

FACTORS DETERMINING TROPHIC STATE OF LAKE SKRZYŃKA AND ITS BIOCOENOTIC STRUCTURE (WIELKOPOLSKI NATIONAL PARK)

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Summary. The influence of catchment on the functioning and trophic state of small polymictic Lake Skrzyńka was investigated. Despite high loads of mineral and organic substances inflowing from dispersed sources, the lake is mesotrophic with marks of dystrophication process. It was found that the low trophic state of the lake resulted from the surrounding peatland where the nutrients from the catchment are greatly modified and effectively immobilised. Peatlands also produce humic substances which migrate to the lake. Biocoenotic structure of the examined lake has features characteristic of both dystrophic and eutrophic lakes.

Key words: catchment, surface run-off, eutrophication, dystrophication, ecotone

INTRODUCTION

The functioning and evolution of water bodies depends on three main factors:

- catchment area, morphology, geology and local hydrological conditions,
- morphology of water body (capacity, depth),
- degree of antropopresion on the reservoir and its catchment.

The aquatic ecosystem with its catchment forms the basic ecological system where an exchange of matter and energy takes place [Hillbricht-Ilkowska 1999]. Agriculturally used catchments are characterized by a relatively open system of matter cycling [Ryszkowski 1975] and therefore they export large amounts of nutrients [Holland *et al.* 1990, Życzńska-Bałoniak *et al.* 1990, Hornberger *et al.* 1994, Kruk 1997, Uusi-Kamppa *et al.* 1997, Lewandowski 1998].

Wooded catchments export significantly smaller loads of nutrients. However, both peatlands and wooded areas are regarded as the major sources of humic compounds causing dystrophication of fresh waters [Kulberg *et al.* 1993, Hornberger *et al.* 1994, Kraska *et al.* 1998, Kortelainen 1999, Klimaszyk *et al.* 2001].

Water-land ecotones exert a significant impact on the functioning of water bodies. The ecotones play a role of a semi-permeable barrier (buffer) in the exchange of matter

and energy [Hillbricht-Ilkowska 1999, Holland *et al.* 1990, Wetzel 1990]. Trophy of the lake water may determine the biocenotic structure [Hutchinson 1967].

According to the catchment evaluation system suggested by Bajkiewicz-Grabowska [1975], features of Lake Skrzynka and its catchment promote eutrophication [Szyper and Gołdyn 2002]. Its shallow depth, small water surface and lack of stratification make Skrzynka Lake prone to degradation. Due to the large area and steep slopes of the catchment, and the fact that it is partially under agricultural use, significant export of nutrients takes place.

According to Vollenweider's criteria, the critical loading level for nitrogen is exceeded 8 and for phosphorus – 14 times, and Skrzynka Lake is one of the most endangered reservoirs in Wielkopolska NP [Szyper and Gołdyn 2002]. However, many years of research [Brzęk 1948, Kraska 1993, Klimaszyk *et al.* 2001] have shown that Lake Skrzynka has the lowest trophic state of all the other Park lakes. The peatland (ecotone) surrounding the reservoir is believed to be responsible for the relatively low trophic state of the lake [Burchardt *et al.* 1999, Szyper and Gołdyn 2002], but it has never been proved.

The aim of the present study was to identify the main factors determining the trophic state and the direction of the evolution of Lake Skrzynka located in the Wielkopolska National Park. The major pathways of the transfer of water and chemical substances in the system catchment-waterbody were recognized. The influence of the trophic state on the biocenotic structure was analysed.

STUDY AREA

A small (1.6 ha) and shallow (max. depth 2.5 m) lake Skrzynka which is located in the Wielkopolska National Park was selected. Its catchment area is relatively large – 78 ha (76% wooded, 20% under agricultural use). Mean catchment slope is 12°. The lake is surrounded by mesotrophic sphagnum peatland.

MATERIAL AND METHODS

The studies were carried out between 1996-2000, the physico-chemical parameters of the surface water of lake, the surface run-off, and the shallow ground water of the peatlands and catchment were analysed.

The analyses were conducted according to standard methods for water analyses [1992]. Water balance was calculated as suggested by Kędziora [1999].

RESULTS AND DISCUSSION

The hydrologic balance made for Skrzynka Lake [Klimaszyk 2000] shows that the reservoir is supplied with water from ground sources, precipitation and surface run-off.

Surface run-off occurs on the steep slopes of the catchment of the lake. These slopes are covered with mixed (coniferous and deciduous) forest and they end in the peatland

surrounding the lake. Ground waters inflow from the outermost part of the catchment (characterised by gentle slopes) which is under agricultural use.

The results of the studies show that waters inflowing into Skrzynka Lake transport great amounts of chemical elements and substances. This might be a factor affecting the trophic state of the reservoir.

Precipitation was the source of mineral pollution for Lake Skrzynka (Tab. 1). Nitrogen and sulfur oxides were responsible for the acid reaction of rain, and may be a reason for the acidification of the surface water.

Table 1. Mean values of physico-chemical parameters of waters inflowing into the lake and surrounding peatland and surface water of Skrzynka Lake (n>30)

Tabela 1. Właściwości fizyczno-chemiczne (średnia) wód dopływających do jeziora Skrzynka i otaczającego je torfowiska i wody powierzchniowej jeziora

Parameters Parametry		Surface runoff Splyw powierzchniowy	Ground water Wody gruntowe	Precipitation* Opady	Lake surface water Wody powierzchniowe jeziora
colour kolor	mg Pt · dm ⁻³	285	300	1	27
pH		4.4	7.3	4.5	6.3
COND	μSm cm ⁻¹	92	1020.6	22	64.5
NH ₄	mg N · dm ⁻³	1.761	1.471	1.22	0.76
NO ₂	mg N · dm ⁻³	0.0025	0.001	0.01	0.0009
NO ₃	mg N · dm ⁻³	1.67	1	1.56	0.14
SO ₄	mg SO ₄ · dm ⁻³	9.5	435.8	6.7	2.1
Cl	mg Cl · dm ⁻³	6.8	43.5	3.2	8.6
P tot,	mg P · dm ⁻³	0.81	0.104	n.i.	0.36
PO ₄	mg P · dm ⁻³	0.356	0.034	0.022	0.008
Fe	mg Fe · dm ⁻³	0.75	4.888	0.02	0.14
Ca	mg Ca · dm ⁻³	4.38	158.13	3.6	4.7
Mg	mg Mg · dm ⁻³	1.61	39.46	0.5	2.45
DOC	mg C · dm ⁻³	35.2	37.1	n.i.	11.63

*[Walna 1998]

n.i. – not investigated – brak badań

COND = conductivity – przewodnictwo elektrolityczne właściwe

DOC – dissolved organic carbon – rozpuszczony węgiel organiczny

Surface run-off from the wooded part of the catchment might be an important factor affecting water quality of Skrzynka Lake. Run-off was characterised by a high concentration of dissolved organic carbon (DOC) (Tab. 1) High DOC concentration was responsible for the brown colour of the run-off water and pH always under 5.6. Concentrations of dissolved organic carbon in the examined surface run-off are comparable to the concentration of DOC in the ground waters of peatlands regarded as the main source of fresh waters dystrophication [Hekkinen 1994, Górniak 1996, Elder *et al.* 2000]. It may be concluded that run-off from the catchment may be a factor responsible for acidification (dystrophication) of the waters of Skrzynka Lake. However, high concentrations of biogenic elements – nitrogen and phosphorus – were observed in the run-off (Tab. 1).

The highest concentrations of these elements were recorded in the periods when the precipitation was high and during snow melt.

The mean annual amounts running off with surface run-off from 1 ha of the wooded catchment were as follows: >6 kg of nitrogen, 0,5 kg of phosphorus. This greatly exceeds the values recorded in many other wooded catchments and some agricultural catchments [Ryszkowski *et al.* 1988, Hillbricht-Ilkowska 1994, Likens *et al.* 2001]. It shows that surface run-off may be a source of eutrophication of Lake Skrzyńka waters.

Ground waters flowing off from the agriculturally used part of the catchment were characterised by high concentrations of soluble mineral substances (mean conductivity over 1020 $\mu\text{Sm/cm}$), sulphates (Tab. 1), calcium ($158 \text{ mg Ca} \cdot \text{dm}^{-3}$) and magnesium (Tab. 1). High concentrations of biogenic elements were also observed in ground water. However, compared to run-off, the concentration of phosphorus (both dissolved and suspended form) was smaller (Tab. 1).

Because of the large catchment area, Skrzyńka Lake must be supplied with large amounts of nutrients, as well as mineral and organic substances. However, the concentration of those elements and compounds is relatively low (Tab. 1), and according to the classification of Carlson, the lake is mesotrophic.

Table 2. Mean values of physico-chemical parameters of ground water from peatland surrounding Lake Skrzyńka ($n = 30$)

Tabela 2. Właściwości fizyczno-chemiczne wody gruntowej torfowiska otaczającego jezioro Skrzyńka

Parameters Parametry		80 meters from the lake 80 m od jeziora	10 meters from the lake 10 m od jeziora
colour	$\text{mg Pt} \cdot \text{dm}^{-3}$	477	91.2
pH		4.9	5.21
COND	$\mu\text{Sm cm}^{-1}$	347.3	65.4
NH_4	$\text{mg N} \cdot \text{dm}^{-3}$	2.4	0.909
NO_2	$\text{mg N} \cdot \text{dm}^{-3}$	0.3	0.0004
NO_3	$\text{mg N} \cdot \text{dm}^{-3}$	1.25	0.371
SO_4	$\text{mg SO}_4 \cdot \text{dm}^{-3}$	36.7	5.7
Cl	$\text{mg Cl} \cdot \text{dm}^{-3}$	35.2	22.4
P tot,	$\text{mg P} \cdot \text{dm}^{-3}$	0.151	0.097
PO_4	$\text{mg P} \cdot \text{dm}^{-3}$	0.076	0.022
Fe	$\text{mg Fe} \cdot \text{dm}^{-3}$	2.3	1.356
Ca	$\text{mg Ca} \cdot \text{dm}^{-3}$	39.56	5.38
Mg	$\text{mg Mg} \cdot \text{dm}^{-3}$	14.05	2.663

It was found that the low trophic state of the lake resulted from the surrounding peatland (Tab. 2). Concentrations of most of chemical elements and compounds were gradually reduced in the ground water of peatland: from the highest values in the outermost part of the peatland to the lowest values in the innermost part, near the edge of the lake.

The mean concentration of ammonium nitrogen was reduced by 60%, nitrates by 70%, sulphates by 80%, calcium by 85%, conductivity by 80%, orthophosphates by 30% and total phosphorus by 35%. The level of reduction of nitrogen concentration in peatland surrounding lake Skrzynka is similar to the data presented in other studies [Mitsch and Gosselink 1993, Hillbricht-Ilkowska 1994, Frankenbach and Meyer 1999]. The majority of nitrogen is retained in riparian vegetation and denitrified. A great number of denitrifying facultative anaerobic bacteria were observed in the ground water in the peatland surrounding Skrzynka Lake.

The relatively low reduction of total phosphorus in the peatland may be caused by increased sulphates inflow from the agricultural catchment ($>430 \text{ mg} \cdot \text{dm}^{-3}$). In anoxic conditions SO_4 can dislodge phosphate ions from the ferrous-organic complexes leaching them out of the wetland [Mitsch and Gosselink 1993, Kruk 1998]. Thus, it is clear that the peatland plays the role of a buffer for diffuse pollution from the catchment area. Nevertheless, the loads accumulated in the peatland may be mobilised after the drying out of peat. This may cause rapid lake eutrophication.

The peatland is also responsible for the dystrophication of Lake Skrzynka. It stops loads of calcium flowing from the catchment, and delivers to the lake great amounts of humic substances (DOC) affecting the acidification of lake water.

The structure of macrophyte and plankton communities of Skrzynka lake indicates dystrophy of the water; however, eutrophic species also occur. Besides the desmids, indicators of dystrophic waters, small green algae from the group Chlorococcales, often present in the eutrophic lakes, also dominated among phytoplankton [Burchardt *et al.* 1998].

Similarly, in the case of zooplankton communities the dominance of species characteristic of dystrophy with the smaller participation of eutrophy forms was observed. Zooplankton of Skrzynka Lake was of rich taxonomical structure and encountered considerably low densities. In the examined lake the value of the Shannon-Weaver biodiversity index was high and reached the level of 3.12.

CONCLUSIONS

The main factor determining trophic state of lake Skrzynka is peatbog (ecotone) surrounding reservoir. Great amounts of substances transported from the outermost part of catchment are greatly modified and effectively immobilised. Humic acids inflowing from the peatland are responsible for water acidification and dystrophication. Biocenotic structure of Skrzynka Lake reflects the dystrophic as well as eutrophic impact of the catchment area.

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CZYNNIKI WARUNKUJĄCE TROFIĘ JEZIORA SKRZYŃKA I JEGO STRUKTURA BIOCENOTYCZNA (WIELKOPOLSKI PARK NARODOWY)

Streszczenie. Analizowano wpływ zlewni na kształtowanie się struktury troficznej oraz kierunku ewolucji niewielkiego polimiktycznego jeziora Skrzyńka. Pomimo znacznych ładunków zanieczyszczeń (mineralnych i organicznych) docierających ze źródeł przestrzennych, jezioro utrzymuje status mezotroficzny z oznakami dystrofizacji. Przyczyną tego stanu jest torfowisko otaczające zbiornik, które rozprasza i zatrzymuje zanieczyszczenia migrujące ze zlewni i zaopatruje jezioro w substancje humusowe.

Struktura biocenotyczna jeziora ma cechy charakterystyczne zarówno dla zbiorników dystroficznych, jak i eutroficznych.

Słowa kluczowe: zlewnia, spływ powierzchniowy, eutrofizacja, dystrofizacja, ekoton