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**SUBMERGED MACROPHYTES AS INDICATOR OF ECOLOGICAL STATUS
OF LAKES (POLESIE LUBELSKIE REGION, POLAND)**

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Introduction

The assessment of the ecological status of the aquatic ecosystem is a requirement of the European Directive, called the Water Framework Directive (WFD, 2000/60/EC). Three elements are taken into account for the assessment of the ecological status of lakes: biological indicators (composition, abundance and structure of aquatic organisms - phytoplankton, macrozoobenthos, fish and macrophytes), physical and chemical indicators as well as hydromorphological indicators.

For many years, macrophytes have been recognized as good indicators of the ecological status of aquatic ecosystems (Kolada 2008, Sender et al 2017). In Poland, the Macrophyte Ecological State Index (ESMI) is officially recognized and accepted for monitoring of standing water (Ciecierska et al 2010).

In the area of the Polesie Lubelskie region there are 62 lakes with an area of over 1 ha (Chmielewski 2009). The reason for their creation is related to the warming of the climate that occurred at the turn of the Pleistocene and the Holocene and the development of a thermo-mass (Wojtanowicz 1994). Lakes of Polesie, among others due to their different origin, were defined as so-called "Type-specific" (Ciecierska, Kolada 2014). Therefore, it is justified to apply many indicators defining their ecological status.

The purpose of the study was to determine the ecological status of three lakes in the Łęczna-Włodawa Lake District, based on various macrophyte indicators.

Study area and methods

Study was carried out in 2015 and 2016. The analyzes included three lakes of the Łęczna-Włodawa Lakeland: Lipieniec (L), Miejskie (M) and Białe Włodawskie (BW). The main criterion for the application of the majority of indicators for assessing the ecological status of lakes was the presence and dominance of submerged macrophytes. The studied lakes varied in terms of surface, depth and the dominant type of buffer zone use (Table 1).

Three indicators were used for the study. The SPI index has been developed for research on New Zealand lakes. It is possible to apply only in those lakes in which there are submerged macrophytes, and their share in the phytolitoral area is not less than 10%, as well as invasive species are present (Clayton, Edwards 2006). The RI reference index was developed for the monitoring of German lakes (Schaumburg et al 2004, Stelzer et al. 2005). The RI Index applies only to lakes with submerged and floating leaf macrophytes. The Polish Ecological Status Index (ESMI) is based on the analysis of all macrophyte groups but in the context of communities (Ciecierska et al. 2010).

Table 1

Characteristic of investigated lakes and its littoral zone

| Parametr lake | Białe Włodawskie | Lipieniec | Miejskie | |
|---|-------------------------------|-----------|----------|-------|
| lake surface (ha) | 104,36 | 3.7 | 45.52 | |
| depth (m) | 33.6 | 7.1 | 2.2 | |
| secchi disc visibility SD (m) | 3.85 | 2.8 | 0.8 | |
| land use type (%) | standing waters | 0.07 | 1.2 | 1.5 |
| | peat bog with succession | | | 26.17 |
| | marshy meadow with succession | 12.92 | 33.2 | 3.7 |
| | forests | 21.09 | 41.5 | 6.83 |
| | Shrub communities | 1.68 | 1.7 | 3.01 |
| | farmlands | 0.27 | 21.8 | 36.27 |
| | fallow | | 0.08 | 11.21 |
| | compact infrastructure | 62.9 | 0.5 | 9.68 |
| Shoreline length (m) | 4706.6 | 732.3 | 2867.1 | |
| Area restricted by 2.5m izobath (ha) | 30.31 | 1.15 | 43.45 | |
| Area of phytolittoral (ha) | 31,9 | 2,7 | 20,9 | |
| Area covered with emergent macrophytes (%) | 23,2 | 2,1 | 11,2 | |
| Area covered with submerged macrophytes (%) | 72,7 | 77,8 | 53,6 | |

Results and discussion

According to the SPI index overall lake condition was high for Lake Lipieniec, excellent for Lake Białe Włodawskie and moderate for Lake Miejskie (Table 2). All three lakes had extensive native submerged vegetation, with maximum depth records exceeding 5.6 m in lake BW and reaching 3.1 m in Lake L and 1.8 in Lake M. This translated to Native Condition Index values ranging between 40% and 80% (Table 2). Impact by invasive species was negligible to low, with an Invasive Impact Index of approximately 22% for the two deeper lakes and just 18.5% for Lake M. The low scoring for invasive impact was driven by the presence of only *Elodea canadensis* which was only accompanying species.

According to the RI Index investigated lakes represented good and moderate ecological status (Table. 3). It means that there are slightly changes in the composition and abundance of macrophytes in lakes BW and L. In the Lake M the composition of macrophytes differ moderately from the type specific communities and significantly distorted, moderate changes in abundance (Stelzer et al. 2005).

Table 2

Evaluation of studied lakes according to the SPI index

| Lake SPI index | Białe Włodawskie (BW) | Lipieniec (L) | Miejskie (M) |
|-----------------------------------|--------------------------|------------------|-----------------|
| Max depth of plant occurrence (m) | 5.6 | 3.1 | 1.8 |
| Meadow depth (m) | 5.0 | 2 | 1.5 |
| Total number of sub. species | 15 | 4 | 4 |
| Native species among submerged | 14 | 3 | 3 |
| Native ratio (%) | 76-95 | 51-75 | 26-50 |
| Native Condition Index (%) | 80 | 66.6 | 40 |
| Invasive Impact Index (%) | 22.2 | 22.2 | 18.5 |
| Lake SPI Index (%) | 71.4 | 60 | 45.7 |
| EVALUATION | excellent | high | moderate |

Table 3

Classification of investigated lakes according to RI index values

| Index Lake | Białe Włodawskie | Lipieniec | Miejskie |
|-----------------|------------------|-----------|----------|
| RI Index | 3.41 | 8.51 | 0 |
| EQR | 0.52 | 0.54 | 0.50 |
| EVALUATION | good | good | moderate |

Analyses of studied lakes demonstrated the presence of very similar number of communities range from 10 to 11 (Tab.4). The average number of plant communities among 153 Polish reference lakes ranged from 21 to 23 (Ciecierska et al., 2006). Therefore, for the studied lakes, the number was much lower than the average. The species number in the lakes of the Wel river basin ranged from 28 to 54 (Kolada et al. 2011). While in the studied lakes of Polesie Lubelskie it was from 10 in the Lake L to 22 in the Lake BW. The Polesie Lakes were poorer in terms of the number of species. However, the coverage of lakes by macrophytes was high and ranged from 30.6 to 72.9%. The limit for deep reference lakes is 67%, and shallow 53% (Ciecierska, Kolada 2014).

The ecological status of lakes based on ESMI was rated as good in jeziorze Białe Włodawskie and Miejskie and very good in Lake Lipieniec (Tab. 4).

Table 4

Evaluation of studied lakes according to the ESMI index

| Index Lake | Białe Włodawskie | Lipieniec | Miejskie |
|--|---------------------|-----------|----------|
| Number of phytolittoral communities (S) | 11 | 10 | 11 |
| phytolittoral area (%) | 30.6 | 72.97 | 45.91 |
| Index of colonization (Z) | 0.88 | 63.45 | 1.06 |
| Index of max. phytocenotic diversity (H) | -1.19 | -2.18 | -2.53 |
| Ecological Status ESMI | 0.35 | 1.00 | 0.67 |
| EVALUATION | good | very good | good |

The assessment based on selected indicators gave slightly different results. Lakes from Łęczna-Włodawa Lakeland belong mostly to small and shallow lakes. They represent almost all trophic types. Often their phytolittoral is dominated by emergent macrophytes (Sender 2009). Most of the lakes in the study Lake District area are characterized by geographical identity and origin from the so-called reference lakes from Poland. Each of the applied indexes gives additional information: on the participation of invasive species (SPI), the number of communities, their share in phytolittoral surface, as well as distribution in the lake (ESMI), the abundance of sensitive and tolerant species (RI).

Therefore, the assessment of the ecological status of lakes should be based on many indicators, including various groups of aquatic organisms.

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