POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 25(4): 401–414, Y. 2010

DOI 10.2478/v10020-010-0037-3

ECOLOGICAL STATUS AND PHYTOCOENOTIC DIVERSITY OF MACROPHYTES OF LAKE SZELĄG WIELKI (NORTH – EAST POLAND)*

***Mirosław Grzybowski*[1], *Józef Szarek*[2], *Krystyna A. Skibniewska*[3], *Janusz Guziur*[4]**

[1] Chair of Applied Ecology
[2] Chair of Pathophysiology, Forensic Veterinary Medicine and Administration
[3] Chair of the Foundations of Safety
[4] Department of Fish Breeding and Rearing
University of Warmia and Mazury in Olsztyn

K e y w o r d s: ESMI, phytocoenotic diversity, Lake Szeląg Wielki.

A b s t r a c t

This study was aimed at determining whether a pesticide tomb affects the ecological status of Lake Szeląg Wielki and to recognize how it affects phytocoenotic diversity of its vegetation. In addition, the results obtained will contribute to a database update and to the evaluation of the usability of a new Polish macrophytic method for the assessment of the ecological status of lakes. Analyses conducted in Lake Szeląg Wielki demonstrated that its ecological status was good, though the pesticide tomb had a modifying effect on the phytocoenotic diversity of aquatic and rush plants.

STAN EKOLOGICZNY I RÓŻNORODNOŚĆ FITOCENOTYCZNA MAKROFITÓW JEZIORA SZELĄG WIELKI (PÓŁNOCNO-WSCHODNIA POLSKA)

***Mirosław Grzybowski*[1], *Józef Szarek*[2], *Krystyna A. Skibniewska*[3], *Janusz Guziur*[4]**

[1] Katedra Ekologii Stosowanej
[2] Katedra Patofizjologii, Weterynarii Sądowej i Administracji
[3] Katedra Podstaw Bezpieczeństwa
[4] Katedra Biologii i Hodowli Ryb
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: ESMI, różnorodność fitocenotyczna, Jezioro Szeląg Wielki.

Address: Mirosław Grzybowski, University of Warmia and Mazury, ul. Michała Oczapowskiego 5, 10-719 Olsztyn, Poland, phone: +48 (89) 523 37 42, e-mail: grzybomi@uwm.edu.pl
* Research granted from dcientific sources as a research project in 2006–2009 MniSW no: N305 006 31/0326

Abstrakt

Przeprowadzone badania miały na celu stwierdzenie czy mogilnik pestycydowy wpływa na stan ekologiczny jeziora Szeląg Wielki i rozpoznać jak wpływa na różnorodność fitocenotyczną roślinności tego zbiornika. Uzyskane wyniki przyczyniają się do aktualizacji danych i oceny przydatności nowej polskiej metody makrofitowej – oceny stanu ekologicznego jezior. Przeprowadzone analizy wykazały, że stan ekologiczny jeziora Szeląg Wielki był dobry, mimo że mogilnik pestycydowy wywierał wpływ na zmianę różnorodności fitocenotycznej roślinności wodnej i szuwarowej jeziora.

Introduction

Lakes are an inherent element of environment, they constitute living--spaces for a variety of flora and fauna species and are an important element of a balanced landscape persistence. Phytocoenoses are subject to cyclic alterations, fluctuations and succession which, in the classic perspective, constitutes an oriented process of development, i.e. substitution of phytocoenoses over time (FALIŃSKA 1996, SCHEFFER 1998). These natural processes are accompanied by anthropogenic effects, of which especially hazardous appear to be landfills of overdue pesticides, the so-called "pesticide tombs". Lake Szeląg Wielki (Figure 1) is located in close proximity to a closed pesticide tomb (< 1 km). Pesticide tombs pose one of the most severe threats to the natural environment in Poland. Since 2003, complex analyses of edaphic and aquatic habitats have been carried out on their surrounding areas (GRZYBOWSKI et al. 2003, 2004, 2005 a,b, 2006, 2007 a,b, SAWICKA-KAPUSTA et al. 2005, SKIBNIEWSKA et al. 2003, SZAREK et al. 2004, 2006, 2007 a,b,c, ZAKRZEWSKA et al. 2005, ZMYSŁOWSKA et al. 2005).

This study was aimed at determining whether a pesticide tomb affects the ecological status of Lake Szeląg Wielki and to recognize how it affects phytocoenotic diversity of its vegetation. In addition, the results obtained will contribute to a database update and to the evaluation of the usability of a new Polish macrophytic method for the assessment of the ecological status of lakes.

Characteristics of study area

Lake Szeląg Wielki is located in the Ostróda Commune of the Iławski Lake District, belonging to the Warmia and Mazury Province. The aquifer is a typical ribbon-like narrow and very elongated lake (Table 1). It entries three small watercourses, two of which bring water from neighboring lakes: Szeląg Mały and Tabórz. Runoff from the aquifer proceeds south-west from

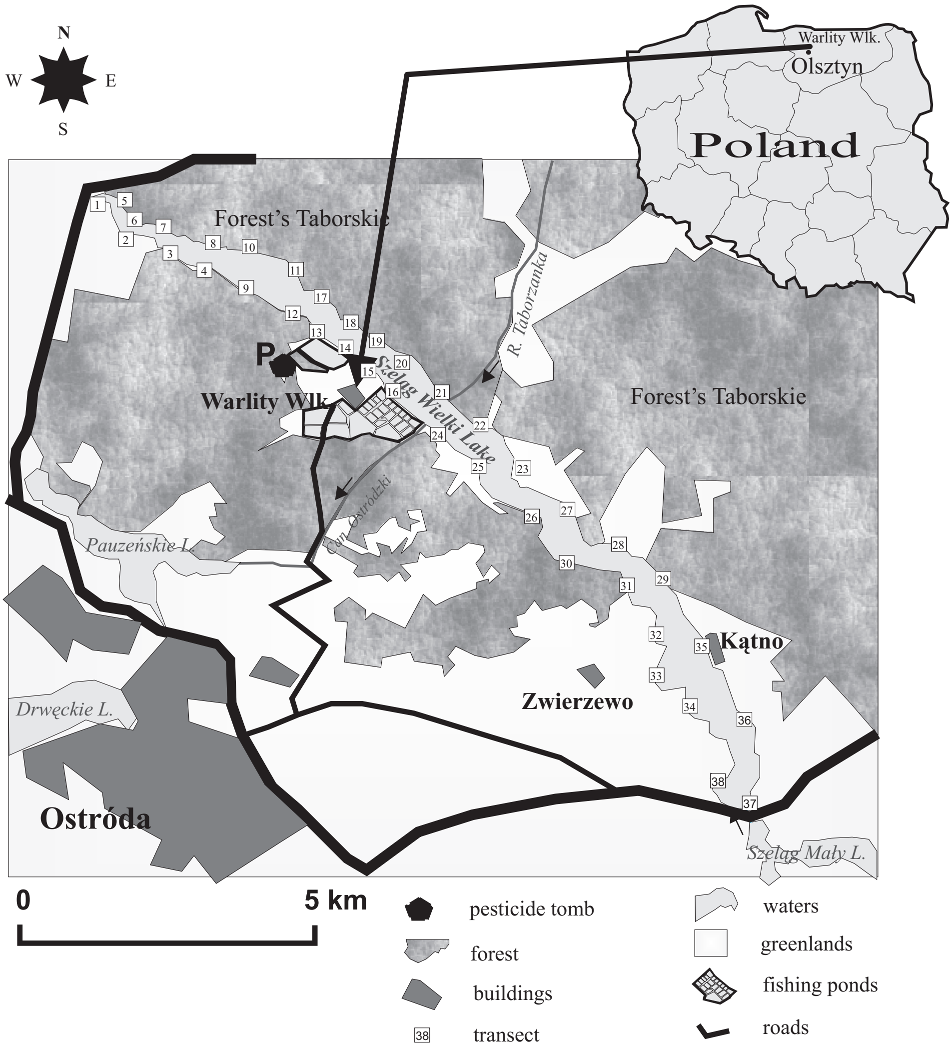

Fig. 1. Location of study area

Pauzeńskie Lake and Drwęckie Lake (Figure 1). The lake possesses a poorly developed shoreline (Table 1). The zone of littoral and sublittoral is narrow. The littoral occupies ca. 15% of bottom area.

Table 1

Morphometric data of the Lake Szeląg Wielki

Morphometric data (IIF, 1964)	
Area [ha]	599.0
Area of littoral [ha]	89.85
Area restricted by 2.5 m izobath [ha]	144.25
Volume [thousand m^3]	81 111.2
Maximal depth [m]	35.5
Mean depth [m]	13.5
Maximal length [m]	12 500
Maximal width [m]	900
Shoreline length [m]	28 000
Shoreline development	3.2
Exposure index	25.1

A pesticide tomb (PT) was in operation in the years 1968–2004 on a hill to the south-west of the lake, covering an area of 0.7 ha. The tomb was used as a landfill of 54 tonnes of toxic substances disposed in 36 silos and 2 unprotected cavities. The pesticide tomb under study was situated in sandy formations and even a small leakage of the chambers poses a threat to contamination of ground waters and the neighboring ecosystems of Lake Szeląg Wielki (Figure 1).

Following abiotic typology (KOLADA et al. 2005), Szeląg Wielki was classified as a stratified, charophyte deep lake. During summer stagnation, epilimnion reaches to a depth of 8 m and constitutes 36% of lake surface area and it is characterized by good aerobic conditions. In the stratum of metalimnion, there is a distinct reduction of oxygen concentration that intensifies gradually in the stratum of hypolimnion – which constitutes 44% of the lake bottom area. Oxygen depletion at the bottom does not occur and the mean oxygen saturation of lake hypolimnion exceeds 25% (CYDZIK et al. 1995, GRZYBOWSKI et al. 2005a, *Morfometric...* 1964).

Indices of the primary production, including the concentration of chlorophyl, dry matter of seston and water transparency, indicate its moderate trophy (CYDZIK et al. 1995). Bacteriological analyses of the lake demonstrated its very good sanitary status. In addition, water concentrations of the pesticides examined were within the binding reference values, yet these are mostly trace amounts (CYDZIK et al. 1995).

Lake Szeląg Wielki is characterized by high resistance to degradation – I category (CYDZIK et al. 1995). Worthy of notice is its small annual water exchange that prevents the introduction of contaminants from the basin area to the lake. The prevalence of forests and relatively low recreational pressure exert an additional beneficial effect on the lake.

Methods

The ecological status of Lake Szeląg Wielki was evaluated with the use of an Ecological Status Macrophyte Index (ESMI) calculated in transects of lake phytolittoral. Methods of macrophytic assessment of the ecological status of lakes based on transects are applied in the monitoring system of European countries, including Germany (SCHAUMBURG et al. 2004a,b), Austria (CIECIERSKA et al. 2006), and Finland (LEKA et al. 2002, LEKA 2005), are recommended by the CEN standard (CEN 2003). The method consists of:

– plotting transects 20–30 in width perpendicularly to the shoreline;

– determining the maximum depth of plant occurrence (depth reach of macrophytes) which defines transect's length and the area the study is conducted on;

– estimating total percentage coverage of transects with plants;

– identifying all plant communities occurring in a transect and estimating their percentage coverage as compared to the total area occupied by plants converted in the scale of BRAUN-BLANQUET (1964).

For analyses of plants, the number of transects was determined from the formula *MLT* – minimal required number of transects (JENSÉN 1977, KESKITALO, SALONEN 1994).

Next, calculations were performed for the Ecological Status Macrophyte Index (CIECIERSKA et al. 2006). The ESMI is a multimetrix constructed from indices of species composition and macrophytes abundance (CIECIERSKA et al. 2006):

$$ESMI = 1 - \mathrm{ep}\left[-\frac{H}{H_{\max}} \cdot Z \cdot \exp\left(\frac{N}{P}\right)\right]$$

where:

The index of biocenotic diversity [H] (SAMOSIEJ 1987) has been calculated from Shannon-Wiener formula (SHANNON, WEAVER 1949):

$$H = -\sum \frac{n_i}{N} \ln \frac{n_i}{N},$$

where:
H – the phytocoenotic diversity index,
n_i – mean coverage of each phytocenosis (i) within phytolittoral is an arithmetic mean of its coverage in particular transects, after conversion of degrees of the BRAUN-BLANQUET scale into mean percentage coverage according to Table 2.
N – the phytolittoral area (100%).

Table 2

Scale of coverage degree used in the ESMI method (CIECIERSKA et al. 2006)

Range of coverage classes [%]	Braun-Blanquet Scale	Mean coverage [%]
75–100	5	86
50–75	4	61
25–50	3	34
5–25	2	15
1–5	1	3
0.1–1	+	0.5
0.1	r	0.1

The maximum value of phytocoenotic diversity (H_{max}) was determined from the following formula:

$$H_{max} = \ln S,$$

where:
S – the number of plant communities forming the phytolittoral,
Z – colonization index $Z = \frac{N}{izob.2{,}5}$,
izob.2.5 – littoral area restricted with 2.5 izobath (ha).

The obtained value of the ESMI index enables determining the ecological status of a lake (Table 3).

Table 3

Boundaries of classes of the ecological status for charophyte deep lakes based on macrophytes (CIECIERSKA et al. 2006)

Ecological status	Range of ESMI values
	charophyte deep lakes
Very good	0.680–1.000
Good	0.340–0.679
Moderate	0.170–0.339
Poor	0.090–0.169
Bad	< 0.090
	lack of submersed plants

The method of transects was also used in the evaluation of β-diversity according to WHITTAKER (1977) as the change among various phytocoenoses within one type of landscape.

In order to determine whether the pesticide tomb affects the ecological status of the lake, statistically significant differences were sought in phytocoenotic abundance, diversity index and phytocoenoses contribution in transects located in proximity to, and at a distance from, the pesticide tomb between the analyzed transects plotted for the phytolittoral of Lake Szeląg Wielki. The Pielous Evenness Index [*J*] was also computed (MAGURRAN 1988):

$$J = \frac{H_{obs}}{\log s}$$

where:
s – the number of phytocoenoses of a community in a transect.

The first stage of the statistical analysis involved verification of the distribution of results with the normal distribution by means of a Shapiro-Wilk test [*W*]. In the case of finding the normal distribution, use was made of a parametric Student's t-test (significance level of α = 0.05), which assumes the normal distribution of results or differences between results. For the evaluation of significance of differences between mean values whose distribution was not consistent with the normal distribution, a U Mann-Whitney test (significance level of α = 0.05) was used. The above-mentioned statistical analyses were carried out using Statistica 7.1 software (StatSoft, Inc. 2005). As transects remote from PT those located at least 2 km from the perpendicular line plotted so as to cut through two points were arbitrarily adopted: a point on the Lake Szeląg Wielki shoreline being the closest to the pesticide tomb and a point marked by the centre of a source of xenobiotics. Diversity computations were performed with Multi Variate Statistical Package (MVSP) ver. 3.1 software.

Results

Analyses carried out in the study enabled determining the number of transects in the phytolittoral of Lake Szeląg Wielki necessary for surveying, MLT = 38 transects. Analyses of transects demonstrated the presence of 22 communities (Table 4). The greatest range of plant occurrence in Lake Szeląg Wielki, i.e. 4.8 m, was noted for phytocenosis with *Fontinalis antipyretica*.

Community	Transect															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	mean coverage [%]															
Scirpetum lacustris (Allorge 1922) Chouard 1924	3	·	·	3	·	15	·	·	·	·	·	·	·	34	·	.
Phragmitetum australis (Gams 1927) Schmale 1939	15	61	34	61	61	61	34	86	3	86	3	·	·	61	·	.
Glycerietum maximae Hueck 1931	·	·	15	·	15	·	·	·	3	·	·	·	·	·	·	.
Equisetetum fluviatilis Steffen 1931	·	·	15	·	·	·	·	·	·	·	·	61	·	·	·	.
Typhaetum latifoliae Soó 1927	61	·	·	·	·	·	·	·	·	·	·	·	·	·	·	.
Typhaetum angustifoliae (Allorge 1922) Chouard 1924	·	·	·	0.1	·	·	3	·	·	·	·	·	·	·	·	.
Acoretum calami Kobendza 1948	·	·	·	·	·	·	·	·	34	·	·	·	·	·	·	.
Sparganietum erecti Roll. 1938	·	·	·	·	·	·	·	·	3	·	·	34	·	·	·	.
Eleocharitetum palustris Sennikov 1919	·	·	·	·	·	·	·	·	·	·	·	·	61	·	·	.
Sagittario-Sparganietum emersi R.Tx. 1953	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	.
Caricetum rostratae Ruebel 1912	·	·	·	·	·	·	3	·	·	·	·	·	·	·	·	.
Caricetum acutiformis Sauer 1937	·	·	·	·	·	·	·	·	·	1.5	·	·	·	·	15	.
Comm. with *Buttomus umbellatus*	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	15
Iridetum pseudoacori Eggler 1933	·	·	·	·	·	·	·	·	15	·	·	·	·	·	86	.
Lemno-Spirodeletum Soó 1927	·	·	·	·	·	·	·	0	0.1	·	·	·	·	·	·	0.5
Potametum perfoliati Koch 1926	·	·	0.5	·	·	·	3	·	15	·	34	·	·	·	·	.
Potametum natantis Soó 1927	·	·	·	·	·	·	·	·	·	·	0	·	·	·	·	.
Myriophylletum spicati Soó 1927	·	·	15	·	3	·	·	·	·	·	·	·	·	·	·	86
Elodeetum canadensis (Pign. 1953) Pass. 1964	·	·	·	·	·	·	·	·	3	·	·	·	·	·	·	.
Ceratophylletum demersi Hild 1956	·	34	3	34	3	·	15	15	·	·	·	·	34	·	·	.
Ranunculetum circinati (Bennema et West. 1943) Segal 1965	·	·	15	·	·	·	3	·	·	·	61	·	·	·	·	.
Fontinaletum antipyreticae Hub. 1957	·	15	·	·	·	15	34	·	15	·	·	·	·	·	·	.
Depth of plants occurrence in a transect	2	3.5	3.2	4.5	2	4	6	1.6	4.8	1.9	2.6	1.2	1.8	2.2	0.8	2
Percentage coverage of transect wth plants	90	90	100	90	90	80	100	90	100	95	80	90	90	100	90	90
Shanon-Wiener Index [*H*]	1.41	1.39	2.40	1.12	1.56	1.24	2.15	0.61	2.60	0.61	1.11	0.94	0.94	0.94	0.61	0.65
Evenness [*J*] Pielou	0.70	0.88	0.80	0.56	0.67	0.79	0.72	0.61	0.78	0.61	0.70	0.94	0.94	0.94	0.61	0.41
Num.Syntax.	4	3	8	4	5	3	8	2	10	2	3	2	2	2	2	3
Group	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1

Group: differentiates transects into those located in its proximity at a distance < 2 km from pesticide tomb (1)

Table 4

transects of Lake Szeląg Wielki

Transect																					
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
mean coverage [%]																					
·	·	·	·	15	·	·	·	·	·	·	·	34	·	·	3	·	·	·	·	·	.
·	86	86	61	61	61	15	·	·	·	·	34	61	61	61	34	·	61	34	3	15	61
·	·	·	·	·	15	·	·	·	·	·	34	·	·	·	·	·	·	·	3	·	.
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3	·	·	.
·	·	·	·	·	·	·	·	·	·	61	·	·	·	·	·	·	·	·	·	15	.
·	·	·	·	·	·	·	·	·	·	·	·	·	34	34	61	·	·	·	·	·	.
·	·	·	34	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	34	·	.
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	64	·	·	3	·	.
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	.
86	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	.
·	·	3	·	·	·	3	·	86	·	·	3	·	·	·	·	·	·	·	·	·	.
·	·	·	·	3	·	·	86	·	·	·	·	·	·	·	·	34	·	15	·	61	.
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	.
·	·	·	·	·	·	·	·	·	34	·	·	·	·	·	·	·	·	·	15	·	.
·	·	·	0.1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.1	·	.
·	15	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	15	·	.
·	·	·	·	15	·	·	·	·	·	0	34	·	·	·	·	·	·	·	·	·	.
·	·	·	·	·	15	·	·	·	61	·	·	·	·	·	·	·	·	15	·	·	.
15	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	34	3	·	3
·	·	3	·	·	·	·	·	·	·	·	·	·	·	·	·	0.5	0.1	·	·	3	15
·	·	3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	0.1	·	·	·	.
·	·	·	·	·	3	61	·	·	·	·	·	·	·	·	·	·	34	·	15	·	3
1.6	2.4	3	2.6	2.8	4	5.4	0.4	0.6	1.8	2	2.2	2.4	2.6	2.6	2.9	3.4	4.8	3.4	4.8	3.2	4.2
90	100	100	90	100	90	95	100	100	100	90	100	100	100	100	100	100	100	90	100	100	100
0.61	0.61	0.78	0.99	1.41	1.41	1.41	0.00	0.00	0.94	0.94	1.73	0.94	0.94	0.94	1.11	0.97	1.13	2.03	2.60	1.41	1.56
0.61	0.61	0.34	0.50	0.70	0.70	0.70	0.00	0.00	0.94	0.94	0.86	0.94	0.94	0.94	0.70	0.61	0.49	0.87	0.78	0.70	0.67
2	2	5	4	4	4	4	1	1	2	2	4	2	2	2	3	3	5	5	10	4	5
1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

and those remote at a distance > 2 km from pesticide tomb (2)

The ecological status of the lake determined based on the ESMI was rated as good (Table 5). Results of analyses carried out for the normality of distribution of phytocoenotic diversity variables were collated in Table 5. The normal distribution was demonstrated for the variable: Shannon-Wiener diversity index. A lack of consistency with the normal distribution was observed in the case of the two other variables, i.e.: Pielou Evenness index [*J*] and the number of phytocoenoses in a transect (Table 6).

Table 5

Szeląg Wielki and reference lakes' phytocoenotic parameters

Lake name	Area of 2.5 m izobath	Area of phyto-littoral (N) [ha]	Number of phyto-littoral commu-nities (*S*)	Index of phyto-coenotic diversity (*H*)	Index of colo-nization (*Z*)	Index of max. phytoco-enotic diversity (H_{max})	Syna-ntthro-pization index (*Ws*)	Ecological Status Macro-phyte Index (*ESMI*)
Szeląg Wielki	144.25	141.9	22	1.94	1.02	3.14	0.53	0.47

Table 6

Shapiro-Wilk's test for variables of phytocoenotic diversity

	N	*W*	*P*	Distribution
Index Shannon-Wiener	38	0.945448	0.063080	*N*
Pielou Evenness	38	0.856309	0.000185	n.n
Num_Syntax	38	0.828293	0.000042	n.n

W – value of Shapiro-Wilk coefficient; *p* – level of significance, *n* – normal distribution $W>W(\alpha;n)$; n.n – not normal distribution $W<W(\alpha;n)$; W_{max} (0.05;38) = 0.863

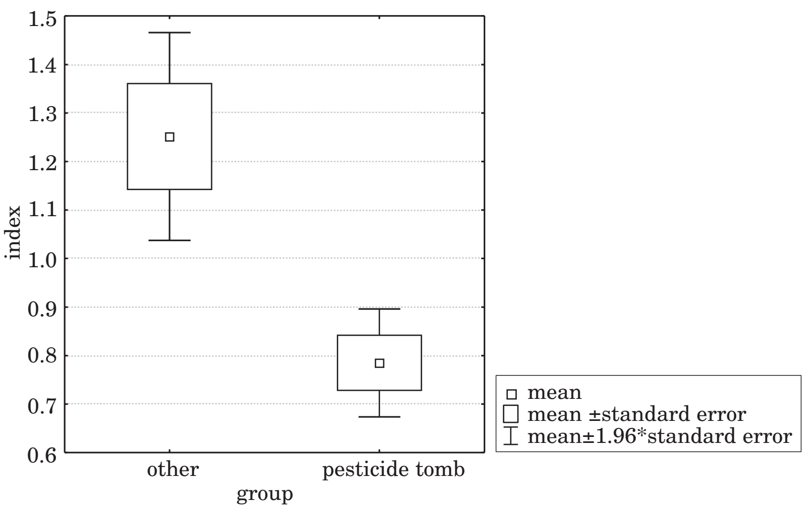

Fig. 2. Differences between mean values of Shannon-Wiener index for phytocoenoses located in the proximity of the pesticide tomb and those remote from it (Student's t-test, $\alpha = 0.05$; $p < 0.03$)

In analyses of the Shannon-Wiener index use was made of the Student's t-test. The results obtained were statistically significant ($\alpha = 0.05$; $p < 0.03$) and indicated significant differences between phytocoenoses of transects located close to the pesticide tomb (> 2 km) or remote from it (< 2 km) – Figure 2.

The analysis of the number of phytocoenoses and phytocoenotic diversity index was carried out based on a Mann-Whitney U test. The results obtained were statistically significant for the number of phytocoenoses: (U = 101.5; p = 0.3194) and for the Pielou phytocoenotic diversity index (U = 87.5, p = 0.1398).

Discussion

Aquatic and rush vegetation is of key significance for the proper functioning of the entire lacustrine ecosystem, in addition it displays high susceptibility to changes in all habitat factors of an aquatic ecosystem (BAATTRUP-PEDERSEN et al. 2001, SMOLDERS et al. 2001, CIECIERSKA 2004, SCHAUMBURG et al. 2004a,b). The higher the taxonomic and syntaxonomic diversity of phytolittoral, the higher the ecological status of a lake (ENDLER et al. 1999, GRZYBOWSKI, ENDLER 2003, CIECIERSKA et al. 2006). The mean value of the Shannon-Wiener diversity index (H) for aquatic and rush plants in Lake Szeląg Wielki (Table 4), that of Pielou Evenness index (J) (Table 4), as well as the mean number of phytocoenoses (Table 4) was typical of poorly eutrophic lakes (ENDLER et al. 1999, MURPHY 2002). The presence of 22 communities observed in the examined transects indicates that the method of transects fully reflects the phytocoenotic diversity of a lake; the number of macrophytic phytocoenoses observed during phytosociological assays of Lake Szeląg Wielki was identical (GRZYBOWSKI et al. 2007b). A good ecological status of Lake Szeląg Wielki, determined based on the ESMI index, was the same as in the case of 39 lakes out of the 153 ones examined with this method (CIECIERSKA et al. 2006), which were also characterized by a similar phytocoenotic composition, but differed in terms of the presence of green algae (*Charophyceae*) whose communities are an important indicator of high macrophytic evaluation of the ecological status of lakes (FORSBERG 1964, KRAUSE 1981). They were not detected in Lake Szeląg Wielki.

The total number of plant communities in a lake results, among other things, from diversity of habitat conditions of littoral (JENSÉN 1977, ROONEY, KALFF 2000). The size of a lake, its length and development of its shoreline affect the number of microhabitats for macrophytes. Lake Szeląg Wielki is characterized by favorable habitat conditions. The average number of plant communities among 153 reference lakes originating from a data base of lakes selected for requiring lake surveillance in Poland following the Directive 2000/60/EC (*Directive* 2000/60/EC...) ranges from 21 to 23 depending on the type of lake (CIECIERSKA et al. 2006). In Lake Szeląg Wielki there were 22 communities detected, which indicates considerable phytocoenotic diversity of its phytolittoral.

Conclusions

Analyses conducted in Lake Szeląg Wielki demonstrated that:

– its ecological status was good;

– the pesticide tomb affected its ecological status;

– the pesticide tomb had a modifying effect on the phytocoenotic diversity of aquatic and rush plants.

Translated by JOANNA JENSEN

Accepted for print 16.02.2010

References

BAATTRUP-PEDERSEN A., ANDERSSON B., BRANDRUD T.E., KARTTUNEN K., RIIS T., TOIVONEN H. 2001. *Macrophytes*. [In:] *Biological monitoring in Nordic rivers and lakes*. Ed. J. Skriver. National Environmental Research Institute, Denmark, Temanord, 513: 53–60.

BRAUN-BLANQUET J. 1964. *Pflanzsoziologie. Grundzuge der Vegetationskunde*. – 3 Aufl. Springer, Wien-New York.

CEN 2003: EN-14184, *Guidance standard for the surveying of macrophytes in lakes*. CEN/TC230/WG2/TG3:N72, Comite Europeen de Normalisation.

CIECIERSKA H., 2004. *Różnorodność fitocenotyczna litoralu jezior Mazurskiego Parku Krajobrazowego – stan obecny i zmiany*. Teka Komitetu Ochrony Kształtowania Środowiska Przyrodniczego, Lublin, 1: 32–38.

CIECIERSKA H., KOLADA A., SOSZKA H. GOŁUB M. 2006. *Opracowanie podstaw metodycznych dla monitoringu biologicznego wód powierzchniowych w zakresie makrofitów i pilotowe ich zastosowanie dla części wód reprezentujących wybrane kategorie i typy*. T. II *Jeziora*. IOŚ, UWM. Warszawa-Poznań-Olsztyn.

CYDZIK D., KUDELSKA D., SOSZKA H. 1995. *Atlas stanu czystości jezior Polski badanych w latach 1989–1993*. Biblioteka Monitoringu Środowiska PIOŚ, Warszawa.

ENDLER Z., GRZYBOWSKI M., JUŚKIEWICZ B. 1999. *Przegląd fitocenoz wodnych i szuwarowych Pojezierza Mazurskiego*. Zeszyty WSP, Prace biologiczne, Zeszyt II: 35–43.

FALIŃSKA K. 1996. *Ekologia roślin. Podstawy teoretyczne, populacja, zbiorowisko, procesy*. PWN, Warszawa, 21–97.

FORSBERG C. 1964. *Phosphorus, a maximum factor in the growth of Characeae*. Nature, 201: 517–518.

GRZYBOWSKI M., ENDLER Z. 2003. *Zmiany zbiorowisk makrofitów podmiejskiego Jeziora Trackiego pod wpływem antropopresji*. Acta Sci. Pol., Formatio Circumiectus, 2(2): 149–156.

GRZYBOWSKI M., SZAREK J., SKIBNIEWSKA K.A., SAWICKA-KAPUSTA K., GUZIUR J., ENDLER Z. 2003. *Assessment of flora development in the Iława district Lake Szeląg Wielki*. 1st Workshop *"Persistent Toxic Substances Contamination of the European Region."* Brno, Czech Republic, 10–12: 161–164.

GRZYBOWSKI M., SZAREK J., ZMYSŁOWSKA I., GUZIUR J., ENDLER Z., SKIBNIEWSKA K. 2004. *Ecological* *characteristic of pesticide tomb in the Warmia region on the basis of index numbers of vascular plants*. Pol. J. Environ. Stud., 13(6): 683–692.

GRZYBOWSKI M., SKIBNIEWSKA K., GUZIUR J., SZAREK J., ENDLER Z., ZMYSŁOWSKA I. 2005a. *Zawartość Pb i Cd w wybranych gatunkach roślin wokół mogilnika pestycydowego*. J. Elementol., 10(2): 289–293.

GRZYBOWSKI M., SZAREK J., SKIBNIEWSKA K., SAWICKA-KAPUSTA K., GUZIUR J., ENDLER Z. 2005b. *The characteristics of plants in the littoral zone of Lake Szeląg Wielki in the Iława Lake District threatened by a pesticide tomb*. Fresenius Environ. Bull., 14(5): 357–362.

GRZYBOWSKI M., SKIBNIEWSKA K.A., SZAREK J., GUZIUR J., ENDLER Z., ZMYSŁOWSKA I., SAWICKA--KAPUSTA K., ZAKRZEWSKA M. 2006. *The ecological characteristics of antropogenic forest phytocoenoses threatened by a pesticide tomb*. Pol. J. Natur. Sc., 21(2): 769–791.

GRZYBOWSKI M., SZAREK J., SKIBNIEWSKA K.A., GUZIUR J. 2007a. *Evaluation of diversity of submerged and emerged flora of Lake Szeląg Wielki as threatened by a pesticide tomb*. Pol. J. Nat. Sc., 25(2): 154–172.

GRZYBOWSKI M., SZAREK J., SKIBNIEWSKA K.A., GUZIUR J., LEW S., MIESZCZYŃSKI T., GESEK M. 2007b. *Evaluation of alpha diversity of an anthropogenic forest threatened by pesticide tomb*. Pol. J. Nat. Sc., 25(1): 63–80..

Morfometric data of Szeląg Wielki Lake. 1964. Institute of Inland Fishery, Olsztyn.

JENSÉN S. 1977. *An objective method for sampling the macrophyte vegetation in lakes*. Vegetatio 33: 107–118.

KESKITALO J., SALONEN K. 1994. *Manual for integrated monitoring. Subprogramme Hydrobiology of Lakes*. National Board of Waters and the Environment, Helsinki, Vesi-Ja Ymparistohallinnon Julkasuja, Seria B, 16: 28–30.

KOLADA A., SZOSZKA H., CYDZIK D., GOŁUB M. 2005. *Abiotic typology of Polish lakes*. Limnologica, 35(3): 145–150.

KRAUSE W. 1981. *Characeen als Bioindikatoren für den Gewässerzustand*. Limnologica, 13(2): 399–418.

LEKA J. 2005. *Macrophytes as a tool to assess the ecological status of lakes*. [In:] *Sampling. Presentations of three training seminars on Quality Assurance (QA). Biological methods of Water Framework Directive and Waste water sampling techniques*. Ed. H. Lääne, W. Heinonen. Suomen ympäristökeskuksen moniste. 328: 60–64.

LEKA J., YALTA-HULKKONEN K., KANNINEN A., AIRAKSINEN O. 2002. *Aquatic macrophytes in the dassification of ecological status of boreal lakes: Testing field study methods and aerial photographing as tool for monitoring*. [In:] *Typology and ecological dassification of lakes and rivers*. Eds. M. Ruoppa, K. Karttunen. TemaNord., 566: 93–96

MAGURRAN A. 1988. *Ecological diversity and its measurement*. Princeton, New Jersey: Princeton University Press.

MURPHY K.J. 2002. *Plant communities and plant diversity in softwater lakes of northern Europe*. Aquatic Botany, 73: 287–324.

Directive 2000/60/EC of the European Parliament and of the Council of the European Union 23 October, 2000 establishing a framework for Communities in the field of water policy. Official Journal of the European Union, issue L., 327 pp.

ROONEY N., KALFF J. 2000. *Inter-annual variation in submerged macrophyte community biomass and distribution: the influence of temperature and lake morphometry*. Aquat. Bot., 68: 321–335.

SAMOSIEJ L. 1987. *Wpływ antropopresji na roślinność litoralu jezior w krajobrazie rolniczym południowych Kujaw*. Lodz University [unpublished work].

SAWICKA-KAPUSTA M., ZAKRZEWSKA M., KUTRZEBA L., SKIBNIEWSKA K.A., SZAREK J., GUZIUR J., GRZYBOWSKI M., ZMYSŁOWSKA I. 2005. *Zawartość metali ciężkich w narządach myszy leśnej (Apodemus flavicollis) z lasów w pobliżu mogilnika pestycydowego*. J. Elementol, 10(3): 781–786.

SHANNON C.E., WEAVER W. 1949. *The mathematical theory of communication*. Urbana, University of Illinois Press.

SCHAUMBURG J., SCHRANZ CH., HOFMANN G., STELZER D., SCHNEIDER S., SCHMEDTJE U. 2004a. *Handlungsanweisung für die ökologische Bewertung von Seen żur Umsetzung der EU-Wasserrahmenrichtlinie. Makrophyten und Phytobenthos*. Bayerisches Landesamt für Wasserwirtschaft, München.

SCHAUMBURG J., SCHRANZ CH., HOFMANN G., STELZER D., SCHNEIDER S., SCHMEDTJE U. 2004b. *Macrophytes and phytobenthos as indicators of ecological status in German lakes – a contribution of the implementation of the Water Framework Directive*. Limnologica, 34: 302–314.

SCHEFFER M. 1998. *Ekology of Shallow Lakes*. Chapman and Hall, London.

SKIBNIEWSKA K.A., GUZIUR J., GRZYBOWSKI M., SZAREK J. 2003. *DDT in the soil of a pesticide tomb and surrounding ecosystems*. [In:] *On Analitical and Environmental Problems*. Ed. Z. Gallbacs.

SMOLDERS A.J.P., LAMERS L.M.P., ROELOFS J.G.M. 2001. *Aquatic macrophytes in assessment and monitoring of ecological status of aquatic environments*. TemaNord, 563: 23–31.

StatSoft, Inc. 2005. STATISTICA (data analysis software system), version 7.1. www.statsoft.com.

SZAREK J., SKIBNIEWSKA K.A., LIPIŃSKA J., GUZIUR J., BABIŃSKA I., ANDRZEJEWSKA A., GRZYBOWSKI M., KAPUSTA-SAWICKA K., ZMYSŁOWSKA I., ZAKRZEWSKA M. 2004. *Zagrożenie ekosystemów wodnych na przykładzie mogilnika pestycydowego w Warlitach Wielkich*. [In:] *Ochrona zdrowia ryb – aktualne problemy*. Eds. A.K. Siwicki, J. Antychowicz, W. Szweda. Wyd. IRŚ, Olsztyn, 203–210.

SZAREK J., SKIBNIEWSKA K.A., GUZIUR J., WOJTACKA J., GRZYBOWSKI M., BABIŃSKA I., ANDRZEJEWSKA A., SAWICKA-KAPUSTA K., ZMYSŁOWSKA I., ZAKRZEWSKA M., CHEŁSTOWSKA D. 2006. *Pathomorphological pattern of hepatopancreas in carp (Cyprinus carpio L.) originating from a pond near a pesticide tomb*. [In:] *Biotechnology 2006*, Environmental biotechnology. Ed. V. Řehout. Scientific Pedagogical Publishing, Česke Budějovice, Czech Republic, pp. 899–901.

SZAREK J., SKIBNIEWSKA K.A., GUZIUR J., WOJTACKA J., GRZYBOWSKI M., BABIŃSKA I., ANDRZEJEWSKA A., SAWICKA-KAPUSTA K., FELSMANN M., ZAKRZEWSKA M., ZMYSLOWSKA I. 2007a. *Pathomorphological pattern of the hepatopancreas and kidneys in carp (Cyprinus carpio Linnaeus, 1758) bred in a pond near a pesticide tomb in Ilawskie Lake District in the years 2004 and 2006*. Proceedings of the III International Conference *"Fishery",* Ideja Print, Loznica, Republic of Serbia. pp. 198–206.

SZAREK J., SKIBNIEWSKA K.A., GRZYBOWSKI M., GUZIUR J., SAWICKA-KAPUSTA K., ZAKRZEWSKA M., ANDRZEJEWSKA A., ZMYSLOWSKA I., FELSMANN M. 2007b. *Pathomorphology as a tool in searching for sources of environmental pollution.* Proceedings of the International Conference on Environmental Management, Engineering, Planning and Economics. Skiathos, GRAFIMA Publ., Thessaloniki, Greece, 7–12.

SZAREK J., SKIBNIEWSKA K.A., WOJTACKA J., GUZIUR J., BABIŃSKA I., ANDRZEJEWSKA A., SAWICKA--KAPUSTA K., GRZYBOWSKI M., ZAKRZEWSKA M., ZMYSŁOWSKA I., FELSMANN M. 2007c. *Effect of the pesticide tomb in Ilawskie Lake District on the morphological pattern of the liver and kidneys of the black-striped field mouse (Apodemus agrarius, Pallas 1771) in the year 2004 and 2006.* Pol. J. Pathol., 58(2): 147.

WHITTAKER R.H. 1977. *Evolution of species diversity in land communities.* Evol. Biol., 10: 1–67.

ZAKRZEWSKA M., SAWICKA-KAPUSTA M., ALEKSANDROWICZ P., STOCHMA M., SZAREK J., GRZYBOWSKI M., SKIBNIEWSKA K.A., GUZIUR J., ZMYSŁOWSKA I. 2005. *Poziom metali ciężkich w tkankach nornicy rudej (Clethrionomys glareolus) z terenu oddziaływania mogilnika pestycydowego.* J. Elementol., 10(3): 851–856.

ZMYSŁOWSKA I., SZAREK J., GOLAŚ I., GRZYBOWSKI M., GUZIUR J., SKIBNIEWSKA K.A. 2005. *Oddzialywanie mogilnika pestycydowego na mikroflorę promieniowców i grzybów w środowisku wodnym i glebowym..* Zesz. Probl. Post. Nauk Roln., 505: 529–543.