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LONG-TERM CHANGES IN AQUATIC AND SWAMP VEGETATION IN SELECTED LAKES OF SEJNY LAKE DISTRICT°

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Summary. Changes in aquatic and swamp vegetation were analysed in 12 lakes of Sejny Lake District over a 25-year period. It was found that the charophyte communities had retreated from some lakes and were eventually replaced by communities of the class *Potametea*. The expansion of *Ceratophylletum demersi* and *Myriophylletum spicati* communities as well as the increase of the area of *Phragmitetum australis* and *Thelypteridi-Phragmitetum* phytocoenoses were observed. These trends reflect the general direction of vegetation succession in mesotrophic and eutrophic lakes: *Charetea→Potametea→Phragmitetea*. The permanent changes in vegetation are associated with changes in littoral water chemistry, i.e. increase in lake fertility and alkalinization.

Key words: aquatic and swamp vegetation, overgrowth process, vegetation succession, changes in vegetation and water chemistry, Sejny Lake District

INTRODUCTION

Every lake is, geologically speaking, only a temporary entity. Over the course of time lake basins are steadily filled in with sediment, overgrown with vegetation and eventually turn into mire or terrestrial formation [e.g. Moor 1969, Pott 1983, Marek 1992]. Aquatic and swamp communities, which undergo a series of successional stages, play an important role in the process of overgrowing and shallowing of lakes [Krausch 1964, Tomaszewicz 1979, Pott 1983, Kłosowski 1999]. Since these changes occur over long periods of time, the process of overgrowing of lakes is estimated on the basis of the present state of vegetation, by comparing the zonal distribution of the aquatic, swamp and mire vegetation of lakes in different stages of overgrowth. The results of such indirect research methods of monitoring successional changes of vegetation should be treated with caution as they do not take into consideration the dynamic character of succession process [Podbielkowski and Tomaszewicz 1994].

Direct observations of the vegetation change in permanent plots at regular intervals over a long period of time are considered to be the best method of monitoring successional changes in vegetation. However, the duration of succession period in lakes exceeds the life span of one generation and therefore few such studies have been carried out

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to date in Poland. They were usually concerned with only one lake [Solińska-Górnicka and Romański 1998, Lorens and Sugier 1999, Solińska-Górnicka and Symonides 2001]. It is essential that studies of vegetation changes should be made repeatedly on a larger number of lakes, which would allow us to to make some generalizations. Detailed phytosociological investigations conducted on 66 lakes in Sejny Lake District during 1975-1978 [Tomaszewicz and Kłosowski 1985] enabled to detect permanent changes in vegetation over a 25-year period. The studies were initiated in 2002 and are conducted in several phases. In the present work the results of studies carried out on the vegetation of 12 lakes 25-years ago and in the years 2002-2003 were analysed. The objectives of this study were to:

– document and assess the scale of changes in vegetation in the 12 lakes examined over a 25-year period,

– determine whether the changes in vegetation are accompanied by changes in water chemistry of the lake littoral,

– determine the main successional trends in vegetation.

MATERIAL AND METHODS

The following lakes were sampled: Białe near Giby, Buchta, Czarne, Dowcień, Gieret, Kaczan, Kunis, Płaskie near Klejwy, Pomorze, Sejny, Wiłkokuk and Zelwa. The same research methods were applied as 25 years ago. Sigma-association method [Gehu 1977] was employed to estimate changes in vegetation. As a result, the contribution of particular communities to the vegetation of each lake was determined using a modified [Szafer and Zarzycki 1972] Braun-Blanquet scale. Phytosociological relevés were performed in places from which the previously recorded phytocoenoses had disappeared and were replaced by other phytocoenoses. In addition, physical and chemical properties, of water were analysed. Water samples were taken three times (May, July and September) from several locations within the littoral zone of each of the lakes studied. More than a dozen properties of water were analysed. In the present work the following properties were taken into consideration: pH, total alkalinity, COD – $KMnO_4$, SO_4^{2-}, and PO_4^{3-}. All the determinations were carried out by methods described by Hermanowicz *et al.* [1976]. The mean value was calculated for each property of water analysed in particular lakes. The past aquatic (Tab. 1) and swamp (Tab. 2) vegetation of the 12 lakes examined 25 years ago was compared to the present vegetation. Data regarding the properties of water analysed during the two sampling periods are presented in Fig. 1.

RESULTS

It may be inferred from Table 1, that significant changes in the composition of aquatic vegetation occurred in most of the lakes analysed in this study. Considerable changes in vegetation were observed particularly in the lakes in which charophyte communities had dominated in the 1970's. In the case of 5 lakes (Dowcień, Kunis, Płaskie near Klejwy, Wiłkokuk, Zelwa) much of their area was occupied by these communities. By contrast all the charophyte communities had disappeared from Lakes Dowcień and

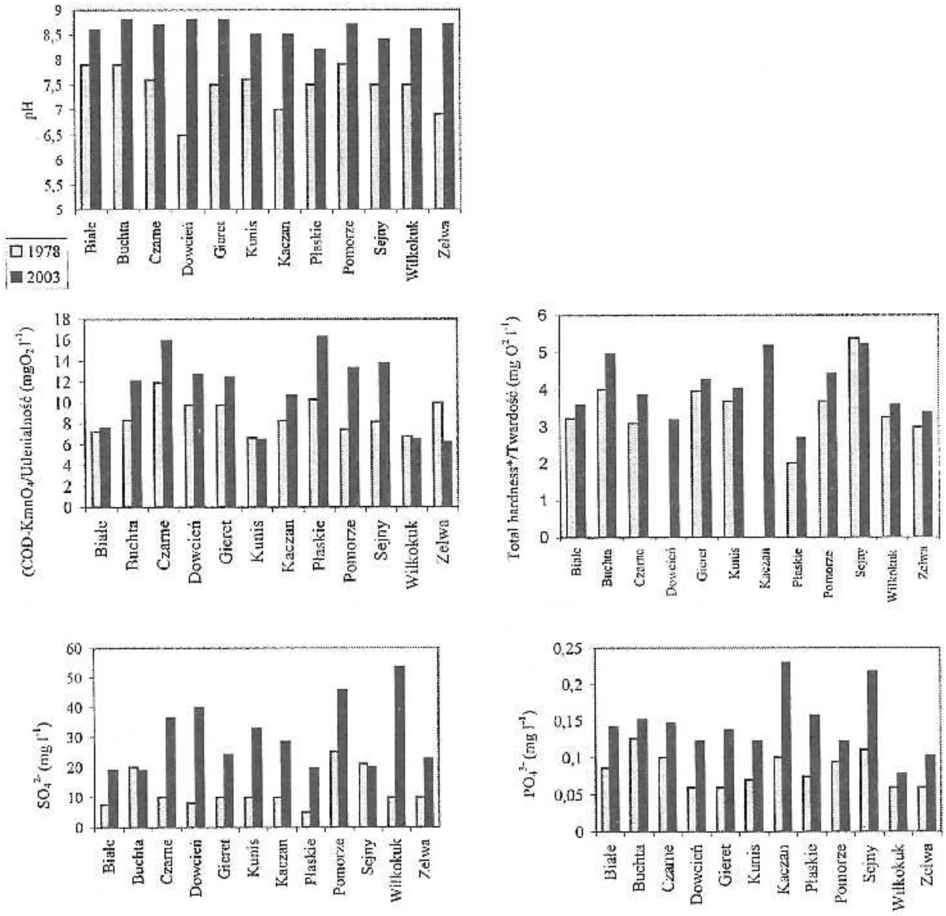

Fig. 1. Littoral water chemistry in the 12 lakes studied in 1978 and 2003
*Lakes Dowcień and Kaczan – no data from 1978
Rys. 1. Chemizm wód litoralnych w 12 badanych jeziorach w roku 1978 i 2003
*Jeziora Dowcień i Kaczan – brak danych z roku 1978

Kunis (Dowcień – *Charetum tomentosae*; Kunis – *Charetum tomentosae*, *Charetum contrariae*, *Nitellopsidetum obtusae*). The phytocoenoses of *Charetum fragilis* were eliminated from Lake Płaskie near Klejwy, whereas those of *Charetum tomentosae* took a more restricted distribution in the lake. In these three lakes the charophyte communities were replaced by communities of the class *Potametea* (Kunis – *Ceratophylletum demersi*; Dowcień – *Potametum natantis*; Płaskie near Klejwy – *Myriophylletum spicati*). Apparently smaller changes occurred in Lakes Wiłkokuk and Zelwa. In Lake Wiłkokuk the area of *Charetum tomentosae* was slightly reduced. The area of *Charetum rudis*, *Charetum contrariae* and *Charetum fragilis* phytocoenoses remained fairly constant. The patches of *Charetum jubatae*, which previously had been identified in the lake, were absent. In Lake Zelwa the *Charetum rudis* and *Charetum jubatae* phytocoenoses were no longer present, whereas those of *Charetum tomentosae* and *Charetum fragilis* extended their range.

Table 1. Aquatic plant communities in the 12 lakes studied in 1978 (A) and 2003 (B)
Tabela 1. Zbiorowiska roślin wodnych w 12 badanych jeziorach w 1978 (A) i 2003 roku (B)

Communities – Zbiorowiska	Lakes investigated – Badane jeziora																							
	1'		2		3		4		5		6		7		8		9		10		11		12	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Lemno-Spirodeletum											1	2	2						+					
Drepanocladus lycopodioides																					r			
Charetum tomentosae							2						3		4	1	+				4	3	+	1
Charetum rudis	r								r						+	1					+	+	1	
Nitellopsidetum obtusae													+		+	+			+				+	+
Charetum contrariae													2								r	r	+	r
Charetum fragilis															+						r	r	+	1
Charetum jubatae									r												+		1	
Nupharo-Nymphaeetum	+	+	4	2	3	3	+		2	+	3	4	1	2	+	+	3	3	3	4	2	1	2	1
Hydrocharitetum m-r	r	+	+	+			1		+	+	+		1	1	2	+			r		r	+	r	+
Potametum natantis	+	1	+		1	+	+	1	+	+			+	+	1	+		r	1	r	+	+	+	1
Polygonetum natantis	+	1															r	r						
Nymphaeetum candidae											r													
Ceratophylletum demersi		+	+	1		r						2	+	3		r	+	+	+	+				
Elodeetum canadensis	1								1										+		+		+	
Potametum perfoliati		1		r	r			r	r	r							r	r	+	r			r	+
Potametum lucentis		r	+	+	+	+							+			+	r		+					+
Ranunculetum circinati	r	+							+				+				r	r	+					
Myriophylletum spicati		+					r	1		r						2		+			r	+		+
Myriophylletum verticillati		r									1			+						+	+	+		+
Potametum compressi							r						+											
Potametum pectinati									r									r						
Potametum friesii													+											
Potametum obtusifolii			r	+																				
Hydrilletum verticillatae														+	r	r								

1-12 = lakes – jeziora: 1 – Białe near Giby; 2 – Buchta; 3 – Czarne; 4 – Dowcień; 5 – Gieret; 6 – Kaczan; 7 – Kunis; 8 – Płaskie near Klejwy; 9 – Pomorze; 10 – Sejny; 11 – Wiłkokuk; 12 – Zelwa

Table 2. Swamp plant communities in the 12 lakes investigated in 1978 (A) and 2003 (B)
Tabela 2. Zbiorowiska szuwarowe w 12 badanych jeziorach w 1978 (A) i 2003 roku (B)

Communities – Zbiorowiska	Lakes investigated – Badane jeziora																							
	1		2		3		4		5		6		7		8		9		10		11		12	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Phragmitetum australis	4	4	+	1	3	4	3	4	4	5	2	1	1	3	2	2	3	3	3	2	2	3	3	3
Acoretum calami	+	r	r		+	+			+	+	r				+	+	+	+	+				+	
Scirpetum lacustris	2	+	+		+	+	2		+	+			1	1	1	1	1	+	1	+	r	+	1	+
Typhetum angustifoliae	+	+	1	3				+	1	+							3	3			+	+	3	2
Typhetum latifoliae			+					+	+	+	+	+	+	+	+	+	r			+			r	
Equisetetum fluviatilis	2	r				+	2		+		2		+	+	1	+			1	+				
Glycerietum maximae			+	+					+	+	+	+	+	+			r	+	+	+				
Sparganietum erecti	r									+			+	+					r	1		+		+
Scirpetum maritimi																							r	
Cladietum marisci																					1	1	+	+
Thelypteridi-Phragmitetum			+	2	1	1	2	2	+		2	3	+	+	1	1		r	+	+	+	1	+	+
Oenantho-Rorippetum											r													
Eleocharitetum palustris		r							r				r	+				r	r	r				
Sagittario-Sparganietum															r	r	r		r				r	r
Caricetum rostratae	+	+	+		+	+	1		1	+	1		+	1	1	1	r	r	+	+			r	+
Caricetum acutiformis	r	+	2	+	+	+			+		2	2			+	r		+	+	+	+	+	+	
Caricetum elatae			+				+				r		r	+			+						r	
Caricetum ripariae											r	+												
Caricetum gracilis			r																					
Caricetum paniculatae											r													
Phalaridetum arundinaceae			r								r	+											r	
Sparganietum minimi																					+			

1-12 = lakes – jeziora: 1 – Białe near Giby; 2 – Buchta; 3 – Czarne; 4 – Dowcień; 5 – Gieret; 6 – Kaczan; 7 – Kunis; 8 – Płaskie near Klejwy; 9 – Pomorze; 10 – Sejny; 11 – Wiłkokuk; 12 – Zelwa

The present study also revealed that the area of *Ceratophylletum demersi* phytocoenoses increased in some of the lakes, e.g. in Lakes Kunis, Buchta and Kaczan (Tab. 1). The above phytocoenoses were also recorded (covering only a small area) in the lakes in which they were absent 25 years ago (Białe near Giby, Czarne, Płaskie near Klejwy). Another trend observed in the lakes is the disappearance of *Elodeetum canadensis* phytocoenoses from 5 of the 12 lakes examined (Białe near Giby, Gieret, Sejny, Wiłkokuk, Zelwa). In addition to these directional changes in vegetation, the following observations were made: the contribution of the *Nupharo-Nymphaeetum albae* phytocoenoses to the vegetation increased in some of the lakes (Kaczan, Kunis, Sejny), but declined in others (Buchta, Gieret, Wiłkokuk, Zelwa). The phytocoenoses of *Potametum natantis*, *Potametum perfoliati* and *Hydrocharitetum morsus-ranae* experienced a similar change.

In the case of swamp communities (Tab. 2), the *Equisetetum fluviatilis* (Lakes Białe near Giby, Kaczan, Dowcień, Płaskie near Klejwy, Sejny, Gieret) and *Scirpetum lacustris* (Białe near Giby, Dowcień, Pomorze, Sejny, Zelwa) phytocoenoses had a tendency to retreat from the lakes. In addition the decline of the *Caricetum rostratae* phytocoenoses (Dowcień, Gieret, Kaczan) was observed in some of the lakes. By contrast the area of *Phragmiteum australis* (Buchta, Czarne, Dowcień, Gieet, Kunis, Wiłkokuk) and *Thelypteridi-Phragmitetum* (Buchta, Kaczan, Wiłkokuk) increased. As in the case of aquatic plant communities, swamp communities (e.g. *Typhetum angustifoliae*) increased in area of occurrence in some of the lakes (Buchta), but declined in others (Gieret, Zelwa).

The changes in the vegetation composition in the 12 lakes studied were accompanied by changes in water chemistry (Fig. 1). In all the lakes examined the water pH increased by 1-1.5 units, i.e. from neutral and slightly alkaline to strongly alkaline. Furthermore, the concentration of phosphates increased as well (two-fold in the case of Dowcień, Gieret, Kaczan, Płaskie near Klejwy, Sejny). A two- (Białe near Giby, Gieret, Pomorze, Zelwa) to several-fold (Czarne, Dowcień, Kaczan, Kunis, Płaskie near Klejwy, Wiłkokuk) increase in the sulphate concentration was observed in all the lakes examined except Buchta and Sejny. In addition, there was an increase in the concentration of dissolved organic matter (see values of COD – $KMnO_4$) and water hardness in most of the lakes examined.

DISCUSSION

The results obtained in this study indicate that the retreat of charophyte communities which were eventually replaced by *Potametea* communities as well as the expansion of the *Ceratophylletum demersi* and *Myriophylletum spicati* phytocoenoses occur on a larger scale and have a permanent character. Similar trends accompanying the process of shallowing and overgrowing of lakes and associated increase in their trophy were observed by other authors as well [e.g. Melzer 1976, Lang 1981, Arts 2002]. The increase in the occurrence of *Phragmitetum australis* and *Thelypteridi-Phragmitetum* phytocoenoses in the lakes is also permanent, which is a typical feature of the lakefill process [Tomaszewicz 1977, 1979, Solińska-Górnicka and Romański 1998, Kłosowski 1999]. These trends, therefore, reflect the general direction of successional changes in vegetation in mesotrophic and eutrophic lakes: *Charetea→Potametea→ Phragmitetea* [Moor 1969, Tomaszewicz 1979]. The rate of these changes is accelerated as the trophy of the lake and water hardness increase. The present results confirm that the permanent successional trends in vegetation are associated with changes in water chemistry, e.g. increase in the concentration of phosphates, sulphates and dissolved organic matter (COD – $KMnO_4$) as well as pH and water hardness, which are linked with progressing eutrophication and alkalinization of lakes [see Arts 2002]. The increase in the occurrence of the particular phytocoenoses in some of the lakes and their decline in others (e.g. *Nupharo-Nymphaeetum albae*, *Typhetum angustifoliae*) are not stable and are probably determined by the fluctuations of the water level, movement of sediments, etc.

CONCLUSIONS

In the 12 lakes examined most of the changes in lake vegetation occur on a larger scale and are permanent. These changes manifest the general direction of vegetation succession in mesotrophic and eutrophic lakes: *Charetea→Potametea→Phragmitetea*. The permanent successional trends in vegetation are associated with changes in water chemistry i.e. increase in trophy and alkalinization.

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WIELOLETNIE ZMIANY ROŚLINNOŚCI WODNEJ I SZUWAROWEJ WYBRANYCH JEZIOR POJEZIERZA SEJNEŃSKIEGO

Streszczenie. Określono zmiany roślinności wodnej i szuwarowej w 12 jeziorach Pojezierza Sejneńskiego, jakie zaszły po około 25 latach. Zaobserwowano wycofywanie się zbiorowisk ramienic z niektórych jezior i zajmowanie ich siedlisk przez zbiorowiska klasy *Potametea* – zwłaszcza ekspansję fitocenoz *Ceratophylletum demersi* i *Myriophylletum spicati*, a także wzrost udziału *Phragmitetum australis* i *Thelypteridi-Phragmitetum*. Tendencja zmian jest trwała i przebiega zgodnie z ogólnym kierunkiem sukcesji w jeziorach mezo- i eutroficznych: *Charetea→Potametea→Phragmitetea*. Trwałe przemiany roślinności związane są ze zmianami jakości wody strefy litoralnej, a zwłaszcza ze wzrostem jej żyzności i alkalinizacją.

Słowa kluczowe: roślinność wodna i szuwarowa, procesy zarastania, sukcesja roślinności, zmiany roślinności i właściwości wody, Pojezierze Sejneńskie