POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	50	4	489–513	2002

Regular research paper

Marek KLOSS, Izabela WILPISZEWSKA

Department of Plant Ecology, Institute of Ecology PAS, Dziekanów Leśny, 05-092 Łomianki, Poland; e-mail: ekolog@warman.com.pl; ekofito@pan.pl

DIVERSITY, DISTURBANCE AND SPATIAL STRUCTURE OF WETLAND VEGETATION ALONG A LAKE SHORE: JORKA RIVER-LAKE SYSTEM (MASURIAN LAKELAND, POLAND)

ABSTRACT: In 1997–1999, phytosociological studies of the riparian vegetation were conducted in the Jorka River-Lake system, Masurian Lakeland, Poland. This vegetation performs an important function as a barrier for various chemicals, counteracting lake eutrophication. In total, 26 plant communities were identified. The riparian vegetation was represented by phytocoenoses of the classes: *Alnetea glutinosae, Salicetea purpureae, Querco-Fagetea, Artemisietea* and *Molinio-Arrhenatheretea.* The littoral vegetation comprised phytocoenoses of the classes *Phragmitetea* and *Potamogetonetea.* Plant communities typically occur in the form of strips along rivers or lake shores, and on rare occasions in the form of mosaics of overlapping patches. The degree of the transformation of riparian vegetation relative to its natural state was estimated. The plant cover was disturbed by man along 80% of the shoreline length. Spatial distribution of phytocoenoses was analysed in details along 13 transects.

KEY WORDS: riparian vegetation, phytosociological units, spatial distribution of plant communities, man transformation of vegetation, Masurian Lakeland, Poland.

1. INTRODUCTION

Riparian vegetation rose much interest in landscape studies, especially since the 1980s (Nilsson 1981, Schlosser and Karr 1981, Holland 1988, Decamps *et al.* 1990, Risser 1990, Gregory *et al.* 1991). The most comprehensive definition of the term "riparian" was proposed by Malanson (1993), who distinguished three levels of its understanding as:

- the actual river banks,
- in a broader interpretation, ecosystems bordering on the river, and
- habitats influenced by the river.

In this paper, the term "riparian" will be used in the last two meanings and applied also to lake surroundings.

Papers describing riparian ecosystems can be classified into three groups:

- concerning riparian vegetation of different climatic zones (Osterkamp and Hupp 1984, Ericsson and Schimpf 1986, Medina 1986, Nilsson 1986, Salo *et al.* 1986, Pautou 1988, Wyant and Ellis 1990, Nilsson *et al.* 1991).

• considering riparian ecosystems as land-water ecotones (Holland 1988, Naimann *et al.* 1988, Risser 1990, Decamps *et al.* 1990, Hillbricht-Ilkowska 1993, Hillbricht-Ilkowska and Węgleńska 1995), and

• indicating the role of riparian ecosystems as barriers retaining various chemical substances, which is of great importance to the landscape, especially to the agricultural landscape, as it improves the quality of ground water (Schlosse and Karr 1981, Johnston *et al.* 1984, Lowrance *et al.*1984, Peterjohn and Correll 1984, Jacobs and Gilliam 1985, Cooper *et al.* 1987, Fail *et al.* 1987, Childers and Gosselink 1990, Johnston *et al.* 1990, Correl *et al.* 1991, Hillbricht-Ilkowska and Kostrzewska-Szlakowska 1993, Malanson 1993, Hillbricht-Ilkowska 1995, Daniels and Gilliam 1996).

As soon as the role of riparian ecosystems in reducing eutrophication has been recognized, many research centres started monitoring changes occurring in these ecosystems (Baker 1989, Nilsson *et al.* 1991). Numerous papers have been published indicating the important ecological role of riparian ecosystems in the landscape, along with their economic, social, legal, aesthetic and biological aspects (Brinson *et al.* 1981, Desaigues 1990, Malanson 1993). The progressive destruction of riparian habitats is observed with anxiety (Yon and Tendron 1981). To give an example, over the last 50 years, about 70% of the natural riparian habitats were lost in the USA (Brinson *et al.* 1981).

In Poland, the study on riparian habitats adjacent to rivers and lakes were mostly limited to their phytosociology. First more comprehensive researches were conducted in the Suwalskie Lakeland (Kłosowski and Tomaszewicz 1994) and also in the Masurian Lakeland in the Krutynia River-Lake system (Kłosowski and Tomaszewicz 1996).

The present paper concerns the riparian vegetation of the Jorka River-Lake system in the Masurian Lakeland. The major objectives of the paper are to:

• identify the plant communities in the riparian vegetation,

• evaluate the transformation degree of riparian vegetation as compared to its original state,

• determine the spatial distribution of riparian vegetation along selected sections,

• estimate the possible role of riparian vegetation as a barrier reducing eutrophication in the landscape.

2. STUDY AREA AND METHODS

The study was conducted in the Jorka river catchment covering an area of 60 km^2 in the Masurian Lakeland, north-eastern Poland (Fig. 1). The major components of the hydrographic network of the Jorka basin are lakes: Majcz Wielki (174 ha), Inulec (161 ha), Głębokie (46 ha), Zełwążek (12 ha) and Jorzec (41 ha). Jorka is the main river (12.1 km long). Its catchment is characterized by diverse relief. A distinctive feature of this region is the occurrence of numerous hills and various kinds of hollows (Kloss *et al.* 1987, Kruk 1987). Hilly postglacial landscape, characterizing the investigated area, was formed from morain deposits made up chiefly of boulder clay. Steep gradients and low substrate infiltration capacity are responsible for a large runoff to streams and lakes. Its size is

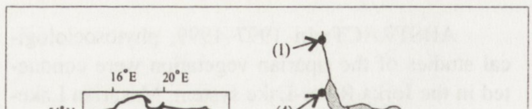

Fig. 1. The Jorka River-Lake system • – location of transects, ( ) – number of transects

constrained by a large number of areas without surface outflow and numerous intermittent streams (Bajkiewicz-Grabowska 1985).

Riparian vegetation has been examined in the Jorka River-Lake system during 1997–1999. Phytosociological records were made using the Braun-Blanquet (1964) method in representative phytocoenoses on both sides of the Jorka River and on the shores of Lakes: Majcz Wielki, Inulec, Głębokie, Zełwążek, and Jorzec. In total, 98 records were made. Most of them are set in tables showing species composition and structure of plant communities. Synthetic tables show the following parameters: the class of constancy (S) or the number of appearances (L) when the number of records was less than 5, and the coefficient of cover (P). The data concern the individual species of examined phytocoenoses. Sporadic species are neglected in the tables. The following scale of species constancy was used: I – species present in 1–20% of the records, II – species present in 21–40% of the records, III – species present in 41–60% of records, IV – species present in 61–80% of the records, and V – species present in 81–100% of the records. The cover coefficient for a species is a quotient of the sum of mean percent cover of a species for all records in the table in which the species was present and the total number of records in the table, multiplied by 100. The identification of plant communities was used for estimating the transformation degree of phytocoenoses compared with their natural state.

Spatial distribution of plant communities was analysed along 13 transects established at right angles to the shoreline (Fig. 1). They started on a mineral upland and ended in the open water of a lake or a stream. Only in one case the whole width of river valley was crossed by a transect. The transects were situated in places representing different degrees of vegetation transformation, and in places where experiments were conducted concerning the barrier-protective role of wetland zones (Rzepecki 2002). The transects were levelled with a Pentax GW-20 leveller.

Vascular plants were named after Mirek *et al.* (1995), bryophytes after Ochyra and Szmajda (1978), plant syntaxa after Matuszkiewicz (1981), and alderwoods after Jasnowska and Jasnowski (1991).

3. RESULTS

3.1. LIST OF PHYTOSOCIOLOGICAL SYNTAXA

In total, 26 plant communities were identified, that can be distinguished in the field as biochores occupying a defined space in the landscape. It has been found that the following groups of plant communities made up the riparian vegetation:

I. Riparian vegetation

A. Wood and shrub swamps of the class *Alnetea glutinosae* Br.-Bl. et Tx. 1943

1. *Carici acutiformis-Alnetum* Scamoni 1953
2. *Carici elongatae-Alnetum* Koch 1926
3. Community with *Betula pubescens*
4. *Salicetum pentandro-cinereae* Pass 1961

B. Willow shrub of the class *Salicetea purpureae* Moor 1958

1. Community with *Salix fragilis*

C. Riparian carrs of the class *Querco-Fagetea* Br.-Bl. et Vlieg. 1937, alliance *Alno-Padion* Knapp 1942

1. *Padus avium-Alnus glutinosa* community
2. *Circaeo-Alnetum* Oberd. 1953
3. *Alnus glutinosa-Eupatorium cannabinum* community

D. Oak-hornbeam forests of the class *Querco-Fagetea* Br.-Bl. et Vlieg. 1937, alliance *Carpinion betuli* Oberd. 1953

1. *Tilio-Carpinetum* Traczyk 1962 (transformed phytocoenoses)

E. Communities of hygrophilous and nitrophilous perennials of the class *Artemisietea* Lohm., Prsg. et Tx. 1950

1. *Urtica dioica-Eupatorium cannabinum* community
2. Community with *Urtica dioica*
3. *Urtica dioica-Phalaris arundinacea* community

F. Meadow-pasture communities of the class *Molinio-Arrhenatheretea* Tx. 1937

1. *Aegopodio-Petasitetum hybridi* Tx. 1949
2. *Cirsio-Polygonetum Bistortae* Tx. 1951
3. *Scirpetum sylvatici* Knapp 1946
4. Community with *Deschampsia caespitosa*
5. Community with *Dactylis glomerata*

II. Littoral aquatic vegetation

A. Reedbed communities of the class *Phragmitetea* Tx. et Prsg. 1942

1. *Caricetum rostratae* Rübell 1912

2. *Caricetum appropinquatae* (Koch 1926) Soo' 1938
3. *Caricetum acutiformis* Sauer 1937
4. *Phragmitetum australis* (Gams 1927) Schmale 1939
5. *Thelypteridi-Phragmitetum* Kuiper 1957
6. *Acoretum calami* Kobendza 1948
7. *Typhetum latifoliae* Soo' 1927
8. *Sparganietum erecti* Roll 1938

B. Macrohydrophyte communities of the class *Potamogetonetea* Tx. et Prsg. 1942
1. *Nupharo-Nymphaeetum albae* Tomasz. 1977

3.2. CHARACTERISTICS OF PLANT COMMUNITIES

Forest and shrub communities of the class *Alnetea glutinosae* (Table 1) are associated with very wet habitats, often flooded for a long time. They were common in the Jorka basin, mainly on lake shores and in depressions with stagnant water. Alderwood swamps were represented by two types of phytocoenoses: *Carici acutiformis-Alnetum* and *Carici elongatae-Alnetum*. The major component of these stands was *Alnus glutinosa.* Reed alderwood swamps occurred in direct neighbourhood of water. The herb layer was dominated by reedbed species: *Carex acutiformis* and *Phragmites australis.*

Typical alderwood swamps were characterized by the presence of *Betula pubescens* in the tree layer. In the herb layer, the role of reedbed species declined, whereas *Thelypteris palustris* and *Carex elongata* were highly constant. The layer of mosses was more abundant. Patches of *Carici elongatae-Alnetum* rarely occurred in direct contact with lake water. Alder swamps were genetically associated with *Salicetum pentandro-cinereae*. The latter formed dense shrubs dominated by *Salix cinerea* accompanied by *Salix pentandra, Salix aurita, Salix viminalis* and *Alnus glutinosa.* In the study area willow clumps were common in neighbourhood of lakes and in depressions without runoff. Communities with *Betula pubescens* occurred on the western shore of Majcz Wielki Lake. The treestands were dominated by birches with admixture of *Alnus glutinosa* and *Pinus sylvestris*. In the herb layer *Sphagnum* moss was frequent along with species associated with transition bogs: *Sphagnum fimbriatum, Sphagnum palustre, Carex lasiocarpa* and *Menyanthes trifoliata.* Among the communities of the class *Alnetea glutinosae,* forest with *Betula pubescens* occupied the poorest sites.

The shore of Inulec Lake supported riparian carrs with *Salix fragilis* of the class *Salicetea purpureae.* The tree layer consisted of *Salix fragilis* and *Alnus glutinosa.* The shrub layer was built of *Salix cinerea, Salix viminalis, Salix pentandra, Tilia cordata* and *Acer platanoides*. The sparse herb layer consisted of *Urtica dioica, Rubus idaeus, Humulus lupulus, Geum urbanum, Moehringia trinervia* and *Galium aparine.* Phytocoenoses with *Salix fragilis* bordered directly on open water.

Characteristic communities associated with running waters were floodplain forests of the alliance *Alno-Padion* and class *Querco-Fagetea* (Table 2). They were mainly represented by patches of *Circaeo-Alnetum*. The tree layer was dominated by *Alnus glutinosa*, rarely with admixture of *Fraxinus excelsior*. The characteristic physiognomy of the herb layer was due to *Urtica dioica, Humulus lupulus* and *Galium aparine.* They occupied wet soils at the river channel. The community *Alnus glutinosa-Eupatorium cannabinum* was a degraded form of the riparian carr *Circaeo-Alnetum*. Patches of this community were characterized by abundant herb layer made up of nitrophilous perennials. Its floristic composition was similar to that of phytocoenoses of the class *Artemisietea*. For this reason, the patches of *Alnus glutinosa-Eupatorium cannabinum* community were classified to the latter class (Table 4 A). On the slopes of the Jorka river, there were also patches of another riparian carr, i.e. *Padus avium-Alnus glutinosa* community. They covered moist soils beyond the reach of river flooding. In the tree layer, in addition to *Alnus glutinosa,* a co-dominant species was *Padus avium.* The herb layer was poor and similar to that in *Tilio-Carpinetum* phytocoenoses.

Patches of communities with characteristics of *Tilio-Carpinetum*, alliance *Carpinion betuli* (Table 3) were rare components of riparian vegetation. They developed on high escarps inclined towards a lake or river (Table 3, columns 1, 3, 4). Sometimes they bordered on the lake behind the zones of alderwoods and riparian carrs (Table 3, column 2).

Nitrophilous communities of perennials of the class *Artemisietea* (Table 4) occurred mainly near the Jorka river. They were represented by three communities: *Urtica dioica-*

Table 1. Riparian vegetation of the Jorka River-Lake system – Plant communities of the class *Alnetea glutinosae* Br.-Bl. et Tx. 1943

A – *Salicetum pentandro-cinereae* Pass. 1961

B – *Carici acutiformis-Alnetum* Scamoni 1953

C – *Carici elongatae-Alnetum* Koch 1926

D – *Betula pubescens* community

Other explanations (Tables 1–6): S – constancy; P – coefficient of cover;

L – number of appearances

In the frames – groups of differential species

Community	A		B		C		D	
Number of records	6		12		6		2	
Mean cover of tree layer *a* in %	10		60		60		65	
Mean cover of shrub layer *b* in %	72		20		47		55	
Mean cover of herb layer *c* in %	67		88		75		50	
Mean cover of moss layer *d* in %	27		18		44		55	
Mean area of record in m^2	98		105		92		100	
Mean number of species	39		31		35		61	
Trees:	S	P	S	P	S	P	L	P
Alnus glutinosa a	III	168	V	5625	V	5500	2	1125
Alnus glutinosa b	III	168	V	817	V	711	2	1880
Alnus glutinosa c	.	.	III	4	.	.	2	10
Padus avium b	.	.	III	3	III	147	.	.
Padus avium c	I	2	I	2	.	.	1	5
Sorbus aucuparia b	III	5	II	3	III	2	1	875
Sorbus aucuparia c	I	2	I	2	III	5	1	250
Acer platanoides c	III	5	I	1	III	2	1	5
Fraxinus excelsior b	.	.	II	1	II	147	.	.
Fraxinus excelsior c	.	.	II	2	II	42	.	.
Betula pubescens a	.	.	I	42	V	543	2	5000
Betula pubescens b	.	.	II	2	III	147	2	10
Betula pendula a	I	2	I	2	.	.	1	5
Betula pendula b	I	2	.	.	.	.	.	.
Quercus robur c	.	.	I	2	.	.	2	10
Salix pentandra a	III	918	.	.	.	.	.	.
Salix pentandra b	III	377	.	.	.	.	.	.
Salix alba a	II	85	.	.	.	.	.	.
Salix alba b	II	3	.	.	.	.	.	.
Pinus sylvestris a	.	.	.	.	.	.	2	25
Pinus sylvestris c	.	.	.	.	.	.	2	10
Alnetea glutinosae:								
Salix cinerea b	V	5917	V	1336	V	2208	2	880
Salix cinerea c	I	83	II	3	II	42	.	.
Solanum dulcamara	V	462	V	1125	V	417	2	25
Lycopus europaeus	V	255	V	296	V	173	1	5
Thelypteris palustris	II	3	III	377	V	4167	2	500
Ribes nigrum b/c	II	3	I	1	I	2	.	.
Dryopteris cristata	I	2	.	.	.	.	1	5
Calamagrostis canescens	.	.	I	42	I	2	.	.
Salix aurita b	I	292	.	.	.	.	.	.
Carex elongata	.	.	.	.	III	5	.	.

Community	A		B		C		D	
Querco-Fagetea:								
Geum urbanum	II	85	I	1	I	2	1	5
Plagiomnium undulatum	III	87	I	187	I	2	I	5
Viburnum opulus	I	2	.	.	I	2	1	250
Euonymus europaeus b/c	I	2	.	.	II	3	1	5
Festuca gigantea	.	.	I	2	II	3	1	5
Brachypodium sylvaticum	.	.	I	1	II	42	1	5
Impatiens noli-tangere	I	2	I	42	.	.	.	.
Eurhynchium sp.	I	2	I	83	.	.	.	.
Glechoma hederacea	II	85	.	.	.	.	.	.
Phragmitetea:								
Carex acutiformis	IV	672	V	4500	V	90	1	250
Phragmites australis	III	918	V	2062	V	878	1	5
Scutellaria galericulata	IV	7	V	9	IV	88	2	255
Galium palustre	V	172	V	586	V	172	2	255
Equisetum fluviatile	IV	88	V	275	IV	88	2	10
Peucedanum palustre	I	2	III	46	II	85	2	10
Carex appropinquata	I	2	III	5	II	85	1	250
Iris pseudoacorus	II	3	III	5	III	87	1	5
Lysimachia thyrsiflora	I	2	I	1	II	3	1	5
Phalaris arundinacea	I	2	I	1	II	3	.	.
Alisma plantago-aquatica	I	2	I	1	I	2	.	.
Cicuta virosa	I	2	I	1	II	3	.	.
Carex pseudocyperus	.	.	II	2	IV	88	1	5
Rumex hydrolapathum	I	2	I	2	.	.	.	.
Carex elata	II	3	.	.	II	3	.	.
Glyceria maxima	.	.	II	44	.	.	.	.
Molinio-Arrhenatheretea:								
Lysimachia vulgaris	V	92	V	90	V	90	2	25
Cirsium oleraceum	IV	378	III	46	II	3	1	5
Deschampsia caespitosa	V	8	II	2	III	87	2	10
Lythrum salicaria	V	90	III	4	II	3	2	25
Angelica sylvestris	II	85	III	6	III	5	2	10
Cirsium palustre	IV	7	II	3	I	2	2	10
Caltha palustris	I	2	III	5	I	2	1	5
Myosotis palustris	III	5	III	47	II	85	.	.
Poa trivialis	V	1333	III	584	III	295	.	.
Filipendula ulmaria	III	168	II	43	.	.	1	5
Climacium dendroides	III	87	.	.	III	250	2	500
Crepis paludosa	I	2	.	.	.	.	1	5
Geum rivale	II	293	I	1	.	.	.	.
Symphytum oficinale	II	3	I	1	.	.	.	.
Other species:								
Plagiomnium affine	V	1583	V	774	V	960	2	880
Rubus idaeus	II	85	II	44	II	167	1	5
Eupatorium cannabinum	II	3	IV	420	III	628	1	5
Frangula alnus b	I	83	I	354	IV	253	2	1880
Frangula alnus c	II	3	I	2	V	10	2	255

Community	A		B		C		D	
Calliergonella cuspidata	IV	1210	III	730	V	2750	2	500
Dryopteris carthusiana	IV	88	III	12	II	3	2	10
Epilobium palustre	I	2	II	3	III	5	1	5
Plagiothecium denticulatum	IV	460	II	292	IV	333	1	5
Rhizomnium punctatum	II	167	II	2	III	458	2	875
Rhamnus cathartica	I	2	I	1	I	2	1	5
Comarum palustre	I	2	I	1	II	3	1	5
Urtica dioica	V	2252	IV	152	II	3	.	.
Mentha aquatica	I	2	III	191	II	917	.	.
Cardamine amara	II	3	III	4	III	5	.	.
Galeopsis tetrachit	III	5	II	2	I	2	.	.
Epilobium parviflorum	I	2	I	1	.	.	1	5
Valeriana dioica	I	83	.	.	I	2	2	255
Carex lasiocarpa	I	2	.	.	II	85	2	255
Menyanthes trifoliata	I	83	.	.	II	85	2	875
Brachythecium salebrosum	II	42	.	.	II	166	1	250
Polytrichum formosum	.	.	I	1	I	2	1	5
Lemna minor	I	2	I	1	I	2	.	.
Agrostis gigantea	I	2	I	1	I	2	.	.
Ranunculus repens	I	2	II	2	.	.	.	.
Geranium robertianum	.	.	II	2	II	85	.	.
Humulus lupulus	IV	542	III	4	.	.	.	.
Galium aparine	II	3	I	2	.	.	.	.
Epilobium hirsutum	III	87	I	42	.	.	.	.
Athyrium filix-femina	III	3	II	2	.	.	.	.
Oxalis acetosella	.	.	I	2	I	2	.	.
Fissidens adianoides	.	.	.	.	III	5	2	875
Pohlia nutans	I	83	.	.	.	.	1	250
Lemna trisulca	I	2	I	1	.	.	.	.
Stellaria palustris	.	.	.	.	II	3	1	5
Calla palustris	.	.	.	.	II	85	1	5
Sphagnum teres	.	.	.	.	II	3	1	5
Salix viminalis b	III	628	.	.	.	.	.	.
Moehringia trinervia	III	3	.	.	.	.	.	.
Brachythecium rutabulum	.	.	III	45	.	.	.	.
Sphagnum fimbriatum	.	.	.	.	.	.	2	1880
Sphagnum palustre	.	.	.	.	.	.	2	880
Festuca ovina	.	.	.	.	.	.	2	880
Dicranum polysetum	.	.	.	.	.	.	2	250
Aulacomnium palustre	.	.	.	.	.	.	1	875
Sphagnum recurvum	.	.	.	.	.	.	1	250

Table 2. Riparian vegetation of the Jorka River-Lake system – Plant communities of the alliance *Alno-Padion* Knapp 1942
A – *Padus avium-Alnus glutinosa* community; B – *Circaeo-Alnetum* Oberd. 1953. Other explanations – see Table 1

Community	A		B	
Number of records	5		8	
Mean cover of tree layer *a* in %	68		69	
Mean cover of shrub layer *b* in %	38		25	
Mean cover of herb layer *c* in %	23		93	
Mean cover of moss layer *d* in %	22		10	
Mean area of record in m^2	100		150	
Mean number of species	24		26	
Trees:	S	P	S	P
Alnus glutinosa a	V	3750	V	6875
Alnus glutinosa b	I	2	III	2
Padus avium a	V	3450	I	2
Padus avium b	V	3452	IV	599
Padus avium c	V	108	I	62
Acer platanoides a	IV	1752	II	2
Acer platanoides b	II	4	II	2
Acer platanoides c	III	6	III	5
Sorbus aucuparia b	V	108	II	4
Sorbus aucuparia c	III	6	I	1
Crategus monogyna b	II	4	.	.
Crategus monogyna c	II	4	I	1
Tilia cordata c	I	2	I	1
Fraxinus excelsior a	.	.	III	5
Fraxinus excelsior b	.	.	II	2
Betula pendula a	.	.	I	1
Populus tremula a	I	2	.	.
Alnetea glutinosae:				
Salix cinerea b	.	.	IV	1439
Salix cinerea c	.	.	II	220
Ribes nigrum b/c	.	.	II	65
Solanum dulcamara	.	.	II	4
Lycopus europaeus	.	.	II	2
Querco-Fagetea:				
Plagiomnium undulatum	V	1302	II	282
Geum urbanum	V	454	IV	69
Atrichum undulatum	V	454	I	1
Aegopodium podagraria	V	106	II	437
Eurhynchium angustirete	III	202	II	64
Festuca gigantea	I	2	II	4
Ribes spicatum b/c	III	6	I	1
Corylus avellana b/c	II	450	.	.
Galeobdolon luteum	I	350	.	.
Viburnum opulus	II	4	.	.
Impatiens noli-tangere	.	.	II	221
Scrophularia nodosa	.	.	II	4
Euonymus europaeus b/c	.	.	II	4

Community	A		B	
Phragmitetea:				
Carex acutiformis	.	.	IV	191
Phragmites australis	.	.	IV	285
Phalaris arundinacea	.	.	II	64
Scutellaria galericulata	.	.	II	2
Galium palustre	.	.	II	4
Molinio-Arrhenatheretea:				
Anthriscus sylvestris	III	104	III	5
Deschampsia caespitosa	III	6	II	2
Lysimachia vulgaris	I	2	II	2
Taraxacum officinale	I	2	I	1
Cirsium oleraceum	I	2	IV	6
Angelica sylvestris	I	2	III	66
Filipendula ulmaria	.	.	IV	659
Poa trivialis	.	.	III	906
Cirsium palustre	.	.	II	2
Caltha palustris	.	.	II	3
Scirpus sylvaticus	.	.	II	2
Other species:				
Urtica dioica	IV	8	V	3062
Humulus lupulus	I	100	V	1907
Rubus idaeus	II	4	IV	1032
Plagiomnium affine	II	102	III	595
Sambucus nigra b/c	V	456	III	474
Plagiothecium denticulatum	III	450	III	222
Geranium robertianum	I	2	IV	129
Dryopteris carthusiana	II	4	IV	6
Moehringia trinervia	III	104	I	62
Ranunculus repens	I	2	II	2
Frangula alnus b/c	II	102	I	1
Galeopsis tetrachit	III	6	II	2
Cirsium arvense	I	2	II	2
Athyrium filix-femina	II	4	II	2
Rhamnus cathartica c	I	2	I	1
Stellaria media	II	4	I	2
Galium aparine	.	.	V	940
Eupatorium cannabinum	.	.	II	125
Epilobium hirsutum	.	.	I	62
Rhizomnium punctatum	.	.	I	62
Mycelis muralis	III	452	.	.
Fissidens taxifolius	II	102	.	.
Polygonatum multiflorum	II	4	.	.
Chaerophyllum aromaticum	.	.	I	62
Brachythecium salebrosum	.	.	I	62

Table 3. Riparian vegetation of the Jorka River-Lake system – Plant communities of the alliance *Carpinion betuli* Oberd. 1953, disturbed phytocoenoses of *Tilio-Carpinetum* Tracz. 1962.

Cover of tree layer *a* in %	80	80	80	60
Cover of tree layer a_1 in %	80	60	40	60
Cover of tree layer a_2 in %		40	60	.
Cover of shrub layer b in %	50	60	30	60
Cover of herb layer *c* in %	60	50	30	30
Cover of moss layer *d* in %	+	10	+	5
Area of record in m^2	100	100	225	100
Number of species	25	41	45	15
Trees:				
Alnus glutinosa a_1	2	3	.	+
Alnus glutinosa b	.	+	.	.
Alnus glutinosa c	.	+	.	.
Sorbus aucuparia b	+	+	.	+
Sorbus aucuparia c	.	+	+	.
Picea abies a_1	.	1	1	.
Picea abies a_2	.	3	+	.
Acer platanoides a_1	3	.	.	+
Acer platanoides b	+	.	.	+
Acer platanoides c	+	.	.	2
Fraxinus excelsior a_1	2	.	.	.
Fraxinus excelsior a_2	.	1	.	.
Fraxinus excelsior b	+	2	.	.
Fraxinus excelsior c	+	1	.	.
Quercus robur a_1	.	.	.	4
Quercus robur a_2	.	.	+	.
Quercus robur c	.	+	+	.
Carpinus betulus a_2	.	.	4	.
Carpinus betulus b/c	.	.	1	.
Padus avium b	+	.	.	1
Betula pubescens a_1	.	2	.	.
Pinus sylvestris a_1	.	.	3	.
Salix alba a_1	+	.	.	.
Alno-Padion:				
Plagiomnium undulatum	+	2	.	.
Stachys sylvatica	+	.	+	.
Festuca gigantea	.	+	.	.
Fagetalia:				
Aegopodium podagraria	2	+	+	2
Asperula odorata	1	2	1	.
Hepatica nobilis	.	2	1	.
Daphne mezereum c	.	+	+	.
Brachypodium sylvaticum	.	+	+	.
Lathyrus vernus	.	+	1	.
Impatiens noli-tangere	.	+	.	.
Paris quadrifolia	.	+	.	.
Stellaria holostea	.	.	+	.
Galeobdolon luteum	.	.	+	.
Polygonatum multiflorum	.	.	+	.

Querco-Fagetea:				
Corylus avellana b/c	1	3	3	4
Geum urbanum	1	+	+	+
Eurhynchium angustirete	+	+	+	.
Viola reichenbachiana	.	+	+	.
Carex digitata	.	+	+	.
Actaea spicata	.	+	+	.
Mycelis muralis	.	+	1	.
Anemone nemorosa	.	+	+	.
Euonymus verrucosa b/c	.	+	+	.
Euonymus europaeus c	+	+	.	.
Moehringia trinervia	+	.	+	.
Campanula trachelium	1	.	.	.
Poa nemoralis	.	+	.	.
Viburnum opulus c	.	+	.	.
Melica nutans	.	.	+	.
Dryopteris filix-mas	.	.	+	.
Viola mirabilis	.	.	.	+
Other species:				
Urtica dioica	+	+	+	.
Rubus idaeus	.	1	+	+
Plagiomnium affine	+	1	.	1
Dactylis glomerata	+	.	+	.
Oxalis acetosella	1	.	+	.
Majanthemum bifolium	.	+	+	.
Viola riviniana	.	.	1	+
Sambucus nigra b	3	.	.	.
Chaerophyllum aromaticum	3	.	.	.
Circaea alpina	.	2	.	.
Calamagrostis arundinacea	.	.	1	.
Campanula rapunculoides	.	.	.	1
Anthriscus sylvestris	+	.	.	.
Galeopsis pubescens	+	.	.	.
Lapsana communis	+	.	.	.
Dryopteris carthusiana	.	+	.	.
Deschampsia caespitosa	.	+	.	.
Frangula alnus c	.	+	.	.
Cornus sanguinea c	.	+	.	.
Angelica sylvestris	.	+	.	.
Athyrium filix-femina	.	+	.	.
Crepis paludosa	.	+	.	.
Hieracium lachenalii	.	.	+	.
Polygonatum verticillatum	.	.	+	.
Crategus monogyna c	.	.	+	.
Geranium robertianum	.	.	+	.
Campanula persicifolia	.	.	+	.
Fragaria vesca	.	.	+	.
Vaccinium myrtillus	.	.	+	.
Solidago virgaurea	.	.	+	.
Convallaria majalis	.	.	+	.
Clinopodium vulgare	.	.	.	+
Polytrichum formosum	.	.	.	+

Eupatorium cannabinum, Urtica dioica and *Urtica dioica-Phalaris arundinacea*. These phytocoenoses represented a degenerated phase of riparian carrs *Circaeo-Alnetum*.

Alderwood swamps, floodplain forests, and also reedbeds bordered in places directly on meadow communities of the class *Molinio-Arrhenatheretea* (Table 5). In the outflow area of the river below Jorzec lake, meadows reached directly the Jorka River channel. In depressions, on organic or organic-mineral soils, there were patches of *Cirsio-Polygonetum* or *Scirpetum sylvatici*. *Cirsio-Polygonetum* formed phytocoenoses co-dominated by *Polygonum bistorta, Cirsium oleraceum* and *Filipendula ulmaria*. In addition to *Scirpus sylvaticus*, patches of *Scirpetum silvatici* comprised *Epilobium hirsutum, Cirsium oleraceum* and *Carex acutiformis*. These communities occurred near water seepages. An interesting community was *Aegopodio-Petasitetum hybridi*. A typical physiognomy of the herb layer was due to *Petasites hybridus*. Patches of this community occurred at the Jorka River outlet to Jorzec Lake. On overdried organic-mineral soils, there were the places occupied by phytocoenoses with *Deschampsia caespitosa*. Tussocks of *Deschampsia caespitosa* were adjacent to *Festuca rubra, Holcus lanatus, Anthoxanthum odoratum* and *Carex leporina*. Patches of moist meadows did not form strips but enclaves within other plant communities. In higher places, on mineral soils, there were phytocoenoses dominated by *Dactylis glomerata*. The herb layer consisted of the species typical of fresh habitats: *Phleum pratense, Leontodon autumnalis, Achillea millefolium* and *Trifolium repens*. These meadows were dispersed across the Jorka basin, most often at some distance from the river bank or lake shore.

Reedbeds of the class *Phragmitetea* (Table 6, columns A-H) belong to typical littoral aquatic vegetation. Among sedge communities, most common were patches of *Caricetum acutiformis*. They represented the first vegetation strip at the water side, or occurred in submerged depressions. The dominant species was *Carex acutiformis*, and other species included *Phragmites australis, Equisetum fluviatile, Iris pseudoacorus, Scutellaria galericulata* and *Lysimachia vulgaris*. Other sedge communities such as *Caricetum rostratae* and *Caricetum appropinquatae* were rare on Majcz Wielki Lake. The most common community of reedbed is *Phragmitetum australis*. Patches of this community grew along shores of all lakes. Often this was the only strip of the littoral aquatic vegetation bordering on land communities. Phytocoenoses of this community constituted almost monospecific aggregations of *Phragmites australis*. They were accompanied by *Carex acutiformis, Typha latifolia, Typha angustifolia* and *Rumex hydrolapathum*. Aquatic plants such as *Nuphar luteum* and *Lemna minor* were often present in patches. Other phytocoenoses of the reedbed: *Thelypteridi-Phragmitetum, Acoretum calami, Typhetum latifoliae* and *Sparganietum erecti* were rare. In the Jorka River channel, the best developed reedbeds occurred between Lakes Jorzec and Tałty. They were represented by patches of *Sparganietum erecti, Phragmitetum communis* and *Typhetum latifoliae*.

Phytocoenoses of *Nupharo-Nymphaeetum albae*, of the class *Potamogetonetea*, were components of the communities of littoral aquatic vegetation (Table 6, column I). Their patches were dominated by *Nuphar luteum*. The community of macrophytes formed the first zone of vegetation on the water. The patches of this community rarely adjoined the shore, as typically they were separated from the land by the zone of reedbeds.

3.3. EVALUATION OF THE TRANSFORMATION OF RIPARIAN VEGETATION

Characteristic vegetation strips along rivers and around lakes are corridors whose continuity is important to the flow of water, nutrients and species. Riparian vegetation, width and shape of its different zones, and also their floristic structure determine the direction of these processes.

Taking into account the above aspects, the analysis was made of the transformation of riparian vegetation from its natural state within the whole Jorka River-Lake system. From its outlet from Majcz Wielki Lake to the inflow to Tałty Lake, the Jorka River is 12 175 m long, including 5 725 m of the river itself.

Three categories of disturbance to the riparian vegetation were distinguished (Table 7):

I – weak disturbance – riparian vegetation consists of alderwood swamps and floodplain forests, occasionally of oak-hornbeam forests in a state close to natural,

Table 4. Riparian vegetation of the Jorka River-Lake system – Plant communities of the alliance *Alno-Padion** Knapp 1942 and the class *Artemisietea* Lohm. Prsg. et Tx. 1950.
A – *Alnus glutinosa-Eupatorium cannabinum** community
B – *Urtica dioica-Eupatorium cannabinum* community
C – *Urtica dioica* community
D – *Urtica dioica-Phalaris arundinacea* community.
Other explanations – see Table 1

Community	A		B		C		D	
Number of records	2		6		6		2	
Mean cover of tree layer *a* in %	20		+		0		0	
Mean cover of shrub layer *b* in %	35		1		0		0	
Mean cover of herb layer *c* in %	90		100		100		100	
Mean cover of moss layer *d* in %	8		16		7		0,1	
Mean area of record in m^2	45		37		75		40	
Mean number of species	45		32		16		18	
Artemisietea:	L	P	S	P	S	P	L	P
Urtica dioica	2	500	V	3833	V	7917	2	3750
Eupatorium cannabinum	2	1750	V	1252	I	2	.	.
Arctium lappa	1	5	IV	88	IV	170	.	.
Myosoton aquaticum	.	.	IV	252	I	2	2	1125
Calystegia sepium	1	250	II	375	.	.	.	.
Artemisia vulgaris	.	.	II	3	I	2	.	.
Chaerophyllum aromaticum	.	.	.	.	II	627	.	.
Rumex obtusifolius	.	.	II	3	.	.	.	.
Molinietalia:								
Cirsium oleraceum	2	880	V	2083	II	3	1	5
Deschampsia caespitosa	2	255	III	87	II	85	1	5
Epilobium hirsutum	.	.	II	293	II	3	2	1750
Lysimachia vulgaris	2	255	II	3	II	3	.	.
Cirsium palustre	.	.	I	83	II	85	2	10
Lythrum salicaria	.	.	II	3	I	2	1	5
Myosotis palustris	1	5	II	3	.	.	.	.
Valeriana officinalis	1	5	.	.	I	2	.	.
Filipendula ulmaria	.	.	.	.	II	3	2	10
Angelica sylvestris	.	.	IV	88	.	.	.	.
Scirpus sylvaticus	.	.	II	85	.	.	.	.
Galium uliginosum	.	.	I	63	.	.	.	.
Molinio-Arrhenatheretea:								
Anthriscus sylvestris	2	10	V	253	III	87	.	.
Geum rivale	2	10	V	8	I	2	.	.
Taraxacum officinale	2	10	III	5	.	.	.	.
Dactylis glomerata	2	10	I	2	.	.	.	.
Poa trivialis	.	.	IV	1083	IV	792	.	.
Holcus lanatus	1	5	I	2	.	.	.	.
Vicia cracca	.	.	.	.	I	2	1	5
Heracleum sphondylium	.	.	I	2	I	2	.	.
Phragmitetea:								
Phalaris arundinacea	1	5	III	5	IV	7	2	1750
Carex acutiformis	2	10	IV	958	II	167	1	250
Galium palustre	1	5	V	253	III	5	1	5
Scutellaria galericulata	1	5	I	2	I	2	.	.
Phragmites australis	1	5	III	87	III	87	.	.
Equisetum fluviatile	1	5	.	.	I	2	.	.
Glyceria maxima	.	.	.	.	i	2	2	10

Community	A		B		C		D	
Iris pseudoacorus	.	.	IV	7	.	.	.	.
Carex elata	.	.	.	.	.	.	2	10
Other species:								
Cirsium arvense	2	10	II	3	II	3	1	5
Glechoma hederacea	1	5	II	85	I	83	1	5
Plagiomnium undulatum	2	500	III	667	I	292	.	.
Plagiomnium affine	2	880	III	792	I	2	.	.
Galium aparine	.	.	IV	668	V	1087	2	2750
Ranunculus repens	1	5	IV	7	I	2	.	.
Lycopus europaeus	1	5	III	5	I	2	.	.
Equisetum arvense	1	5	I	2	.	.	2	10
Galeopsis tetrachit	.	.	II	3	II	3	2	10
Rubus idaeus	2	2750	II	3	II	3	.	.
Alnus glutinosa a	2	1750	II	3	.	.	.	.
Alnus glutinosa b\c	2	880	.	.	.	.	.	.
Salix cinerea b\c	2	880	II	85	.	.	.	.
Sorbus aucuparia b	2	1125	I	2	.	.	.	.
Sorbus aucuparia c	2	10	.	.	.	.	.	.
Eurhynchium hians	2	10	IV	330	.	.	.	.
Aegopodium podagraria	.	.	III	667	II	85	.	.
Humulus lupulus	.	.	III	377	I	85	.	.
Mentha aquatica	2	10	IV	378	.	.	.	.
Geranium robertianum	2	10	IV	7	.	.	.	.
Solanum dulcamara	.	.	IV	7	I	2	.	.
Scrophularia nodosa	1	5	V	8	.	.	.	.
Moehringia trinervia	2	10	III	5	.	.	.	.
Tussilago farfara	1	5	I	2	.	.	.	.
Sambucus nigra b\c	1	5	I	2	.	.	.	.
Crategus monogyna b\c	2	10	I	2	.	.	.	.
Athyrium filix-femina	1	5	III	5	.	.	.	.
Padus avium b	1	5	I	2	.	.	.	.
Carex hirta	1	5	I	83	.	.	.	.
Rumex crispus	.	.	I	2	I	2	.	.
Epilobium parviflorum	.	.	I	2	I	2	.	.
Calliergonella cuspidata	.	.	.	.	II	375	1	5
Brachythecium sp.	.	.	.	.	III	87	1	5
Agropyron repens	.	.	.	.	I	2	1	5
Stellaria nemorum	.	.	I	2	.	.	1	5
Acer platanoides b\c	2	10	.	.	.	.	.	.
Frangula alnus b\c	2	255	.	.	.	.	.	.
Fragaria vesca	2	255	.	.	.	.	.	.
Quercus robur b\c	2	10	.	.	.	.	.	.
Ribes spicatum c	2	10	.	.	.	.	.	.
Atrichum undulatum	2	255	.	.	.	.	.	.
Oxalis acetosella	.	.	III	5	.	.	.	.
Lapsana communis	.	.	II	3	.	.	.	.
Polygonum persicaria	.	.	II	3	.	.	.	.
Agrostis stolonifera	.	.	II	85	.	.	.	.
Bromus inermis	.	.	.	.	III	5	.	.
Carduus crispus	.	.	.	.	II	3	.	.

Table 5. Riparian vegetation of the Jorka River-Lake system – Plant communities of the class *Molinio-Arrhenatheretea* Tx. 1937.
A – *Aegopodio-Petasitetum hybridi* Tx. 1949
B – *Cirsio-Polygonetum bistortae* Tx. 1951
C – *Scirpetum sylvatici* Knapp 1946
D – *Deschampsia caespitosa* community
E – *Dactylis glomerata* community

Community	A	B	C	D		E		
Cover of herb layer *c* in %	100	100	100	100	100	100	100	100
Cover of moss layer *d* in %	5	0	0	0	0	0	0	0
Mean area of record in m^2	100	50	100	50	25	30	50	50
Number of species	17	29	15	31	29	32	26	33
Molinietalia:								
Deschampsia caespitosa	.	+	.	3	3	+	.	+
Filipendula ulmaria	.	2	+	1	.	.	.	.
Cirsium oleraceum	.	2	2	1	.	.	.	.
Polygonum bistorta	.	2	.	+	.	.	.	.
Alopecurus pratensis	.	1	.	+	.	.	.	.
Geum rivale	.	.	.	.	1	+	.	.
Petasites hybridus	5	.	.	.	.	.	.	.
Scirpus sylvaticus	.	.	4	.	.	.	.	.
Epilobium hirsutum	.	.	2	.	.	.	.	.
Galium uliginosum	.	.	2	.	.	.	.	.
Stellaria palustris	.	+	.	.	.	.	.	.
Lythrum salicaria	.	.	+	.	.	.	.	.
Lysimachia vulgaris	.	.	+	.	.	.	.	.
Juncus effusus	.	.	.	+	.	.	.	.
Lychnis flos-cuculi	.	.	.	+	.	.	.	.
Crepis paludosa	.	.	.	.	+	.	.	.
Molinio-Arrhenatheretea:								
Poa pratensis	.	2	.	1	1	1	1	1
Festuca rubra	.	+	.	1	2	1	1	1
Taraxacum officinale	+	+	.	.	+	1	2	2
Cerastium holosteoides	.	+	.	+	.	.	+	+
Anthriscus sylvestris	1	+	.	.	+	+	+	.
Plantago lanceolata	.	.	.	+	+	+	1	+
Phleum pratense	.	.	.	+	1	+	2	+
Heracleum sphondylium	+	+	.	.	.	.	+	+
Holcus lanatus	.	1	.	+	+	+	.	.
Galium mollugo	.	+	.	.	2	+	.	+
Vicia cracca	.	+	.	+	.	.	+	+
Rumex acetosa	.	+	.	+	+	+	.	.
Ranunculus acris	.	.	.	+	1	+	.	1
Leontodon autumnalis	.	.	.	+	.	+	1	1
Dactylis glomerata	.	.	.	.	+	4	3	3
Trifolium repens	.	.	.	.	.	2	3	2
Achillea millefolium	.	.	.	.	.	1	+	1
Bellis perennis	.	.	.	.	.	+	.	+
Trifolium pratense	.	.	.	.	.	.	+	+
Trifolium dubium	.	.	.	.	.	.	1	+
Poa trivialis	1	.	.	.	.	.	.	.

Community	A	B	C	D		E		
Lathyrus pratensis	.	.	1	.	.	.	.	.
Tragopogon pratensis	.	.	.	.	.	.	+	.
Cynosurus cristatus	.	.	.	.	.	+	.	.
Arrhenatherum elatius	.	.	.	.	+	.	.	.
Phragmitetea:								
Carex acutiformis	.	1	.	1	+	.	.	.
Phragmites australis	+	.	.	.	.	.	.	.
Poa palustris	.	1	.	.	.	.	.	.
Equisetum fluviatile	.	.	2	.	.	.	.	.
Phalaris arundinacea	.	+	.	.	.	.	.	.
Scutellaria galericulata	.	.	+	.	.	.	.	.
Other species:								
Veronica chamaedrys	+	1	.	+	3	+	.	+
Urtica dioica	1	2	2	.	+	+	.	.
Plantago major	.	.	.	+	+	+	+	+
Ranunculus repens	+	2	.	3	.	+	.	.
Equisetum arvense	+	+	.	+	+	.	.	.
Potentilla anserina	.	+	.	+	.	+	.	+
Rumex crispus	.	+	.	+	.	.	+	+
Carex hirta	.	+	.	+	2	.	+	.
Cirsium arvense	+	.	1	.	+	.	+	.
Cardaminopsis arenosa	.	1	.	+	+	.	.	.
Lolium perenne	.	.	.	.	.	2	1	1
Galium aparine	2	.	1	.	.	.	.	.
Glechoma hederacea	+	.	.	.	.	.	.	+
Anthoxanthum odoratum	.	.	.	2	1	.	.	.
Carex leporina	.	.	.	1	+	.	.	.
Stellaria graminea	.	.	.	.	2	.	.	+
Prunella vulgaris	.	.	.	.	.	1	.	+
Tussilago farfara	.	.	.	.	.	+	+	.
Hypochoeris radicata	.	.	.	.	.	+	.	+
Artemisia vulgaris	.	.	.	.	.	.	+	+
Matricaria inodora	.	.	.	.	.	.	+	+
Aegopodium podagraria	1	.	.	.	.	.	.	.
Brachythecium sp.	1	.	.	.	.	.	.	.
Humulus lupulus	.	.	2	.	.	.	.	.
Impatiens noli-tangere	.	.	1	.	.	.	.	.
Mentha arvensias	.	.	.	1	.	.	.	.
Carex nigra	.	.	.	1	.	.	.	.
Stellaria nemorum	+	.	.	.	.	.	.	.
Geranium robertianum	+	.	.	.	.	.	.	.
Linaria vulgaris	.	+	.	.	.	.	.	.
Stellaria media	.	+	.	.	.	.	.	.
Glyceria fluitans	.	.	.	+	.	.	.	.
Medicago falcata	.	.	.	.	.	+	.	.
Agropyron repens	.	.	.	.	.	+	.	.
Agrostis capillaris	.	.	.	.	.	.	1	.
Odontites serotina	.	.	.	.	.	.	+	.
Hypericum perforatum	.	.	.	.	.	.	.	+
Senecio jacobea	.	.	.	.	.	.	.	+

Table 6. Riparian vegetation of the Jorka River-Lake system – Plant communities of the classes *Phragmitetea* Tx. et Prsg. 1942 and *Potamogetonetea** Tx. et Prsg. 1942.

A – *Caricetum rostratae* Rübell 1912
B – *Caricetum appropinquatae* (Koch 1926) Soo' 1938
C – *Caricetum acutiformis* Sauer 1937
D – *Phragmitetum australis* (Gams 1927) Schmale 1939
E – *Thelypteridi-Phragmitetum* Kuiper 1957
F – *Acoretum calami* Kobendza 1948
G – *Typhetum latifoliae* Soo' 1927
H – *Sparganietum erecti* Roll 1938
I – *Nupharo-Nymphaeetum** Tomasz. 1977
Other explanations – see Table 1

Community	A	B	C		D		E	F	G	H	I
Number of records	1	1	7		11		1	1	1	1	1
Mean cover of herb layer *c* in %	70	100	92		84		100	60	80	80	80
Mean cover of moss layer *d* in %	0	0,1	0,7		0,5		10	0	0	0	0
Mean area of record in m^2	20	20	26		36		50	20	20	20	20
Mean number of species	14	20	16		11		26	4	6	4	5
Phragmitetea:	P	P	S	P	S	P	P	P	P	P	P
Rumex hydrolapathum	10	10	II	4	II	3	500	.	10	.	.
Typha latifolia	10	10	II	1	II	365	.	.	3750	.	.
Cicuta virosa	500	10	II	1	I	4	10	.	.	.	.
Carex pseudocyperus	500	500	II	1	I	2	500	.	.	.	.
Phragmites australis	500	.	III	253	V	6477	3750	.	.	.	.
Carex acutiformis	10	.	V	6607	IV	185	.	.	10	.	.
Iris pseudoacorus	.	10	III	4	I	1	10	.	.	.	.
Carex rostrata	6250	.	I	71	I	2	10	.	.	.	.
Galium palustre	.	500	III	74	II	92	500	.	.	.	.
Peucedanum palustre	10	10	I	1	.	.	10	.	.	.	.
Equisetum fluviatile	.	.	III	74	I	46	10	.	.	.	.
Sparganium erectum	.	.	I	1	I	45	.	.	.	6250	.
Schoenoplectus tabernaemontani	.	.	I	1	II	161	.	500	.	.	.
Phalaris arundinacea	.	.	II	3	I	1	10	.	.	.	.
Scutellaria galericulata	.	.	III	4	I	1	10	.	.	.	.
Carex appropinquata	10	6250	.	.	.	.	500	.	.	.	.
Glyceria maxima	.	.	.	.	I	1	.	.	.	500	.
Typha angustifolia	.	.	.	.	II	295	500	.	.	.	.
Carex riparia	.	.	II	3	I	1	.	.	.	.	.
Ranunculus lingua	500	.	I	1	.	.	.	.	.	.	.
Carex elata	.	.	I	1	I	1	.	.	.	.	.
Acorus calamus	.	.	I	1	.	.	.	6250	.	.	.
Lysimachia thyrsiflora	.	.	II	3	.	.	10	.	.	.	.
Carex vesicaria	.	.	.	.	I	46	.	.	.	.	.
Eleocharis palustris	500	.	.	.	.	.	.	.	.	.	.
Veronica beccabunga	.	.	.	.	I	2	.	.	.	.	.
Schoenoplectus lacustris	.	.	.	.	I	1	.	.	.	.	.
Alisma plantago-aquatica	.	.	I	1	.	.	.	.	.	.	.

Community	A	B	C		D		E	F	G	H	I
Potamogetonetea:											
Ceratophyllum demersum	.	.	I	1	II	48	.	500	500	1750	500
Nuphar luteum	.	.	.	.	III	843	.	500	1750	500	6250
Hydrocharis morsus-ranae	500	.	I	71	II	773	10	.	.	.	.
Nymphaea alba	.	.	.	.	I	2	.	.	.	.	10
Batrachium circinatum	.	.	.	.	I	2	.	.	.	.	500
Stratiotes aloides	.	.	.	.	II	48	.	.	.	.	.
Myriophyllum spicatum	.	.	.	.	I	2	.	.	.	.	.
Lemnetea:											
Lemna minor	10	1750	I	1	III	139	500	.	10	.	.
Lemna trisulca	.	.	I	1	II	356	.	.	.	.	.
Spirodela polyrhiza	.	.	.	.	I	2	.	.	.	.	.
Other species:											
Thelypteris palustris	10	1750	I	250	I	46	3750	.	.	.	.
Solanum dulcamara	.	500	III	144	III	94	10	.	.	.	.
Salix cinerea	.	500	I	3	II	3	10	.	.	.	.
Eupatorium cannabinum	.	10	I	3	I	45	.	.	.	.	.
Plagiomnium affine	.	10	I	71	I	1	1750	.	.	.	.
Lythrum salicaria	.	10	III	74	I	1	10	.	.	.	.
Mentha aquatica	.	500	II	73	I	2	.	.	.	.	.
Lycopus europaeus	.	.	III	146	II	93	10	.	.	.	.
Alnus glutinosa	.	10	I	1	I	1	.	.	.	.	.
Epilobium palustre	10	500	.	.	I	1	10	.	.	.	.
Stellaria palustris	.	10	I	1	.	.	10	.	.	.	.
Lysimachia vulgaris	.	.	IV	7	I	1	.	.	.	.	.
Fontinalis antypiretica	.	.	.	.	II	162	.	.	.	.	10
Cardamine amara	.	.	I	1	II	3	.	.	.	.	.
Urtica dioica	.	.	III	77	I	2	.	.	.	.	.
Epilobium hirsutum	.	.	III	144	I	1	.	.	.	.	.
Epilobium parviflorum	.	.	II	3	I	1	.	.	.	.	.
Calliergonella cuspidata	.	.	.	.	I	45	10	.	.	.	.
Poa trivialis	.	.	I	71	.	.	.	.	.	.	.
Mentha verticillata	.	.	III	74	.	.	.	.	.	.	.
Cirsium oleraceum	.	.	III	4	.	.	.	.	.	.	.
Filipendula ulmaria	.	.	III	4	.	.	.	.	.	.	.
Myosotis palustris	.	.	III	4	.	.	.	.	.	.	.
Agrostis gigantea	.	.	I	71	.	.	.	.	.	.	.

Table 7. Distribution of disturbed riparian vegetation (compare Fig. 1)

Disturbance degree of riparian vegetation		Length of shoreline m/%							
		Majcz Wielki Lake	Inulec Lake	Głębokie Lake	Zełwążek Lake	Jorzec Lake	Jorka river – right bank	Jorka river – left bank	Total
Heavy III	m	1550	8275	3275	1375	2100	4210	3505	24290
	%	19	74	75	73	47	74	61	59
Moderate II	m	1025	2100	1075	275	1450	1035	1305	8265
	%	13	19	25	15	33	18	23	20
Weak I	m	5550	750	0	225	900	480	915	8820
	%	68	7	0	12	20	8	16	21
Total	m	8125	11125	4350	1875	4450	5725	5725	41375

II – moderate disturbance – riparian vegetation consists of disturbed alderwood swamps and floodplain forests in mosaics with communities of nitrophilous perennials,

III – heavy disturbance – riparian vegetation consists of meadow-pasture communities or phytocoenoses of nitrophilous herbs that can be accompanied by single trees (mainly *Alnus glutinosa*).

Taking into consideration the whole Jorka Rive-Lake system, it turned out that the vegetation along the shores of Majcz Wielki Lake maintained its natural character the best (category I, 68% of the shoreline) (Table 7). This was due to the presence of a vast forest complex in the catchment of this lake. The area was characterized by a high biological diversity and exactly here the most of diverse plant communities of high floristic richness were found. Water quality of this lake was also the best.

The most disturbed plant cover was found at the shore of Głębokie Lake (category III, 75% of the shoreline). Similar effect of management impact, in particular of farming, was observed in the case of Inulec (category III, 74% of the shoreline) and Zełwążek (category III, 73% of the shoreline) Lakes. Waters of the three lakes were heavily eutrophicated. Generally, in the entire river-lake system, the riparian vegetation was significantly altered along almost 80% of the shoreline as a consequence of man disturbance, it maintained nearly natural character along the remaining 20% of the shoreline. (Table 7).

3.4. SPATIAL DISTRIBUTION OF RIPARIAN VEGETATION

Depending on the geomorphology, riparian vegetation zones were from a few to several hundred metres wide. The vegetation of these zones was clearly diverse, and various kinds of plant communities formed strips along the river course or lake shores. The spatial distribution of phytocoenoses was analysed in detail along 13 transects (Fig.1) crossing riparian vegetation representing different categories of disturbance.

I – weak disturbance

a. – the transect at eastern shore of Majcz Wielki Lake (Figs 1 and 2).

The following zones of riparian vegetation were identified in the landward direction: *Nupharo-Nymphaeetum* 5 m wide and *Phragmitetum* 14 m wide. On the land there was a riparian swamp forest *Carici acutiformis-Alnetum* about 15 m wide. The tree layer consisted mainly of *Alnus glutinosa*. Tree stand was about 10 m tall. Further, the high banks were overgrown with phytocoenoses of *Tilio-Carpinetum*. The tree layer comprised *Pinus sylvestris, Carpinus betulus, Picea abies* and *Quercus robur*. The tallest tree in this layer was about 30 m.

b. – two transects at the southern shore of Majcz Wielki Lake (Fig. 1).

The riparian vegetation was represented by the alder wood *Carici acutiformis-Alnetum* from 13 to 18 m wide. The tree stand consisted of black alder about 12–15 m tall. Swamp forest occupied a flat area, slightly tilted towards the lake. On the water side, this community bordered on 4–5 m wide zone of a

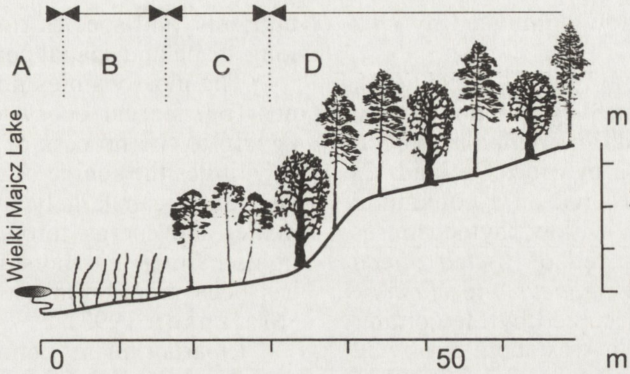

Fig. 2. Transect of riparian vegetation, eastern shore of Majcz Wielki Lake (compare Fig.1)
A – *Nupharo-Nymphaeetum albae,* B – *Phragmitetum,* C – *Carici acutiformis-Alnetum,* D – *Tilio-Carpinetum.*

sedges *Caricetum acutiformis,* followed by a zone of *Nupharo-Nymphaeetum.*

c. – four transects at Jorzec Lake (Fig. 1).

Riparian phytocoenoses formed two strips. On slightly tilted slope, bordering on arable land from the west, there was a carr *Circaeo-Alnetum* 10–12 m wide. The tree stand was dominated by *Alnus glutinosa* 20–25 m tall. The flat, swampy area in the vicinity of the lake was occupied by *Carici acutiformis-Alnetum.* Phytocoenoses of the alder swamp with sedges were from 8 to 20 m wide. The tree layer consisted of black alders from 15 to 20 m tall. Littoral aquatic communities bordering on forests were reedbeds represented by overlapping phytocoenoses such as *Caricetum acutiformis, Typhetum latifoliae, Phragmitetum* and *Sparganietum erecti.* The next zone was occupied by macrohydrophytes *Nupharo-Nymphaeetum* in a strip about 6 m wide.

II – moderate disturbance

a. – four transects in the Jorka River section between Głębokie and Zełwążek Lakes (Figs 1, 3).

The vegetation of the land-water ecotone formed three distinct strips of phytocoenoses. The river channel in this section was deprived of aquatic plants and reedbed vegetation.

The flat area in the vicinity of the river was covered with nitrophilous herbs *Urtica dioica-Eupatorium cannabinum,* in a 6–8 m wide strip. Higher on the gentle slope there was a substitute community *Alnus glutinosa-Eupatorium cannabinum,* from 4 to 10 m wide. It was formed when most of alders were cut. The next community on the

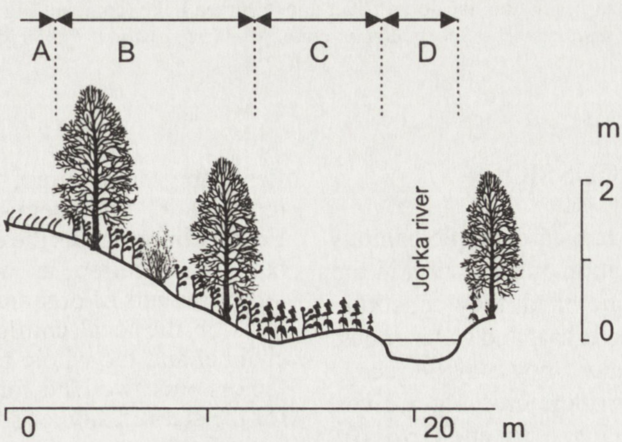

Fig. 3. Transect of riparian vegetation, the Jorka River between Lakes Głębokie and Zełwążek (compare Fig.1)
A – Meadow with *Dactylis glomerata*, B – *Alnus glutinosa-Eupatorium cannabinum*, C – *Urtica dioica-Eupatorium cannabinum,* D – the Jorka River.

transect was a meadow dominated by *Dactylis glomerata.*

b. – the transect at Inulec Lake (Fig. 1).

The littoral aquatic vegetation was represented by the reedbed *Phragmitetum.* It occupied a strip about 12 m wide. On land, the zone of reedbed bordered on a community with *Salix fragilis.* In willow phytocoenoses, the herb layer consisted of *Urtica dioica, Galium aparine, Rubus idaeus* and *Humulus lupulus.* The zone occupied by the community with *Salix fragilis* was about 5 m wide. On the land side it bordered on crop fields.

III – heavy disturbance

a. – transect at the Jorka River (Figs 1, 4).

The river channel was overgrown with phytocoenoses *Sparganietum erecti,* about 5 m wide. The western bank supported moist meadows *Cirsio-Polygonetum bistortae,* in a strip up to 150 m wide along the river. The eastern bank was covered with the community *Urtica dioica-Phalaris arundinacea.* The latter zone was narrower than the former, i.e. about 30 m wide.

nutrients, and species flow due to their oblong shape and spatial configuration.

The most visible and important component of riparian ecosystems is vegetation. Owing to the process of photosynthesis, it constitutes the source of organic matter. The vegetation can largely modify the input of matter and energy through its influence on light, thermal, and moisture conditions, what has been recognized as the "oasis effect" (Malanson 1993).

Riparian plant communities moderate the consequences of river floods, limit fluvial erosion, and also intensify sedimentation processes by increasing ground roughness and thereby reducing the rate of water flow (Malanson 1993, Daniels and Gilliam 1996, Puchalski *et al.* 1996).

Especially, riparian forests play an important part in stabilizing physical factors of riparian habitats (Brinson and Verhoeven 1999). For example, the shadow of trees and shrubs growing on the bank creates specific microclimate, in particular, it modi-

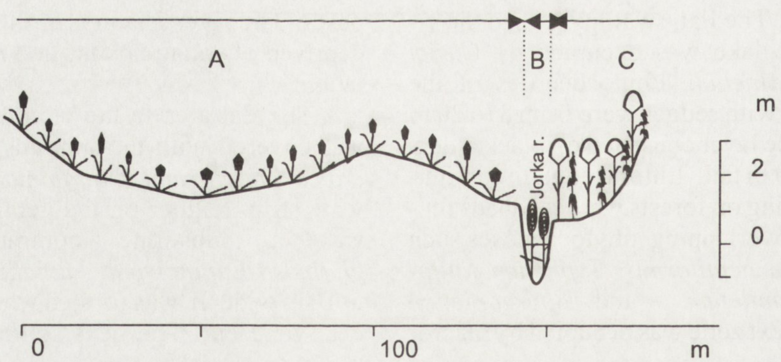

Fig. 4. Transect of riparian vegetation, the Jorka River above Jorzec Lake (compare Fig.1)
A – *Cirsio-Polygonetum bistortae,* B – *Sparganietum erecti,* C – *Urtica dioica-Phalaris arundinacea.*

4. DISCUSSION

Riparian ecosystems are unique habitats in terms of their location and function in the landscape. On the one hand, they constitute ecotones between terrestrial and water zones, and, on the other hand, they may be recognized as specific corridors crossing a given region. According to Forman and Godron (1981, 1986), corridors represent one of the three basic components of landscape structure ensuring continuity of water, energy,

fies water temperature, this being important to aquatic and semi-aquatic organisms. Equally important is the effect of tree roots on bank stabilization, as well as the effect of large amounts of organic matter produced by trees on the local configuration of the river channel and the whole complex of local site factors. Just wetland forests are responsible for the stabilization of soil and for water balance. Furthermore, they are refuges of animal populations, but most of all they control water quality by removing and retaining nutrients (Brinson and Verhoeven 1999), mainly nitrogen and phosphorus (Daniels and Gilliam 1996).

The latter, that is, a response to the question whether riparian vegetation can be an effective barrier to eutrophication, rose most interest. Many researches argue that it can. It should be noted that the efficiency of vegetation zones as barriers depends on many factors, and this is a complex issue involving various interactions among components of riparian ecosystems, and mainly dependent on the structure and heterogeneity of phytocoenoses.

There is a general agreement that vegetation buffer zones are most efficient for nitrogen. The basic processes responsible for a rapid removal of nitrogen from these ecosystems include the uptake of nitrates by plants and microbiological denitrification. The first of these processes can be additionally intensified by harvesting and removal of plant biomass (Haycock *et al.* 1993). The second one is variable in time, and most intense in winter and early spring due to its independence to atmospheric temperature. According to cited authors, in western Europe as much as 80% of the nitrogen load is exported from agricultural catchments during three winter months, i.e. during high-discharge periods. Hence, it seems that the controlled activation of denitrification can have a significant effect on the balance of this element (Pinay *et al.* 1994). The lowest denitrification rate was observed in summer and autumn (Pinay *et al.* 1993). Seasonal variations of denitrification rate stress the role of vegetation in the buffering process through uptake of nitrates for growth in summer and autumn, corresponding to the period of low water tables when denitrification is limited by soil aeration and it may be at a minimum (Haycock *et al.* 1993, Pinay *et al.* 1993). The experiments also showed that prolonged overdrying of floodplain soils in summer has a negative effect on this process (Van Oorschot *et al.* 2000). From the other hand in water-logged alder stands it was observed very low denitrifying activity in the winter season and highest in spring and summer due to the anaerobic conditions (Struwe and Kjøller 1990).

It has been found that riparian forests can act as filters for nutrients in both ground and surface waters. It has been estimated that a 50 m wide forest strip can efficiently remove 45 kg of nitrates/ha/year from subsurface waters flowing from agricultural areas in Maryland, USA (Peterjohn and Correl 1984). In Europe, riparian forests accumulate 75% of nitrogen and 45% of phosphorus supply with fertilizers applied in agriculture (Pinay 1986). Mander (1991) observed that a 10 m wide tree strip comprising alders and willows can retain most of the phosphorus load and about half of nitrogen, lead, and cadmium loads in waters flowing from farms to rivers.

According to different authors, the efficiency of both forest and meadow buffer zones 5 to 50 m wide varied from 54 to 98% of the nitrate runoff. It fluctuated from 40 to 100% in ground waters under forests and from 10 to 60% in ground waters under meadows (Puchalski *et al.* 1996).

Following the results cited above it should be expected that the riparian vegetation of the Jorka River analysed in the present paper also functions as a biogeochemical barrier modifying nutrient inflow from adjacent agrocoenoses. The cited papers concern mainly riparian forests and meadows that are common in the Jorka River-Lake system. Reedbeds and willow shrubs are equally common there. They are characterized by a great sorption capacity for different nutrients, especially for nitrogen, phosphorus and potassium (Oświt 1980, Traczyk 1985, Wilpiszewska 1990).

Riparian vegetation of the Jorka catchment consists of many different types of phytocoenoses. In total, 26 plant communities were identified. They form specific spatial systems realizing as strips along rivers or lake shores, and on rare occasions they create mosaics of overlapping phytocoenoses. Similar patterns were found in the distribution of riparian vegetation of the another Masurian river, i.e. Krutynia River (Kłosowski and Tomaszewicz (1996). In the entire Jorka River-Lake system, nearly 80% of the shoreline is modified as a result of man disturbance. Most of the Jorka catchment area is agricultural land. This implies a serious threat of surface water eutrophication. In fragmented small forests along the shores there are traces of uncontrolled cutting of trees and cattle grazing. Plant communities adjacent to lakes are intensively penetrated by tourists. Also inappropriate drainage, causing the overdrying of hydrogenic habitats and release of nitrogen and phosphorus compounds from them, accounts for changes in plant cover. Among other things, these changes involve expansion of nitro- and phosphophilous species. The damaged natural communities are replaced by substitute communities such as *Alnus glutinosa-Eupatorium cannabinum* and *Urtica dioica-Eupatorium cannabinum*. One of the responses to heavy man impact is the development of plant communities highly predominated by one or at most by a few species in a patch, for example, a community with *Urtica dioica*.

Finally, it should be noted that riparian ecosystems and their phytocoenoses require further comprehensive studies. At the same time, efforts need to be undertaken to protect and manage them in a sustainable way. It would be desirable to maintain a zone of natural plant communities along the entire length of a stream or lake shore. The riparian vegetation, in places where it has been heavily disturbed or devasted, should be restored as far as possible.

Generally, there is evidence that riparian tree stands along streams and rivers are effective barriers preventing eutrophication if the minimum width of these systems equals at least the height of the tallest mature trees in these stands (Fetherston *et al.* 1995). A detailed proposal for the management of riparian buffer zones in a typical postglacial agricultural landscape has been presented by Hillbricht-Ilkowska (1999). All such activities will undoubtfully improve water quality and stabilise the water balance in the catchment area.

ACKNOWLEDGEMENTS: The study was supported by the Polish Committee for Scientific Research; project number 6 PO4F 02411.

5. SUMMARY

The investigations were carried out in 1997 – 1999 in the catchment of Jorka River in the Masurian Lakeland (north-eastern Poland). Riparian vegetation situated along Jorka river banks and along shores of lakes: Majcz Wielki, Inulec, Głębokie, Zełwążek and Jorzec (Fig. 1) was analysed, according to Braun-Blanquet method (Tables 1 – 6). In total 26 plant riparian communities were identified. The riparian vegetation was represented by 17 phytocoenoses of the classes: *Alnetea glutinosae, Salicetea purpureae, Querco-Fagetea, Artemisietea* and *Molinio-Arrhenatheretea*. The littoral aquatic vegetation comprised 9 phytocoenoses of the classes *Phragmitetea* and *Potamogetonetea*. A transformation degree of riparian vegetation from the natural state was examined (Table 7). Three levels of transformation were distuinguished : I – weak, II – moderate, III – heavy. In the entire river-lake system, riparian vegetation was disturbed due to anthropopression along 80 % of the shoreline and only 20 % of the shoreline was covered with riparian vegetation in the state close to natural. A spatial system of riparian phytocoenoses was examined in 13 transects presenting different degrees of vegetation disturbances (Figs 2–4). The riparian vegetation was considered to play in landscape the role of barrier against nutrients, therefore it is recommended to protect it and preserve it all along the shoreline. Such procedure would improve water quality and stabilise the hydrological balance in the catchment area.

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(*Received after revising January 2002*)