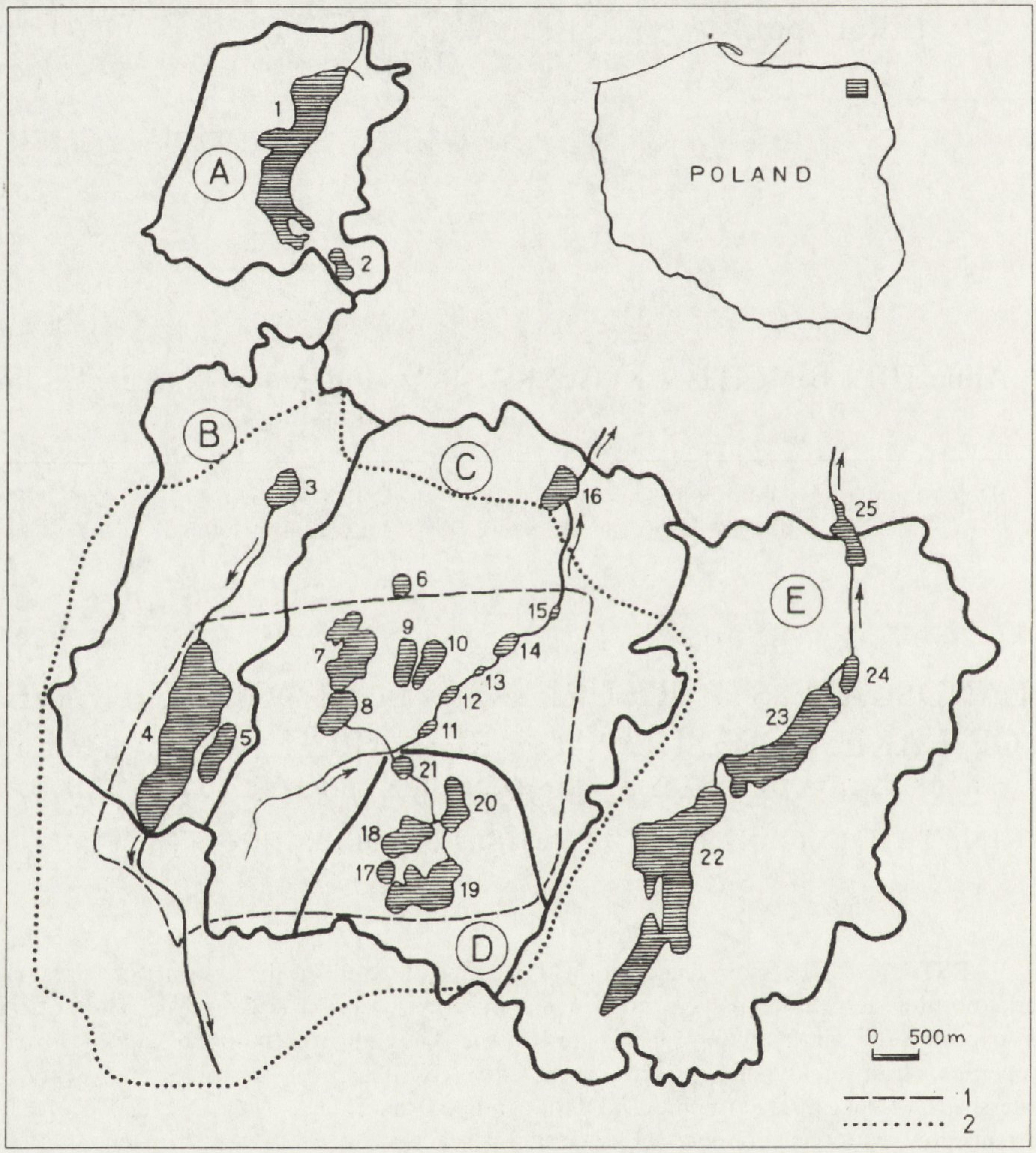

Fig. 1. Simple outline of investigated area; distribution of lakes (1–25) in main watersheds of the Suwałki Landscape Park (SLP) and its neighbourhood (A–E)
1 – border of SLP, 2 – border of the buffer zone of SLP (A – Pissa r. watershed, B – Czarna Hańcza r. watershed, C – Szeszupa r. watershed, D – Szurpiłówka r. watershed – the main Szeszupa tributary in the SLP, E – Szelmentka r. watershed. Names of lakes – cf. Table 1

Several tens of lakes in the SLP are the farthest to the north, collection of natural lakes in Poland with relatively clean waters as compared with lakes from other regions, including the most westward situated Masurian lakes.

Small resident population, moderate tourism, lack of intensive agriculture (prevalence of meadow and pasture management), numerous forest fragments and a relatively great distance from the sources of industrial and municipal emission, explain why this region is generally under a weak human impact. The unique relief and relatively clean lakes are the reasons why the whole landscape in this region is protected including several local nature reserves (see the preface).

The collection of papers in this volume has aimed at: (1) recognition and description of landscape structure in categories of the kind, distribution and size of landscape patches, and of the main landscape processes: relief and climate-forming, including the transport of selected forms of matter between the land surroundings and lake ecosystems; (2) recognition of the present state of lakes, their relations with the watershed, hazards which may affect their further evolution and water purity, as well as determining their distinct character as regards biological diversity due to localisation in the southern range of the boreal zone; (3) indication of main protection measures, including local ones.

The above presented results and conclusions are significant not only for regional management and protection of environment, but also for modern landscape ecology, mostly as regards interrelations between the functioning of lake ecosystems and landscape structure.

2. LANDSCAPE STRUCTURE

Many papers in this volume describe the spatial differentiation of SLP landscape, and especially of its main components such as relief (Smolska 1993), geological substrate, cover and land use (Bajkiewicz-Grabowska 1993a) and climate (Błażejczyk and Grzybowski 1993). In case of SLP and the whole hilly lakeland, this is a mosaic highly differentiated structure.

It has been found, among other things, that on a relatively small area of the SLP there is a mosaic of several types of topoclimate (Błażejczyk and Grzybowski 1993), among which prevail those connected with river valleys and depressions (where heat exchange takes the form of evaporation from an active surface such as meadow or lake), plains and slopes (air turbulence decides about heat exchange). Lakes do not affect significantly the microclimate of surrounding land. But the climate of lake surroundings shows a tendency towards the deposition of cold, humid air and a diurnal rhythm of appearance and disappearance of mists. This character of microclimate of the hilly lakeland favours the accumulation and the influence of air pollution. Therefore, the SLP area and the whole Suwałki region are not isolated from long distance and transfrontier migration of pollution, because in the climate of this region marine western cycling of air masses dominates (62%) (Hryniewicz and Przybylska 1993). Due to this precipitation pH is low (3.8–4.8) and may cause acidification of the ground, whereas annual sulphur accumulation (with precipitation and by direct absorption by the ground) remains at a level of 1–2 $g\ S \cdot m^{-2}$. It is the so-called critical value, determined for Scandinavian conditions as not causing changes even in the most sensitive ecosystems. Because of a generally high buffer effect of the substrate (i.e., soils and waters) the above supply of acid ions and sulphur do not cause yet noticeable changes on bigger areas. Nevertheless, locally (also with regard to the above described microclimatic properties) it may stimulate the so-called "natural" acidification of agricultural soils (by accelerated washing out of calcium), dystrophic lakes and some swampy sites (of low pH and calcium content), some of which may be significant for nature protection as floristic reserves.

Precipitation (both wet and dry, i.e., dust which is an erosion product) in the landscape is a significant supplier of compounds accelerating the eutrophication. For example, it has been estimated that annual phosphorus input with precipitation reaches 0.06 g $\cdot$ m^{-2} per year or 20 mg $\cdot$ m^{-2} per month (Hillbricht-Ilkowska 1993a), whereas that of ammonium and nitrate nitrogen attains a value of the order 1–1.5 g $\cdot$ m^{-2} per year (Hryniewicz and Przybylska 1993).

Spatial range and intensity of water erosion have been estimated on the SLP area in connection with land use (Smolska 1993). Upper and central parts of 9–24° slopes utilised agriculturally are the most degraded (between 0.04 to 7 tons $\cdot$ ha^{-1} per year). About 1/3 of SLP area undergoes this process. Permanent meadow formation on slopes not used as pastures, eliminates considerably the erosion. These areas should be an object of intensive antierosion protection.

Differentiation of relief, geological substrate and land cover seems to be the reason for a considerable chemical distinct character of river and lake waters connected with various watersheds (of rivers Szelmentka, Szeszupa and Czarna Hańcza), and also for more differentiated (see below) values of phosphorus surface runoff (Hillbricht-Ilkowska 1993a).

An attempt to describe the SLP structure (Mozgawa 1993) has been made on the basis of various morphometric indices concerning landscape "patches" (i.e., habitats, ecosystems) distinguishable on aerial photographs 1:10000. The following indices were chosen: size (surface) of the patch, density in the watershed and length of contact (ecotonal) lines. These "patches" were divided into three categories, according to their buffer properties as regards matter input to the lakes. Distinguished were wetlands and swampy communities (including those overgrown by forests) as systems having the strongest buffer properties, forests and meadows as systems with differentiated but moderate buffer properties as related to swampy communities, and arable fields and urban areas as systems without barrier functions ("null" barrier properties). Wetlands (peat bogs, pools, wet meadows etc.) are connected with areas permanently or periodically excluded from the surface runoff. They cover about 27% of the whole SLP area, so their contribution is significant. Although in the four analysed, representative lake watersheds (Table 1), these areas cover only 8–12 percents, their dispersion (number of "patches" per km^2) does not differ much from corresponding values for other kinds of "patches". However, the average size of wetland "patch" and relative length of border line connected with it (the so-called ecotone index) are the lowest for all types of "patches". This is a result of the lowest percentage in the watershed.

Table 1. Range of mean values of some indices of landscape structure in 4 watersheds of lake: Hańcza (1050 ha), Kojle-Perty (230 ha), Kamenduł (94 ha) and in the Szeszupa valley (794 ha) (acc. to Mozgawa 1993), studied by the photointerpretation method

	Landscape "patches" having buffer properties (in respect to inflow of matter and pollutants into lake waters)		
	Strong	moderate	null
Percentage in the watershed	8–12	46–72	18–30
Size of patch (ha)	0.64–1.89	1.95–4.5	1.87–3.89
Number of patches per km^2	4–12	8–23	8–13
Ecotone index* ($km \cdot km^{-2}$)	2.5–3.9	9.9–14.7	5.3–7.5

*Ratio of (ecotone) border line length (km) to the patch area (km^2).

It is difficult to state precisely how efficient are the values of dispersion in the watershed, size of "patch" and ecotone index from the point of lake protection. But in the light of results proving the weak natural eutrophication rate of the majority of SLP lakes, including those with watersheds described in Table 1, it can be said that the landscape structure as shown in this table seems to favour the slowing down of the eutrophication rate.

Generally this structure is expressed by: (1) relatively low contribution of systems without barrier properties (i.e., mostly arable land and fields), not exceeding 30% of watershed area; (2) great dispersion of other kinds of habitats (forests, meadows, wetlands) of patch area unit up to several hectares and with a high ecotone index.

Possible disturbance of this structure, e.g., by drying wet habitats, and by greater percentage of area and dispersal of arable land shall favour a greater phosphorus input to the lake. Thus, there is a necessity to protect components (patches) and SLP characters, retaining its current structure. These are mostly the wetland patches.

Two kinds of wetlands are distinguished in detail, connected with shore vegetation and in direct contact with lake, stream or river water (Kłosowski and Tomaszewicz 1993) and aquatic and marshy vegetation overgrowing small natural ponds, and pools (Ozimek and Rybak 1993).

Analysis of aerial photographs (Mozgawa 1993) shows that for lakes in Table 1 the percentage of wetlands having the greatest barrier properties in the zone up to 150 m from the lake shoreline is 5–45%, whereas that of moderate barrier properties (forests and meadows) – 40–80%. The smallest percentage of barrier systems (50%) is in the case of lake Hańcza watershed.

Vegetation of shore zone has been identified in detail in several fragments of the Szeszupa valley (Kłosowski and Tomaszewicz 1993). Usually this vegetation has a typical zonal character. From land towards water occur successively:

arable lands or utilised meadow → alder swamp → sedge community (Caricetum) → lake littoral. For fragments of the examined Szeszupa valley, lack of continuity in its zonal character is observed; these are local disturbances. There are not any moss-sedge communities and patches of Salicetum, frequent on the Masurian Lakeland, but there is a more numerous occurrence of patches of nitrophilous and hygrophilous perennials, such as patches with *Urtica dioica*, growing between alder and sedge communities or at the lakeside, and also the riverside herbal plants. In this vegetation, and especially in the Caricetum zone, i.e., sedge communities adjoining the borderline of water and land, the nitrates, ammonia nitrogen and phosphates greatly decrease in the root layer soil waters (Kłosowski and Tomaszewicz 1993). This confirms the cumulative properties of these communities and thus the barrier ones, in relation to trophic matter surface runoff. Analysis of succession variability of vegetation overgrowing the little pools allows to confirm also the cumulative properties of these habitats (Ozimek and Rybak 1993).

The above considerations show that wetland habitats should be generally maintained in the landscape, and especially in the lakeside zone and even reconstructed in places, where as a result of drying up or mechanical destruction (e.g. cattle driving), they were either damaged or transformed.

3. TROPHIC AND BIOTIC STATE OF LAKES AND THEIR RELATIONS WITH THE WATERSHED

The main and most synthetic indices on the state of lakes and their watershed are given in Table 1. Due to them the group of 25 SLP lakes, its buffer zone and nearest neighbourhood (i.e., lakes of upper parts of the Szeszupa, Szelmentka and Czarna Hańcza watersheds) can be characterised as a compact pure water resources in the landscape.

All these lakes, regardless of their depth and size and locality in the drainage basin, already display moderate eutrophication symptoms. According to the generally accepted classification they may be considered as mesotrophic or transitory meso-eutrophic lakes (I or II trophic type, Table 2). This is indicated by at least two out of three trophy parameters: phosphorus and chlorophyll concentration and water transparency. Trophy indices based on them (Table 2) are usually below 56 units, i.e., below the value assumed as boundary one for lakes of eutrophic type (Carlson 1977).

The historical data concern mostly the water transparency and the later ones indicate a low eutrophication rate in the majority of lakes or lack of changes over the past fifthy years. In these lakes there are no algal blooms typical for advanced eutrophy, algal biomass is usually below 5 mg of fresh weight per litre, most frequently below 1 mg $\cdot$ l^{-1}, the percentage of blue-green algae is very small (Simm – unpublished data). The abundance and structure of animal plankton including the presence of cold- and oxygen-loving species, reflects also generally low eutrophication.

On the other hand, the majority of the watersheds of these lakes. (14 out of 20) show a high or at least moderate trophic impact on lakes (Bajkiewicz-Grabowska 1993b). It is a result of great drainage basin areas related to lake surface, high flow-through regime of lakes and high sloping conditions. This means that these lakes are generally under a great influence of the watershed, but their natural resistance, high or moderate in 12 out of 20 lakes, delays the eutrophication rate. This resistance is connected with the flow-through regime and/or lake depth.

In the group of investigated lakes (Table 2), twelve are especially valuable. These are big and/or deep mesotrophic lakes: Szelment Wielki, Szelment Mały (in the upper part of the Szelmentka watershed), Kamenduł, Jaczno, Perty and Kojle (in the Szeszupa watershed), Jeglówek, Kluczysko, Szurpiły (in the Szurpiłówka one of the Szeszupa tributary watershed), unique, mesotrophic lake Hańcza, in the Czarna Hańcza watershed, and small accompanying shallow lakes Boczniel and Jegliniszki.

Out of the above mentioned lakes, only Hańcza is protected as a reserve because of its geomorphologic-geological structure and limnological character, but restrictions on the protected area do not include pollutants from farms and villages in the direct watershed and on the shore itself, which run into the lake.

Parallel analysis of present state of lakes included their risk to eutrophication progress with special consideration to phosphorus supply. For several watersheds of lakes within SLP (Hillbricht-Ilkowska 1993b) mean monthly phosphorus surface runoff in summer was between 0.001 and 0.07 kg · ha^{-1}. Lower values were in watersheds with prevalence of wasteland, wet meadows and small afforestations, whereas the highest ones were in watersheds with prevalence of fields and farm buildings. The variability of phosphorus runoff units in SLP watersheds stays within the range found for watersheds of Great Masurian Lakes District some 100 km to the west, but belonging to the same zone of Baltic lakelands.

Comparison of watersheds of these two regions with a similar land cover shows that SLP watersheds have higher surface runoff because of higher land slope than Masurian lake watersheds. This allows to conclude, that amongst others, the intensity of erosion decides about phosphorus load to watersheds of the SLP lakes. This conclusion confirms the statistically significant relation between total phosphorus concentration in summer in surface layers of lakes and the estimated annual load of this element from the drainage basin and atmospheric precipitation (Hillbricht-Ilkowska 1993b). This relation proves that mostly the areal supply including watershed runoff decides about the input of main eutrophying element to the lake. With this in mind, analysed are the reasons explaining why despite such a close relation of the trophic state of lakeland and watershed and generally greater susceptibility of SLP lakes to matter inflow, these lakes are as a rule less advanced in eutrophy and have a low eutrophication rate.

Table 2. Main characteristic of lakes and their watersheds
P – polymictic lake (shallow and mixed frequently), D – dimictic lake (deep, mixed twice a year)
lack of SD, O_2, decrease of SD, O_2 – lack of changes or a decrease in: water transparency (SD), oxygen concentration in near-bottom water layers (O_2)

Watershed lake*	Watershed impact on the lake	Natural resistance** of lakes	Trophic type**	Range of Carlson trophy indices**	Categories of eutrophication hazard***	Eutrophication symptoms over past fifty years***
I. Pissa r. (Lithuania)						
1. Wiżajny	–	–	P I/II	60–69	–	–
2. Wistuć	–	–	P I/II	66–70		
II. Czarna Hańcza r.						
3. Jegliniszki	low	low	P I	53–57	I	lack of (SD)
4. Hańcza	low	high	D I	8–55	I	decrease of (O_2)
5. Boczniel	–	–	P I	8–60	–	
III. Szeszupa r.						
6. Czarne near Smolniki	–	–	–	48–83		lack of (SD)
7. Jaczno	moderate	moderate	D I	40–59	I	–
8. Kamenduł	moderate	moderate	D II	46–69	I	lack of (SD)
9. Kojle	low	moderate	D I	36–54	I	–
10. Perty	low	moderate	D I	39–44	I	lack of (SD)
11. Gulbin	high	low	P I	51–58	II	lack of (SD)
12. Okrągłe	high	moderate	P I	52–61	I	lack of (SD)

13. Krajwelek	high	low	P I/II	53–68	I	lack of (SD)
14. Przechodnie	high	low	P I	54–62	I	lack of (SD)
15. Postawelek	high	low	P I	53–57	I	lack of (SD)
16. Pobondzie	high	low	P I	52–60	I	lack of (SD)
IV. Szurpiłówka r.						
17. Kluczysko	–	–	D I/II	31–56	–	–
18. Jeglówek	low	moderate	D I	32–50	III	lack of (SD)
19. Szurpiły	low	high	D I	32–54	II	lack of (SD)
20. Kopane	moderate	moderate	D I	44–57	II	lack of (SD)
21. Udziejek	high	low	P I/II	60–66	II	lack of (SD)
V. Szelmentka r.						
22. Szelment Wielki	moderate	high	D I	33–54	III	lack of (SD, O_2))
23. Szelment Mały	moderate	high	D I/II	44–65	II	decrease of (SD, O_2)
24. Iłgieł	high	low	P I/II	48–83	III	lack of (SD)
25. Kupowo	high	moderate	P I/II	49–76	I	lack of (SD)

*B a j k i e w i c z - G r a b o w s k a 1993b. **H i l l b r i c h t - I l k o w s k a and W i ś n i e w s k i 1993. ***H i l l b r i c h t - I l k o w s k a 1993b.

One of the reasons may be the fact that in the majority of SLP lakes (12 out of 20) (Table 1) total annual phosphorus load (from the watershed and with precipitation) in generally below the permissible one (I category of hazard) and in other words it is too small to cause the visible symptoms of eutrophication (such as e.g., algal blooms). But in five other lakes the annual load is greater than permissible but less than dangerous (II category of hazard, Table 2), and in successive three ones – more than dangerous (III category of hazard, Table 2).

The other reason may be the low bioavailability for producers assimilation of phosphorus supplied from the watershed, (i.e., mostly due to soil erosion) as it is generally bound with mineral and organic particles washed out from ground and soil. This has been assumed (Hillbricht-Ilkowska 1993a) by comparing the chemical composition of lake waters and streams running into lakes or on the basis of analysis of phosphorus fraction suspended and dissolved in watercourses of a different flow. This seems to be confirmed by a lack or poor relation between total phosphorus concentration (TP) in SLP lakes in summer and such eutrophication symptoms as water transparency, algal biomass and chlorophyll concentration. It is also confirmed by the fact that for the majority of SLP lakes (including all mesotrophic ones) regressions between TP concentrations in water and the above eutrophication symptoms observed for other lake groups including Masurian, do not apply. The SLP lakes do not fit into this general pattern because at a comparable phosphorus load from the watershed and similar in-lake concentration their eutrophication symptoms are weaker than in e.g., Masurian lakes. It is probably due to weaker assimilation of phosphorus supplied to the lake (as it comes mostly from surface runoff, i.e., from the watershed), and its absorption on calcium carbonate particles resulting from the biological decalcification in the lakes. This process is mostly noticed in deep, mesotrophic lakes, such as e.g., lake Hańcza.

Despite the satisfactory ecological state of SLP lakes and processes effectively delaying eutrophication, some results as well as some lakes indicate that this state may change easily and the barrier of lake resistance may be broken. The purer the mesotrophic lake the more sensitive it is to further input of nutrients. The above mentioned significant relation between annual TP load and its in-lake concentration indicates that the possible increase of this load may increase TP concentration in lakes. And although part of this phosphorus is not directly assimilated, still the rise of absolute values may cause further eutrophication symptoms.

The N:P weight ratio, both in alimentation waters and in lake waters is rather high (about 20, frequently higher) (Hillbricht-Ilkowska 1993a, Hillbricht-Ilkowska and Wiśniewski 1993). This proves the phosphorus deficit and thus circumstances preserving the mesotrophic state, but greater P load (in relation to N) and thus a decrease of this ratio may accelerate eutrophication.

Generally, the weak eutrophication may, as observed above, be connected with the fact that P input takes place mostly from diffuse sources and is low in relation to lake capacity. However, there are several outstanding exceptions. These are lakes, where the eutrophication progress is observed by comparing some current indices and from the past fifty years. Such are the shallow lakes of the Szeszupa (decrease in water transparency, stronger – the lower is the lake in the river course) and lake Szelment Mały (decrease in water transparency and oxygen content in hypolimnion) (Table 2). In all these cases there is a well documented assumption that point-sources, i.e., sewage discharge from urban areas, contribute greatly to phosphorus forms. In the Szeszupa valley in the SLP there are many farms, whereas near lake Szelment Mały there is a village. High phosphorus concentrations (of the order 0.1 mg $\cdot$ l^{-1} and low N:P ratio (10) in this lake and those situated lower (Iłgieł, Kupowo) and in the river flowing into them, prove this endangerment (Hillbricht-Ilkowska and Wiśniewski 1993). The sporadically recorded oxygen decrease in the near-bottom layers of Hańcza lake indicates indirectly the risk of eutrophication (Table 2). At this lake there are many villages and tourist objects. The present state of lakes Wiżajny and Wistuć shows the effect of permanent endangering of lakes by the inflow of nutrients from arable fields and farm buildings (Table 2).

The above discussion of most important results of analysis of the trophic state of lakes and their relations with the watersheds shows that at present, in order to protect lakes against accelerated eutrophication, at least the present level of phosphorus inflow from the watersheds in a differentiated landscape should be maintained. This may be attained by preserving the present structure of land use in this watershed, but eliminating efficiently the further increase of ploughed land and pastures in watersheds and the existing and possibly occurring point sources of phosphorus load. The latter requirement should be stressed. The area examined due to a differentiated natural landscape, not much transformed by agriculture, settlements and tourism allows to preserve the natural eutrophication rate, unavoidable but sufficiently slow, characteristic of undisturbed systems and comparable with eutrophication rate in historical periods. However, all sources of load of easily assimilated phosphorus may rapidly accelerate eutrophication rate, as proved amongst others by the above mentioned lake Szelment Mały.

Some studies on SLP lakes prove their limnological distinctness not connected directly with trophism. Detailed studies on zooplankton of the SLP lakes (Karabin and Ejsmont-Karabin 1993) and comparison of them with the Great Masurian Lakes District show that despite differences due to generally lower trophic state (smaller total zooplankton numbers and biomass in SLP lakes than in Masurian lakes), the distinct characters of zooplankton structure are probably caused by the fact that the SLP lakes are evolutionarily younger than lakes of Great Masurian Lakes District and they are also located in more northern, cold climatic zone. And thus, in SLP lakes a greater biodiversity is observed, i.e., more cladoceran species co-occurring in one lake, and also the occurrence of cold-loving species: *Daphnia longiremis* Sars, *Bosmina obtusirostris* Sars, *B. kessleri* Uljanin. In deep lakes the community of these cladocerans occurs in spring in the whole water column, whereas in summer it "goes down" to deeper colder hypolimnion layers. In some SLP lakes (Hańcza, Szurpiły, Szelment Wielki) relict crustacean species, such as the post-glacial relict *Pallasea quadrispinosa* Sars (Żmudziński 1990), have been found in the past and are occurring now.

In the SLP lakes there are relatively more rotifers, and especially of the Polyartha genus, prevailing over Keratella, which is a typical component of rotifer plankton in Masurian lakes. Low phytoplankton abundance seems to favour the occurrence of rotifers generally and especially of the genus Polyartha as they are efficient and active particle feeders. This is why they prevail over such filtrators as cladocerans or rotifers of the genus Keratella.

Greater species diversity of cladocerans, including species of greater body size (of the order 1.0–1.8 mm – as e.g., the above mentioned) and relict species in SLP lakes in comparison with other Masurian lakes may explain also the low biomass of non-predatory fish in lakes examined, and thus their poor impact on zooplankton. Zooplankton is a constant diet component of fry and frequently of adult individuals of all more abundant fish species caught in SLP lakes (Jachner 1989). On the other hand, low biomass of nonpredatory fishes may be due to a considerable percentage of predators: pike and perch. Such assumption is based on data on mean annual fish catches in the years 1981–1984 in 12 SLP lakes (data of Polish Association of Anglers). The catches remain on a level of few to 20 kg $\cdot$ ha^{-1}, but this value does not include poaching and angling, which is estimated as 5–10 kg, $\cdot$ ha^{-1}. In the catches dominate roach, rudd and bream, whereas in lakes Szurpiły and Hańcza also the European whitefish. Pike and perch contributed 15–40% to annual catches from 11 lakes.

4. INDICATIONS FOR PROTECTION OF LAKES, WATERSHEDS AND LANDSCAPE

The above considerations and main research results provide the basis for protection and management measures for SLP region. First of all, they should restrain the water erosion, and eliminate efficiently the surface runoff and input to lakes. A diagram of such arrangement of areas adjacent to surface waters is given in Figure 2. In the I zone, wet, swampy habitats with woody vegetation of riverside carr and alder type directly covering the lake or river shore and changing into typical lake littoral, should be maintained. The II zone, varying in breadth, depending on the slope angle and length should not be ploughed, grazed nor intensively fertilised and should be used mostly for cultivation of vegetation having the appropriate spatial composition (zonal or garland system) of a erosional anti-erosional and anti-eutrophication capacity. These may be different kinds of at afforestations with woody or shrub plants, or grass communities such as multispecies mowed meadows providing abundant and rich ground cover and dense root system. Intensive plant cultivation, plough land, breeding and cattle grazing should be conducted in the III zone, beyond the area of direct effect on the water body.

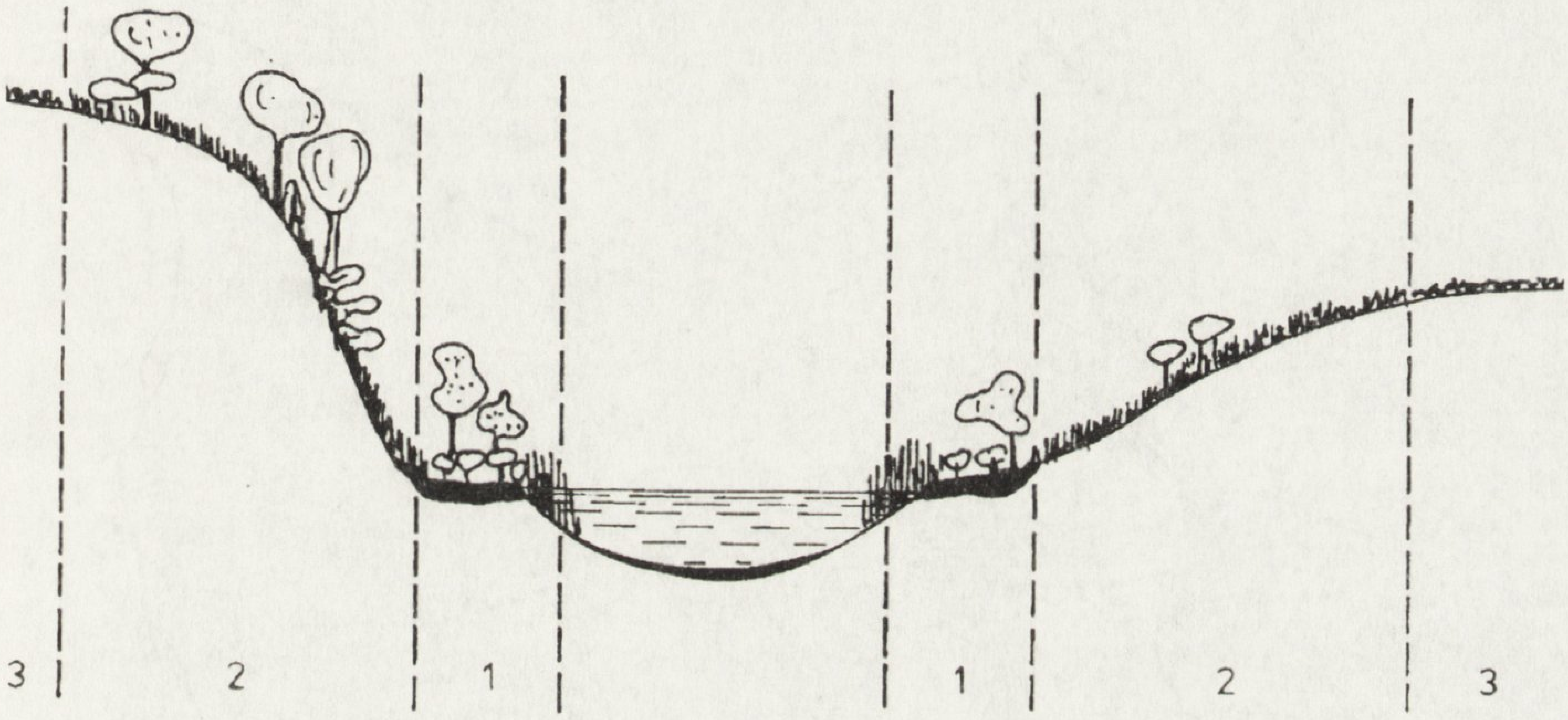

Fig. 2. Management of the direct watershed of lake and river in hilly landscape from the point of anti-erosional and anti-eutrophication protection of lake and river waters
1 – protective zone for wet habitats, swamp vegetation and lake littoral, 2 – zone of landscape management on lake side slopes zonal or garland afforestions, shrub planting, grasslands, natural and mowed meadows, 3 – zone of arable cultures, plough land

Here, it is extremely important to maintain the natural state of land use and land cover as well as current dispersal in the landscape of particular habitats. This amongst others, requires a ban for drying and removal of natural pools, wetland patches etc. and a ban on damaging shore vegetation, and especially sedge communities. It should be considered whether this vegetation should be reconstructed in its proper habitats, where it was damaged.

Another significant protective action is the elimination of existing and possibly future sewage discharges providing easily assimilated phosphorus, which could break down the resistance of lakes. Thus, it is necessary to control the management of sewage and liquid manure in the direct vicinity of lakes and their tributaries.

Out of lakes examined, only lake Hańcza is treated as a reserve and protected are first of all the relief of direct neighbourhood of the lake and its shores (numerous stony beaches). Due to special value of lakes of the whole SLP area, it is suggested to take under protection other lakes from the group of large or deep mesotrophic lakes, as well as to enlarge the protection of lake Hańcza (Fig. 3).

The following lakes are postulated for protection: (1) Lake Szurpiły (and part of its watershed). This is a deep, mesotrophic lake, of low watershed impact and high natural resistance of lake (Table 2), relict crustaceans occur there. The lake is a compact landscape system with lakes Kluczysko and Jeglówek and surrounding hills as well as the archeological site from mediaeval age. There is a proposition to create a natural-archaeological reserve on some 250 ha including the above

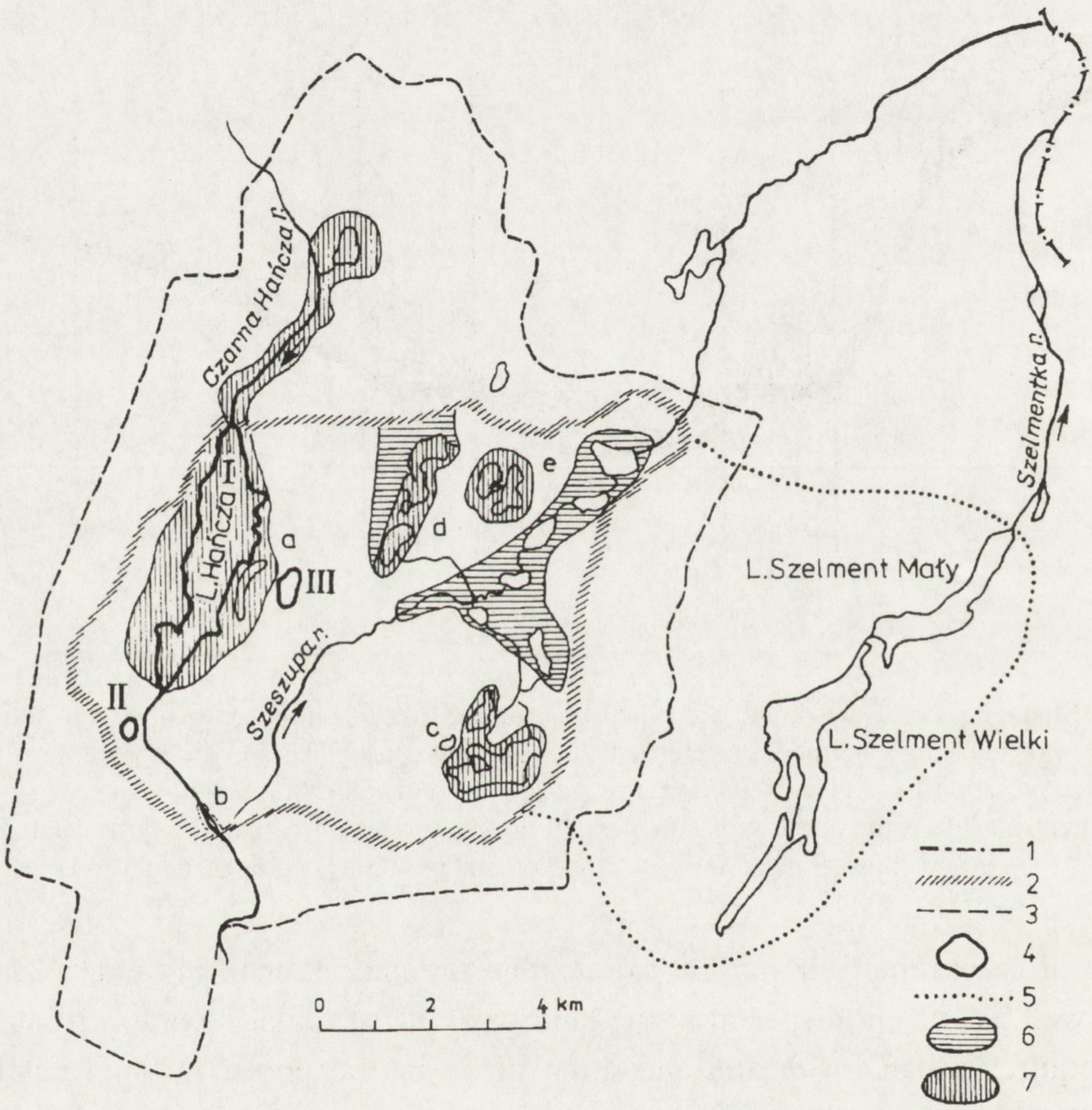

Fig. 3. The schematic diagram of the Suwałki Landscape Park and propositions of protection treatments

1 – state border, 2 – border of SLP, 3 – border of the buffer zone, 4 – existing reserves: I – Lake Hańcza, II – Bachanowo boulders, III – Łopuchowskie boulders, 5 – proposition for expanding the SLP area, 6 – area for intensive anti-erosional protection, 7 – new and enlarged reserves: a – enlarged lake Hańcza reserve included is Czarna Hańcza r. valley (from lake Jegliniszki to lake Hańcza) and part of lake Hańcza direct watershed (because of the necessity of protecting the quality of lake waters), b – "Turtul esker" reserve, c – archaeologic-limnological reserve "Szurpiły lakes", d – reserve including lakes Jaczno and Kamenduł and springs on the slope westwards from lake Jaczno, e – reserve including lakes Kojle and Perty

mentioned lakes and surrounding land in up to 150 m broad zone. (2) Group of lakes Kojle-Perty-Kamenduł-Jaczno (and part of the surrounding land). These are not big lakes, but deep with highly transparet water and especially abundant submerged vegetation. Because of low rate of discharge, great depth and surrounding hills which are a protection against winds, they are susceptible to hypolimnion deoxygenating, which may favour the cumulating of pollution (although over the last 50 years water transparency did not change). The reserve would also include the springs occurring around lake Jaczno. The whole area to be taken under protection is about 230 ha. Perhaps two smaller reserve areas should be formed: for group of lakes Kojle and Perty and separately for lakes Jaczno and Kamenduł. (3) Enlargement of the reserve area around lake Hańcza to protect also part of its watershed (and not only the shores). This is indispensable to counteract the eutrophication of this unique Polish lake, the deepest and purest lowland lakes where relict species occur. Lake Jegliniszki and top section of the river Czarna Hańcza, from lake Jagliniszki to its outlet to lake Hańcza should be taken into consideration as to be included in the reserve area. This would protect also the main inflow to lake Hańcza, draining at present arable and animal breeding areas, being thus exposed to high pollution. It is indispensable to do something about the management of sewage and liquid manure in villages and tourist center around the lake, in order to remove their runoff from the lake. Thus, it is suggested to enlarge the reserve area up to some 1 000 ha and to protect also lake waters, shores and partly of terrestrial surroundings.

Finally, the possibility of enlarging the SLP area by the whole lake system of the upper Szelmentka, i.e., some 5 200 ha to the east of its present border of SLP and its buffer zone. This is indispensable because of the necessity to protect two pure, deep, mesotrophic lakes Szelment Wielki and Szelment Mały.

5. REFERENCES

1. Bajkiewicz-Grabowska E. 1993 – Physiogeographical and hydrographical characteristics of Suwałki Landscape Park (north-eastern Poland) – Ekol. pol. 41: 7–26.
2. Bajkiewicz-Grabowska E. 1993 – Assessment of watershed impact and sensitivity of lakes to degradation in Suwałki Landscape Park (north-eastern Poland) – Ekol. pol. 41: 43–52.
3. Błażejczyk K., Grzybowski J. 1993 – Climatic significance of small aquatic surface and characteristic of local climate in the lakeland of the Suwałki Landscape Park (north-eastern Poland) – Ekol. pol. 41: 105–121.
4. Carlson R. E. 1977 – A trophic state index for lakes – Limnol. Oceanogr. 22: 361–369.
5. Hillbricht-Ilkowska A. 1993a – Biogeochemical diversity of fluvial waters and their effect on lake ecosystems in Suwałki Landscape Park (north-eastern Poland) – Ekol. pol. 41: 173–193.
6. Hillbricht-Ilkowska A. 1993b – Phosphorus loading to lakes of Suwałki Landscape Park (north-eastern Poland) and its relation to lake trophy indices – Ekol. pol. 41: 221–236.
7. Hillbricht-Ilkowska A., Wiśniewski R. J. 1993 – Trophic differentiation of lakes of the Suwałki Landscape Park (north-eastern Poland) and its protective zone – present state, changes over years position in trophic classification of lakes – Ekol. pol. 41: 195–219.
8. Hryniewicz R., Przybylska G. 1993 – Actual and predicted air pollution and deposition rates of pollutants in north-eastern Poland – Ekol. pol. 41: 75–104.
9. Jachner A. 1989 – Biomanipulacja. IV. Zagęszczenie i aktywność pokarmu ryb planktonożernych [Biomanipulation. IV. Density and feeding activity of planktivorous fish] – Wiad. ekol. 34: 143–163.
10. Karabin A., Ejsmont-Karabin J. 1993 – Zooplankton communities versus lake trophy in the Suwałki Landscape Park (north-eastern Poland) – Ekol. pol. 41: 237–268.
11. Kłosowski S., Tomaszewicz H. 1993 – Analysis of distribution structure and habitat conditions of riparian vegetation in the river-lake system of the upper Szeszupa (Suwałki Landscape Park, north-eastern Poland) – Ekol. pol. 41: 123–156.
12. Mozgawa J. 1993 – Photointerpretation analysis of landscape structure in lake watersheds of Suwałki Landscape Park (north-eastern Poland) – Ekol. pol. 41: 53–73.

13. O z i m e k T., R y b a k J. I. 1993 – Macrophytes of small water bodies of the Suwałki Landscape Park (north-eastern Poland) – Ekol. pol. 41: 157–171.

14. S m o l s k a E. 1993 – The dynamic of contemporary merphogenetic processes in the Szeszupa river catchment area (Suwałki Landscape Park, north-eastern Poland) – Ekol. pol. 41: 27–41.

15. Ż m u d z i ń s k i L. 1990 – Past and recent occurrence of Malacostraca glacial relicts in Polish lakes – Ann. zool. fenn. 27: 227–230.