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PHYTOCENOTIC DIVERSITY OF LITTORAL IN LAKES OF THE MASURIAN LANDSCAPE PARK – CURRENT STATE AND CHANGES

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Summary. 16 deep and 25 shallow lakes, located in the Masurian Landscape Park were studied. The results obtained show that phytocenotic diversity affects the ecological status (ESMI value) of deep lakes to a higher degree than that of shallow lakes. An opposite tendency was observed for colonization index (phytolittoral expanse). Long-term vegetation changes in deep lakes of the Masurian Landscape Park are induced first of all by anthropopressure, whereas in shallow lakes such changes are also caused by fish and birds.

Key words: phytocenotic diversity index (H), colonization index (Z), ecological state macrophyte index (ESMI)

INTRODUCTION

Biocenotic diversity is one of the most important indicators of the ecological status of all ecosystems, including aquatic ones. The phytocenotic diversity of littoral is also one of the indicators determining the ecological status of lakes according to the framework Directive of the European Union on Action in the Field of Water Policy [2000].

RESEARCH AREA

The littoral of 41 lakes located in the Masurian Landscape Park was studied (Table 1). The surface features of the Park were formed as a result of the Würm glaciation, between the Poznan and Pomeranian phases.

METHODS

The phytocenotic diversity of the lakes examined was determined on the basis of the phytocenotic diversity index H, calculated applying the Shannon-Weaver formula,

Table 1. Morphometry of lakes in lakes of Masurian Landscape Park
Tabela 1. Cechy morfometryczne jezior Mazurskiego Parku Krajobrazowego

Lake Jezioro	Area lake Powierzchnia jeziora (ha)	Max depth Głębokość max (m)	Mean depth Głębokość średnia (m)
Kuc	127.4	36.1	9.0
Lisunie Małe	13.7	10.0	6.5
Majcz Wielki	163.5	16.4	6.0
Jegocin	127.4	36.1	9.0
Probarskie	201.4	31.0	9.2
Mokre	841.0	51.0	12.7
Nawiady	199.8	29.8	9.0
Wierzbowskie	104.4	18.1	4.8
Zdrużno	250.2	25.9	5.4
Białoławki	211.1	36.1	9.8
Guzianka Mała	36.8	13.3	2.7
Tyrkło	236.1	29.2	9.7
Guzianka Duża	59.6	25.5	6.5
Jegocinek	52.3	17.9	7.1
Bełdany	940.6	46.0	10.0
Mikołajskie	497.9	25.9	11.2
Kołowinek	19.6	6.4	3.6
Skarp	23.4	10.5	5.7
Kiełbonki	30.0	4.2	2.2
Mojtyny	28.2	8.0	3.3
Lisunie Duże	13.8	8.5	3.5
Duś	35.5	6.0	2.8
Nawiadki	25.5	6.0	2.8
Majcz Mały	20.0	3.3	1.8
Łuknajno	680.0	3.2	0.6
Płociczno	16.8	4.7	2.3
Krutyńskie	55.0	5.5	1.7
Inulec	178.3	10.1	4.6
Zdrężno	12.1	7.5	2.0
Tuchlin	219.3	4.9	2.9
Gardyńskie	82.6	11.5	2.5
Kołowin	78.2	7.2	4.0
Wigryny	24.8	3.2	1.7
Wejsuny	38.0	11.8	3.6
Pawełek	7.6	3.6	1.8
Kierwik	59.6	16.6	6.1
Uplik	60.6	9.2	2.8
Nicponek	10.0	4.0	2.0
Wągiel Duży	150.0	13.3	4.2
Wągiel Mały	26.8	7.0	3.0
Zjadle	11.0	3.5	1.8

Table 2. Lake groups according to the ecological state [Rejewski 1981, Rejewski and Ciecierska 2004]
Tabela. 2. Grupy jezior według stanu ekologicznego

Lakes groups Grupy jezior	Value of macrophyte ecological state index (ESMI)* Wartości makrofitowego wskaźnika stanu ekologicznego jezior (MWSE)
Very good – Bardzo dobry	1.00-0.60
Good – Dobry	0.60-0.40
Moderate – Umiarkowany	0.40-0.30
Sufficient – Dostateczny	0.30-0.20
Bad – Zły	0.20-0.00

*ECMI = 1 – exp (– H × Z / H_{max})

where the quantitative character is the area occupied by particular communities [Rejewski 1981]. The value of this index depends first of all on the number of phytocenoses forming lake phytolittoral. The phytocenotic diversity index is the highest when the areas of particular communities are the same. The colonization index *Z*, reflecting phytolittoral expanse (ratio between total phytolittoral area and area occupied by the 2.5 m isobath), was also calculated. These two indices, together with the ecological state macrophyte index (ESMI), provided the basis for evaluating the ecological status of particular lakes (Table 2).

RESULTS AND DISCUSSION

The results obtained for deep and shallow lakes were analyzed separately (Table 3). The index H was higher for deep lakes (2.01-0.46) than for shallow ones (1.96-0.93), because deep lakes represent a meso- to hypertrophic series, whereas shallow ones – a eutro- to hypertrophic series. The colonization index Z was lower for deep lakes (1.88-0.47) than for shallow ones (2.00-0.19). This shows that the ecological status of deep lakes is affected to a higher degree by the phytocenotic diversity index H than the colonization index Z. In shallow lakes the colonization index Z is of greater importance.

The ecological status of most lakes situated in the Masurian Landscape Park, both deep and shallow, was described as very good or good (Tables 2, 3). These water bodies are characterized by well-developed vegetation of the *Chara* type, recorded at a depth of 7.0-3.5 m in deep lakes, and 4.0-1.0 m in shallow ones.

An example of long-term vegetation changes in deep water bodies may be Lake Kuc, Lake Majcz Wielki (hydrologically closed) and Lake Mikołajskie. In Lake Kuc (agricultural catchment area) the phytocenotic diversity index H displays a falling tendency, because although the number of plant communities is gradually increasing, they cover relatively small areas. The most significant changes were observed in the case of stoneworts (1995 – 65.7% of phytolittoral, 2003 – 28.3%), which were replaced by immersed plants of the class *Potametea* (1995 – 14.4%, 2003 – 55.6%): *Ceratophyllum demersum*

and *Myriophyllum spicatum*. A similar process was also noted in Lake Majcz Wielki (afforested catchment area), but to a much lower extent. An increase in the phytocenotic index II was accompanied by a decrease in the number of phytocenoses whose area distribution was similar, indicating stable habitat conditions. In Lake Majcz Wielki light conditions did not change over the experimental period (4.0 m), and in Lake Kuc transparency diminished from 6.5 m to 4.5 m. Despite considerable changes, these water bodies are still characterized by a very good ecological status. Advanced changes caused by anthropopressure (mostly recreation) can be observed in Lake Mikołajskie. This lake is one of the Great Masurian Lakes and until the 1990s it received domestic and industrial effluents from the town of Mikołajki. The phytocenotic diversity index H was here the lowest of all the lakes examined (0.46). Only 11 plant communities were observed, immersed plants constituted 9.2% of phytolittoral, and transparency was 1.0 m. The ecological status of this lake was bad.

An example of long-term vegetation changes in shallow water bodies may be Lake Kołowin (hydrologically closed) and Lake Łuknajno – a reserve of mute swans (*Cygnus olor*). In Lake Kołowin (afforested catchment area) all ichthyofauna vanished in 1984 as a result of accidental poisoning with pesticides (chlorofluorohydrocarbons). Analyses of its water and vegetation performed three years after this ecological catastrophe showed that its status could still be classified as very good. The phytocenotic diversity index H was high (2.44) [Środa 1990], and the phytolittoral was formed by many communities (28), 49.0% of phytolittoral were immersed plants, mostly *Charetea*. The colonization index Z was also high (1.39), and plants were observed to a depth of 5.0 m, with water transparency of 5.0 m. However, the studies conducted in 1996 indicated much poorer condition of the lake's vegetation: stoneworts disappeared completely, the number of communities decreased (18), phytolittoral area was by 23.0% smaller, the indices H and Z decreased considerably (1.30 and 1.07, respectively), plants were observed to a depth of 2.0 m only. The water quality deterioration was caused by silver carp (*Hypophthalmichthys* sp.) stocking, repeated several times in the years 1987-1992. Water transparency decreased to 2.5 m. The condition of the lake improved after the last adult silver carps had been caught (1996-1997). The vegetation started to recover, in the years 1998-2003 there appeared the stoneworts *Chara tomentosa, Ch. rudis, Ch. fragilis* and *Nitellopsis obtusa*, and other species of immersed plants [Ciecierska 2003]. The phytolittoral area increases a little every year, which is reflected by the colonization index Z (1.07-1.17). The investigations carried out in the years 1998-2000 show that the status of the lake's vegetation remains unstable (significant annual changes). The vegetation systems gradually recover to their original state, but along a different developmental path, which is consistent with the principles of ecology and the concept of alternative stable states [Scheffer 1998]. Another example of changes is Lake Łuknajno (agricultural catchment area), where the area covered by stoneworts is successively diminishing (1966-1970 – 79.4% of phytolittoral [Polakowski *et al.* 1973], 1993 – 56.3% [Królikowska 1996], 2003 – 52.4%). Their place is taken by elodeids, mostly *Najas marina* and *Potamogeton pectinatus* (1.1%, 1.8%, 11.7%, respectively) and nymphaeids, mostly *Stratiotes aloides* (0.0%, 4.6%, 8.8%, respectively). The phytocenotic diversity index H increased from 1.3 in the years 1966-1970 to 1.79 in 1993, to fall slightly in 2003 (1.75). The number of plant communities was also increasing systematically over the period analyzed, amounting to 9, 13 and 23 in successive years. Stoneworts were replaced by phytocenoses of the thermophilous species *Najas marina*, and *Stratiotes aloides*. This

Table 3. Values of indices characterising biocenotic and spatial strukture of the vegetation in deepth and shellow (gray) lakes Masurian Lakeland Park

Tabela 3. Wartości wskaźników charakteryzujących biocenotyczne i strukturalno-przestrzenne układy roślinności głębokich i płytkich (szary) jezior Mazurskiego Parku Krajobrazowego

Lake Jezioro	Phytolittoral area Pow. fitolit. (ha)	Number of phytolittoral communities Liczba zbiorowisk S	Phytocenotic diversity index Wskaźnik zróżnicowania fitocenotycznego H	Maximal phytocenotic diversity index Max wskaźnik zróżnicowania fitocenotycznego H_{max}	Colonization index Wskaźnik zasiedlenia Z	Ecological state macrophyte index ESMI Makrofitowy wskaźnik stanu ekolog. MWSE	Eiological state Stan ekologiczny
Kuc	55.1	28	2.01	3.33	1.88	0.677	
Lisunie Małe	2.61	15	1.71	2.71	1.63	0.650	
Majcz Wielki	68.6	19	1.89	3.33	1.73	0.625	
Jegocin	47.9	24	2.08	3.26	1.51	0.618	
Kołowinek	12.2	18	1.96	2.89	2.10	0.758	
Skarp	9.0	14	1.78	2.64	1.92	0.725	
Kiełbonki	29.9	11	1.41	2.40	2.06	0.703	very good bardzo dobry
Mojtyny	22.2	20	1.34	2.64	2.22	0.676	
Lisunie Duże	7.8	19	1.74	2.94	1.69	0.632	
Duś	33.5	15	1.60	2.71	1.67	0.628	
Nawiadki	11.8	8	1.49	2.08	1.36	0.621	
Płociczno	12.9	13	1.54	2.56	1.59	0.616	
Majcz Mały	19.9	25	1.76	3.22	1.69	0.602	
Probarskie	68.6	26	1.79	3.26	1.49	0.559	
Mokre	103.1	31	1.87	3.43	1.06	0.439	
Nawiady	50.2	21	1.56	3.04	1.35	0.499	
Wierzbowskie	30.3	18	1.53	2.89	1.17	0.462	
Zdrużno	70.7	28	1.24	3.33	1.72	0.528	good dobry
Krutyńskie	54.9	25	1.91	3.22	1.29	0.534	
Inulec	49.5	24	1.70	3.18	1.12	0.451	
Zdrężno	2.5	8	1.61	2.08	0.77	0.449	
Tuchlin	105.2	11	1.17	2.40	1.21	0.446	

Gardyńskie	56.5	15	1.58	2.71	1.00	0.441	good dobry
Kołowin	24.7	22	1.55	3.14	1.10	0.418	
Łuknajno	645.0	23	1.75	3.14	0.95	0.413	
Białoławki	59.9	20	1.23	3.00	1.03	0.344	moderately umiarkowany
Wejsuny	18.6	15	1.16	2.71	1.15	0.389	
Wigryny	22.5	11	0.89	2.40	1.05	0.322	
Pawełek	3.7	7	1.32	1.95	0.74	0.316	
Guzianka Mała	15.0	18	1.41	2.89	0.72	0.296	sufficient dostateczny
Tyrkło	25.3	23	1.17	3.14	0.77	0.248	
Kierwik	9.6	13	0.93	2.56	0.77	0.243	
Uplik	26.4	22	1.09	3.09	0.79	0.242	
Guzianka Duża	9.6	19	1.29	2.94	0.47	0.187	bed zły
Jegocinek	8.8	7	0.53	1.95	0.75	0.181	
Bełdany	105.0	22	0.73	3.09	0.60	0.133	
Mikołajski	26.9	11	0.46	2.40	0.52	0.096	
Nicponek	0.7	11	1.98	2.40	0.25	0.187	
Wągiel Duży	12.7	19	1.70	2.94	0.35	0.183	
Wągiel Mały	3.5	7	1.07	1.95	0.30	0.153	
Zjadłe	0.9	12	1.33	2.48	0.19	0.053	

indicates progressing eutrophication and shallowing, also confirmed by rapidly developing communities with water fern (*Thelypteris palustris* – 4.1%), not recorded before. Quick vegetation changes taking places in Lake Łuknajno are probably caused by swans. Their population, although reduced a little, still consists of 1000 birds. The agricultural catchment area of this lake has not been used since the 1990s.

Changes connected with anthropopressure are slower in deep lakes, especially those with afforested catchment areas. Shallow lakes are affected not only by human activities carried out in their catchment areas, but also fish farming and biotic factors, e.g. avifauna.

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RÓŻNORODNOŚĆ FITOCENOTYCZNA LITORALU JEZIOR MAZURSKIEGO PARKU KRAJOBRAZOWEGO – STAN I ZMIANY

Streszczenie. Wykazano większą zależność pomiędzy zróżnicowaniem fitocenotycznym a stanem ekologicznym (wartości wskaźnika WSE) w jeziorach głębokich (16 zbiorników) niż jeziorach płytkich (25 zbiorników) Mazurskiego Parku Krajobrazowego. Natomiast odwrotną zależność uzyskano w stosunku do wartości wskaźnika zasiedlenia (rozległość fitolitoralu). Na wieloletnie zmiany roślinności jezior głębokich Mazurskiego Parku Krajobrazowego ma przede wszystkim wpływ antropopresja, natomiast w jeziorach płytkich mają również ryby i ptaki.

Słowa kluczowe: wskaźnik zróżnicowania fitocenotycznego (I), wskaźnik zasiedlenia (Z), makrofitowy wskaźnik stanu ekologicznego (ESMI)