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DIRECTION OF HYDROBOTANIC CHANGES OF MESOTROPHIC LAKE (EAST POLAND)

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Abstract. The study included mesotrophic Lake Piaseczno, located in the Łęczna-Włodawa Lake District. The aim of the study was to evaluate changes of water vegetation of a mesotrophic lake subjected to strong recreational pressure. Specifically we sought to better understand which natural landscapes and anthropogenic developments stimulate or impede macrophyte development and spread. The study was conducted in July in 1997, 2007 and 2017 in three transects: the peat-bog (northern part of the lake), the recreational area (southeast part) and the agricultural area (east). The phytolittoral zone was analyzed from the shoreline to the maximum range of macrophytes occurrence. The study included all groups of macrophytes. Macrophytes in the mesotrophic Lake Piaseczno are still subjected to successive changes. Clearly increased diversity among emergent macrophytes, while a group of submerged macrophytes decreased. The largest changes among analyzed groups of macrophytes occurred in recreational and agricultural transects. Macrophytes have increased the range of occurrence, which may be due to hydrological changes associated with raising the overall water level, thus with increasing the area of the littoral. Impoverishment of diversity among elodeids shows the processes associated with the increase in Lake trophy.

Key words: macrophytes, Lake Piaseczno, long term changes, land management

INTRODUCTION

Among more than 7.000 lakes in Poland, most of them are eutrophic, that is fertile. Trophy is a key factor determining living conditions in lakes [Stańczykowska 1975, Mikulski 1982, Chełmicki 2001]. Lakes are variable ecosystems [Mikulski 1982], which is characterized by a progressive succession. The process of lakes succession is natural and inevitable. Speed and direction of these transformations associated with their maturation are influenced by many factors, including the physical and chemical properties of water [Closs *et al*. 2004].

Mesotrophic lakes are characterized by high transparency of water (4 to 7 meters), the presence of *Chara* communities, significant oxygenation, especially of bottom beds [Choiński 2007] are particularly valuable in nature. However, these lakes are subject to transformation either. Biocenoesis inhabiting these lakes, macrophytes among them, also react to changes.

As macrophytes inhabit the littoral zone that contacts the lake shore, they are sensitive to environmental conditions along shorelines and surrounding land areas [Thiebaut *et al*. 2002]. Macrophytes serve as biofilters for surface flow [Bai *et al*. 2012] and influence lower trophic levels in lakes [Bakker *et al*. 2010] also prevent erosion of the lakeshore and provide shelter for fish and waterfowl [Engloner 2009].

The aim of the study was to evaluate changes of water vegetation of a mesotrophic lake subjected to strong recreational pressure. Specifically we sought to better understand which natural features of lake catchment and anthropogenic developments stimulate or impede macrophyte development and spread. In addition to surveying existing conditions of macrophyte species, we also used data that was collected 20 years ago, in the same study sites, to better understand how the macrophytes in lake has changed over the last two decades.

STUDY AREA AND METHODS

The study included mesotrophic Lake Piaseczno, located in the Łęczna-Włodawa Lake District. It belongs to small lakes (area about 83 ha) and relatively deep (maximum depth about 38 m). Lake Piaseczno in 1919 was oligotrophic [Lityński 1919] and it was so-called by the end of 1950s [Radwan *et al*. 1995]. In 1970s, the lake was α-mesotrophic, in the littoral of the lake *Isoetes lacustris* occurred [Fijałkowski 1959].

Since late 1980s, the eutrophication process of Lake Piaseczno has been proceeding, as indicated by the value of the physico-chemical parameters of the water and planktonic indexes [Radwan *et al*. 1995] as well as plant communities composition [Ozimek 1976, Popiołek 1988]. In the early 2000s, symptoms of eutrophication were still visible [Sender 2007].

The changes in the lake's Piaseczno trophy were largely due to the intensive recreational use of the lake and the development of recreational facilities in its vicinity. Trophy changes are also caused by: permeability of sandy agricultural land, directly adjacent to the lake, global decrease in water level in the Łęczna-Włodawa Lake District, and degradation of peat bog situated in the northern part of the lake [Radwan *et al*. 1995, Sender 2007, Sender and Maślanko 2013].

The study was conducted in July in 1997, 2007 and 2017 in three transects: the peat bog (northern part of the lake), the recreational area (southeast part) and the agricultural area (east). The phytolittoral zone was analyzed from the shoreline to the maximum range of macrophytes occurrence.

The study included all groups of macrophytes: emergent, floating leaved, pleustonic plants and submerged. Species composition of macrophytes was determined (nomenclature according to Matuszkiewicz 2013), density of emergent macrophytes, range of occurrence, biomass and dominance in the biomass in each group [Szmeja 2006, Sender 2011]. In the analogical period and research stations, the water transparency by the visibility of the Secchi disk, and other physico-chemical features like: pH, electrolytic conductivity and phosphate and oxygen content in the lake water were analyzed.

RESULTS AND DISCUSSION

Macrophytes of Lake Piaseczno were subjected to intensive changes over a period of 20 years. In 1997, the analyzed transects were populated by 14 species in total, but in 2017 there were 28 species. A particular increase in the number of species occurred among emergent macrophytes. In 1997, the dominant group were submerged macrophytes (Table 1).

An increase in the number of emergent macrophytes species mainly due to intensive changes in the management of the shoreline and fluctuations in the water table. Changes connected with water level fluctuations lead to variation in species zonation, distribution and richness [Lacoul and Freedman 2006]. Water level fluctuations determine also the extent of colonization of submerged plants. For example in the storage reservoir, where there are large fluctuations in water level, three sub-zones within the littoral zone were distinguished [Krolova *et al*. 2013].

Periodic dryness or reduced water level can be a factor stimulating the development of vegetation. Ecosystems in the floodplain area have a considerable potential for the development of vegetation. The results of the Dutch researchers suggest that a decrease in water level or being completely dry is a factor stimulating the development of vegetation [Van Geest *et al*. 2007]. Periodically draining in the studied ponds is an area between the shaft and the shoreline zone of the fish pond, where there is the largest number of plant species and which is the place of living of insects and, especially, birds (150 species). However, macrophytes with floating leaves were indifferent to fluctuations in water levels [Van Geest *et al*. 2005].

Landscape and hydrological characteristics mainly played an important role in species composition-environmental conditions relationships, while chemical characteristics were less significant [Hrivnák *et al*. 2013]. The chemical parameters of the waters to a large degree determine the occurrence of macrophytes; however, this is not the only type of pressure. Also, the development of the catchment area and of the littoral zone of the aquatic ecosystems has a significant effect on water and rush plant communities.

Table 1. Macrophytes occurrence in the analyzed transects of Lake Piaseczno in particular years of research (+ singly; 1 = 1–5%; 2 = 5–25%; 3 = 26–50%; 4 = 51–75% and 5 = 76–100%, following the phytosociologic approach Braun-Blanquet, 1976)

Group/species	1997	2007	2017
Submerged macrophytes			
Ceratophyllum demersum L.	1	2	3
Chara fragilis			**3**
Chara delicatula	+	+	+
Chara globularis		+	
Elodea canadensis	1	1	
Myriophyllum alternifolium	3	4	**5**
Myriophyllum spicatum	+		
Nitella flexilis	+	+	
Nitellopsis obtusae			**2**
Potamogeton crispus	+		
Potamogeton lucens	1	+	+
Potamogeton praelongus	1	+	
Fontinalis antipyretica	+		+
Emergent macrophytes			
Alisma plantago-aquaitca		+	+
Eleocharis palustris	1	1	1
Iris pseudoacorus			+
Juncus articulatus		+	
Lycopus europeans		+	+
Lysymachia thyrsiflora		+	+
Lythrum salicaria		+	+
Myostis palustris		+	
Phragmites australis	2	4	4
Rumex hydrolapathum		+	+
Scirpetum lacustris	+	+	+
Scutellaria galericulata		+	
Thelypteris palustris		+	
Typha angustifolia	+	1	1
Bidens tripartitus L.			+
Calla palustris L.			+
Carex pseudocyperus L.			+
Carex vesicaria L.			+
Equisetum fluviatile			+
Mentha aquatica L.			+
Galium palustre		+	+
Scirpus sylvaticus L.			+
Thelypteris palustris		+	+
Pleustonic plants			
Utricularia vulgaris		1	1
Lemna minor			+
Floating leaved			
Nymphea alba/candida		1	+
Number of species	14	25	29

From the beginning of 2000 in Lake Piaseczno there was marked increase of water level. This resulted in the flooding of the shallow coastal zone, which was almost immediately inhabited by the plants.

Studies into the effect of the method of development of the littoral zone of lakes in the state of Wisconsin show that housing development definitely has a negative effect on submerged and floating-leaf plants. Such an effect was not observed for emergent vegetation. On the other hand, a lower share of forests in the catchment basin reduced the development of all macrophyte groups [Jennings *et al*. 2003, Akasaka *et al*. 2010]. The intensifying of recreational use and still unregulated sewage management around Lake Piaseczno result in adverse changes. As a result of this situation, the number of submerged species is reduced, while the diversity of helophytes increased.

The largest changes among emergent macrophytes occurred in the peat-bog transect. The range of their occurrence increased by 0.3 m. The number of species (8 species) and biomass (about 67 $g_{sm} \cdot m^{-2}$) also increased, as well as the width of the helophyte belt from 20 m in 1997 to 28 m in 2017. Changes in the range of macrophyte occurrence were not significant in other transects. At the end of the 90s there was no emergent macrophytes in recreational transect, while in 2017 there were 3 species, forming a 3m wide belt. The dominant species in Lake Piaseczno, irrespective of its location and year, was common reed (Table 2).

In the subsequent years of the study the range of submerged macrophytes occurrence up to 1 m, especially in the recreational transect has increased. Unfortunately, homogenization was evident among this group of macrophytes. In each of transects the number of species decreased, even by half. Despite species degradation in agricultural and recreational transects, the biomass of submerged macrophytes grew and was higher than emergent one. Only in peat-bog transect, the biomass of submerged macrophytes significantly decreased and was lower than the biomass of helophytes (Table 2).

As a rule, changes of the analyzed factors in individual transects were statistically significant. Only the range of emergent macrophytes occurrence in particular years of study was not statistically significant. Significant changes were also observed in the number of species and biomass both groups of macrophytes in subsequent years (Table 3).

Fluctuations in the water level have a large impact on macrophytes, but they are not the only type of pressure. The management of catchment area and coastal zone of aquatic ecosystems also has a significant impact on aquatic vegetation. The study of the shoreline area of the lakes of Wisconsin confirms that the presence of housing affects negatively, primarily on submerged vegetation and floating leaves plants [Jennings *et al*. 2003]. A similar situation took place in Lake Piaseczno in the recreational transect. The submerged macrophytes disappeared from the shallower places, and inhabit the deeper parts of the lake, but simultaneously reducing the

Table 2. Differentiation of Lake Piaseczno macrophytes in particular research sectors (E – emergent, S – submerged; Ph. aust. – *Phragmites australis*, Myr. alter. – *Myriophyllum alternifolium*, Ch. frag. – *Chara fragilis*, Nitel. flex. – *Nitella flexilis*)

Specification	Unit	Peat-bog transect			Agricultural transect			Recreational transect		
		1997	2007	2017	1997	2007	2017	1997	2007	2017
Range of E macrophytes	m	1.1	1.3	1.4	1.1	1.2	1.2	0	1.2	1.3
Width of E macrophytes	m	20	25	28	3	5	7	0	2	3
Range of S macrophytes	m	6.5	6.2	6.7	5.5	5	6.1	5.5	5.3	6.5
Density of E macrophytes	$ind \cdot m^{-2}$	57	48	62	43	50	53	21	20	24
Number of E species	ind.	2	7	10	2	4	8	0	3	3
Number of S species	ind.	9	5	5	9	7	4	10	7	5
E biomass	$g_{sm} \cdot m^{-2}$	378	312	445	195	202	237	0	84	96
S biomass	$g_{sm} \cdot m^{-2}$	122	67	108	94	99	298	151	216	270
Dominant species in E biomass		*Ph. aust*	*Ph. aust*	*Ph. aust*	*Ph. aust*	*Ph. aust*	*Ph. aust*	-	*Ph. aust*	*Ph. aust*
Dominant species in S biomass		*Myr. alter*	*Ch frag*	*Ch frag*	*Myr. alter*	*Myr. alter*	*Myr. alter*	*Nitel flex*	*Myr. alter*	*Myr. alter*

Table 3. Results of two-way ANOVA (site, year) for macrophytes in Lake Piaseczno (n = 72; ns – not significant)

	Site	Site by year
Range of E macrophytes	ns	$F = 8.98$; $p < 0.001$
Width of E macrophytes	$F = 17.07$; $p < 0.001$	ns
Range of S macrophytes	$F = 6.87$; $p < 0.001$	ns
Density of E macrophytes	$F = 5.62$; $p < 0.001$	ns
Number of E species	$F = 2.58$; $p < 0.001$	$F = 31.1$; $p = 0.044$
Number of S species	$F = 2.86$; $p = 0.01$	$F = 35.7$; $p = 0.01$
E biomass	$F = 25.8$; $p = 0.016$	$F = 19.21$; $p = 0.001$
S biomass	$F = 6.16$; $p = 0.001$	$F = 0.59$; $p < 0.001$

diversity. All shallow littoral zone of Lake Piaseczno were inhabited with emergent macrophytes, irrespective of the shore zone use type.

CONCLUSIONS

Macrophytes in the mesotrophic Lake Piaseczno are still subjected to successive changes. Clearly increased diversity among emergent macrophytes, while a group of submerged macrophytes decreased.

The largest changes among analyzed groups of macrophytes occurred in recreational and agricultural transects.

Macrophytes have increased the range of occurrence, which may be due to hydrological changes associated with raising the overall water level.

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KIERUNEK ZMIAN HYDROBOTANICZNYCH MEZOTROFICZNEGO JEZIORA (WSCHODNIA POLSKA)

Streszczenie. Badaniami objęto mezotroficzne jezioro Piaseczno, położone na terenie Pojezierza Łęczyńsko-Włodawskiego. Celem badań była ocena zmian roślinności wodnej jeziora w okresie 20 lat, poddanego silnej presji rekreacyjnej. Badania prowadzono w latach 1997, 2007 i 2017, w lipcu, w trzech transektach: torfowiskowym (część północna jeziora), rekreacyjnym (część południowo-wschodnia), rolniczym (wschodnia). Analizowano strefę fitolitoralu od linii brzegowej do maksymalnego zasięgu występowania makrofitów. Badaniami objęto wszystkie grupy makrofitów. Makrofity jeziora Piaseczno podlegają sukcesywnym przemianom. Wyraźnie zwiększyła się różnorodność wśród makrofitów wynurzonych, natomiast zmniejszyła makrofitów zanurzonych. W rekreacyjnym oraz rolniczym transekcie makrofity podlegały największym zmianom. Większy zasięg występowania obu grup makrofitów mógł być spowodowany zmianami hydrologicznymi w zlewni jeziora, związanymi z podniesieniem poziomu wód, a zatem ze zwiększeniem powierzchni litoralu. Wyraźne ubożenie różnorodności wśród elodeidów świadczy o procesach związanych ze wzrostem żyzności wód jeziora.

Słowa kluczowe: makrofity, jezioro Piaseczno, zmiany długoterminowe, użytkowanie terenu