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TRANSFORMATION OF FLORA VERSUS THE ECOLOGICAL STATUS OF THE WYSKOĆ WATERCOURSE IN THE LAST THIRTY YEARS*

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ABSTRACT. Macrophytes in two sections of the Watercourse Wyskoć were studied again after thirty years. The Watercourse Wyskoć is the drainage ditch within the agricultural areas of the General Chłapowski Landscape Park in the Wielkopolska Region. The changes of species composition and the area occupied by macrophyte communities influenced Macrophyte River Index (MIR) and the class and ecological status of the watercourse. The results of investigations have pointed out the increase of eutrophication level in both ditch sections. More important changes took place in the section, which crossed the peat meadows drained between 1976 and 2007. The ecological status of this section of the watercourse has deteriorated more significantly than in the second section situated among the area which had been drained before 1976. The changes in flora included the appearance and increase of importance of macrophyte species, which are indicators of high eutrophication level (L = 2 and 3). This includes such species as *Ceratophyllum demersum*, *Ceratophyllum submersum*, *Lemna minor*, *Typha latifolia, Glyceria maxima, Sparganium erectum.* The changes also included disappearance or decrease in size of the area occupied by the species which pointed out moderate eutrophication level (L = 6, 5 and 4) e.g. *Chara fragilis*, *Sparganium emersum*, *Elodea canadensis*, *Nuphar lutea.*

KEY WORDS: flora, changes, Macrophyte River Index, eutrophication, ecological status, drainage ditch

INTRODUCTION

The European Water Framework Directive (2000/60/WE Directive) obliged all UE countries to improve environmental conditions of the aquatic ecosystem before 2015. Macrophytes are one of four basic biological elements used to estimate the ecological status. It is the element that has been taken into consideration in aquatic ecosystems classification.

The Macrophyte River Index (MIR) was elaborated (Szoszkiewicz et al. 2006) to estimate the ecological status of Polish rivers. The index changes depending on the trophic requirements of plant species occurring in rivers.

Intensification of agriculture is the biggest threat for water quality of freshwater ecosystems in rural areas. This process became stronger in the last thirty years and at the same time changes of surface water chemistry pointed out the progress in eutrophication. Therefore the authors decided to study again (after thirty years) the flora of the ditch draining agricultural areas within the General Chłapowski Landscape Park. The aim of this study was to characterise the changes in the flora and in the ecological status of the Watercourse Wyskoć between 1976 and 2007.

STUDY AREA, MATERIAL AND METHODS

The study was carried out in the Wielkopolska Region, within the General Chłapowski Landscape Park. The Wyskoć Watercourse is the most important watercourse collecting water from fields and meadows within this area and together with the smaller watercourses that are its tributaries, constitutes the drainage system. The studies on the flora were carried out between 1976 and 1979 in two sections of the ditch. The first section was 1025 m long and was situated near the village Rogaczewo. The second was 150 m long and was situated in the neighbourhood of the village Zbęchy (Fig. 1). The section in Rogaczewo (A) is adjoined along the north bank by mowed meadows from the class *Molinio-Arrhenatheretea,* which had been drained before the first investigated period. On the southern shore, besides meadows (half of its length), there were cultivated fields (1/4) and afforestation (1/4). The second section of the watercourse was located close to the village and the Lake Zbęchy, among peat meadows with dominating plant communities from the alliance *Magnocaricion* and with considerable share of communities from the class *Scheuchzerio-Caricetea nigrae.* Drainage of meadows in the 1980's and at the beginning of the 1990's led to

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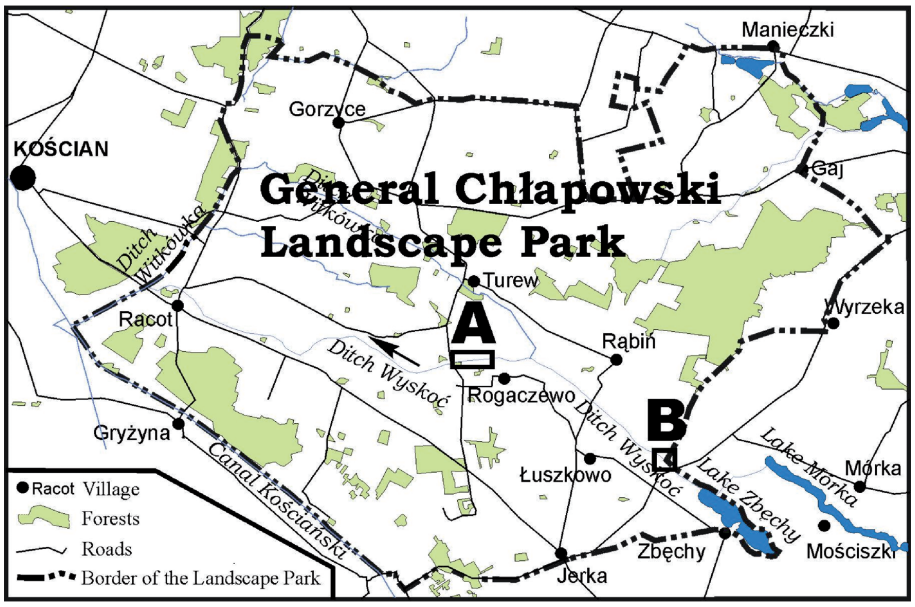

FIG. 1. Map of the General Chłapowski Landscape Park with two surveyed sections of the Wyskoć Watercourse: A – near village Rogaczewo, B – near village Zbęchy

their overdrying and as a result caused transformation of meadow vegetation into more uniform and dominated by communities from the class *Molinio-Arrhenatheretea*.

Long-term studies of the chemical compounds in surface waters which were carried out from 1973 to 1991 showed that the level of eutrophication of Wyskoć Watercourse was rising successively at that time (BARTOSZEWICZ 1994). The main reason of the water quality deterioration was the intensification of agriculture (it started to escalate especially in the 70's) and development of the food processing industry in the 1990's. A great threat to water quality in the period between the present and the previous study were growing nitrate concentrations in groundwater and large non-point nitrogen loads from farmland. Between 1973 and 1991 water quality of the Watercourse Wyskoć estimated on the basis of concentrations of nutrients were worsening gradually. The strongest increase was observed in the concentration of phosphates and ammonium nitrogen. An analysis conducted in August 2007 showed that water quality deteriorated even further (unpubl. data). Drainage and melioration carried out in the ditch and its vicinity (drainage of meadows) were reflected also in chemical water quality and in the physical conditions in the watercourse, and affected water flow rate, depth, and type of substrate.

The ecological status of the Watercourse Wyskoć was estimated in accordance to the Macrophyte Method for Rivers Grade which was proposed and prepared by SZOSZKIEWICZ et AL. (2006) to use for estimation of the ecological status of rivers in Poland. The study of macrophytes in 2007 was carried out strictly according to this method. The ecological status of both sections of the Wyskoć Watercourse in the 70's and the changes in the flora between 1976 and 2007 were stated on the basis of results of study of the flora and plant associations of the Wyskoć Watercourse (GOŁDYN 1984) and other unpublished data of the author from that period. Between 1976 and 1979 the list of macrophytes and the cover expressed in percentage for each species was estimated as well. This data made it possible to estimate the ecological status of the watercourse thirty years ago.

The Macrophyte River Index that is necessary to estimate the ecological status according to the European Water Framework Directive was calculated using the formula:

$$MIR = \frac{\sum L_i \cdot W_i \cdot P_i}{\sum W_i \cdot P_i} \cdot 10$$

where:

MIR – Macrophyte River Index,
L_i – indicator value of the species,
W_i – weight coefficient of the species,
P_i – cover coefficient of the species, according to the 9-gradual scale.

The value of the MIR index may vary between 10 (the most degraded rivers) and 100 (the best water quality) (SZOSZKIEWICZ et AL. 2006).

RESULTS

The changes in flora and ecological status of the Wyskoć Watercourse in the vicinity of the village Rogaczewo (A)

The watercourse banks in Rogaczewo (1025 m of length) are occupied by trees and shrubs. They shade the water surface and make the growth of vegetation on many parts completely impossible. The length of the watercourse without vegetation during the investigations increased by 120 m (650 m in 1976 and 770 m in 2007). The plant patches in places where they are able to grow are more compact then in the 70s. This is the cause of the increase of mean plant cover from 15% in 1976 to 22% in 2007.

The differences in share of plant species in plant cover of the watercourse in 1976 and 2007 is showed in Figure 2. In 1976 this section of the watercourse was dominated by plant species, which are moderate trophic indicators (L = 5, 4) (Table 1). The most common species were *Elodea canadensis* (8% in the investigated section

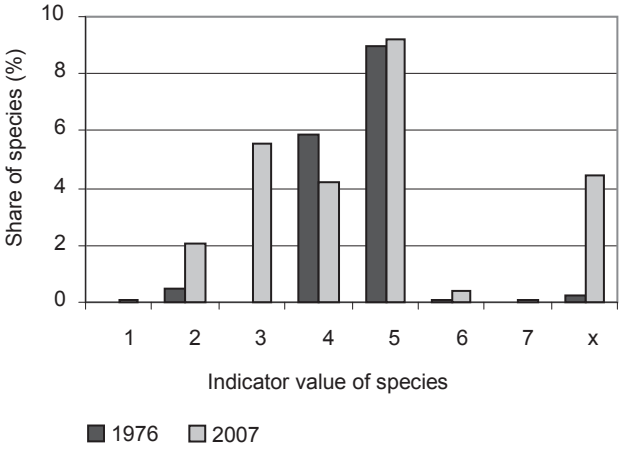

Fig. 2. The share of species with various indicator values in plant cover of the watercourse section A (near Rogaczewo) in 1976 and 2007; x – species which are not indicators of MIR

of the watercourse in average, L = 5) and *Sparganium emersum* (5% in average, L = 4). The other species of plants were not common and their presence was not significant. The Macrophyte River Index of this section of the watercourse in 1976 was 42.7. The ecological status established on the basis of MIR value was good (Table 2, 3).

In 2007 the species that are indicators of moderate eutrophic level were still dominating (L = 4, 5) (Table 1). The most common was *Elodea canadensis*, the same as in 1976 (mean cover 9%, L = 5). During the time between the first and the second period of the study the patches of *Sparganium emersum* have completely disappeared. Larger areas are now occupied by *Berula erecta* patches (3%, L = 4). Moreover, new species known as indicators of moderate eutrophic level (L = 4) have appeared recently. The presence of the group of species typical for strong eutrophic water was particularly symptomatic in 2007. They occurred in 1976 only sporadically. The most important among them are: *Glyceria maxima* (mean cover 4.5% in the whole section of the ditch, L = 3), *Lemna minor* (2%, L = 2), and *Sparganium erectum* (1%, L = 3). These species appeared and occupied significant areas in the watercourse as a result of water pollution with nutrients from non-point sources. It is reflected in lower value of the Macrophyte River Index (MIR = 38). This value, although it is considerably lower than in 1976, still indicates good ecological status (Table 2, 3).

The number of plant species in this section of the watercourse in 1976 was 11. In 2007 an increase of vascular plant species number to 28 was observed (Table 1). Among the species which are indicators of the river status, also the algae *Cladophora fracta* (L = 1) occurred in 2007.

The changes in flora and ecological status of the Wyskoć Watercourse in the vicinity of the village Zbęchy (B)

The section of the watercourse in the vicinity of the village Zbęchy is situated among wide peat meadows which separate the watercourse from arable fields. The shores are occupied by reed and sedge plants and they are not shaded by trees. In both study periods macrophytes were more common in this section than in that

Table 1. The list of indicator plant species (according to MIR) stated in the section A (Wyskoć Watercourse in Rogaczewo) in 1976 and 2007

Species	P 1976	P 2007	L	W
Alisma plantago-aquatica	-	1	4	2
Berula erecta	2	4	4	2
Butomus umbellatus	3	-	5	2
Carex acutiformis	-	2	4	1
Ceratophyllum demersum	-	1	2	3
Elodea canadensis	5	5	5	2
Equisetum fluviatile	1	-	6	2
Glyceria plicata	-	2	5	1
Glyceria maxima	-	5	3	1
Hydrocharis morsus-ranae	-	2	6	2
Iris pseudoacorus	-	1	6	2
Lemna minor	2	3	2	2
Lemna trisulca	1	-	4	2
Mentha aquatica	-	1	5	1
Myosotis palustris	-	1	4	1
Nuphar lutea	2	2	4	2
Potamogeton natans	-	1	4	1
Rorippa amphibia	-	1	3	1
Rumex hydrolapathum	-	1	4	1
Sagittaria sagittifolia	2	-	4	2
Sium latifolium	-	1	7	1
Sparganium emersum	4	-	4	2
Sparganium erectum	-	3	3	1
Typha latifolia	-	2	2	2
Veronica anagallis-aquatica	-	1	4	2
Cladophora fracta	-	1	1	2

P – cover coefficient of the species, according to the 9-gradual scale, L – indicator value of the species, W – weight coefficient of the species.
Other species present in the investigated section of the watercourse, that are not considered as indicator plant species of MIR:
Agrostis stolonifera – 1976, 2007, *Bidens frondosa* – 2007, *Epilobium parviflorum* – 2007, *Eupatorium cannabinum* – 2007, *Galium palustre* – 2007, *Lycopus europaeus* – 2007, *Phragmites australis* – 1976, 2007, *Solanum dulcamara* – 2007.

Table 2. Ecological status of the investigated sections of the Wyskoć Watercourse

Section	Macrophyte River Index (MIR)		Ecological status		Class of the ecological status	
	1976	2007	1976	2007	1976	2007
A – Rogaczewo	42.7	38.0	good	good	II	II
B – Zbęchy	44.1	32.3	good	moderate	II	III

in Rogaczewo (the plant cover was about 90% in 1976 and about 80% in 2007). In 1976 the most commonly occurring plant species were indicators of moderate eutrophication level (L = 4, 5, 6) (Table 4, Fig. 3). The most

Table 3. Range of Macrophyte River Index (MIR) for the class of the ecological status for sandy-bed and organic-bed rivers (acc. to Szoszkiewicz et al. 2006)

Class of the ecological status	MIR
I – very good	≥ 44.5
II – good	44.5-35
III – moderate	35.0-25.4
IV – sufficient	25.4-15.8
V – bad	< 15.8

compact plant patches in this section of the watercourse were created by *Sparganium emersum* (mean coverage was 44%, L = 4), *Elodea canadensis* (24%, L = 5), *Nuphar lutea* (20%, L = 4), and *Chara fragilis* (12%, L = 6). For that season, the Macrophyte River Index of the watercourse amounted to 44.1. So, the ecological status should be regarded as good but it should be mentioned that MIR estimation was near the limit value (44.5) between good and very good status (Table 2, 3). In 2007 the species typical for high eutrophic level dominated in the same section of the watercourse (L = 2) (Table 4, Fig. 3). These were: *Ceratophyllum demersum* (mean coverage in the investigated watercourse section was 32%), *C. submersum* (7%), *Lemna minor* (14%), *Typha latifolia* (16%). Considering other species, large areas were occupied by *Hydrocharis morsus-ranae* assemblages (20%, L = 6). *Chara fragilis* and two other stoneworts, which were presented in this section of the watercourse in 1976 as well as *Sparganium emersum* and *Elodea canadensis* have disappeared. The patches of *Nuphar lutea* are currently very small. The abundant occurrence of plant species that are typical for high eutrophic level and the decrease in the share of species that are indicators of the moderate eutrophic level influence MIR value and the ecological status of this section of the Watercourse Wyskoć. MIR is lower than 30 years ago and the ecological status is only moderate (Table 3, 4). The number of plant species in this section of the watercourse in 1976 was 33 (30 vascular plant species and three stoneworts).

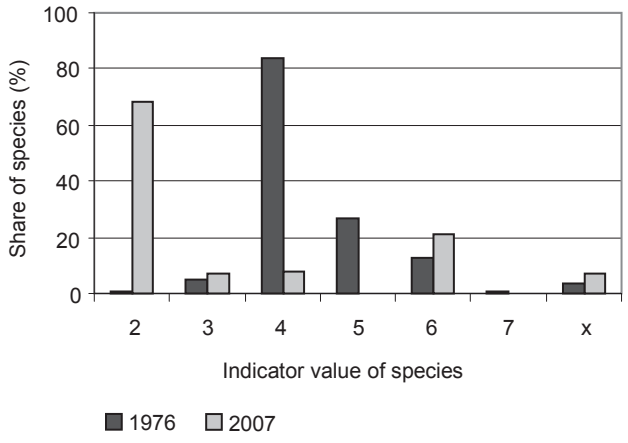

Fig. 3. The share of species with various indicator values in plant cover of the watercourse section B (near Zbęchy) in 1976 and 2007; x – species which are not indicators of MIR

In 2007 only 25 vascular plant species were observed (Table 4).

Table 4. The list of indicator plant species (according to MIR) stated in the section B of the Wyskoć Watercourse in Zbęchy in 1976 and 2007

Species	P 1976	P 2007	L	W
Acorus calamus	1	–	2	3
Alisma plantago-aquatica	1	–	4	2
Alopecurus geniculatus	–	1	4	1
Batrachium circinatum	3	–	5	2
Berula erecta	3	4	4	2
Carex acutiformis	–	2	4	1
Carex riparia	1	–	4	2
Ceratophyllum demersum	–	7	2	3
Ceratophyllum submersum	–	5	2	3
Chara fragilis	6	–	6	2
Eleocharis palustris	1	–	6	2
Elodea canadensis	6	–	5	2
Glyceria maxima	1	3	3	1
Hippuris vulgaris	1	–	4	1
Hydrocharis morsus-ranae	1	6	6	2
Hydrocotyle vulgaris	1	–	5	1
Iris pseudoacorus	1	3	6	2
Lemna minor	–	6	2	2
Lemna trisulca	1	–	4	2
Lysimachia vulgaris	–	1	4	1
Mentha aquatica	1	2	5	1
Myosotis palustris	1	–	4	1
Nuphar lutea	6	1	4	2
Polygonum amphibium	1	–	4	1
Potamogeton natans	1	–	4	1
Rorippa amphibia	1	–	3	1
Rumex hydrolapathum	1	3	4	1
Sagittaria sagittifolia	6	–	4	2
Schoenoplectus lacustris	–	1	4	2
Sium latifolium	1	2	7	1
Sparganium emersum	7	–	4	2
Sparganium erectum	4	5	3	1
Typha latifolia	1	6	2	2

Explanations – see Table 1.
Other species present in the investigated section of the watercourse, that are not considered as indicator plant species of MIR:
Agrostis stolonifera – 1976, *Bidens frondosa* – 2007, *Calystegia sepium* – 2007, *Carex pseudocyperus* – 2007, *Chara polyacantha* – 1976, *Chara vulgaris* – 1976, *Epilobium hirsutum* – 2007, *Lycopus europaeus* – 2007, *Lysimachia nummularia* – 1976, *Lythrum salicaria* – 1976, 2007, *Phragmites australis* – 1976, 2007, *Scutellaria galericulata* – 2007, *Teucrium scordium* – 1976

DISCUSSION

In last 30 years the trend of the flora transformation in both studied sections of the Wyskoć Watercourse was similar but the range of the transformation was different. The increase of eutrophication level is indicated

by the disappearance of plant communities, which are typical for the moderate eutrophication level and appearance and abundant growth of macrophytes, which are indicators of strongly eutrophic waters.

The results have shown that the threat to surface water quality is not only intensification of agriculture but also changes in the management of the catchment area, which disturb nutrients uptake by plants in the neighbourhood of watercourses and therefore cause an increase in their leaching and outflow to the surface waters. The ecological status of the watercourse section isolated by peat meadows from the surface pollution flowing out from the fields decreased by a class. On the other hand, smaller changes took place in another section that was not well isolated. This points out that the changes occurring on meadows influence the eutrophication level of the watercourse. In the 70s peat meadows along the section of the watercourse in the neighbourhood of the village Zbęchy were humid and rich in plant species typical for fens, which are rare in the Wielkopolska Region (Gołdyn 1977, Denisiuk 1980). Water in the watercourse came from the Zbęchy Lake and was rich in aquatic plant species. The ecological status of the lake was good (Gołdyn et al. 2008 a). In the same period the status of the watercourse section, which was in indirect contact with the lake, was good as well and it nearly reached a very good grade. Stonewort associations were developing abundantly in the lake as well as in the watercourse. Between the periods of investigations, the changes took place on the meadows which were situated close to the watercourse. They were drained in the beginning of the 90s and the effect of this measure was intensified by a precipitation shortage in the following vegetation seasons. At the same time similar changes occurred on the meadows surrounding the lake, which worsened its water quality. As a result, submerged plant communities, including stonewort associations, have almost disappeared, and ecological status of the lake became worse (Gołdyn et al. 2008 a). Nowadays, the section of the watercourse below the outflow from the lake runs across the drained meadows. Most of them were abandoned by farmers before 2005 for about 10 years. Acceleration of the mineralization processes of the peat took place and has resulted in an increase of nutrient content (especially of nitrogen) and eutrophication of the Wyskoć watercourse. The leaching of nutrients during the moorshing process was described by many authors (Okruszko 1991, Herbich 1994, Ilnicki 2002). Their amount is too large to be used by meadows vegetation, particularly when there is a deficit of potassium. It is very common on meadows, which are abandoned by farmers. In these circumstances, the excess of nutrients is leaching and flowing into surface waters.

The studies of water of the Wyskoć Watercourse have shown a successive increase of nutrients content during the last thirty years (Bartoszewicz 1994 and unpublished data). It results in accelerated eutrophication, changes of species in the flora composition and the ecological status deterioration, particularly in the section with adjacent peat meadows. Similar changes were observed in peat pits and in meadows surrounding them (Gołdyn et al. 2008 b, c). Plants from the class *Scheuchzerio-Caricetea nigrae*, that are typical for fens, have almost completely disappeared there and instead of them meadow plants from the class *Molinio-Arrhenatheretea* have developed.

The second section of the watercourse is surrounded by mowed meadows from the class *Molinio-Arrhenatheretea*, which were brought into cultivation just before the first survey period. Arable fields and afforestation are present in the neighbourhood of this section of the watercourse as well. It is certain that this section of the watercourse is more threatened by overland flow that originates from rural catchment. Surrounding meadows have been still cultivated using the same methods for a long time. The stabilization of agricultural practices in the vicinity of the ditch and the fact that there were no such drastic transformations as on peat meadows near the first river section, caused that eutrophication processes and vegetation changes were limited. However, the decrease of the ecological status, though considerably lower than in the section near the Zbęchy village, has pointed out that the level of eutrophication increase in this section of the ditch as well.

Both sections of the Watercourse Wyskoć, which were the object of the study in the present paper, were studied also during investigations that were carried out to test the accuracy of the typology applied in Macrophyte Method for Rivers Grade (Szoszkiewicz et al. 2006). The estimations of MIR and the ecological status of the watercourse estimated by the authors of this method are very similar to the estimations from 2007 which are presented in the present publication.

The changes of vegetation resulted in elimination of patches of *Sparganium emersum* which was the dominating species in all of the Wyskoć Watercourse in the 70's and in the 80's. The withdrawal of this species was caused not only by the water chemistry changes but also by physical features of the ditch. They resulted from human impact (conservation measures, which were regularly carried out until the first half of the 90's) and from shading of banks by trees and shrubs.

In the section with peat meadows adjacent to the banks in the 70's, five species from the actual red lists of threatened species occurred (Siemińska et al. 2006, Zarzycki and Szeląg 2006). These were stoneworts: *Chara fragilis, Chara polyacantha* and *Chara vulgaris* and vascular plants: *Hippuris vulgaris* and *Teucrium scordium*. They all perished during the last thirty years. Stoneworts are indicators of good water quality (Pełechaty et al. 2006, Szoszkiewicz et al. 2006) and eutrophication processes are the reason for their retreating (Blindow 1992, Meijer 2000, Solińska-Górnicka and Symonides 2001, Kłosowski et al. 2004, 2006). The most valuable among them is *Chara polyacantha* – the species in direct danger of extinction in Poland. It is observed only in unpolluted water bodies (Pełechaty and Pukacz 2006). This species was very rarely noted within the General Chłapowski Landscape Park in the 70s and 80s. None of these stands has survived until the present day.

Among new plant species, which grew in Wyskoć Watercourse in 2007, *Bidens frondosa* and *Calystegia sepium* appeared. They were very expansive in the last thirty years in the area of the Park.

CONCLUSIONS

The results of the study show that in the last thirty years the eutrophication level of the Wyskoć Watercourse has increased. More important changes took place in the section, which was surrounded by peat meadows, drained after 1976. The ecological status of this section of the ditch has become worse than in the section situated among the areas, which were drained before 1976. The changes in the flora include the appearance and increase of the share of macrophyte species, which are indicators of high eutrophication level, and disappearance or decrease of the share of species, which point out a moderate eutrophication level.

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