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CHANGES IN THE VEGETATION OF A SMALL LOWLAND RIVER VALLEY (KRĄPIEL, NW POLAND) AFTER DREDGING

Abstract

The paper presented the impact of dredging on the vegetation of a regulated section of a lowland river based on the example of the Krąpiel River (NW Poland). The field research with pre-investment monitoring was conducted over three vegetation seasons in the years 2008–2010. Mechanical dredging and alignment of the river bed caused changes in vegetation structure. Reducing the diversity of habitat contributed to observed impoverishment of plant communities and species that build them. In the first year after dredging, communities from class *Bidentetea tripartitae* (*Chenopodietum rubri*) were dominant along the flood terrace covered with a layer of dredging material. In the second year after dredging,

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terophytes were again replaced by rush communities, dominated by *Phalaridetum*, *Phragmitetum* and locally riparian tall herb communities.

Keywords: riparian vegetation, vegetation changes, regulation of rivers, recolonization

Introduction

Human beings have long interfered with the structure and functioning of rivers and river valleys, shaping them according to their own needs (Allan 1998). Technical procedures exert a significant effect on the river ecosystem. The change they induce in habitat conditions directly affects the vegetation structure in the river bed and in the entire valley (Bondar-Nowakowska, Hachoł 2011). It affects the floral composition of phytocenoses and contributes to the loss of sensitive plant species and the expansion of alien species (Stępień et al. 2016). It reduces habitat heterogeneity (Battrup-Pedersen, Riis 1999) and affects the character and diversity of plant communities and species richness (Jongman 1992; Myśliwy 2010).

Rivers play a major role in the human economy and at the same time are an extremely valuable element of the natural environment. They function as ecological corridors (Burkart 2001; Barbosa et al. 2006), distinguished by their biodiversity in comparison with surrounding elements of the landscape (Najman et al. 1993; Krawczyk 2011). Due to the continual interference with their structure there is a need to learn the complex relationships between elements of river ecosystems and the transformations they undergo in response to human activity (Aquiar et al. 2001; Caffrey et al. 2006; Rambaud et al. 2009).

The objective of the paper was to analyse the impact of dredging on the vegetation of a regulated section of a lowland river based on the example of the Krąpiel River.

Study area

The Krąpiel River, located in north-west Poland, is the largest right tributary of the Ina River. With a length of 65 km, it is classified as a small river. The area of the Krąpiel River catchment, mainly located in the Stargardzki District (Zachodniopomorskie Province), amounts to 596 km^2. From its sources to the

Kania, it has the character of a lowland loess or loamy stream. From the Kania to its mouth, it is classified as a lowland gravel river. The river mostly flows through agricultural areas. Along its substantial section, it flows in a postglacial channel. From Pęzino, it transports water through the moraine plateau area in a deep gorge valley. Almost throughout its length, the Krąpiel River valley is overgrown by deciduous forests. From the sources to the Krzywnica, it flows through a Natura 2000 area – Ostoja Ińska. The mouth section of the river is under protection as Natura 2000 area called Dolina Krąpieli (Raport... 2010).

Along the analysed section, the river flows through a complex of large fish ponds, adjacent to extensive areas overgrown with rush vegetation, regularly flooded in spring. Water inflow in the ponds is regulated by means of a dam located north of the Krzywnica village. The river here has a character of a slowly-flowing canal (current velocity from 0.002 to 0.16 m/s) with a depth of approximately 0.8 m, and mean width of 5 m. Before the investment, the river had muddy bottom, locally entirely overgrown by vegetation. The flood terraces with a width of approximately 5 m and relatively steep slopes were occupied by rush communities, and *Convolvuletalia sepium* communities in the upper parts. Bushes and tree stands dominated by willow developed locally at the water. The dredging of the riverbed combined with clearing of trees and bushes occupying its banks was performed in 2008. The resulting dredging material was mostly deposited on the right bank of the river.

Material and methods

The field research was conducted over three vegetation seasons in the years 2008–2010. Pre-investment monitoring was conducted during the first year of the research. Over the two following years, changes in the vegetation after dredging were observed. The research concerned the section of the Krąpiel River below the dam in Krzywnica, from the former railway bridge to the fork of the Krąpiel and Stara Krąpiel Rivers (N: 53.422909°; E: 15.193214° to N: 53.408067°; E: 15.198897°) (Fig. 1). Phytosociological relevés were performed along the studied river section by means of the Braun-Blanquet method (1964) with additional categories (Barkman et al. 1964). The species nomenclature was adopted following Mirek et al. (2002). The classification of plant communities was adopted following Brzeg and Wojterska (2001). A database was created with the help of the software Turboveg for Windows (Hennekens, Schaminee 2001). Herbarium

collections were deposited in the herbarium of the Department of Plant Taxonomy and Phytogeography of the University of Szczecin.

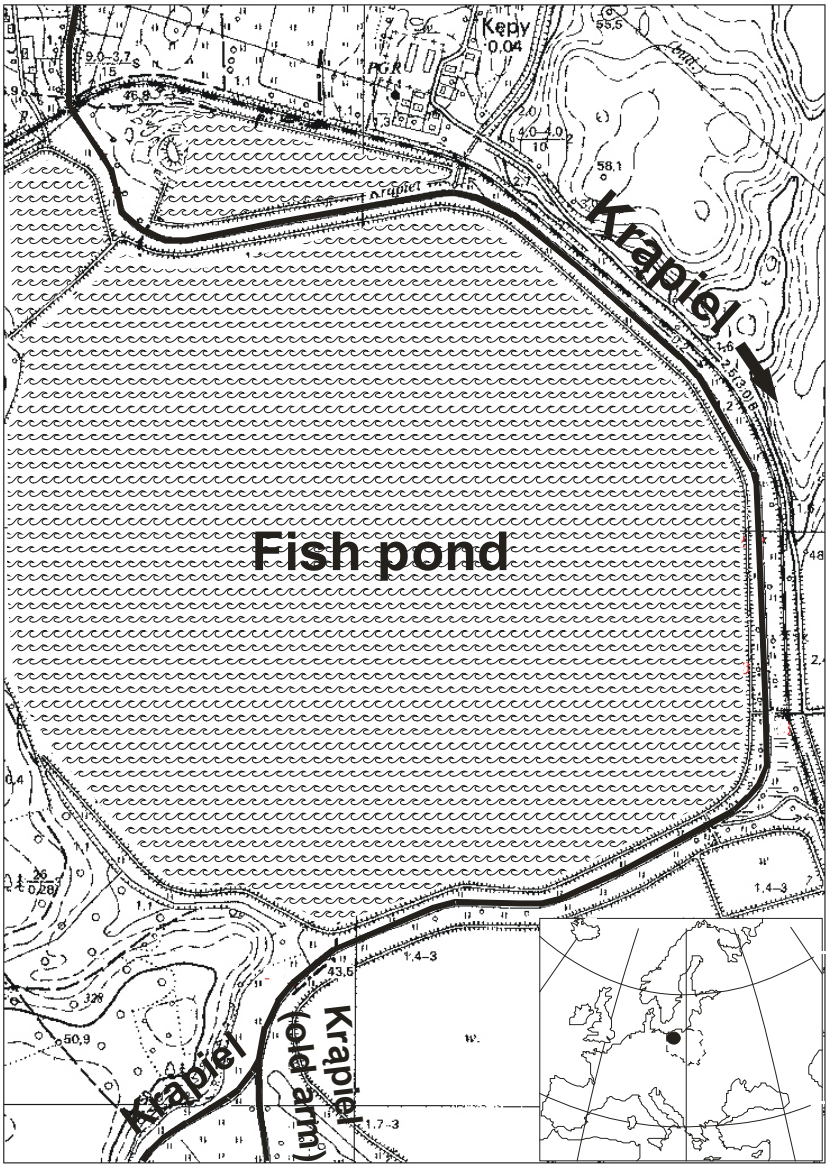

Figure 1. Map of the area of investigation

Results

Over the three years of the study, the occurrence of 25 associations and communities of plants was recorded along the studied section of the Krąpiel River, belonging to 11 classes, 12 orders, and 15 alliances.

Table 1. Systematic list of plant communities developed on the studied section of the Krąpiel River in particular years

	2008	2009	2010
Alnetea glutinosae Br.-Bl. et R.Tx. 1943			
Alnetalia glutinosae R.Tx. 1937			
Alnion glutinosae (Malcuit 1929) Meijer Drees 1936			
Salicetum cinereae Kobendza 1930	+	+	+
Salicetea purpureae Moor 1958			
Salicetalia purpureae Moor 1958			
Salicion albae Soó 1930 em. Moor 1958			
Salicetum triandro-viminalis Lohmeyer 1952	+	+	+
Epilobietea angustifolii R.Tx. et Preising 1950 in R.Tx. 1950			
Atropetalia Vlieger 1937			
Carici piluliferae-Epilobion angustifolii R.Tx. 1950			
Calamagrostietum epigeji Juraszek 1928	+	+	+
Lemnetea minoris (R.Tx. 1955) de Bolós et Masclans 1955			
Lemnetalia minoris (R.Tx. 1955) de Bolós et Masclans 1955			
Lemnion minoris (R.Tx. 1955) de Bolós et Masclans 1955			
Lemnetum minoris Soó 1927	+	+	+
Lemno-Spirodeletum polyrhizae W. Koch 1954 ex Th. Müller et Görs 1960	+		+
Potametea R.Tx. et Prsg. 1942 ex Oberd. 1957			
Potametalia W.Koch 1926			
Potamion pectinati (W.Koch 1926) Görs 1977			
Potametum lucentis		+	+
Elodeetum canadensis Eggler 1933	+		
Nymphaeion Oberd. 1957			
Nymphaeo albae-Nupharetum luteae Nowiński 1928	+	+	+
Ranunculion fluitantis Neuhäusl 1959			
Ranunculo-Callitrichetum polymorphae Soó 1927	+		
community with Nuphar lutea fo. submersa	+	+	+
Montio-Cardaminetea Br.-Bl. et R.Tx. 1943 ex Klika 1948			
Montio-Cardaminetalia Pawł. in Pawł. et al. 1928			
Caricion remotae Kästner 1941			
Cardamino-Chrysosplenietum alternifolii Maas 1959	+	+	+

	2008	2009	2010
Phragmitetea australis (Klika in Klika et Novák 1941) R.Tx. et Preising 1942			
Phragmitetalia australis W. Koch 1926			
Phragmition communis W. Koch 1926			
Phragmitetum communis (W. Koch 1926) Schmale 1939	+	+	+
Glycerietum maximae (Allorge 1922) Hueck 1931	+		+
Acoretum calami Eggler 1933 ex Kobendza 1948	+		
Nasturtio-Glycerietalia Pignatti 1953			
Oenanthion aquaticae Hejný ex Neuhäusl 1959			
Oenantho aquaticae-Roripetum amphibiae Lohmeyer 1950	+	+	+
Sagittario-Sparganietum emersi R.Tx. 1953	+	+	+
Butometum umbellati Konczak 1968	+		
Phalaridion Kopecký 1961			
Phalaridetum arundinaceae Libbert 1931	+	+	+
Isoëto durieui-Juncetea bufonii (Br.-Bl. et R.Tx. 1973 ex Westhoff et al. 1946) Rivas-Martinez 1988			
Nanocyperetalia Klika 1935			
Radiolion linoidis (Rivas-Goday 1961) Pietsch 1973		+	
Juncetum bufonii Felföldy 1942			
Bidentetea tripartitae R.Tx., Loymeyer et Preising in R.Tx. 1950			
Bidentetalia tripartitae Br.-Bl. et R.Tx. 1943			
Chenopodion glauci (R.Tx. in Poli et J.Tx. 1960) Hejný 1974			
Chenopodietum rubri Timár 1947	+	+	+
Molinio-Arrhenatheretea R.Tx. 1937 em. 1970			
Trifolio repentis-Plantaginetalia (R.Tx et Preising in R.Tx. 1950 em. Sissingh 1969 Brzeg 1991 ex Balcerkiewicz et Pawlak 2001			
Cynosurion R.Tx. 1947 em. Brzeg et M.Wojterska 1996			
Lolio-Plantaginetum Beger 1932 em. Sissingh 1969	+	+	+
Artemisietea vulgaris Loymeyer, Preising et R.Tx. in R.Tx 1950			
community with Cirsium arvense			+
Convolvuletalia sepium R.Tx 1950 em. Oberd. in Oberd. et al. 1967			
Calystegion sepium R.Tx 1947 em. 1950			
Soncho palustris-Archangelicetum litoralis R.Tx. 1937	+	+	+
Eupatorietum cannabini R.Tx. 1937	+	+	+
Urtico-Convolvuletum sepium Görs et Th. Müller 1969	+	+	+

1. Shrub communities from classes *Alnetea glutinosae* and *Salicetea purpureae*

Table 2. Communities from *Alnetea glutinosae* and *Salicetea purpureae* class:
A – *Salicetum cinereae*, B – *Salicetum triandro-viminalis*

Succesive No. of relevé	1	2	3	4
Date (year/month/day)	2010.07.15	2008.07.03	2009.08.19	2008.07.12
Area of relevé (m^2)	15	20	20	20
Cover shrub layer (%)	85	90	70	70
Cover herb layer (%)	45	45	70	35
No. of species in the relevé	6	17	12	10
	A	**A**	**B**	**B**
I. Ch. Ass.				
Salix cinerea b	5	5	.	.
Salix viminalis b	.	1	4	3
II. Ch. Alnetea glutinosae				
Alnus glutinosa b	+	2m	.	.
III. Ch. Salicetea purpureae et Salicion albae*				
Salix fragilis b	.	.	2a	2a
Salix alba* b	.	1	.	1
IV. Ch. Artemisietea				
Cirsium arvense	.	.	+	+
Urtica dioica	3	3	2b	2b
Aegopodium podagraria	+	.	2b	.
Galium aparine	2m	2m	+	+
Glechoma hederacea	2a	.	2a	.
Antriscus sylvestris	1	.	2m	.
Calystegia sepium	.	.	2m	2m
Humulus lupulus	.	.	2a	2b
V. Others				
Phragmites australis	.	1	+	+

Sporadic species: **II** Lycopus europeus 2(+), Solanum dulcamara 2(+); **III** Salix purpurea b 3(+), Phalaris arundinacea 4(1); **IV** Galeopsis speciosa 2(2m); **V** Cirsium oleraceum 2(+), Equisetum fluviatile 2(+), Festuca gigantea 2(+), Impatiens noli-tangere 2(+), Iris pseudacorus 2(+), Polygonum amphibium 2(+), Roripa palustris 2(+).

Small fragments of shrubs dominated by willow developed on the river banks, particularly in the lower course of the analysed section. Patches of *Salicetum triandro-viminalis* containing *Salix viminalis* and young *Salix fragilis* showed high coverage in the herbaceous layer of species from class *Artemisietea*, particularly from order *Convolvuletalia sepium*, such as *Urtica dioica*, *Aegopodium podagraria*, *Glechoma hederacea*, *Calystegia sepium*, *Anthriscus sylvestris*, and *Galium aparine*, similarly as small patches of *Salicetum cinereae*. The willow shrubs are systematically removed from the banks of the studied river section in order to facilitate water flow. The shrubs occurring around a seep with a character of a small limnocrene were unaffected by dredging.

2. Communities from class *Epilobietea angustifolii*

Grassy vegetation with *Calamagrostis epigeios* was encountered on the sandy-gravel material deposited as the reinforcement of bridges and the road. Abundant occurrence of meadow species and those from class *Artemisietea* was observed (12.07.2008., c – 100%, 25 m^2, 32 species, Ch. Ass. and *Epilobietea*: *Calamagrostis epigeios* 4, Ch. *Artemisietea*: *Artemisia vulgaris* +, *Erigeron annus* +, *Galeopsis speciosa* r, *Urtica dioica* +, *Galium aparine* +, *Glechoma hederacea* 1, *Rubus caesius* +, *Eupatorium cannabinum* +, *Melandrium album* +, *Berteroa incana* +, *Bromus inermis* +, Ch. *Molinio-Arrhenatheretea*: *Achillea millefolium* +, *Alopecurus pratensis* +, *Festuca pratensis* +, *Poa pratensis* 2a, *Poa trivialis* 2a, *Rumex acetosa* +, *Taraxacum officinale* +, *Dactylis glomerata* 2a, *Arrhenatherum elatius* 2a; others: *Capsella bursa-pastoris* +, *Galium album* +, *Hypericum perforatum* +, *Astragalus glycyphyllos* +, *Vicia hirsuta* +, *Lactuca seriola* r, *Phalaris arundinacea* +, *Polygonum amphibium* +, *Salix fragilis* +, *Valeriana officinalis* +, *Matricaria maritima* subsp. *perforata* +).

3. Communities from class *Lemnetea minoris*

Table 3. Communities from *Lemnetea*: A – *Lemnetum minoris*, B – *Lemno-Spirodeletum polyrhizae*

Succesive No. of relevé	1	2	3	4	5	6	7	8	9	10
Date (year/month/day)	2010. 07.15	2008. 07.12	2009. 07.13	2009. 08.19	2009. 08.19	2008. 07.03	2008. 07.03	2010. 07.15	2010. 07.15	2010. 07.15
Area of relevé (m^2)	1.0	0.5	0.5	0.75	0.75	2.0	1.5	5.0	2.0	2.0
Cover herb layer (%)	95	90	65	90	75	100	100	100	95	90
Number of species	4	4	3	6	3	6	4	8	4	7
	A	A	A	A	A	B	B	B	B	B
I. Ch. Ass. et Lemnetea minoris										
Lemna minor	5	5	3	4	4	3	3	3	2b	3
Spirodela polyrhiza	+	1	.	+	.	4	4	4	5	4
Lemna trisulca	.	.	.	.	.	1	.	.	.	.
II. Ch. Phragmitetea et Phragmitetalia										
Sagittaria sagitifolia	1	+	2b	2a	3	.	.	2b	2b	1
Sparganium emersum	2m	+	.	1	2b	.	.	2a	1	
Glyceria maxima	.	.	2b	.	.	2b	2a	.	.	.
Sium latifolium	.	.	.	.	.	+	+	.	.	2m
Phalaris arundinacea	.	.	.	2b	.	.	.	+	.	.
Phragmites australis	.	.	.	.	.	.	.	.	.	2m
Rorippa amphibia	.	.	.	.	.	.	.	+	.	+
Veronica anagalis-aquatica	.	.	.	.	.	.	.	+	.	2a

Sporadic species: **III.** Others Callitriche cophocarpa 6(1), Nuphar lutea 8(1), Solanum dulcamara 4(+).

Associations of aquatic plants from class *Lemnetea* usually developed phytocoenoses with a small area, only occurring between patches of rooted vegetation, particularly at the river banks, but also in the middle of the channel, strongly overgrown with aquatic and rush vegetation. They were represented by associations of *Lemnetum minoris* and *Lemno-Spirodeletum polyrhizae.* The observed communities were poor in pleuston species, and mainly consisted of *Lemna minor* and *Spirodela polyrhiza*, accompanies by rush species. *Lemna trisulca* was very rarely recorded in the patches.

In 2009, only sinusions of *Lemna minor* were observed, occupying small areas between helophytes, rarely developing patches with an area of more than 0.5 m^2. They only developed in August. This was related to the clearing of aquatic vegetation in the river channel and an increase in the water flow velocity. In 2010, already in July, along sections of the river with a lower discharge, pleustophytes occupied even 70% of the water surface. Phytocoenoses of *Lemno-Spirodeletum polyrhizae* anchored among patches of rooted vegetation were dominant.

4. Communities from class *Potametea*

The river channel, not shaded by trees and bushes in many places, was overgrown by patches of vegetation from class *Potametea*. The largest areas of the muddy and muddy-sandy bottom, particularly in shallow parts of the river not shaded by vegetation, were covered by submerged dense patches of *Elodeetum canadensis*, often developing almost single-species aggregations. Similar phytocoenoses were recorded in the Cybina River Valley (Gołdyn et al. 2005). Due to the frequent contact of patches of the association with *Sagittario-Sparganietum emersi*, arrowhead and European bur-reed occurred in the patches with various coverage. Species from genus *Callitriche* were sometimes encountered.

In particularly shallow places, on sandy or sandy-muddy bottom, phytocoenoses of species-poor association of *Ranunculo-Callitrichetum polymorphae* developed. They formed small, poor in species, convex patches with low contribution of accompanying species, particularly *Elodea canadensis*, *Sparganium emersum*, and *Sagittaria sagitifolia*, similarly as recorded in the Kwacza River (Osadowski 2009). On substrate with contribution of gravel and stones, at faster river current (x m/s) and depth of 0.2 m, larger patches with a high contribution or even prevalence of *Fontinalis antipyretica* developed.

No *Elodeetum canadensis* or *Ranunculo-Callitrichetum polymorphae* were observed along the studied section of the Krąpiel River after dredging. *Elodea canadensis* only occurred in low coverage in patches of other communities from class *Potametea* and in the rush of arrowhead and European bur-reed. Scarce patches of *Potametum lucentis* were recorded, containing only one typical species, namely *Potamogeton crispus*.

In faster current, on sandy-gravel bottom, phytocoenoses from *Nuphar lutea* fo. *submersa* developed, accompanied by species typical of the alliance of *Ranunculion fluitantis – Sagittaria sagittifolia* var. *vallisneriifolia* and *Sparganium emersum* fo. *fluitans*. Patches of the community were only observed at one site behind the bridge. It was not destroyed during dredging. Small patches of *Nymphaeo albae-Nupharetum luteae* were only recorded at two sites. They consisted of *Nuphar lutea* with a high contribution of species from class *Phragmitetea*. In 2008, they were observed at two sites. After dredging, the area of the patches was reduced.

Table 4. Communities from *Potametea* class: A – *Potametum lucentis*, B – *Elodeetum canadensis*, C – *Nymphaeo albae-Nupharetum luteae*, D – *Ranunculo-Callitrichetum polymorphae*, E – community with *Nuphar lutea* fo. *submersa*

Succesive No. of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Date (year/month/day)	2009. 08.19	2008. 07.03	2008. 07.12	2008. 07.12	2008. 07.12	2008. 07.12	2009. 07.13	2008. 07.12	2010. 07.15	2008. 07.03	2008. 07 03	2008. 07.03	2008. 07.12	2009. 08.19	2010. 07.15	2008. 07.03
Area of relevé (m^2)	2.0	3.0	5.0	3.0	2.0	6.0	1.0	3.0	2.0	1.0	2.0	1.5	0.5	4.0	12.0	4.0
Cover herb layer (%)	80	90	80	95	100	95	70	85	95	100	100	100	95	85	80	90
Number of species	5	3	5	4	3	5	4	4	6	3	4	4	4	6	6	4
	A	**B**	**B**	**B**	**B**	**C**	**C**	**C**	**C**	**D**	**D**	**D**	**D**	**E**	**E**	**E**
I. Ch. Ass.																
Potamogeton crispus	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elodea canadensis	+	4	4	5	5	2m	.	2b	+	.	.	.	2m	+	1	2m
Nuphar lutea	.	.	.	.	.	4	3	4	4	.	.	.	.	.	.	.
Callitriche cophocarpa	.	.	2a	2a	+	.	.	.	.	4	2m	2a	5	.	.	.
Nuphar lutea fo. submersa	.	.	.	.	.	.	.	.	.	.	.	.	.	2b	3	4
I. Ch. Potametea* et Ranunculion fluitantis																
Fontinalis antipyretica*	.	.	.	.	.	.	.	.	.	3	5	5	.	.	.	.
Sagittaria sagittifolia var. vallisneriifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	2b	2b
Sparganium emersum fo. fluitans	2a	.	.	.	.	.	.	.	.	.	.	.	.	3	3	2a
II. Ch. Lemnetea minoris																
Lemna minor	2a	.	+	.	.	+	1	1	2a	.	.	+	.	2a	2b	.
Spirodela polyrhiza	.	.	.	.	.	.	.	.	3	.	.	.	.	+	2a	.
Lemna trisulca	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.
IV. Ch. Phragmitetea et Phragmitetalia																
Sagittaria sagitifolia	2m	2b	2m	+	.	3	2b	.	2m	.	.	.	+	.	.	.
Sparganium emersum	.	2m	2a	2b	+	2m	2a	3	2m	2m	2m	1	1	.	.	.

5. Community from class *Montio-Cardaminetea*

At one site in the embankment, on a seep with a character of a small limnocrene, species-poor *Cardamino-Chrysosplenietum* community was observed, surrounded by a *Salicetum triandro-viminalis* shrub (Ch. Ass.: *Cardamine amara* 4, Ch., D*. *Montio-Cardaminetea* et *Caricion remotae*: *Veronica beccabunga* 1, *Epilobium obscurum* +, *Ranunculus repens** +, Others: *Ranunculus sceleratus* 2m, *Equisetum fluviatile* 1, *E. palustre* 1, *Epilobium hirsutum* +, *Lysimachia vulgaris* +, *Bidens frondosa* +, *Lemna minor* +).

6. Rush communities from class *Phragmitetea*

Rush communities were the most important component of the vegetation of the analysed river section. Phytocoenoses of *Sagittario-Sparganietum emersi* developed throughout the river current's cross-section. They were quite poor in floristic terms. Low rushes consisted of both of the species typical of the association, accompanied by other species typical of class *Phragmitetea* in low coverage, such as *Butomus umbellatus* and *Phalaris arundinacea*. On the water surface, pleuston species were anchored among the plants. Dredging only reduced the coverage of the association for a short time. Already in August 2009, its patches developed throughout the river current's cross-section in many places.

Scarce small patches of *Oenantho aquaticae-Roripetum amphibiae* developed on the shallow river banks before and after dredging. They were dominated by *Roripa amphibia*, accompanied by scarce rush species in low coverage.

In the bank zone, in places with stagnant water, *Glycerietum maximae* rush was encountered. Great manna grass, dominant in the patches, was particularly accompanied by other rush species. The rush was not observed in the first year after dredging due to the steep slopes of the river channel. After dredging, no patches of associations of *Butometum umbellati* or *Acoretum calami* were recorded either. The phytocoenoses developed in the form of small patches on the edge of the channel, in contact with other rush communities.

The flood terraces were dominated by common reed and canary grass rushes alternating along the river. Phytocoenoses of *Phragmitetum australis*, dominated by common reed, were accompanied by other rush species, such as *Phalaris arundinacea*, *Carex acutiformis*, *Veronica anagalis-aquatica*, and meadow species from class *Molinio-Arrhenatheretea*, particularly *Poa palustris* and *Poa*

trivialis. The patches adjacent to the water current were accompanied by pleuston species. The contribution of species from class *Artemisietea* was typical, particularly in alliance with *Calystegion sepium*, among others *Urtica dioica*, *Calystegia sepium*, *Myosoton aquaticum*, *Stachys palustris*, and *Symphytum officinale*. This resulted from frequent contact development of riparian tall herb communities on the top of the terrace. Phytocoenoses of *Phalaridetum arundinaceae* were dominated by canary grass, unlike *Phragmitetum* with low contribution of other rush species. The contribution of species from classes *Molinio-Arrhenatheretea* and *Artemisietea* was somewhat higher. This resulted from the frequent development of riparian tall herb communities in contact with rushes at the top of the terrace. In the first year after dredging, summer terophyte communities developed in their place at a number of sites on the dredging material deposited on the flood terrace. In the following year, however, they were replaced again.

Table 5. Communities from *Phragmitetea* class: A – *Phragmitetum*, B – *Glycerietum maximae*, C – *Acoretum calami*, D – *Oenantho aquaticae-Roripetum amphibiae*, E – *Sagittario-Sparganietum emersi*, F – *Butometum umbellati*, G – *Phalaridetum arundinaceae*

Succesive No. of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Date (year/month/day)	2008 07 12	2008 07 12	2010 07 15	2009 07 13	2010 07 15	2010 10 01	2008 07 03	2008 07 03	2008 07 03	2008 07 03	2008 07 03	2009 06 12	2010 07 15	2008 07 03	2008 07 03	2008 07 12	2009 07 13	2008 07 03	2008 07 03	2010 07 15	2010 07 15	2008 07 03	2008 07 12	2009 05 22	2010 10 01	2010 07 15	2010 07 15	2010 07 15
Area of relevé (m^2)	25	25	9	6	3	8	8	3	2	3	3	3	1	3	5	6	8	5	5	10	12	3	25	10	10	16	10	6
Cover of herb layer (%)	100	100	100	100	90	100	100	100	100	100	100	100	95	95	85	80	90	85	100	90	90	100	100	100	95	100	100	100
No. of species in the relevé	23	16	15	16	8	10	10	4	5	7	5	9	9	7	6	8	3	4	8	9	7	8	23	11	8	9	24	13
	A	**A**	**A**	**A**	**A**	**B**	**B**	**C**	**C**	**D**	**D**	**D**	**D**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**F**	**G**	**G**	**G**	**G**	**G**	**G**
I. Ch. Ass.																												
Phragmites australis	5	4	4	5	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	.	.
Glyceria maxima	.	.	.	.	.	5	5	3	2m	.	.	.	.	.	.	.	.	.	.	.	.	2a	.	.	.	.	.	.
Acorus calamus	.	.	.	.	.	.	.	4	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rorippa amphibia	.	.	.	.	+	.	1	.	.	4	5	5	5	.	.	r	.	.	.	+	.	+	.	.	.	.	.	.
Sagittaria sagitifolia	.	.	.	.	1	.	.	.	.	.	.	.	+	2m	5	4	4	4	2a	4	2a	2a	.	.	.	.	.	.
Sparganium emersum	.	.	.	.	.	.	.	.	+	.	.	+	2a	4	2m	2a	2a	.	5	3	4	.	.	.	.	.	.	.
Butomus umbellatus	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	2b	.	+	r	+	.	4	.	.	.	.	.	.
Phalaris arundinacea	2a	2a	2b	1	.	.	1	2a	1	.	.	+	2a	.	+	.	.	.	.	1	+	.	5	5	5	4	4	3
II. Ch. Phragmitetea																												
Carex acutiformis	2a	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Sparganium erectum	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	2m	.	.	.	.	.	.	.	.	.	.
Scrophularia umbrosa	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Veronica anagalis-aquatica	+	.	.	+	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Galium palustre	.	.	.	.	.	1	.	.	.	r	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	r
Sium latifolium	.	.	.	.	2m	.	1	2m	.	1	.	.	1	2m	.	r	.	.	.	.	.	.	.	.	.	.	.	.
Alisma plantago-aquatica	+	.	.	.	.	.	+	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
III. Ch. Molinio-Arrhenatheretea																												
Poa palustris	+	1	2a	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	.	2a	1
Poa trivialis	+	.	2m	2m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2m	.	.	.	.	.

Succesive No. of relevé	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Date (year/month/day)	2008 07 12	2008 07 12	2010 07 15	2009 07 13	2010 07 15	2010 10 01	2008 07 03	2008 07 03	2008 07 03	2008 07 03	2008 07 03	2009 06 12	2010 07 15	2008 07 03	2008 07 03	2008 07 12	2009 07 13	2008 07 03	2008 07 03	2010 07 15	2010 07 15	2008 07 03	2008 07 12	2009 05 22	2010 10 01	2010 07 15	2010 07 15	2010 07 15
Alopecurus pratensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	1	2m
Equisetum palustre	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	1	.
Myosotis palustris	.	.	.	.	1	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
Vicia cracca	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	.	.
IV. Ch. Artemisietea vulgaris et Calystegion sepium*																												
Urtica dioica	1	2b	2m	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2a	2a	2m	.	1	.
Calystegia sepium*	2m	2a	2m	2a	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2a	.	1	2m	r
Myosoton aquaticum*	1	r	2m	2m	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	.
Stachys palustris*	1	+	1	.	.	.	2a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	1	.	1	+
Cirsium arvense	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	+	2a	1	+
Symphytum officinale*	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	.
Carduus crispus*	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.
Elymus repens	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1	.	.
V. Ch. Bidentetea et Bidentetalia tripartitae																												
Polygonum hydropiper	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
VI. Others																												
Elodea canadensis	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	2b	.	.	.	2a		.	.	.	.	.	.	.
Lemna minor	.	.	.	.	3	2b	.	.	.	2m	+	1	.	1	2m	2m	2m	.	2a	1	2a	3	.	.	.	.	.	.
Spirodela polyrhiza	.	.	.	.	2a	2m	.	.	.	1	1	+	.	+	2m	.	.	2m	1	2a	3	2b	.	.	.	.	.	.
Callitriche cophocarpa	.	.	.	.	.	.	r	.	.	+	.	.	.	2m	.	1	.	.	2a	.	.	2m	.	.	.	.	.	.
Calamagrostis epigeios	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2b	.	.
Salix viminalis	.	.	.	+	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Sporadic species: **II** Berula erecta 12(+), 20(1), Glyceria fluitans 27(2m), Glyceria maxima 1(1), 10(3), Oenanthe aquatica 4(r), Rumex hydrolapathum 18(+); **III** Agrostis gigantea 3(2a), 28(3), Anthriscus sylvestris 27(+), Cirsium oleraceum 1(+), Deschampsia cespitosa 25(+), Lysimachia vulgaris 9(+), 23(r), Ranunculus repens 1(+), Rumex crispus 3(r), 23(+), Scirpus sylvaticus 4(+), Trifolium repens 28(+); **IV** Angelica archangelica ssp. litoralis* 24(+), 27(1), Artemisia vulgaris 26(1), 27(+), Epilobium hirsutum* 24(+), 27(+), Eupatorium cannabinum* 27(2m), 28(r), Galeopsis speciosa 23(r), Galium aparine 24(1), 27(+), Glechoma hederacea 23(+), Humulus lupulus* 2(+), 23(+), Rumex obtusifolius 3(+); V Bidens cernua 2(r), Bidens frondosa 4(+), Bidens tripartita 1(+), Chenopodium polyspermum 1(+), Polygonum lapathifolium subsp. lapathifolium 4(2a), Ranunculus sceleratus 1(+), Rorippa palustris 1(+); **VI** Agrostis canina 27(1), Berteroa incana 26(+), Bromus inermis 26(+), Chenopodium album 2(+), 23(+), Echinocystis lobata 4(r), Erysimum cheiranthoides 23(+), Ficaria verna 24(+), Fontinalis antipyretica 19(2m), Galeopsis bifida 2(+), Juncus bufonius 25(1), Lemna trisulca 14(1), 19(+), Lycopus europaeus 27(+), Lythrum salicaria 6(+), 7(1), Mentha aquatica 6(1), Polygonum amphibium 1(+), Salix alba 4(+), Salix fragilis b 7(2m), Scrophularia nodosa 27(1), Solanum dulcamara 27(1), 28(+), Sonchus asper 23(r), Stellaria media 24(+), Tussilago farfara 28(r), Vicia hirsuta 28(+).

7. Communities of terophytes from classes *Isoëto durieui-Juncetea bufonii* and *Bidentetea tripartitae*

Table 6. Communities from *Isoëto-Juncetea* and *Bidentetea* class: A – *Juncetum bufonii*, B – *Chenopodietum rubri*, C – community with *Polygonum persicaria*

Succesive No. of relevé	1	2	3	4	5	6	7	8	9	10	11
Date (year/ month/day)	2009. 07.13	2008. 07.12	2008. 07.12	2008. 07.12	2010. 10.01	2009. 06.12	2009. 07.13	2009. 07.13	2009. 07.13	2009. 07.13	2009. 06.12
Area of relevé (m^2)	4.00	5.00	4.00	4.00	8.00	4.00	4.00	6.00	6.00	6.00	4.00
Cover of herb layer (%)	60	95	95	95	65	100	100	100	100	100	90
No. of species in the relevé	16	29	30	25	13	19	25	27	20	16	32
	A	B	B	B	B	B	B	B	B	B	B
I. Ch. Ass.											
Juncus bufonius	4	2m	2a	1	.	.	.	.	.	.	.
Polygonum lapathifolium subsp. lapathifolium	2m	2a	2a	3	2b	5	3	3	4	4	3
II. Ch., D* Chenopodion glauci											
Chenopodium rubrum	+	1	+	1	.	.	.	.	.	.	+
Atriplex prostrata ssp. latifolia	.	.	.	.	.	+	+	.	+	+	+
Chenopodium polyspermum	.	.	.	.	.	+	.	.	+	+	+
Chenopodium album*	.	.	.	.	+	+	+	+	.	.	+
Matricaria maritima subsp. inodora*	.	.	.	.	.	+	+	+	.	.	.
Rorippa palustris	1	3	2b	2a	2b	2a	2b	2a	.	2a	2m
Bidens tripartita	1	+	1	.	.	.	1	+	1	.	.
Bidens frondosa	+	+	+	1	.	.	.	.	.	.	+
Ranunculus sceleratus	2a	1	+	+	2b	.	.	.	.	.	+
Rumex palustris	.	2m	1	+	.	.	.	.	.	.	.
Rumex maritimus	.	.	.	.	2m	.	+	+	.	.	.
Bidens cernua	1	.	+	.	+	.	.	.	.	.	.
III Ch. Isoëto durieui-Juncetea bufonii											
Cyperus fuscus	.	2m	2a	2m	.	.	.	.	.	.	.
Gnaphalium uliginosum	.	2m	2m	1	.	.	.	.	.	.	.
IV. Ch. Phragmitetea et Phragmitetalia											
Phalaris arundinacea	.	+	1	+	1	.	.	2a	2b	1	2b

Succesive No. of relevé	1	2	3	4	5	6	7	8	9	10	11
Date (year/ month/day)	2009. 07.13	2008. 07.12	2008. 07.12	2008. 07.12	2010. 10.01	2009. 06.12	2009. 07.13	2009. 07.13	2009. 07.13	2009. 07.13	2009. 06.12
Veronica anagalis-aquatica	1	2m	2m	2a	+	.	.	.	.	.	.
Phragmites australis	.	.	.	.	2m	.	2m	1	2m	2m	.
Alisma plantago-aquatica	+	.	1	.	1	.	.	.	.	.	.
Rorippa amphibia	.	+	.	.	.	+	.	.	.	.	+
V. Ch. Molinio-Arrhenatheretea											
Poa palustris	2a	+	+	+	.	.	2b	2b	2m	+	+
Alopecurus geniculatus	.	.	.	.	.	.	.	1	1	2m	.
VI. Ch. Artemisietea vulgaris et Calystegion sepium*											
Urtica dioica	.	.	+	+	.	+	.	+	+	2m	+
Cirsium arvense	.	.	.	.	.	+	r	+	.	+	+
Artemisia vulgaris	.	.	.	+	.	.	.	+	+	.	+
Calystegia sepium	.	1	.	.	.	.	+	.	.	+	+
Melandrium album	.	.	.	.	.	+	.	+	+	.	.
Medicago lupulina	.	.	.	.	.	.	+	+	.	.	+
Myosoton aquaticum*	+	2m	+	2m	.	+	2m	2b	2a	2a	+
Symphytum officinale*	.	2a	.	.	.	.	+	r	r	+	.
Epilobium hirsutum*	1	1	1	+	.	.	.	.	.	.	.
Stachys palustris*	.	1	+	.	.	.	.	.	+	+	.
VII. Others											
Salix purpurea	.	.	+	2m	.	.	.	.	.	.	2m
Polygonum aviculare	.	.	.	.	.	.	2m	.	.	.	2b
Salix fragilis	+	2m	1	.	.	+	.	.	.	.	.
Vicia hirsuta	.	.	.	.	.	+	+	+	+	.	+

Sporadic species: II Alopecurus aequalis 2(+), 4(2a), Echinochloa crus-galli* 4(r), 7(+), Erysimum cheiranthoides* 4(+), 11(+), Polygonum hydropiper 5(2m); IV Carex acutiformis 2(1), 3(+), Oenanthe aquatica 1(+), 5(1), Sagittaria sagitifolia 1(+), 3(r), Sparganium emersum 3(+), Veronica beccabunga 4(+), 5(2m); V Alopecurus pratensis 6(+), Cirsium oleraceum 2(+), Equisetum palustre 2(+), 3(1), Lythrum salicaria 2(+), 3(+), Myosotis palustris 7(+), 11(+), Phleum pratense 8(+), Poa pratensis 3(+), Poa trivialis 8(2a), 11(2a), Ranunculus repens 11(+), Trifolium repens 7(+), 11(+), Vicia cracca 11(+); VI Carduus crispus* 4(+), Elymus repens 8(2a), 9(2a), Equisetum arvense 6(+), 11(+), Galeopsis bifida 6(+), Galeopsis speciosa 8(+), Galium aparine 9(+), Heracleum sphondylium ssp. sibiricum 9(+), Humulus lupulus 10(+), Impatiens parviflora 9(r); VII Apera spica-venti 7(+), Avena sativa 8(r), Brassica napus subsp. napus 6(+), 8(r), Capsella bursa-pastoris 6(+), 11(+), Epilobium adenocaulon 2(+), Erodium cicutarium 7(r), Fallopia convolvulus 7(+), 11(+), Galinsoga parviflora 2(r), Juncus articulatus 3(+), 4(2m), Lycopus europaeus 2(+), Melilotus alba 7(+), 8(+), Phacelia tanacetifolia 7(+), 11(+), Plantago major 3(+), 4(+), Poa annua 11(+), Polygonum amphibium 4(2m), Salix alba 10(+), Salix cinerea 3(+), 8(+), Salix viminalis 9(+), Solanum dulcamara 2(+), Sonchus oleraceus 11(+), Stellaria media 6(+), Triticum aestivum 7(+), Tussilago farfara 8(r).

In the first year after dredging, communities from class *Bidentetea tripartitae* – patches of *Chenopodietum rubri* were dominant along the flood terrace covered with a layer of dredging material. In physiognomic terms, they were distinguished by the dominance of *Polygonum lapathifolium* subsp. *lapathifolium*, frequently developing dense patches. Among typical species from class *Bidentetea*, only *Rorippa palustris* showed higher coverage. The patches contained numerous species from class *Artemisietea*, although few of them sometimes showed higher coverage, such as *Elymus repens*, *Myosoton aquaticum*, and *Urtica dioica*. Relatively high coverage of rush species was observed, namely *Phragmites australis* or *Phalaris arundinacea*.

Patches of the community, developed before dredging on the fragment of the flood terrace cleared from bushes, and observed in the second year after dredging on the bank of the analysed section, were distinguished by a high contribution of numerous species from class *Bidentetea tripartitae*, and contribution of species from class *Isoëto durieui-Juncetea bufonii – Juncus bufonius*, *Cyperus fuscus*, and *Gnaphalium uliginosum*. Species from classes *Artemisietea* were very scarce, except for species in allince with *Calystegion sepium*.

Patches of *Juncetum bufonii* developed right behind the ponds in the first year after dredging. They were observed on a low fragment of the flood terrace cleared from vegetation, covered with a thin layer of dredging material on which water stagnated for a certain time. They were dominated by *Juncus bufonius*. The abundant accompanying species included those typical of class *Bidentetea tripartiae*.

8. Community from class *Molinio-Arrhenatheretea*

Table 7. *Lolio-Plantaginetum* association

Succesive No. of relevé	1	2	3
Date (year/month/day)	2008.07.03	2010.07.15	2008.07.12
Area of relevé (m^2)	8	9	4
Cover of herb layer (%)	95	70	75
No. of species in the relevé	11	9	18
	A	**A**	**B**
I. Ch., D.* Ass.			
Lolium perenne	4	3	2
Plantago major	2m	+	2m
Chamomilla suaveolens*	+	.	.
Polygonum aviculare*	.	+	2
II. Ch., D* Trifolio repentis-Plantaginetalia			
Trifolium repens	2a	.	+
Poa annua*	2a	1	+
III. Molinio-Arrhenatheretea			
Poa trivialis	2m	.	.
Taraxacum officinale	+	.	+
IV. Ch. Artemisietea			
Rubus caesius	.	1	.
Elymus repens	+	+	+
V. Others			
Polygonum persicaria	+	.	+

Sporadic species: **II** Potentilla anserina 1(2a); **III** Festuca rubra 2(2b), Ranunculus repens 1(+); **IV** Arctium tomentosum 3(+), Artemisia vulgaris 3(+), Convolvulus arvensis 3(r), Heracleum sphondylium subsp. sibiricum 3(r), Rubus caesius 2(1), Urtica dioica 3(+); **V** Calamagrostis epigejos 2(1), Capsella bursa-pastoris 3(+), Chenopodium album 3(2m), Matricaria maritima subsp. inodora 3(+), Papaver dubium 3(r), Roripa palustris 3(1).

Spaces amongst concrete grid paving units along the dirt road were occupied by patches of the carpet community (*Lolio-Plantaginetum* association) dominated by two typical species – *Lolium perenne* and *Plantago major*. They developed on a relatively low levee on humid levelled substrate in contact with communities from class *Artemisietea* and *Epilobietea angustifolii*, but sometimes also *Phragmitetea* (*Phalaridetum arundinaceae*).

9. Communities from class *Artemisietea vulgaris*

Table 8. Communities from *Artemisietea* class: A – *Soncho-Archangelicetum litoralis*, B – *Eupatorietum cannabini*, C – *Urtico-Convolvuletum sepium*, D – community with *Cirsium arvense*

Succesive No. of relevé	1	2	3	4	5	6	7	8	9	10
Date (year/month/day)	2008. 07.12	2008. 07.03	2010. 07.15	2010. 07.15	2008. 07.03	2010. 07.15	2010. 07.15	2010. 07.15	2008. 07.12	2010. 07.15
Area of relevé (m^2)	10.0	10.0	12.0	9.0	4.0	8.0	6.0	6.0	10.0	10.0
Cover herb layer (%)	100	100	100	100	100	100	100	100	100	100
Cover shrub layer (%)	0	1	0	0	0	0	0	0	0	0
No. of species in the relevé	16	18	17	26	11	12	10	9	8	14
	A	A	A	B	C	C	C	C	C	D
I. Ch. Ass.										
Angelica archangelica ssp. litoralis	4	3	4	2a	1	2m	.	.	.	.
Eupatorium cannabinum	.	.	1	4	.	.	.	.	.	.
Calystegia sepium	2m	3	2b	3	3	3	5	4	5	2a
Myosoton aquaticum	.	.	+	+	.	.	+	.	.	1
Symphytum officinale	+	2m	.	+	1	.	.	.	.	1
Cirsium arvense	.	r	2m	1	.	.	2a	.	+	5
II. Ch., D* Calystegion sepium										
Stachys palustris	r	2a	.	+	.	.	.	2m	r	.
Epilobium hirsutum	.	.	3	2b	.	.	.	.	.	.
Carduus crispus	2m	.	1	.	.	.	.	.	.	.
Phalaris arundinacea*	.	2a	2a	2m	2a	.	2a	.	.	2a
Phragmites australis*	.	.	.	.	.	.	2m	2b	2a	.
III. Ch. Artemisietea vulgaris and Convolvuletalia sepium*										
Urtica dioica	3	2b	2m	2m	3	3	3	2b	4	2m
Arctium tomentosum	2b	.	.	.	.	2m	.	.	.	+
Elymus repens	.	+	+	.	.	+	2m	.	.	.
Artemisia vulgaris	.	.	.	.	.	2m	.	.	.	+
Galium aparine*	+	.	2b	.	+	2b	2m	2a	2m	.
Anthriscus sylvestris*	2a	.	2m	.	.	2a	2m	.	+	.
Glechoma hederacea*	+	.	.	+	1	+	.	.	.	.
IV. Others										
Poa palustris	.	+	2m	2m	2a	.	.	2m	.	.
Equisetum palustre	+	.	.	2m	.	.	.	.	2a	.
Arrhenatherum elatius	2a	.	.	.	.	2m	.	.	.	.
Salix fragilis b	.	+	.	2a	.	.	.	.	.	.
Humulus lupulus	.	.	+	2m	2m	.	.	.	.	.
Carex acutiformis	.	.	.	.	.	.	.	2m	.	.

Succesive No. of relevé	1	2	3	4	5	6	7	8	9	10
Date (year/month/day)	2008. 07.12	2008. 07.03	2010. 07.15	2010. 07.15	2008. 07.03	2010. 07.15	2010. 07.15	2010. 07.15	2008. 07.12	2010. 07.15
Salix cinerea	.	.	2m	.	.	.	.	.	.	.
Poa trivialis	1	.	.	.	.	+	.	+	.	.
Ranunculus repens	.	r	.	+	1	.	.	.	.	.
Vicia cracca	+	+	.	+	.	.	.	.	.	+
Galium palustre	.	+	.	+	.	.	.	.	.	.
Myosotis palustris	.	.	+	.	+	.	.	.	.	.
Alopecurus pratensis	.	r	.	.	.	+	.	.	.	.

Sporadic species: II Atriplex prostrata subsp. latifolia* 14(r), Lysimachia vulgaris* 4(r), Lythrum salicaria* 2(+), Salix triandra* 4(1); III Ballota nigra 4(+), Galeopsis bifida 8(1), Heracleum sphondylium subsp. sibiricum 1(2a), Rubus caesius* 10(1); IV Agrostis gigantea 10(2a), Alnus glutinosa b 2(+), Bromus inermis 3(2m), Calamagrostis epigeios 10(1), Carex hirta 10(2m), Cirsium vulgare 1(1), Dactylis glomerata 7(+), Filipendula ulmaria 2(+), Juncus effusus 4(+), Lycopus europaeus 4(1), Melandrium album 4(r), Rumex crispus 2(+), Scrophularia umbrosa 4(2a), Stellaria media 10(1).

The phytocoenoses were particularly represented by patches of associations from alliance *Calystegion sepium*. They developed on the boundary of rushes near the top of the flood terrace, under single trees *Salix* and *Alnus*, and in fringes of fragmentarily developed thickets of *Salicetum triandro-viminalis*. The most common association was *Urtico-Convolvuletum sepium*, consisting of shoots of nettle *Urtica dioica*, with abundant *Calystegia sepium* and *Galium aparine*. They were accompanied by scarce other species from class *Artemisietea*, such as *Cirsium arvense*, *Anthriscus sylvestris*, *Glechoma hederacea*, *Elymus repens*, and species from rush contact phytocoenoses, namely *Phragmites australis* and *Phalaris arundinacea*. Scarce patches of *Eupatorietum cannabinii* were observed of edges of scarps, with numerous representation of species from alliance *Calystegion sepium*. Phytocoenoses of *Soncho palustris-Archangelicetum litoralis* were distinguished in physiognomic terms due to the abundant aspect of *Angelica archangelica* subsp. *litoralis*. They were characterised by a considerable contribution of species from alliance *Calystegion sepium*, namely *Calystegia sepium*, *Carduus crispus*, *Symphytum officinale*, *Stachys palustris*, and *Epilobium hirsutum*. Patches of communities from alliance *Calystegion sepium* were abundant before dredging. In the first year after dredging, they only fully developed in places not subject to melioration works. In the second year, they were frequently recorded.

In the second year after dredging, in the upper parts of the levee, scarce patches of an community from class *Artemisietea* were observed, dominated by *Cirsium arvense*. They developed in contact with phytocoenoses from alliance *Calysteg-*

ion sepium and canary grass rush on disturbed substrate covered with a layer of dredging material. The patches showed high contribution of species from alliance *Calystegion sepium*, but also *Phalaris arundinacea* from contact communities.

The structure of vegetation before dredging

Before dredging, the largest areas in the middle of the river channel were occupied by the association *Sagittario-Sparganietum emersi*, accompanied by patches of *Elodeetum canadensis*. At two sites, the occurrence of yellow water-lily was recorded. It occurred in the submerged form, developing an community with *Nuphar lutea* fo. *submersa*. It also developed small patches of *Nupharo-Nymphaeetum* association. On stones near the former railway crossing and near the small bridge, a *Ranunculo-Callitrichetum polymorphae* association developed. The presence of numerous scroll ridges permitted the development of diverse rush communities on their surface (*Phragmitetum communis*, *Phalaridetum arundinaceae*) and in stagnant waters between them, at the foot of the scarp (*Butometum umbellati*, *Acoretum calami*, *Glycerietum maximae*). On the boundary of the rush communities at the bank of the channel, patches of *Oenantho-Rorippetum* association were recorded. *Lemnetum minoris* and *Lemno-Spirodeletum polyrhizae* phytocoenoses developed between the emerged plants. Locally on the surface of the flood terrace, in the close vicinity of the river, on the aggradate muds deposited by high water levels, scarce patches of summer terophyte communities developed, namely *Chenopodietum rubri*. The phytocoenoses were recorded at sites where bushes were cleared in the previous year for the purpose of unblocking the river channel.

Common reed and canary grass rushes developed on the surface of the flood terrace. In the upper parts of the scarp, they were in contact with riparian tall herb communities (*Soncho palustris-Archangelicetum litoralis*, *Urtico-Convolvuletum sepium*). The riparian tall herb communities sometimes developed on the edge of the flood terrace (*Eupatorietum cannabini* and *Soncho palustris-Archangelicetum litoralis*, and more seldom *Urtico-Convolvuletum sepium*). On the top of the scarp, riparian tall herb communities or rush communities were in contact with phytocoenoses of carpet community *Lolio-Plantaginetum* developed on the dirt road. *Calamagrostietum epigeji* community only developed on the deposited material near the bridge and road.

On the flood terrace, in certain fragments of the river, willow shrubs developed (*Salicetum cinereae*, *Salicetum triandro-viminalis*). Amongst the shrubs at one site in the embankment, *Cardamino-Chrysosplenietum* association was recorded. The river banks were locally overgrown by trees – willows and alder, but their low density permitted abundant growth of vegetation in the river current and at the banks.

Such a distribution of vegetation was determined by the location of the analysed section between extensive fish ponds, and by its regulation involving maintenance measures (removal of selected trees and bushes, mowing of scarps).

The structure of vegetation after dredging

Conducting maintenance works in winter (mechanical dredging and desludging of the bottom, profiling the flood terrace and deposition of the dredging material on it, and considerable clearing of trees and bushes) resulted in a substantial change in the vegetation cover of the river valley.

The implemented investment caused changes in the structure of the river channel and the character of the occurring vegetation. The width of the river channel remained unchanged, but its bottom and slopes were levelled, similarly as the surface of the flood terrace, where the obtained dredging material was additionally deposited. The modification of the structure of the river channel involved the destruction of its herbaceous vegetation and clearing of the belts of willow shrubs obstructing the water flow. Only single trees remained. Before the investment, the river bottom showed quite varied character due to numerous scroll ridges and diverse vegetation. It was largely covered by a thick layer of mud and loam. In some fragments, the bottom was sandy or gravel-sandy. After the investment, the levelled bottom was mostly sandy or sandy-loamy with a slight contribution of mud (Zawal et al. 2014; Szlauer-Łukaszewska, Zawal 2014). The transformations of the structure of the river channel and floor terrace, involving a reduction in the diversity of the habitats of the river, affected the character of the occurring vegetation.

The levelled surface within the channel was dominated by the *Sagittario-Sparganietum emersi* association. The first plants were observed in May. They covered almost the entire river channel in August. The recolonisation occurred from the banks towards the middle of the channel (Henry, Amoros 1996). Patches of *Nymphaeo albae-Nupharetum lutea*, and community with *Nuphar lutea* fo.

submersa developed at sites with weaker current, smaller than in the preceding year, were only observed at sites unaffected by dredging. Duckweed communities in the form of small sinusions of *Lemna minor* were weakly represented. They only appeared in high abundance in the second year. Small patches of *Oenantho aquaticae-Roripetum amphibiae* were observed on the boundary of the channel. After dredging, scarce and not recorded before patches of *Potametum lucentis* appeared. They consisted of *Potamogeton crispus*, preferring habitats with gravel substrate and faster water flow, as observed in the Danube River in Hungary (Engloner et al. 2013). The relevant habitat conditions in the Krąpiel River channel were recorded in the vicinity of bridges.

No patches of *Ranunculo-Callitrichetum polymorphae* were encountered after dredging. No specimens from genera *Callitriche* or *Fontinalis antipyretica* in patches of other communities were recorded, either. Mechanical dredging and levelling of the river channel eliminated microhabitats favouring the development of such phytocoenoses. Only in the second year after dredging, the presence of *Callitriche cophocarpa* was recorded in the lower course of the river, where it was not encountered before. Diaspores of the species probably came from the upper, non-dredged section of the river. No patches of *Elodeetum canadensis* were found, although Canadian waterweed appeared in low numbers in other communities in the second half of the summer. Its presence in patches of communities with *Nuphar lutea* preserved during dredging draws particular attention. From this section of the river, it can colonise areas located below by means of its vegetative reproductive organs (Van der Valk 1992; Goodson et al. 2001).

Patches of *Chenopodietum rubri* from class *Bidentetea tripartitae* developed on the flood terrace, constituting the dominant component of the vegetation already from May of the first year after dredging. They covered the layer of the deposited material, containing terophyte diaspores in the forms of soil deposit, as also observed by Assini (2001). A high contribution in the patches was reached by rush species cutting through the deposited layer, namely *Phalaris arundinacea* and *Phragmites communis*. In the lower course of the river, on the low surface of the terrace, a patch of *Juncetum bufonii* developed. In the second year after dredging, terophytes were again replaced by rush communities, dominated by *Phalaridetum* and *Phragmitetum*. Only one patch of *Chenopodietum rubri* was recorded. It developed on the bank of a canal flowing into the river, freshly uncovered during the maintenance works.

Communities from association *Chenopodion* are typical of larger rivers (Borysiak 1994). Banks of smaller rivers such as the Krąpiel River are dominated by communities from alliance *Bidention* (Stępień 2010). A high contribution of species from class *Stellarietea mediae* and *Artemisietea*, and the presence of alien species suggest their anthropogenic character.

The coverage of willow shrubs considerably decreased. Bushes growing within the river channel and at the banks were removed. Only single small trees and bushes growing further on the terrace remained. Larger fragments of the shrubs were only preserved in the lower course of the river, particularly around the small limnocrene with vegetation with wellhead character – *Cardamino-Chrysosplenietum.*

In the first year after dredging, scarce rushes developed at sites with less destroyed surface. Their patches frequently contained high contribution of species from class *Bidentetea tripartitae*. The cutting and levelling of the channel slopes resulted in a decrease in the diversity of the occurring rush communities. No patches of *Acoretum calami* or *Butometum umbellati* were encountered, and scarce patches of *Glycerietum maximae* only developed in the second year. Directly after dredging, radical changes in the cover of riparian tall herb communities from class *Artemisietea vulgaris* were observed. Their small patches only developed on unaffected surfaces. In the second year, abundant reconstruction of the phytocoenoses was observed. A new community also developed dominated by *Cirsium arvense*, not recorded before dredging.

Discussion

The investigated stretch of the river valley, despite regulation and its location between fish ponds, has retained many of its valuable natural features. Owing to its relatively high habitat diversity for this type of transformed stretch of river, prior to the dredging 22 plant communities belonging to 10 classes and 14 alliances formed here. The most valuable communities observed in the river channel were of the alliance *Ranunculion fluitantis*, associated with riffles – sites with a fast current and a coarse substrate. Habitats of type 3260 are protected under the European network Natura 2000 (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora). They represent an impoverished form (Puchalski 2004), without species of the genus *Batrachium*, but they increase the ecological value of the river. Unfortunately, following the

dredging no patches of *Ranunculo-Callitrichetum polymorphae* were noted. The works led to the disappearance of sensitive phytocenoses and species, such as *Callitriche polymorpha* and *Fontinalis antypyretica*, which has also been observed in Danish watercourses (Baattrup-Pedersen et. al. 2002; Pedersen et al. 2006). Patches of a 'ribbon-like leaves' form (community with *Nuphar lutea* fo. *submersa*) remained, as they were not destroyed during the dredging due to their location near the bridge. It should be emphasized, however, that communities of this type are observed in watercourses subject to human impact (Nowak, Nowak 2010).

Although the floodplain was not very wide, after the spring high water autogenic patches of therophytes of the classes *Isoëto durieui-Juncetea bufonii* and *Bidentetea tripartitae*, which are valuable in the river ecosystem, occupied habitats protected by the European Union (3270 – flooded muddy river banks). The patches of communities of the class *Bidentetea* observed after the dredging, formed on the surface of the dredging material deposited on the floodplain, had a disturbed structure and species composition, which is indicative of their anthrpogenic character (Brzeg, Ratyńska 1983; Borysiak 2004).

Most of the communities observed in the area studied are characterized by natural syngenesis (Brzeg, Wojterska 2001). Examples include xenospontaneous associations of *Elodeetum canadensis* and *Acoretum calami*. Some of the communities observed are perdochoric, with their range decreased by human activity. They included the associations *Nymphaeo albae-Nupharetum luteae*, *Cardamino-Chrysosplenietum alternifolii* and *Sagittario-Sparganietum emersi* (loc. cit.). However, Pedersen et al. (2006) observed substantial *Sparganium emersi* cover in watercourses from which vegetation was removed regularly. Following the dredging the Krąpiel river bed quickly became overgrown by arrowhead and European bur-reed.

The dredging caused a decrease in plant diversity, as a direct result of the destruction of plant cover and simplification of the river profile (levelling of the bottom and floodplain and straightening of the banks, as well as deposition of dredging material on the floodplain). A significant factor affecting vegetation is the degree of human impact and the topography of the river bed (Pedersen at all. 2006; Brookes 1986). The transformation and reduction in habitat heterogeneity on the one hand eliminated sensitive phytocenoses and communities associated with a varied littoral zone, while on the other hand it enabled the spread of anthropogenic communities and the penetration of numerous synanthropic species (Stępień et al. 2016).

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PRZEKSZTAŁCENIA ROŚLINNOŚCI W DOLINIE MAŁEJ RZEKI NIZINNEJ (KRĄPIEL, PÓŁNOCNO-ZACHODNIA POLSKA) PO PRZEPROWADZENIU BAGROWANIA

Streszczenie

W pracy przedstawiono wpływ bagrowania na roślinność uregulowanego odcinka rzeki nizinnej na przykładzie rzeki Krąpieli (północno-zachodnia Polska). Badania terenowe, obejmujące monitoring przedinwestycyjny, prowadzono w sezonach wegetacyjnych w latach 2008–2010. Mechaniczne pogłębienie i wyrównanie koryta rzecznego spowodowały zmiany w strukturze roślinności. Zmniejszenie zróżnicowania siedliskowego wpłynęło na zubożenie obserwowanych zbiorowisk roślinnych i budujących je gatunków. W pierwszym roku po pogłębianiu powierzchnię terasy zalewowej, pokrytą warstwą refulatu, zdominowały zbiorowiska z klasy *Bidentetea tripartitae* (głównie *Chenopodietum rubri*). W drugim roku po pogłębianiu, terofity zostały zastąpione przez zbiorowiska szuwarowe (głównie *Phalaridetum*, *Phragmitetum*) oraz, miejscami, przez zbiorowiska welonowe.

Słowa kluczowe: roślinność nadrzeczna, przekształcenia roślinności, regulacja rzek, rekolonizacja

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