Monographiae Botanicae 108

Monika Myśliwy

Diversity and environmental variability of riparian tall herb fringe communities of the order *Convolvuletalia sepium* in Polish river valleys

Monographiae Botanicae 108
Official publication of the Polish Botanical Society

Monika Myśliwy

Diversity and environmental variability of riparian tall herb fringe communities of the order *Convolvuletalia sepium* in Polish river valleys

Wrocław 2019

Editorial office
University of Wrocław
Botanical Garden
H. Sienkiewicza 23, 50-335 Wrocław, Poland
tel.: +48 71 322 5957
email: mb@pbsociety.org.pl

ISSN: 2392-2923 ISBN: 978-83-954123-2-5
DOI: 10.5586/mb.2019.001

Citation: Myśliwy M. Diversity and environmental variability of riparian tall herb fringe communities of the order *Convolvuletalia sepium* in Polish river valleys. Wrocław: Polish Botanical Society; 2019. (Monographiae Botanicae; vol 108). https://doi.org/10.5586/mb.2019.001

Published by Polish Botanical Society
Al. Ujazdowskie 4, 00-478 Warsaw, Poland
pbsociety.org.pl

Contents

About the author

Monika Myśliwy; Institute of Marine and Environmental Sciences, University of Szczecin, Adama Mickiewicza 16, 70-383 Szczecin, Poland; email: monika.mysliwy@usz.edu.pl

Abstract

The riparian tall herb fringe communities of the order *Convolvuletalia sepium* represent an integral part of the natural vegetation in river valleys. The major objective of this study was to assess the relationships between the diversity and variability of these communities and various environmental factors. The survey was conducted in northwestern Poland, along 101 randomly selected 1–2-km long sections of 24 rivers and the Szczecin Lagoon. Samples were collected in 2008–2013 in all types of tall herb fringe vegetation found in the surveyed river sections. Data collected included hydrogeomorphic variables, soil parameters, potential and actual vegetation, and dominant land use form. A total of 24 vegetation units were documented, based on 300 sample plots (relevés). Tall herb fringe communities occurring in valleys of large rivers (*Senecionetum fluviatilis*, *Fallopio-Cucubaletum bacciferi*, *Achilleo salicifoliae-Cuscutetum lupuliformis*, *Convolvulo sepium-Cuscutetum europapaeae typicum* and *chaerophylletosum bulbosi* subass. nov., *Rubus caesius* community, *Solidago gigantea* community) exhibited floristic and ecological differences in comparison with plant communities from small rivers (*Eupatorietum cannabini typicum*, *aegopodietosum* and *cardaminetosum amarae* subass. nov., *Epilobio hirsuti-Convolvuletum sepium*, *Soncho palustris-Archangelicetum litoralis*, *Convolvulo sepium-Cuscutetum europaeae aegopodietosum*, *Urtico-Convolvuletum sepium typicum* and *aegopodietosum*, *Urtica dioica* community, *Galeopsis speciosa* community, *Rubus idaeus* community). This finding fully justified their division into two alliances: the *Senecionion fluviatilis* and the *Archangelicion litoralis*, respectively. Significant differences between the tall herb fringe communities associated with large rivers and the plant communities occurring along small rivers included plant species richness, moss layer cover, contribution of river corridor plants, level of invasion, influence of adjacent plant communities on the floristic composition, relative elevation and distance away from the riverbed, degree of shading, proportions of all grain size fractions, soil pH, contents of organic matter, humus, organic carbon, total nitrogen, bioavailable phosphorus, potassium, magnesium, and calcium in the soil. The differences in environmental characteristics of individual plant communities were significant as well; they showed that most vegetation units were well defined. The variables that best discriminated between riparian tall herb fringe communities included the natural potential vegetation unit *Salici-Populetum*, headwater seeps, soil pH, sample elevation above the river water level, river size, flooding, degree of shading, soil moisture, K_2O and CaO contents, and C/N ratio. The integration of the main riparian gradients (longitudinal, lateral, vertical) and patch perspective (e.g., natural potential vegetation units, and land use forms) significantly improved the comprehensive riparian vegetation patterns, because these two perspectives underpin different processes shaping the vegetation. This study contributed significantly to the knowledge of riparian tall herb fringe communities. Two subassociations are described here for the first time, whereas six others have not been previously reported from Poland. The data summarized in the synoptic table indicated that the species diagnostic for individual plant communities should be revised at the supra-regional scale. Some syntaxonomic issues were also determined. The inclusion of the order *Convolvuletalia sepium* to the class *Epilobietea angustifolii* resolved the problem of classifying the community dominated by *Eupatorium cannabinum*, a species showing two ecological optima: one in riparian tall herb communities and the other in natural

gaps of the tree stands and clearings of fertile alder carrs and riparian woodlands. This also resolved the problem of classifying the communities dominated by *Galeopsis speciosa* and *Rubus idaeus*, intermediate between riparian tall herb and clearing communities. The results of this study may serve as a reference for management of the vegetation in river valleys and promote their conservation. They may also be essential for any future syntaxonomic revision of riparian tall herb fringe communities at a larger geographical extent.

Keywords
rivers; riparian vegetation; *Senecionion fluviatilis*; *Archangelicion litoralis*; environmental conditions; ordination; alien plants; level of invasion

Acknowledgments
I was lucky to encounter much support, assistance, good will, and friendship at each stage of my research. I would like to thank all the individuals who helped me to move forward, and owe particular gratitude to the following persons:

- The late Professor Marian Ciaciura, my first botany teacher;
- Professor Adam Zając, for pointing me toward research on riparian tall herb fringe communities as an important and poorly known group of plant communities, as well as his friendly interest in the progress of this work;
- Professor Eugeniusz Dubiel, for conducting a phytosociological workshop preceding the first stage of my field research;
- Professor Jerzy Zieliński, for checking my identifications of the genus *Rubus* and Professor Ewa Fudali, for identifying the mosses;
- Professor Jürgen Dengler, for his help in assembling the German phytosociological literature;
- Professor Stephan Hennekens, for providing the TURBOVEG software;
- Mr. Marek Podlasiński, Ph.D., D.Sc., for performing soil analyses and preparing the map;
- My colleagues and friends from the Faculty of Biology, University of Szczecin, and particularly to Ms. Edyta Stępień, Ph.D., Professor Helena Więcław, and Mr. Bartosz Kurnicki, M.Sc., for their participation in field work;
- Anonymous Reviewers and Editor-in-Chief Professor Zygmunt Kącki, for their valuable advice and helpful comments on the manuscript and Professor Teresa Radziejewska, for her invaluable help with the English version of the text.

Finally, my heart-felt gratitude goes to my husband, Jerzy Myśliwy, for his patience and unfailing support at each stage of my research, and to my parents, Janina and Bonifacy Radziszewicz, for being with me any time I needed them.

Funding
The research was supported by grants awarded by the Ministry of Science and Higher Education of the Republic of Poland and the National Science Center in Poland (grants Nos. N N305 231935 and N N305 018940), as well as by statutory funds of the Faculty of Biology, University of Szczecin.

Competing interests
No competing interests have been declared.

1. Introduction

Riparian ecosystems exhibit high habitat heterogeneity, complex ecological processes, and multidimensional gradients. Climate and geomorphology influence the longitudinal course of the river, but they are also important throughout the lateral extent of the floodplain, affecting the probability and duration of flood disturbance, as well as soil characteristics [1]. Longitudinal transport of organic matter and nutrients, along with lateral mass movement across the floodplain, are essential for ecological processes in river valleys [2]. The vertical dimension in river valleys is equally important, because it is related to the intensity of flood effects, connectivity of ground- and surface waters, and moisture level [1]. Various concepts in riverine ecology have been developed to achieve a holistic perspective of such a complex system [3].

The river continuum concept (RCC) [4] emphasizes the importance of the longitudinal dimension. It focuses on the continuous upstream–downstream gradient of physical conditions and ecological processes, particularly on changes in material supply and circulation, accompanied by alterations in producer and consumer communities along the length of a river. Some studies have related riparian vegetation variation to longitudinal-scale controls [2,5], but RCC is generally accepted for small to moderately sized rivers, with relatively constant climate and simple geology [6]. The most severe limitation of the model is the fact that it ignores the effects of floods on the structure and function of riverine landscapes [3].

The flood pulse concept (FPC) [7] stresses the lateral (transverse) dimension and explains the river–floodplain relationship, indicating that flooding is the most important factor controlling biota in large river systems. Organisms subjected to a regular flood pulse develop various adaptations and strategies to efficiently utilize this dynamic system and respond to the flood's magnitude, frequency, and duration, e.g., by forming clear zonation of plant communities [1,8,9]. As opposed to large rivers, small rivers exhibit short and mostly unpredictable floods. In such cases, organisms have limited adaptations for utilizing attributes of the aquatic/terrestrial transition zone [7]. Furthermore, transverse-scale controls are very sensitive to land use changes and various types of anthropogenic river regulation [10]. The latter affects dynamics of flooding, sediment transport, groundwater supply, and soil characteristics, which strongly influence riparian vegetation [11].

Tockner et al. [12] argued that FPC is based mainly on large tropical rivers, with a predictable flood pulse of long duration. They extended this concept to temperate areas and upper and middle reaches of rivers with less predictable floods of shorter duration by pointing out the importance of temperature and nutrients in explaining the biological diversity of floodplains, as well as the consequences of expansion–contraction events altering surface waters below the bank full ("flow pulse"). The authors stress that overflow of river water is not the only cause of inundation in river valleys; direct rainfall, overland runoff, and rising groundwater may contribute to the flooding process. Moreover, flow and flood regimes vary regionally based on their dependence on river size, climate, geology, topography, and vegetation cover. More empirical data are needed to understand the dynamics of different riverine floodplains, because their biodiversity patterns and environmental heterogeneity are controlled by different processes [12].

Complex, dynamic, and nonlinear functioning of river-floodplain system is suggested by the hierarchical patch dynamics (HPD) perspective [13], which integrates two theories, one involving spatial heterogeneity (ecosystem dynamics) and the other hierarchy (nested hierarchies of patch mosaics). HPD describes a river network as a mosaic of discontinuous patches at multiple spatial and temporal scales based on geomorphology and hydrology. The biological and physical components of this systems interact and shape the emergent ecosystem-scale characteristics. For example, vegetation is strongly influenced by soil moisture, fertility, and microclimate, but at the same time it moderates soil moisture by evapotranspiration, affects soil fertility by leaf litter deposition, and generates microclimates through shading and transpiration [1].

Finally, the riverine ecosystem synthesis (RES) [3] provides a framework for linking various concepts in riparian ecology, especially the HPD model, with often discontinuous patterns along longitudinal and lateral dimensions, and characterizes the riparian networks from small streams to large rivers. The riverine landscape is structurally highly complex, and individual hydrogeomorphic patches differ in flow regimes, flow histories, and flood pulses, as well as in the physical template, e.g., vertical and lateral shape, mean substrate size, and chemical conditions; all these factors are important in shaping biotic communities. Therefore, biotic communities in comparable types of hydrogeomorphic patches are more similar to each other than to adjacent assemblages in different patch types. To explain riparian vegetation structure and ecosystem functioning, longitudinal and lateral processes, as well as patch-scale dynamics should be considered [3].

The outstanding natural values of river valleys stem both from diversity of habitats and continuity of similar ecosystems they support. As a result, the valleys are usually local biodiversity hotspots and form specific "ecological corridors" for species [14]. Many plants, including a high proportion of threatened species, show a corridor-like distribution pattern [15,16]. Human activities, however, have considerably transformed the natural environment of most of the European river valleys. Changes in water flow regime, coupled with intensified agricultural practices on alluvial plains, have reduced the diversity of riverine landscapes [17–19]. Restoration of river valleys requires comprehensive measures implemented in the entire catchment. These measures must be based on detailed studies, including vegetation surveys, on the structure and composition of natural riparian plant communities, as well as an understanding of environmental drivers associated with observed vegetation variation, which are essential for restoration purposes [20–23].

Riparian vegetation subjected to fluctuations in flooding develops in a specific way. Frequently inundated areas located close to the riverbank support short-lived annuals and fast-growing low grasses and sedges (e.g., *Bidentetea* Tx. et al. ex von Rochow 1951 class). Their development varies annually, depending on water level. Tall grasses that spread vegetatively occur in areas above a certain degree of flooding risk. Such reed strips are usually species-poor and dominated by *Phalaris arundinacea*, and less often by *Phragmites australis* or *Glyceria maxima*. Higher, the area is covered by riverside willow shrubs, such as *Salix purpurea*, *S. triandra*, and *S. viminalis*. They can occupy a large area or form a narrow band where the floodplain is not extensive. The willow scrub is followed by quick-growing, broad-leaved soft-wood trees (*Salix alba*, *S. fragilis*), which often form flooded alluvial forests. The highest-lying areas subjected to flooding are occupied by hardwood forests dominated by *Alnus glutinosa*, *Fraxinus excelsior*, and *Ulmus* species. This sequence of vegetation types can be disturbed by the river itself through erosion, sedimentation, and change of course [24].

Anthropogenic transformations are also very common. For example, willow forests, always present in natural river valleys, are fairly scarce today because of deforestation. Areas formerly covered by alder-ash and ash-elm riparian forests, suitable for agricultural purposes, have been turned into arable land or meadows [25].

Earlier studies explaining complex vegetation-environment relationships in the riverine landscape often dealt with riparian forests [26–32] or secondary vegetation types, such as meadows [22,33,34]. However, the riparian tall herb fringe communities of the order *Convolvuletalia sepium* Tx. ex Moor 1958 represent an integral part of the natural vegetation in river valleys. They are lush, multilayered assemblages of tall herbs and climbing species. They usually grow as narrow belts between riparian rushes and willow or alder scrub, as well as between rush and meadow communities. They occur by rivers, coastal lagoons, lakes, and other water basins, but prefer locations that are periodically or episodically flooded, with fertile and moist soils [35–38]. Because of human disturbance, these communities have greatly expanded to also cover secondary, particularly ruderal, habitats. At the same time, the primary floristic composition of the communities has changed because of expansive, alien species [24,36,37,39]. Riparian habitats are known for their invasibility (sensu Lonsdale [40,41]) [42–47]. Aliens often displace native species and frequently form their own plant communities [48–54]. According to Matuszkiewicz [37], rarely do such monospecific aggregations merit the rank of association; however, many plant associations with neophytes have been identified [55–61]. The tremendous floristic variability, as well as the domination of different species in individual tall herb assemblages, have resulted in numerous associations, subassociations, and facies being identified in the group of communities treated herein. The final number is still under debate, particularly between proponents of narrowly and broadly defined plant association concepts [61–63].

In Central Europe, the order *Convolvuletalia sepium* has been reported as containing from one to three alliances and covering either exclusively fringe communities growing in hygrophilous habitats, or in a broader sense [as the *Galio-Convolvuletalia sepium* (Tx. 1950) Oberd. et al. 1967], also covering mesic fringes. The names *Senecionion fluviatilis* Tx. ex Moor 1958 and *Convolvulion sepium* Tx. 1947, first published by Tüxen [64], are being used either – as suggested by that author – as synonyms of the same alliance [35,65–70] or to denote two different ones: the first consisting of riparian fringe communities occurring on banks of large rivers, and the second covering riparian fringe communities of smaller rivers and streams [37,71,72]. Müller [71] regarded such division as justified floristically and ecologically; however, provided no evidence. Mucina [69] and Siedentopf [63] found no floristic grounds justifying the division. The third alliance *Archangelicion litoralis* Scamoni et Passarge 1963, initially proposed by Tüxen [65] for poorly defined halophile assemblages associated with brackish water shores in the coastal zone, has been accepted by Dengler et al. [73], Koska [62], and by Mucina et al. [70] in their recent synthesis of classification of the European vegetation, whereas Mucina [69], van't Veer et al. [74], Brzeg and Wojterska [61], Matuszkiewicz [37], and others did not see sufficient reasons to distinguish it and included it in the *Senecionion fluviatilis* alliance. In the opinion of Dengler et al. [73], the *Archangelicion litoralis* alliance is identical with that of *Convolvulion sepium* sensu auct. non Tx. 1947. Such problems can be solved by nomenclatural revisions and detailed floristic and ecological studies. Previous research has not investigated differences in environmental conditions among individual associations of tall herbs.

Riparian tall herb fringe communities occur in Poland along shores of some rivers, lakes, and mid-field ponds, as well as in various other systems. The scant information on its floristic composition can be found in published local and regional studies (e.g., [75–82]), as well as in the review by Brzeg [36]. However, as emphasized by numerous authors [36,37,39,83,84], plant communities of the order *Convolvuletalia sepium* in the Polish lowlands are still inadequately understood. Information is lacking regarding the geographic distribution of these communities, their structure, natural dynamics, directions, and magnitude of alterations and threats, as well as protection and restoration methods. To date, no comprehensive habitat research has been undertaken, neither in Poland, nor in Central Europe.

The lack of any synthetic treatment placing this type of vegetation on a supraregional scale, and particularly the distinct gap in their habitat characterization, provided the incentive to undertake this research, with the goal of a comprehensive exploration of these interesting and important plant communities. They are a phytosociological identifier of habitat 6430-3 "Hydrophilous tall herb fringe communities of plains" (Code Physis 37.711, 37.715), listed in Annex 1 of the EU Habitat Directive. Their protection is important for preserving natural processes in river valleys, as well as for the conservation of typical riparian landscapes [39]. For the protection and the successful restoration of this valuable habitat type, it is essential to understand the effects of environmental conditions on their species composition and diversity. Although some studies have already related riparian vegetation to selected environmental factors in floodplains, very few attempts have been made to examine the relative importance of multiple types and scales of variables that influence riparian vegetation [26].

The major objectives of this study were to describe the riparian tall herb fringe vegetation, to evaluate the invasion by alien plants, and to assess the relationships between vegetation and various environmental factors in Polish river valleys. On the basis of personal observations, the author hypothesized that the tall herb vegetation is dependent on river size and local environmental factors assessed at different scales. Therefore, the following questions were addressed:

- What is the species composition and diversity of riparian tall herb fringe vegetation (*Convolvuletalia sepium*)?
- Which environmental factors are most important in differentiating between tall herb fringe communities?
- Do environmental conditions and riparian tall herb fringe communities differ based on river size?
- Do tall herb fringe communities along rivers of various size differ in the level of invasion?

The results obtained will elucidate vegetation patterns in river valleys and the responses of plant species along environmental gradients. This understanding is essential for setting realistic targets for restoration management.

2. Characteristics of the region

The area of northwestern Poland covered by this survey is bordered by the Baltic Sea to the north, by the Warta and Noteć rivers to the south, by the Poland–Germany state border to the west, and by the Vistula River to the east. The area is located in the Polish part of the historical region of Pomerania.

The geobotanical division of Poland presented by Matuszkiewicz [85] places the area in two subprovinces of the Central European Province: the Southern Baltic and the Central European Proper, and in three divisions: the Pomeranian, Brandenburg-Wielkopolska, and Mazovian-Polesie. According to the physical geography-based regional division of Central Europe [86], the area belongs to the Central European Lowland Province and its two subprovinces: the Southern Baltic Coastal areas with three macroregions (the Szczecin, Koszalin, and Gdańsk coasts) and the South Baltic Lakeland, with five macroregions (Western Pomeranian, Eastern Pomeranian, and Southern Pomeranian Lakelands, Toruń-Eberswalde Ice-Marginal Valley, and the Lower Vistula Valley). The first of the subprovinces features seashore landscapes with river mouths and a belt of morainic plains, usually not higher than 100 m a.s.l. The other subprovince is characterized by the presence of a young-glacial landscapes with an abundance of lakes and drainage-less depressions. The landscapes are regionally diverse, with the diversity produced by different phases of the Baltic glaciation and by uplands being intersected by river valleys [86].

The soils of northwestern Poland are dominated by zonal soils, particularly brown soils and luvisols, usually forming a soil mosaic on morainic uplands, and podsols, typical of outwashes of the southern slopes of Pomerania and also of sandy terraces in ice-marginal valleys and river valleys. The nonzonal soils are represented by hydrogenic soils, including chernozems occurring in the Pyrzyce Plain, as well as marshy soils (peat, marsh, and murshic histosols), occupying low-lying valleys, glacial troughs, and meltwater depressions, e.g., the bottom of the Lower Oder Valley. In addition, downstream sections of some river valleys feature fen soils produced by flood deposits [87,88].

The climate of northwestern Poland is primarily affected by the polar-marine air masses advecting from the North Atlantic, manifested in the area as a distinct preponderance of westerly winds. The importance of the Arctic air masses, from the Barents Sea and Northern Russia, and of the polar-continental air masses, from Central Russia, is clearly lower. In Pomerania, the least influential are the tropical air masses advecting from the Azores, North Africa, and the Middle East [88].

The study area experiences an interplay between the oceanic and continental climates. The annual mean air temperature ranges from 7.5°C in the southeastern part of the area to 8.5°C in the western part. The annual amplitude of temperature ranges from 17.5°C in the narrow belt of the seacoast to 19.5°C in the southeastern part of the area [89]. The degree of continentalism of the Pomeranian climate, assessed based on the annual temperature amplitude, ranged from 38% at the coast to 44% in the southeastern part of the region [90]. The precipitation-related oceanism characterized by higher precipitation during the colder half-year relative to annual precipitation, is perceptible in the northern and western part of the area [91]. The total annual precipitation in northwestern Poland varies within a narrow range, from 550 mm in the western and southern parts to 600–650 mm in the morainic hill zone between river valleys of the Rega and Łeba and to 700 mm in the vicinity of the Wieprza and Słupia river valleys. The duration of the growing season ranges from 180 to 190 days in the central and eastern parts of the region to 230 days in the southwestern region [89].

In addition to the region-wide variability in climatic conditions, the study area exhibits high microclimatic variability related to terrain relief and vegetation cover. Specific topoclimates are typical of microregions, such as valley bottoms and slopes, upper areas of morainic uplands, shores of large lakes, and coastal dunes [88].

Northwestern Poland exhibits a well-developed network of rivers (Fig. 1). A chain of frontal moraines and other marginal forms, created during the Pomeranian stage of the last (Vistulian) glaciation, constitutes a boundary between rivers discharging into the Baltic Sea or the terminal sections of the Oder and Vistula on the one hand and those flowing southward to the Toruń-Eberswalde Ice-Marginal Valley on the other [86]. The catchments of the rivers that discharge directly into the Baltic Sea (the Rega, Parsęta with Radew, Wieprza with Grabowa, Słupia, Łupawa, Łeba, and Piaśnica) primarily feature morainic uplands developed on barely permeable morainic clays. In contrast, the catchments of the rivers flowing toward the Toruń-Eberswalde Ice-Marginal Valley (the Warta with Noteć and its tributaries, the Drawa with Korytnica and Płociczna, as well as the Gwda with Piława and Dobrzyca) exhibit primarily lowlands of outwash terraces built of sand and sand-gravel deposits. The major Lower Oder tributaries include the Myśla, Rurzyca, Płonia, and Ina with Krąpiel. The Vistula catchment features the Brda, Wda, and Wierzyca. Some sections of the Pomeranian rivers resemble mountain streams because of a terrain slope angle of 2–3‰ up to 5‰ [92,93].

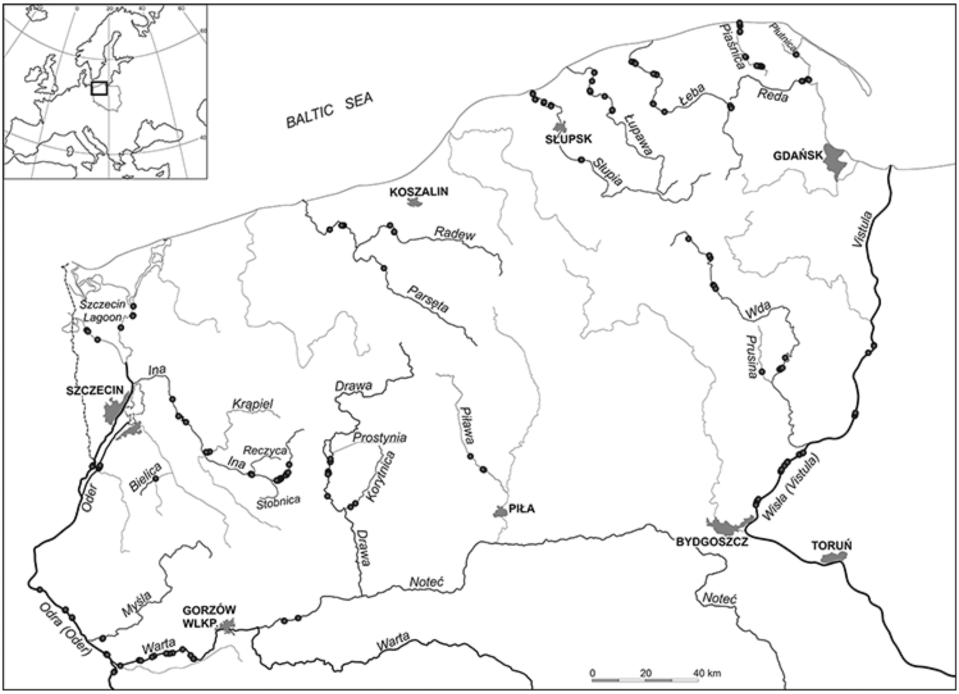


Fig. 1 Location of the vegetation samples (black circles) along the rivers studied in NW Poland.

3. Material and methods

3.1. Study area

The surveys were conducted along 101 randomly selected, 1–2 km sections of 24 rivers and the Szczecin Lagoon (Fig. 1). Hydrogeomorphological classification of river size [94] was adopted to divide rivers into: (***i***) small (comprised of very small rivers – shorter than 100 km, with a catchment area lower than 1,000 km^2, and small rivers – 100–200 km and/or having a catchment area of 1–10,000 km^2), (***ii***) large (comprised of moderately sized rivers – 200–500 km and/or having a catchment area of 10–100,000 km^2, large rivers – longer than 500 km and/or having a catchment area larger than 100,000 km^2, and the Szczecin Lagoon) (Tab. 1).

3.2. Vegetation data

Samples were collected in 2008–2013, in all types of tall herb fringe vegetation found in surveyed river sections. The number of samples from each river depended on the number of selected sections and diversity of riparian vegetation. Vegetation sample plots (relevés) were taken following the Braun-Blanquet [95] approach. The area of the relevé varied between 4 and 30 m^2. All the vascular plant and bryophyte species were recorded with their respective cover-abundances using the classic Braun-Blanquet scale [96]: r (one or a few individuals), + (rare with cover less than 1%), 1 (somewhat abundant with cover less than 5%), 2 (cover 5–25%), 3 (cover 25–50%), 4 (cover 50–75%), and 5 (cover 75–100%). A total of 300 relevés were stored in the database program Turboveg for Windows [97] and transferred into the Polish Vegetation Database [98].

The hierarchical classification of the syntaxonomic system follows Mucina et al. [70], as do scientific names of the superior syntaxa (from alliance to class). The names of plant associations of the order *Convolvuletalia sepium* were checked against the ICPN rules [99] and provided with common synonyms. The names of plant associations of other syntaxonomic groups followed Chytrý [100–103]. The nomenclature of vascular plants followed Mirek et al. [104], whereas that of liverworts and mosses followed Szweykowski [105] and Ochyra et al. [106], respectively. The list of plants invasive in Poland was compiled based on Tokarska-Guzik et al. [107], who adopted the following definition of invasive alien species: those aliens, which threaten biodiversity, human health or wellbeing, and/or socioeconomic interests.

Tab. 1 Characteristics of the rivers surveyed in NW Poland and their classification into size classes.

River	Length (km)	Catchment area (km^2)	Recipient	Number of sections	Number of relevés
Small rivers					
Prostynia	9.0	-	Drawa	1	3
Płutnica	9.0	-	Baltic	1	3
Stobnica	15.0	-	Ina	1	2
Bielica	17.2	-	Kanał Nieborowski	1	1
Reczyca	19.3	-	Ina	1	1
Prusina	27.5	220.0	Wda	1	3
Piaśnica	28.6	325.0	Baltic	4	33
Korytnica	37.0	-	Drawa	3	2
Reda	51.0	485.0	Baltic	3	8
Krąpiel	70.0	640.2	Ina	2	6
Piława	82.0	1,352.0	Gwda	3	3
Radew	83.0	1,091.5	Parsęta	3	3
Myśla	95.6	1,334.0	Oder	3	3
Łupawa	98.7	924.5	Baltic	5	11
Łeba	117.0	1,801.0	Baltic	5	26
Ina	126.0	2,151.0	Oder	7	50
Słupia	138.6	1,620.0	Baltic	5	13
Parsęta	139.0	3,151.0	Baltic	5	5
Drawa	186.0	3,296.0	Noteć	6	9
Wda	198.0	2,325.0	Vistula	7	13
			Total	67	198
Large rivers					
Noteć	391.0	17,330.0	Warta	3	5
Warta	808.0	54,529.0	Oder	8	18
Oder	854.0	118,861.0	Szczecin Lagoon	8	22
Vistula	1,047.0	194,424.0	Gulf of Gdańsk	10	46
Szczecin Lagoon	-	-	-	5	11
			Total	34	102

3.3. Environmental data

For each vegetation sample the following data were collected:

- longitude and latitude of the mid-point of the relevé, as read in decimal degrees (DD format) from a Garmin GPSMap 60CSX GPS receiver;
- riverbed width (m), distance between the vegetation sample and the riverbed (m), and sample elevation (m) above the instantaneous river water level, which were all measured with a GLM 250 VF laser device;
- degree of shading estimated using a 3-point scale: 1 – no shading (full light); 2 – light shading; and 3 – strong shading;
- geomorphology (slope angle and aspect in degrees; in case of flat banks, the aspect indicated the direction that the vegetation sample was facing toward the river);
- water regime (presence of headwater seeps, traces of summer flooding, and drainage ditches), and flow rate as estimated using a 5-point scale, based on Jusik et al. [108]: 1 – no perceptible flow; 2 – smooth flow; 3 – rippled flow; 4 – standing waves; and 5 – chute;
- natural potential vegetation cartographic units from the map at a scale of 1:300,000 developed by Matuszkiewicz [109]; the nomenclature of the units followed that of the map legend;
- adjacent vegetation facing the riverbed on one side and the bank and land on the other, divided into seven major categories: aquatic communities, rushes, meadows and grasses, tall herbs, forests and shrubs, ruderal assemblages, and segetal assemblages;
- the dominant form of land use divided into nine major categories: urban areas, arable land, meadows and pastures, shrubs, deciduous forests, coniferous forests, fish culture ponds, tourism, and transportation (roads, bridges);
- soil samples (three soil samples collected using Egner's soil sampler from the plant root zone (0–20 cm) were mixed to form a single sample representative of a given vegetation sample); each sample was air-dried, crushed, and passed through a set of sieves; the physicochemical soil parameters included [110]: (***i***) organic matter content defined as the loss on ignition (LOI) at 550°C (%), used to divide the soils into mineral (LOI below 10%), mineral-organic (LOI between 10% and 20%), and organic (LOI > 20%); (***ii***) the weight percentage of soil skeleton (over 1 mm diameter) (%); (***iii***) granulometric composition (proportion of sand, silt, and clay), as determined using Bouyoucos's sedimentation method with Casagrande's and Prószyński's modification; the data obtained were used to divide mineral and mineral-organic soils into granulometric categories and agrotechnical weight categories, according to the PSSS [111] classification; (***iv***) soil pH (in 1 M KCl solution), determined potentiometrically; (***v***) soil calcium carbonate ($CaCO_3$) content (%), determined by Scheibler's method; (***vi***) organic carbon (C_{org}) content (%) determined using Tiurin's method, total nitrogen (N_{tot}) content (%) determined with Kjeldahl's method, and the C/N ratio; (***vii***) humus content (%) calculated based on van Bemmelen's coefficient using the formula: $\%humus = \%C_{org} \times 1.724$; (***viii***) the amount of available forms of soil nutrients (mg/100 g soil): phosphorus (P_2O_5) and potassium (K_2O) determined using the Egner–Riehm method, magnesium (MgO) using Schachtschabel's method, and calcium (CaO) determined spectrophotometrically (Unicam Solar 929) after dissolution in 0.5 M HCl; (***ix***) the assessment of bioavailable phosphorus, potassium, and magnesium in soils based on Polish reference standards [112–115]; (***x***) soil moisture content as hand-felt assessed directly in the field using a 4-point scale: 1 – dry; 2 – fresh; 3 – moist; 4 – wet.

3.4. Statistical analyses

3.4.1. Characteristics of the riparian tall herb fringe communities

Prior to phytosociological analyses, a compilation of alliances, plant associations and communities of the order *Convolvuletalia sepium*, distinguished in Poland to date, was prepared based on: (***i***) published reviews [36,37,61,68,116]; (***ii***) monographs on different vegetation types, e.g., peat bogs [117], salt marshes [118], or ruderal areas [58,60,119,120]; (***iii***) publications dealing with vegetation of certain areas, particularly sections of river valleys, e.g., the Vistula [75,121,122], Oder [48,123–125], Warta [76,78,79], lake shores [126,127], mid-field ponds [77,81,128], areas granted protection status or those proposed for protection as nature reserves [129–132], and landscape parks [80,133]; as well as (***iv***) other relevant papers [51,82,134–140].

The publications mentioned served as a basis to prepare lists of diagnostic species (characteristic and differential) for individual communities, which were used to identify vegetation units (see "Appendix 1"). The syntaxonomic approach of Polish authors was also compared with proposals by authors from other European countries, including the original diagnoses of individual plant associations [35,57,59,62–67,69–72,141–160], to obtain a general picture of the variability of riparian tall herb fringe communities.

For all analyses, cover-abundance data of plants in relevés were transformed from the Braun-Blanquet scale into a 1–9 ordinal scale [161] as follows: r = 1; + = 2; 1 = 3; 2 = 5; 3 = 7; 4 = 8; 5 = 9. Shrub-layer and herb-layer records were merged for every plant species, such that each species occurred only once in the dataset [100,116]. The vegetation data yielded a matrix of 300 samples consisting of 282 species.

To obtain groups of relevés that were similar in species composition, agglomerative hierarchical cluster analysis using the average linkage and unweighted pairs of groups (UPGMA) was performed with the software MVSP 3.2 [162]. Jaccard's coefficient as a qualitative and percent similarity, as a quantitative similarity measure, were used [163]. Then, two dendrograms were compiled according to the strict consensus partitioning principle to achieve a new division of relevés, considering the similarity between the two initial classifications [96,164]. Grouped this way, the relevés were placed in an analytical table, and communities having the rank of an association or subassociation were identified based on prepared lists of diagnostic species (see "Appendix 1"), as were those without any syntaxonomic rank. A few floristically aberrant relevés were reassigned to the clusters they were most closely related. Subsequently, the units distinguished were synthesized into a synoptic table containing data representing the percent frequency of individual taxa and their cover-abundance ranges.

Two measures to assess the level of invasion in the tall herb fringe vegetation, as well as the particular plant communities were used: invasive alien species richness per sample and percentage of invasive flora (a ratio of the number of invasive alien species and the total number of species in the sample expressed as a percentage). Community diversity (α-diversity) of the samples was determined with the Shannon–Wiener and evenness indices using the MVSP 3.2 software [162]. Then, the significance of differences among plant community richness and diversity, as well as the moss layer cover and the level of invasion was tested with the nonparametric Kruskal–Wallis test [165] and post hoc comparisons of mean ranks of all pairs of groups using STATISTICA ver. 10 software [166].

3.4.2. Characteristics of environmental conditions

The environmental data were imported into STATISTICA ver. 10 software [166] and the basic descriptive statistics (arithmetic mean, median, minimum and maximum values, standard deviation, coefficient of variation, and skewness) were calculated for all relevés together, as well as for relevés grouped by: (***i***) river size and (***ii***) plant community. Statistical analyses were applied to those groups that were represented by five and more samples. The Shapiro–Wilk test was used to test for normality of the environmental data distribution. Because of deviations from normality, the nonparametric ANOVA equivalents (Kruskal–Wallis test and the median test, with post hoc comparisons of mean ranks of all pairs of groups) for plant communities and the Mann–Whitney *U* test for river size were used to test for significance of differences between the groups. Relationships between various environmental variables were explored using Spearman rank correlations [165].

3.4.3. Patterns of species and sample distribution

The general vegetation patterns were analyzed based on ordination with the software package CANOCO 4.5 [167]. The detrended correspondence analysis (DCA), an indirect ordination method, was applied using detrending species data by segments to determine unimodality of species responses along the ordination axes. The environmental gradient length was expressed in species turnover standard deviation units (*SD*). Subsequently, DCA diagrams were plotted to explore major variation in species composition because the dataset required a unimodal response model [163,168].

The canonical correspondence analysis (CCA) was used to detect patterns of variation in the species data "best" explained by the environmental variables. Because CANOCO centers and standardizes the data, environmental variables expressed in different units were used simultaneously [168]. Ordinal variables, such as the river size, degree of shading, soil moisture, and water flow rate were treated as quantitative [169]. Each nominal response variable was represented by a series of dummy variables (categories) arranged in a presence/absence data matrix. To include adjacent vegetation facing both the riverbed and the bank and land, fuzzy coding [167] was applied. A total of 27 environmental variables (Tab. 2), including seven nominal and binary, represented by a total of 38 categories, were entered into the CCA. Three variables, namely humus, organic carbon, and total nitrogen content, were excluded from the analysis because they were almost perfectly correlated with the organic matter content (LOI) and with each other and produced high variance inflation factors (VIFs) [170].

The pattern of species and sample distribution along the environmental variable gradients were analyzed based on the resultant CCA ordination diagrams [163]. To determine whether the "arch effect" in CCA masked some of the results, the detrended canonical correspondence analysis (DCCA) was also performed using detrending species data by second polynomials [167]. Statistical significance and relative importance of variables in variation of the vegetation were tested by the Monte Carlo permutation test with 499 unrestricted permutations, and the forward selection of environmental variables. Variation in the vegetation explained by all the environmental predictors included in the analysis was calculated from the ratio of the sum of all canonical eigenvalues to the value of total variance (total inertia) and expressed as a percentage. Variation in the vegetation explained by individual variables was calculated from the ratio of Lambda A (conditional effect of each variable in the model) to the total variance and was also expressed as a percentage [167].

The discrepancy between the order of variables sorted based on their conditional effects (Lambda A) exercised upon the species data (i.e., the partial effect that depends on the variables already selected in the model) and the order achieved by the ordination model using each variable as the only explanatory variable (the so-called marginal effect, Lambda 1) results from correlations between the environmental variables. Explanatory variables that were correlated shared some of their explanatory power, the amount of which could be estimated using partial constrained ordinations. Therefore, environmental variables were divided into four groups: (***i***) hydrogeomorphic variables, (***ii***) soil parameters, (***iii***) potential and actual vegetation, and (***iv***) land use (Tab. 2), and then the variation partitioning procedure was applied to calculate the part of the variance explained by each group of factors, after excluding the variance explained by all other groups [168].

Finally, the statistically significant variables that best discriminated among the plant communities were identified using the canonical variates analysis (CVA) with CANOCO 4.5. Hill's scaling with focus on inter-species distances was chosen. A permutation test was used to determine whether the differences between the relevé groups were statistically significant [167].

Tab. 2 Environmental variables included into direct ordination analyses performed with riparian tall herb fringe relevés of NW Poland.

Parameter	Unit / Type of scale	Abbreviation	Parameter	Unit /Type of scale	Abbreviation
I. Hydrogeomorphic variables			**II. Soil parameters**		
I.1. Longitude	°	Long	II.1. Loss on ignition	%	LOI
I.2. Latitude	°	Latit	II.2. Soil skeleton	%	skelet
I.3. Slope	°	Slope	Granulometric group	Nominal	-
I.4. Aspect	°	Asp	II.3. Loose sand	-	LoSa
I.5. River size	Quant. (1–2)	RS	II.4. Slightly loamy sand	-	SLSa
I.6. River bed width	m	RW	II.5. Loamy sand	-	LSa
I.7. River bed-sample distance	m	SDist	II.6. Sandy loam	-	SaL
I.8. Relative sample elevation	m	SElev	II.7. Light loam	-	LiL
I.9. Degree of shading	Quant. (1–3)	Shad	II.8. Loam	-	L
I.10. Headwater seeps	Binary	Seeps	II.9. Loamy silt	-	LSi
I.11. Summer flooding	Binary	Flood	II.10. Clayey silt	-	ClSi
I.12. Drainage ditches	Binary	Ditch	II.11. Organic soil	-	Org
I.13. Flow rate	Quant. (1–5)	Flow	II.12. Soil pH	-	pH
III. Potential and actual vegetation			II.13. Soil moisture content	Quant. (1–4)	Moist
Adjacent phytocoenoses	Nominal	-	II.14. C/N ratio	-	C/N
III.1. Aquatic communities	-	aquatic	II.15. Calcium carbonate	%	$CaCO_3$
III.2. Rushes	-	rushes	II.16. Available phosphorus	mg/100 g	P_2O_5
III.3. Meadows and grasses	-	grasses	II.17. Available potassium	mg/100 g	K_2O
III.4. Tall herbs	-	herbs	II.18. Available magnesium	mg/100 g	MgO
III.5. Forests and shrubs	-	forest	II.19. Available calcium	mg/100 g	CaO

Tab. 2 Continued

Parameter	Unit / Type of scale	Abbreviation	Parameter	Unit / Type of scale	Abbreviation
III.6. Ruderal assemblages	-	ruderal	**IV. Land use**		
III.7. Segetal assemblages	-	segetal	Land use type	Nominal	-
Natural potential vegetation	Nominal	-	IV.1. Urban areas	-	Ur
III.8. *Salici-Populetum*	-	Sa-Po	IV.2. Arable land	-	Ar
III.9. *Fraxino-Alnetum*	-	Fr-Al	IV.3. Meadows and pastures	-	Me
III.10. *Carici elongatae-Alnetum*	-	Ca-Al	IV.4. Shrubs	-	Sh
III.11. *Ficario-Ulmetum typicum*	-	Fi-Utp	IV.5. Deciduous forests	-	DF
III.12. *F-U chrysosplenietosum*	-	Fi-Uch	IV.6. Coniferous forests	-	CF
III.13. *Stellario-Carpinetum*	-	St-Ca	IV.7. Fish culture ponds	-	Po
III.14. *Fago-Quercetum*	-	Fa-Qu	IV.8. Tourism	-	To
III.15. *Melico-Fagetum*	-	Me-Fa	IV.9. Transportation	-	Tr
III.16. *Leucobryo-Pinetum*	-	Le-Pi			
III.17. *Empetro nigri-Pinetum*	-	Em-Pi			

4. Results

4.1. Cluster analysis and identification of plant communities of the order *Convolvuletalia sepium*

The dendrogram (Fig. 2) resulting from the agglomerative hierarchical classification with quantitative comparisons of relevés exhibited five main clusters (A–E). Cluster A had the largest number of relevés (139) and was clearly divided into six subclusters defined as A1, A2, A3, A4, A5, and A6. Subclusters A4 (30 relevés) and A5 (19 relevés) were assigned to the *Epilobio hirsuti-Convolvuletum sepium* and *Soncho palustris-Archangelicetum litoralis*, respectively, on the basis of significant coverage of diagnostic species (Appendix 1), i.e., *Epilobium hirsutum* in the first association and *Angelica archangelica* subsp. *litoralis* in the other. Subcluster A6 contained two vegetation samples dominated by *Cirsium arvense*, which were assigned to the *Cirsium arvense* community. Subclusters A2 (two relevés) and A3 (11 relevés) had samples dominated by alien plants, being *Helianthus tuberosus* and *Impatiens glandulifera*, respectively, which belong to neophytes forming their own plant communities (*Helianthus tuberosus* community, *Impatiens glandulifera* community). Based on the numerical classification of both subclusters and the comparison of the two dendrograms (Fig. S1), four relevés from Subcluster A3 could be assigned to the native plant communities, *Eupatorietum cannabini typicum* (two relevés) and *aegopodietosum* (one relevé), and *Epilobio hirsuti-Convolvuletum sepium* (one relevé), because their diagnostic species (Appendix 1) were still present and quite abundant.

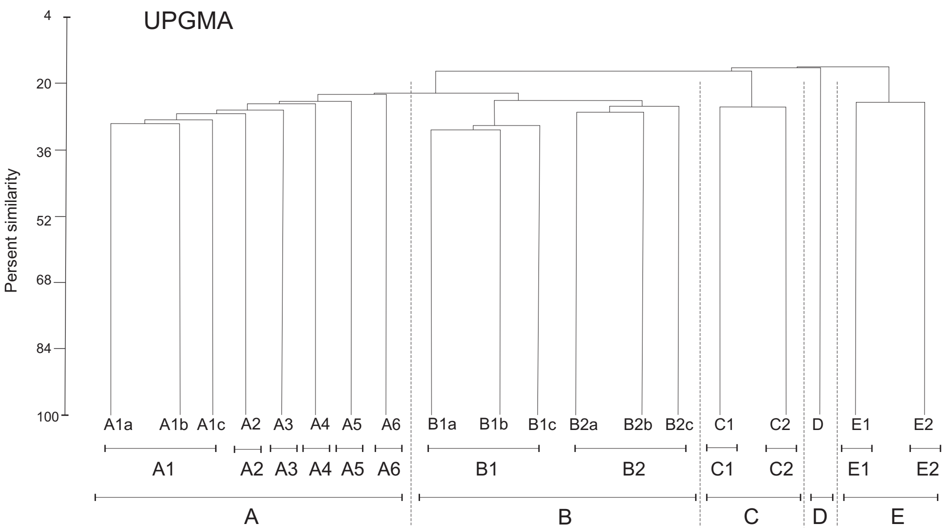


Fig. 2 Cluster analysis of riparian tall herb fringe communities of the order *Convolvuletalia sepium* from NW Poland.

Subcluster A1 (75 relevés) was further divided into three subsets of samples, namely A1a (three relevés), A1b (70 relevés), and A1c (two relevés); however, their identification with particular syntaxa was not clear. Based on the numerical classification and the comparison of the two dendrograms (Fig. S2), as well as the lists of diagnostic species (Appendix 1), four main plant communities were distinguished: *Urtico-Convolvuletum sepium typicum* (11 relevés) and *aegopodietosum* (31 relevés), both syntaxa dominated by *Urtica dioica* and *Calystegia sepium*, the latter subassociation with additional participation of *Aegopodium podagraria* and *Lamium maculatum*; the *Urtica dioica* community (15 relevés), characterized by the lack of *Calystegia sepium* and the total domination of nettle; the *Convolvulo sepium-Cuscutetum europaeae aegopodietosum* (13 relevés) with constant presence of *Cuscuta europaea*, as well as *Aegopodium podagraria* and *Lamium maculatum*. Additionally, based on characteristic species (Appendix 1), four relevés were assigned to *Soncho palustris-Archangelicetum litoralis* and one relevé to *Eupatorietum cannabini aegopodietosum*. These five relevés were linked to Cluster A1 because of a significant contribution of *Urtica dioica* and *Calystegia sepium* and the lower abundance of species characteristic of the associations they represent.

Cluster B, containing 102 relevés, was the second largest cluster in the dataset. It was divided into two main subclusters defined as B1 and B2 (Fig. 2). Subcluster B1 contained 92 relevés. It was further divided into three subsets defined as B1a (46 relevés), B1b (42 relevés), and B1c (four relevés). Based on the numerical classification of subcluster B1a (Fig. S3) and the lists of diagnostic species (Appendix 1), two main associations were distinguished: *Convolvulo sepium-Cuscutetum europaeae* with two subassociations, i.e., *typicum* (19 relevés) and *aegopodietosum* (four relevés), both syntaxa with *Cuscuta europaea* as the characteristic species of the association, and the latter with the additional presence of species from the *Aegopodion podagrariae* alliance and that of *Achilleo salicifoliae-Cuscutetum lupuliformis* (21 relevés), with *Cuscuta lupuliformis* and *Achillea salicifolia* as the species characteristic of the association. Additionally, on the basis of dominant species and the lack of diagnostic species, one relevé was assigned to the *Rubus caesius* community and one relevé was assigned to that of *Urtico-Convolvuletum sepium typicum*.

The numerical classification of the two other subclusters, B1b and B1c (Fig. S4), allowed to distinguish five main plant communities: *Senecionetum fluviatilis* (nine relevés) with significant cover of *Senecio fluviatilis* as the characteristic species (Appendix 1); the *Fallopio-Cucubaletum bacciferi* (nine relevés) characterized by the constant and abundant presence of *Cucubalus baccifer* as the characteristic species; the *Rubus caesius* community (three relevés) characterized by the lack of diagnostic species and the total domination of *Rubus caesius*; the *Solidago gigantea* community (nine relevés), which was totally dominated by the name-giving invasive neophyte; and *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* subass. nov. (15 relevés) with *Cuscuta europaea* as species characteristic of the association and additional participation of *Chaerophyllum bulbosum*, which gives this community specific physiognomy and makes it different from the previously described subassociations (Appendix 1). Additionally, one relevé was characterized by the lack of *Chaerophyllum bulbosum* and was assigned to *Convolvulo sepium-Cuscutetum europaeae typicum*; this relevé was linked to Subcluster B1b because of a small amount of *Solidago gigantea*, the species present in all the relevés of this subcluster and, in turn, absent in Subcluster B1a.

Subcluster B2 groups 10 relevés further divided into three subsets of samples, namely B2a (five relevés), B2b (two relevés), and B2c (three relevés), exhibiting a low level of similarity with Subcluster B1 in terms of species composition (Fig. 2). Moreover, Subclusters B2a and B2c floristically clearly refer to Subcluster A1. Based on the numerical classification of Subcluster B2 and the comparison of the two dendrograms (Fig. S5), Subcluster B2b with two relevés and dominated by *Fallopia dumetorum* was classified as the *Fallopia dumetorum* community and one relevé from B2a dominated by *Rubus caesius* was classified as the *Rubus caesius* community. The next two relevés were assigned to the *Convolvulo sepium-Cuscutetum europaeae aegopodietosum* because of the presence of *Cuscuta europaea* as the characteristic species of the association and *Aegopodium podagraria* and *Lamium maculatum* as the diagnostic species of the subassociation (Appendix 1). Two relevés were assigned to the *Urtico-Convolvuletum sepium aegopodietosum* based on the dominance of *Urtica dioica* and *Calystegia sepium*, as well as the presence of *Aegopodium podagraria* and *Lamium maculatum*, whereas the last three relevés, which were characterized by the lack of *Calystegia sepium*, were classified as the *Carduus crispus* community (two relevés) and the *Urtica dioica* community (one relevé) based on the dominant species.

The relevés grouped into Cluster C (Fig. 2) were distinct because of the abundance of *Eupatorium cannabinum*, a species characteristic of the *Eupatorietum cannabini* association. This cluster was clearly divided into two subclusters defined as C1 (28 relevés) and C2 (seven relevés). Based on the numerical classification and the comparison of the two dendrograms (Fig. S6), two subassociations (one typical and the other with *Aegopodium podagraria*) were distinguished within Subcluster C1. In turn, Subcluster C2 was referred to a new subassociation, the *Eupatorietum cannabini cardaminetosum amarae* subass. nov., because of the specific species composition. Cluster D contained two relevés, both dominated by the alien species *Reynoutria japonica*, and was therefore assigned to the *Reynoutria japonica* community. Finally, Cluster E was divided into two subclusters, namely E1 (15 relevés) and E2 (seven relevés), which represented two specific plant communities: the *Rubus idaeus* community and the *Galeopsis speciosa* community, respectively.

Considering the results of the numerical classification, riparian tall herb fringe communities identified in northwestern Poland were included into the syntaxonomic system in the following way:

Class *Epilobietea angustifolii* Tx. et Preising ex von Rochow 1951
- Order *Convolvuletalia sepium* Tx. ex Moor 1958
    - *Reynoutria japonica* community (*Convolvuletalia sepium*)
    - *Rubus idaeus* community (*Convolvuletalia sepium*)
    - *Galeopsis speciosa* community (*Convolvuletalia sepium*)
    - Alliance *Senecionion fluviatilis* Tx. ex Moor 1958
        - *Senecionetum fluviatilis* Müller ex Straka in Mucina 1993
        - *Fallopio-Cucubaletum bacciferi* Passarge 1976
        - *Achilleo salicifoliae-Cuscutetum lupuliformis* Tx. ex Passarge 1993
        - *Convolvulo sepium-Cuscutetum europaeae* Tx. ex Lohmeyer 1953
            - *C.s.-C.e. chaerophylletosum bulbosi* Myśliwy subass. nov. hoc loco
            - *C.s.-C.e. typicum* Kopecký 1969
            - *C.s.-C.e. aegopodietosum* Lohmeyer 1975
        - *Rubus caesius* community (*Senecionion fluviatilis*)
        - *Fallopia dumetorum* community (*Senecionion fluviatilis*)
        - *Solidago gigantea* community (*Senecionion fluviatilis*)
    - Alliance *Archangelicion litoralis* Scamoni et Passarge 1963
        - *Urtico-Convolvuletum sepium* Görs et Müller 1969

U.-C.s. typicum Görs 1974
U.-C.s. aegopodietosum Görs 1974
Soncho palustris-Archangelicetum litoralis Tx. 1937
Epilobio hirsuti-Convolvuletum sepium Hilbig et al. 1972
Eupatorietum cannabini Tx. 1937
E.c. typicum Görs 1974
E.c. aegopodietosum Görs 1974
E.c. cardaminetosum amarae Myśliwy subass. nov. hoc loco
Cirsium arvense community (*Archangelicion litoralis*)
Carduus crispus community (*Archangelicion litoralis*)
Urtica dioica community (*Archangelicion litoralis*)
Impatiens glandulifera community (*Archangelicion litoralis*)
Helianthus tuberosus community (*Archangelicion litoralis*)

4.2. Description of plant communities

The riparian tall herb fringe communities of the order *Convolvuletalia sepium* contained on average 16 species per vegetation sample plot, ranging from 5 to 31 species. The Shannon–Wiener index averaged 3.77 (range: 2.1–4.77) and the evenness index was relatively high (average: 0.95). Statistically significant differences in the number of species were found between the vegetation samples from large rivers and the more species-poor samples from small rivers. Similarly, the respective Shannon and evenness indices differed significantly as well, being higher for large rivers. Between-community comparisons of species richness and diversity revealed significant differences between *Urtico-Convolvuletum sepium* on the one hand and *Convolvulo sepium-Cuscutetum europaeae* and *Soncho palustris-Archangelicetum litoralis* on the other (Fig. 3).

The riparian tall herb fringe communities belonged to multilayered assemblages. The shrub layer was absent from more than 80% of vegetation samples. In more than 10% of samples, the shrub layer attained coverage as small as 5%, and the maximum shrub layer coverage was 35%. The herb layer often covered 100% of the relevé area, with 85–95% coverage being less common. The communities studied were characteristic in their herb layer, which was subdivided into two or three sublayers differing in height. In 70% of vegetation sample plots, the moss layer was absent. In approximately 20% of samples, mosses covered 5–10% of the relevé area. There were also individual riparian tall herb fringe vegetation samples with the moss layer covering 50% and more of the relevé area. Additionally, a significant difference in the moss layer coverage was found between vegetation samples from large river valleys and those from small rivers where the coverage was greater (Fig. 3). A comparison between plant communities revealed a significant difference between the *Eupatorietum cannabini* and *Convolvulo sepium-Cuscutetum europaeae*; the moss layer coverage in the latter vegetation unit was lower. Vegetation samples with both the shrub and moss layers and two or three herbaceous sublayers were relatively rare (5% of samples).

Of the 282 species recorded in the riparian tall herb fringe communities in northwestern Poland, 27 (9.6%) are species alien to the natural flora of this area, including 11 archaeophytes,

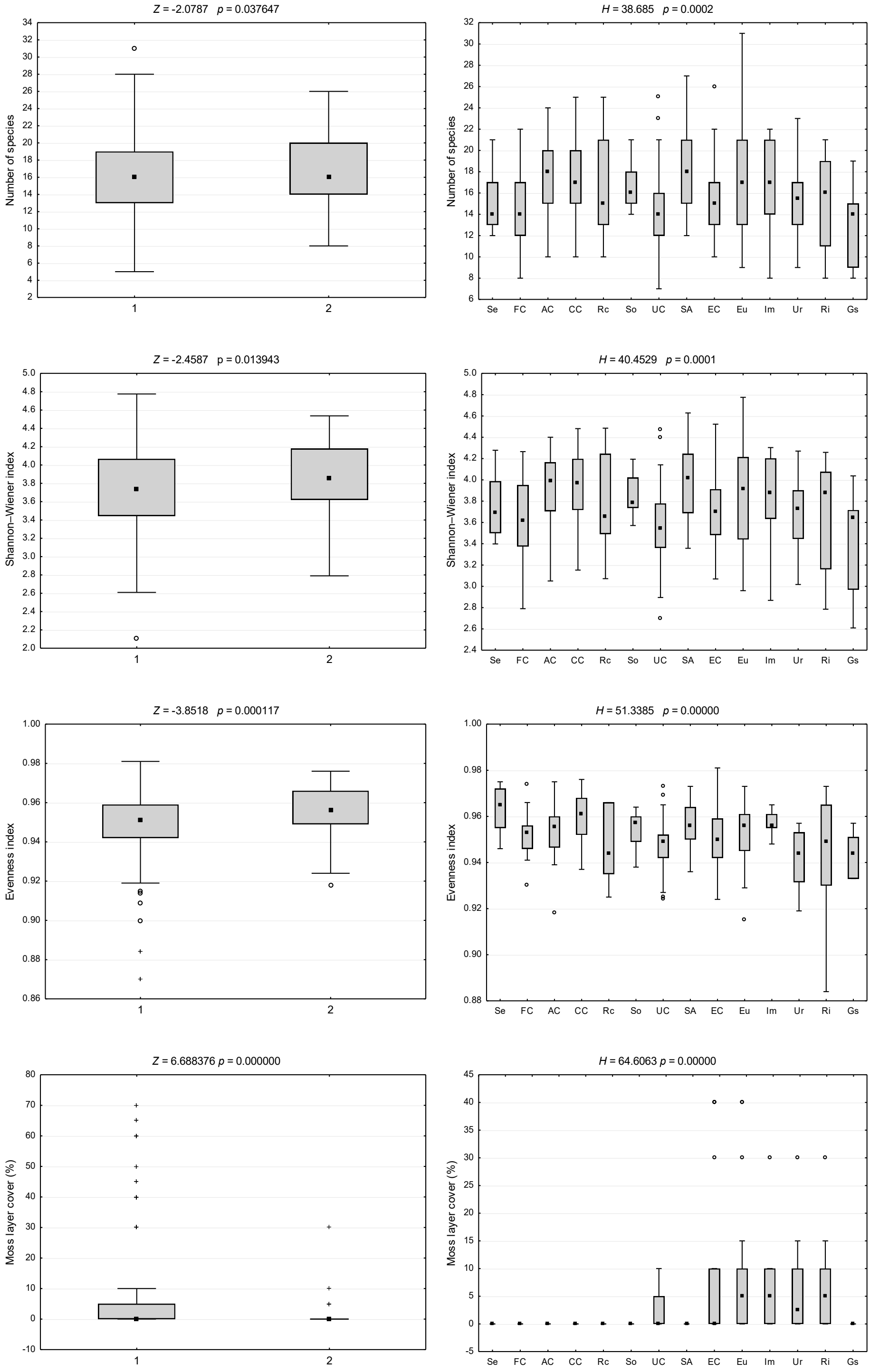

Z = -2.0787 p = 0.037647
Number of species
1
2
H = 38.685 p = 0.0002
Number of species
Se FC AC CC Rc So UC SA EC Eu Im Ur Ri Gs
Z = -2.4587 p = 0.013943
Shannon–Wiener index
1
2
H = 40.4529 p = 0.0001
Shannon–Wiener index
Se FC AC CC Rc So UC SA EC Eu Im Ur Ri Gs
Z = -3.8518 p = 0.000117
Evenness index
1
2
H = 51.3385 p = 0.00000
Evenness index
Se FC AC CC Rc So UC SA EC Eu Im Ur Ri Gs
Z = 6.688376 p = 0.000000
Moss layer cover (%)
1
2
H = 64.6063 p = 0.00000
Moss layer cover (%)
Se FC AC CC Rc So UC SA EC Eu Im Ur Ri Gs

Fig. 3 Box and whisker plots of species richness and diversity in riparian tall herb fringe communities of the order *Convolvuletalia sepium* in NW Poland: comparison of small (1) and large (2) rivers as well as individual plant communities. The box length is the interquartile range; small squares indicate the median; circles represent outlier values; crosses reflect extreme values. Results of Mann–Whitney *U* (*Z* and *p* values) and Kruskal–Wallis (*H* and *p* values) tests are given. Complete names of plant communities: Se – *Senecionetum fluviatilis*; FC – *Fallopio-Cucubaletum bacciferi*; AC – *Achilleo salicifoliae-Cuscutetum lupuliformis*; CC – *Convolvulo sepium-Cuscutetum europaeae*; Rc – *Rubus caesius* community; So – *Solidago gigantea* community; UC – *Urtico-Convolvuletum sepium*; SA – *Soncho palustris-Archangelicetum litoralis*; EC – *Epilobio hirsuti-Convolvuletum sepium*; Eu – *Eupatorietum cannabini*; Im – *Impatiens glandulifera* community; Ur – *Urtica dioica* community; Ri – *Rubus idaeus* community; Gs – *Galeopsis speciosa* community.

i.e., plants which arrived and established themselves before the end of the fifteenth century (46 records) and 16 neophytes, i.e., plants which arrived and established themselves after the fifteenth century (169 records). Vegetation samples contained from zero to five alien species (average 0.7). All alien species occurred in a total of 128 relevés, which represented 42.7% of all samples. The most frequently recorded archaeophytes included *Fallopia convolvulus*, *Silene alba*, and *Lactuca serriola*, which were recorded in 13, 12, and 10 relevés, respectively. Neophytes were more common, with the most common being *Solidago gigantea*, recorded in 37 relevés.

4.2.1. *Senecionetum fluviatilis* Müller ex Straka in Mucina 1993 (Se) (Fig. 4)

Syn.: *Senecionetum fluviatilis* (Zahlheimer 1979) T. Müller in Oberdorfer et al. 1983. Incl.: "Flussgreiskraut-Schleier-Gesellschaft" Runge 1975, *Senecio fluviatilis-Gesellschaft* Zahlheimer 1979.

Floristic composition, physiognomy, and structure. This vegetation unit grouped 12–21 species per sample (average 15). The shrub layer was sporadic and hardly compact, the moss layer being absent altogether. The herb layer frequently covered 100% of the sample area and consisted of two or three sublayers. The highest sublayer was approximately 150 cm tall, and was composed of *Senecio fluviatilis* and *Urtica dioica*, *Cirsium arvense*, *Scrophularia nodosa*, and *Carduus crispus*. The most frequent grasses were: *Elymus repens*, *Phalaris arundinacea*, *Poa palustris*, and *Bromus inermis*. The middle sublayer was 50–70 cm tall, and was dominated by *Rubus caesius*. The lowest herb sublayer was formed mostly by *Glechoma hederacea*. The creepers, such as *Calystegia sepium*, *Galium aparine*, *Humulus lupulus*, *Cuscuta europaea*, *Cucubalus baccifer*, were also an important component of the community.

The *Senecionetum fluviatilis* association was often invaded by *Solidago gigantea*, a species being present in 78% of samples representing this association, and occasionally attaining fairly extensive coverage (Se in Tab. 3).

Conditions of occurrence. The community most often occurred on sunny or slightly shaded sites. The riverbanks were flat or sloping (to 30°), 2.5–4.5 m high, facing east, northwest, or southeast. The vegetation samples were collected 1–20 m away from the riverbed, within a reach of the natural potential vegetation unit *Salici-Populetum*. The soils were mineral,

Fig. 4 *Senecionetum fluviatilis* in Vistula valley (photo M. Myśliwy, 2012-06-30).

alkaline, moist or fresh, most often being light or sandy loams. Arable land or shrubs were the dominant land use forms. Riverward, vegetation samples were most often in contact with other tall herb fringe communities, with the communities dominated by *Calamagrostis epigejos* or *Salix viminalis*. Landward, samples neighbored weedy communities in grain crops, riparian forests of *Salicion albae*, *Salix viminalis* shrubs, or ruderal vegetation.

Distribution in northwestern Poland. The Vistula River valley.

4.2.2. *Fallopio-Cucubaletum bacciferi* Passarge 1976 (FC) (Fig. 5)

Incl.: *Cucubalus-Polygonum dumetorum*-Gesellschaft Passarge 1965.

Floristic composition, physiognomy, and structure. Samples of this vegetation unit contained from 8 to 22 plant species (average: 14). The shrub layer was very rare. When occurring, it was poorly compacted. The moss layer was absent. The herb layer most frequently covered 100% of the relevé area and was divided into two or three sublayers. The highest herb sublayer (140–160 cm tall, 200 cm at the maximum) was composed of *Urtica dioica*, *Chaerophyllum bulbosum*, *Phalaris arundinacea*, *Elymus repens*, and *Carduus crispus*, as well as the neophyte *Solidago gigantea*. *Rubus caesius*, with its creeping stems, formed the middle sublayer (50–70 cm tall) and covered up to half of the relevé area. The lowest herb sublayer was most often composed of *Glechoma hederacea*. In addition to *Cucubalus baccifer*, which attained

Fig. 5 *Fallopio-Cucubaletum* in Vistula valley (photo M. Myśliwy, 2012-07-02).

the optimum and largest coverage in this association, the climbing species often included *Humulus lupulus*, *Cuscuta europaea*, *Calystegia sepium*, *Galium aparine*, and sporadically *Fallopia dumetorum* (FC in Tab. 3).

Conditions of occurrence. The vegetation unit occurred on flat or sloping (to 30°), 0.7–3.5(6) m high riverbanks, facing east, southeast, or northwest, and experiencing varying degrees of shading. The vegetation samples were usually collected 2–20 m away from the riverbed, within a reach of the natural potential vegetation unit *Salici-Populetum*. The soils were mineral, alkaline or neutral, fresh, and usually classified as loamy sands and sandy loams. Shrubs and arable land were often the dominant land use forms. Riverward, vegetation samples were in contact with the *Phalaridetum arundinaceae*, and less frequently with a riparian forests of *Salicion albae*, whereas landward they were in contact with the riparian willow-poplar forests, hygrophilous forms of shrubs of the order *Prunetalia spinosae*, weedy communities in grain crops, and others.

Distribution in northwestern Poland. The Vistula River valley.

4.2.3. *Achilleo salicifoliae-Cuscutetum lupuliformis* Tx. ex Passarge 1993 (AC) (Fig. 6–Fig. 10)

Syn. *Achilleo cartilagineae-Cuscutetum lupuliformis* (Hueck 1930) Tx. 1950, *Convolvulo-Rubetum caesii* Pass. 1967 sensu Borysiak 1994, *Achilleo salicifoliae-Cuscutetum lupuliformis* Tx. ex Brzeg et Wojterska 2001.

Floristic composition, physiognomy, and structure. This vegetation unit consisted of 10–24 plant species per sample (average 18). The shrub layer, which was fairly common (45% of the relevés, 5–35% of cover), was mainly composed of *Salix viminalis* and *S. fragilis*, and seldom of *S. purpurea* or *Ulmus laevis*. A moss layer was not recorded. In the herb layer, the highest coverage was typical of medium-tall (50–70 cm) plants, including *Rubus caesius*, *Stachys palustris*, *Achillea salicifolia*, *Atriplex prostrata* subsp. *latifolia*, *Bidens frondosa*, *Vicia cracca*, *Erysimum cheiranthoides*, *Rorippa palustris*, and *Galium elongatum*. The highest (usually 110–170 cm tall) herb sublayer was formed by *Urtica dioica*, *Phalaris arundinacea*, *Elymus repens*, *Artemisia vulgaris*, *Carduus crispus*, and *Calamagrostis epigejos*. *Glechoma hederacea* formed the lowest herb sublayer. Creeping plants, which included *Calystegia sepium*, *Cuscuta lupuliformis*, *Galium aparine*, *Fallopia dumetorum*, and less frequently *Cuscuta europaea*, as well as the invasive *Echinocystis lobata*, were an important component of the community (AC in Tab. 3).

Conditions of occurrence. The community occurred on flat or sloping (15–30°) riverbanks, most often less than 1 m high, facing usually southwest or north. The sites were fully sunlit, or occasionally lightly shaded. The vegetation samples were encountered 2–20 (40) m away from the riverbed, within a reach of the natural potential vegetation unit *Salici-Populetum*. The soils were mineral or mineral-organic, neutral or slightly acidic, fresh, and most often loamy or slightly loamy sands. Shrubs or meadows and pastures usually were the dominant land use forms. Riverward, vegetation samples most often were in contact with the riparian willow forests, summer therophytes of the class *Bidentetea*, or rushes (*Phalaridetum arundinaceae*, *Phragmitetum australis*). Landward, they adjoined the *Phalaridetum arundinaceae*, other tall herb fringe communities, ruderal communities, and others.

Distribution in northwestern Poland. Valleys of the Warta, Oder, Noteć, and Vistula rivers.

4.2.4. *Convolvulo sepium-Cuscutetum europaeae* Tx. ex Lohmeyer 1953 (CC)

Syn.: *Convolvulo sepium-Cuscutetum europaeae* Tx. 1947, *Cuscuto-Calystegietum sepium* (Tx. 1947) Passarge 1976.

This vegetation unit occurred primarily in warm microhabitats of lowland river valleys. This was one of the most common communities of the riparian fringe herbs in northwestern Poland. The association was divided into three subassociations (CCh, CCt, and CCa in Tab. 3):

- ***Convolvulo sepium-Cuscutetum europaeae*** Tx. ex Lohmeyer 1953 ***chaerophylletosum bulbosi*** Myśliwy **subass. nov. hoc loco** (CCh) (Fig. 11, Fig. 12). **Type:** Tab. 4, Relevé 6 holotypus hoc loco. **Differential species of subassociation:** *Chaerophyllum bulbosum*

Fig. 6 *Achilleo salicifoliae-Cuscutetum lupuliformis* in Warta valley (photo J. Myśliwy, 2011-08-23).

Fig. 7 *Achilleo salicifoliae-Cuscutetum lupuliformis* in Warta valley (photo M. Myśliwy, 2013-07-24).

Fig. 8 *Achilleo salicifoliae-Cuscutetum lupuliformis* in Warta valley (photo M. Myśliwy, 2012-07-10).

Fig. 9 *Achilleo salicifoliae-Cuscutetum lupuliformis* in Warta – the same patch as above 1 year later, with larger cover of *Cuscuta* species (photo M. Myśliwy, 2013-07-24).

Fig. 10 *Achilleo salicifoliae-Cuscutetum lupuliformis* in Noteć valley (photo M. Myśliwy, 2013-07-25).

(transgr. *Acer negundo*, *Rumex confertus*). **Floristic composition, physiognomy, and structure:** Plant community with 12–25 species per relevé (the mean species richness exceeded 17). The shrub layer, covering 5–10%, occurred sporadically and was composed of, inter alia, *Salix viminalis*, *Ulmus laevis*, *Viburnum opulus*, and *Prunus spinosa*. The moss layer was absent. This subassociation was distinct because of the permanent and abundant presence of *Chaerophyllum bulbosum* and the intrusion of neophytes typical of large river valleys: *Solidago gigantea*, *Acer negundo*, and *Rumex confertus*. In addition to *C. bulbosum* and *S. gigantea*, the highest herb sublayer (140–200 cm) was composed of *Urtica dioica*, *Carduus crispus*, *Cirsium arvense*, *Phalaris arundinacea*, and *Elymus repens*, and less frequently *Artemisia vulgaris*, *Scrophularia nodosa*, *Calamagrostis epigejos*, *Tanacetum vulgare*, and *Bromus inermis*. The middle sublayer (50–70 cm) featured *Rubus caesius*, *Stachys palustris*, *Symphytum officinale*, *Vicia cracca*, *Erysimum cheiranthoides*, and *Bidens frondosa*. The lowest sublayer was composed mostly of *Glechoma hederacea*. Characteristic components were the climbers *Cuscuta europaea*, *C. lupuliformis*, *Humulus lupulus*, *Calystegia sepium*, and *Galium aparine* (CCh in Tab. 3, Tab. 4). **Conditions of occurrence:** The community most often occurred on sunlit, flat, and relatively high (1–4.5 m) banks, facing southeast, east, or northwest. Vegetation samples were taken 2–25 m away from the riverbed, within a range of the natural potential vegetation unit *Salici-Populetum*. The soils were mineral, neutral or alkaline, moist or fresh, usually being sandy or light loams. Shrubs and arable land were most often the dominant land use forms. From the river, the samples were adjacent to rushes (*Phalaridetum arundinaceae*), the *Salix viminalis* community, willow or poplar carrs, and others. Landward they adjoined other tall herb fringe communities, rushes, and willow shrubs and carrs. **Distribution in northwestern Poland:** The Vistula River valley.

Fig. 11 *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* subass. nov. in Vistula valley (photo J. Myśliwy, 2012-07-02).

Fig. 12 *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* subass. nov. in Vistula valley (photo M. Myśliwy, 2012-07-02).

- ***Convolvulo sepium-Cuscutetum europaeae*** Tx. ex Lohmeyer 1953 ***typicum*** Kopecký 1969 (CCt) (Fig. 13, Fig. 14). **Floristic composition, physiognomy, and structure:** The samples of the typical subassociation contained 10–23 plant species (the mean number exceeded 17). In approximately 25% of relevés the shrub layer was present and covered 5–20% of the area, and consisted primarily of *Salix fragilis*. The moss layer was absent. The herb layer covered 85–100% of the relevé area, with a maximum mean height of 170 cm; however, there were two or three sublayers differing in height. Compared to the previously described subassociation, *Echinocystis lobata* was more frequent, and accompanied by *Myosoton aquaticum*, *Atriplex prostrata* subsp. *latifolia*, and *Poa trivialis* (CCt in Tab. 3). Some of the phytocoenoses were devoid of the greater dodder (*Cuscuta europaea*), in which case *Phragmites australis*, *Bromus inermis*, *Poa trivialis*, *Carduus crispus*, *Artemisia vulgaris*, *Melandryum album*, *Humulus lupulus*, and *Galium aparine* were more frequent. **Conditions of occurrence:** The community was recorded on sunlit, flat, or tilted (to 45°) slopes facing south, southwest, southeast, and other directions. Vegetation samples were elevated on average 1 m above the river water level and occurred from 1 to 30 m away from the riverbed, within a range of the natural potential vegetation unit *Salici-Populetum*, and less frequently that of *Fraxino-Alnetum* or *Ficario-Ulmetum typicum*. The soils were mineral and mineral-organic, neutral and less frequently slightly acidic or alkaline, fresh or less frequently moist, usually loamy sands, slightly loamy sands, or sandy loams. The dominant land use forms were shrubs or meadows and pastures. Riverward, the samples most often adjoined rushes (*Phragmitetum australis*, *Phalaridetum arundinaceae*) and less frequently the riparian willow forests or the *Salix viminalis* shrubberies. The landward side was adjacent to fresh or moist meadow communities, tall herbs, ruderal plants, and other plant communities. **Distribution in northwestern Poland:** Valleys of the rivers Warta, Oder, Vistula, Ina, and Noteć, and the Szczecin Lagoon.
- ***Cuscuto europaeae-Convolvuletum sepium*** Tx. ex Lohmeyer 1953 ***aegopodietosum*** Lohmeyer 1975 (CCa) (Fig. 15, Fig. 16). **Floristic composition, physiognomy, and structure:** The relevés of this subassociation included 13–23 species (mean number exceeded 17). More than 20% of the relevés featured a shrub layer with *Salix viminalis* or *S. fragilis*. More than 35% of the relevés had a moss layer covering 5–10% of the surface area and composed mainly of *Brachythecium rivulare*, *B. rutabulum*, *B. oedipodium*, and *Eurhynchium hians*. The vegetation unit was distinct because of the presence of *Lamium maculatum*, *Aegopodium podagraria*, and *Heracleum sphondylium* subsp. *sibiricum*. However, it lacked some important species from the *Senecionion fluviatilis* alliance: *Stachys palustris*, *Erysimum cheiranthoides*, *Bidens frondosa*, *Bromus inermis*, and *Calamagrostis epigejos*, with *Rubus caesius* occurring rarely. Conversely, *Galeopsis speciosa*, *Stellaria nemorum*, *Cirsium oleraceum*, and *Filipendula ulmaria* occurred fairly frequently (CCa in Tab. 3). **Conditions of occurrence:** The community occurred on flat or tilted (to 45°) slopes facing different directions (mostly west, northeast, and northwest), and were sunlit or somewhat shaded. Vegetation samples usually did not protrude above the river water level more than 1 m. They were recorded at a distance from 0 to 7 m away from the riverbed, within a range of the natural potential vegetation unit *Fraxino-Alnetum*, and less frequently that of *Carici elongatae-Alnetum* or *Stellario-Carpinetum*. The soils were mineral and mineral-organic, slightly acidic or acidic, fresh or moist, usually being slightly loamy or loamy sands. The dominant types of land use were shrubs or meadows and pastures. On the river side, vegetation samples adjoined aquatic communities, rushes (*Phragmitetum*

Fig. 13 *Convolvulo sepium-Cuscutetum europaeae typicum* in Warta valley (photo M. Myśliwy, 2012-07-10).

Fig. 14 *Convolvulo sepium-Cuscutetum europaeae typicum* in Ina valley (photo M. Myśliwy, 2013-08-10).

Fig. 15 *Convolvulo sepium-Cuscutetum europaeae aegopodietosum* in Parsęta valley (photo M. Myśliwy, 2011-06-24).

Fig. 16 *Convolvulo sepium-Cuscutetum europaeae aegopodietosum* in Prusina valley (photo M. Myśliwy, 2009-07-16).

australis, *Phalaridetum arundinaceae*, and *Sparganietum erecti*), or less frequently, shrubs of *Salix viminalis*, *S. cinerea*, or *Alnus glutinosa*. Landward they were in contact with fresh or moist meadows, willow shrubberies, and alder carrs. **Distribution in northwestern Poland:** Valleys of the rivers Ina, Krąpiel, Słupia, Łeba, Parsęta, Radew, and Prusina.

4.2.5. *Rubus caesius* community (*Senecionion fluviatilis*) (Rc) (Fig. 17)

Floristic composition, physiognomy, and structure. This vegetation unit contained on average 17 plant species per sample (range 10–25). Floristically, the community was similar to the *Achilleo salicifoliae-Cuscutetum lupuliformis* and *Convolvulo sepium-Cuscutetum europaeae* associations, but its structure was simplified because it lacked a shrub layer, the moss layer occurred sporadically, and the herb layer, which usually consisted of only two sublayers, covered 90–100% of the relevé area. In addition to the dominant *Rubus caesius*, the most frequent taxa included *Calystegia sepium*, *Urtica dioica*, *Humulus lupulus*, *Galium aparine*, *Phalaris arundinacea*, *Phragmites australis*, *Lysimachia vulgaris*, *Vicia cracca*, and *Dactylis glomerata*, whereas *Cuscuta lupuliformis* and *C. europaea* were missing, as were some other species important in the *Senecionion fluviatilis* alliance: *Stachys palustris*, *Atriplex prostrata* subsp. *latifolia*, *Fallopia dumetorum*, and *Bromus inermis* (Rc in Tab. 3).

Conditions of occurrence. The community occurred on sunny or slightly shaded sites. The riverbanks were flat or sloping (10–15°), slightly elevated, facing east, northwest, or northeast.

Fig. 17 *Rubus caesius* community in Oder valley, after early summer flood (photo M. Myśliwy, 2010-07-03).

The vegetation samples were collected 3–50 m away from the riverbed, within a reach of the natural potential vegetation units *Salici-Populetum* or *Fraxino-Alnetum*. The soils were mineral and mineral-organic; slightly acidic, neutral, or alkaline; fresh, usually being sandy loams, loamy sands, and loose sands. The dominant land use forms were meadows and pastures or shrubs, transportation, and tourism. Riverward, vegetation samples were most often in contact with trampling communities, rushes (*Caricetum ripariae*, *Phalaridetum arundinaceae*), or riparian willow forests, whereas landward they were in contact with the *Phragmitetum australis* and *Salix viminalis* shrubs and others.

Distribution in northwestern Poland. Valleys of the rivers Oder, Vistula, and Piaśnica.

4.2.6. *Fallopia dumetorum* community (*Senecionion fluviatilis*) (Fa) (Fig. 18)

Two vegetation samples (Fa in Tab. 5), found in the Vistula River valley were characterized by the dominance of *Fallopia dumetorum*, accompanied by *Humulus lupulus*, *Carduus crispus*, *Artemisia vulgaris*, *Galeopsis bifida*, *Erysimum cheiranthoides*, *Chenopodium album*, and *Conyza canadensis*. The community was recorded on sunny, flat riverbanks, facing east. Vegetation samples were elevated 5–6 m above the river water level, occurred 0 and 5 m away from the riverbed, and within a range of the natural potential vegetation unit *Salici-Populetum*. Soils were mineral, alkaline, fresh, and classified as loamy and loose sands. They adjoined summer therophytes of the class *Bidentetea* and other tall herb fringe communities.

Fig. 18 *Fallopia dumetorum* community in Vistula valley (photo M. Myśliwy, 2012-07-04).

4.2.7. *Solidago gigantea* community (*Senecionion fluviatilis*) (So) (Fig. 19)

Floristic composition, physiognomy, and structure. This vegetation unit contained 14–21 plant species per sample (average number exceeded 16). The sparse shrub layer covered 5–10%, whereas the moss layer was absent. The herb layer covered 95–100% of the relevé area and was divided into two or three sublayers. The neophyte *Solidago gigantea*, a dominant of the highest sublayer (130–190 cm) was accompanied by *Urtica dioica*, *Cirsium arvense*, *Calamagrostis epigejos*, and *Elymus repens*, and in the middle sublayer (50–90 cm) by *Poa palustris*, *Vicia cracca*, *Erysimum cheiranthoides*, and *Stachys palustris*. The lowest herb sublayer was most often composed of *Glechoma hederacea*. A permanent component of the unit were the creepers *Humulus lupulus*, *Galium aparine*, and *Calystegia sepium* (So in Tab. 3). The floristic composition of relevés in large river valleys differed from those recorded in small river valleys. The first group also contained *Rubus caesius*, *Scrophularia nodosa*, *Cucubalus baccifer*, *Senecio fluviatilis*, *Chaerophyllum bulbosum*, and *Cuscuta europaea*, whereas those from small rivers supported *Stellaria nemorum*, *Filipendula ulmaria*, *Epilobium hirsutum*, and *Eupatorium cannabinum*, with *Calystegia sepium* exhibiting higher coverage.

Conditions of occurrence. The community occurred on slightly shaded sites. The riverbanks were flat and facing east, less frequently northeast, and had varying height. The vegetation samples were collected 0–20 m away from the riverbed, within a range of the natural potential vegetation unit *Salici-Populetum*; however, in small river valleys this was the *Fraxino-Alnetum*, *Stellario-Carpinetum*, or *Fago-Quercetum* unit. The soils were mineral, alkaline, moist, or fresh, usually classified as loamy sands. The dominant land use forms were arable land, with more

Fig. 19 *Solidago gigantea* community in Vistula valley (photo M. Myśliwy, 2012-07-03).

seldom meadows and pastures and others. Riverward, vegetation samples were most often in contact with *Salix viminalis* shrubs or the riparian willow forests, whereas landward they adjoined weed communities in grain crops, wet meadows, tall herbs, and willow carrs.

Distribution in northwestern Poland. Valleys of the rivers Vistula, Słupia, Łupawa, and Krąpiel.

4.2.8. *Urtico-Convolvuletum sepium* Görs et Müller 1969 (UC)

Syn.: *Urtico-Calystegietum* sensu auct. Incl.: *Urtica dioica-Convolvulus sepium*-Gesellschaft Lohmeyer 1975.

Floristic composition, physiognomy, and structure. This vegetation unit was very common in northwestern Poland and belonged to species-poor riparian fringe herb communities (on average 14 plant species per sample, range 7–25). The shrub layer was sporadic. When it occurred, it was composed of *Salix fragilis*, *S. cinerea*, *S. purpurea*, or *Ribes nigrum*. In 40% of relevés, the moss layer was present, and was primarily composed of *Plagiomnium undulatum*, *Brachythecium rutabulum*, *B. oedipodium*, *B. rivulare*, and *Eurhynchium hians*. The herb layer covered 90–100% of the sample area and was divided into two, or less frequently three, sublayers. The core of the unit were the lush aggregations of *Urtica dioica* with *Calystegia sepium* and *Galium aparine*. Also present were *Phragmites australis*, *Galeopsis speciosa*, *Cirsium arvense*, *Elymus repens*, *Filipendula ulmaria*, *Poa trivialis*, *Phalaris arundinacea*, *Carex acutiformis*, *Anthriscus sylvestris*, and – in the lowest herb sublayer – *Glechoma hederacea*. The unit differed from the association *Convolvulo sepium-Cuscutetum europaeae* because of the absence of *Cuscuta europaea*, *Rubus caesius*, *Erysimum cheiranthoides*, and *Bidens frondosa*, as well as the distinctly lower occurrence of *Fallopia dumetorum*, *Stachys palustris*, and *Poa palustris*. The association was divided into two subassociations (UCt and UCa in Tab. 3):

- ***Urtico-Convolvuletum sepium*** Görs et Müller 1969 ***typicum*** Görs 1974 (UCt) (Fig. 20). The typical subassociation most frequently supported *Cirsium arvense*, which could occur in large patches and form facies. The contributions of *Vicia cracca*, *Lathyrus pratensis*, *Dactylis glomerata*, and *Iris pseudacorus* were more frequent as well, whereas species from the *Aegopodion podagrariae*, as well as the *Plagiomnium undulatum*, *Elymus repens*, and *Carex acutiformis* were missing (UCt in Tab. 3). **Conditions of occurrence:** The community occurred on sunny or slightly shaded, flat, or tilted (20–40°) slopes facing various directions. The vegetation did not protrude above the river water level to more than 1.5 m, and the sample distance from the riverbed averaged 8.5 m. Soils were mineral or mineral-organic, neutral or slightly acidic, fresh or dry, and were usually classified as slightly loamy, loamy, or loose sands. Vegetation samples were most often assigned to the natural potential vegetation unit *Fraxino-Alnetum*, and occasionally to the *Carici elongatae-Alnetum* or *Stellario-Carpinetum* unit. Meadows and pastures, and less frequently deciduous forests, shrubs, and transportation, were the dominant land use forms. Riverward the samples most often adjoined rushes (*Phragmitetum australis*, *Phalaridetum arundinaceae*), and less frequently *Salix cinerea* shrubberies, whereas landward meadows, tall herbs, and ruderal communities occurred. **Distribution in northwestern Poland:** Valleys of the rivers Piaśnica, Reda, Płutnica, Oder, Ina, and Myśla, and the Szczecin Lagoon.

Fig. 20 *Urtico-Convolvuletum sepium typicum* in Płutnica valley (photo M. Myśliwy, 2009-08-13).

- ***Urtico-Convolvuletum sepium*** Görs et Müller 1969 ***aegopodietosum*** Görs 1974 (UCa) (Fig. 21). This subassociation was distinct because of the presence of *Aegopodium podagraria*, *Lamium maculatum*, *Stellaria nemorum*, and *Heracleum sphondylium* subsp. *sibiricum* (UCa in Tab. 3). Some relevés showed facies-like presence of *Humulus lupulus* or *Carduus crispus*. The moss layer was more frequent. **Conditions of occurrence:** The community occurred on flat or tilted (10–70°) slopes, experiencing varying degrees of shading and facing different directions. The elevation of vegetation samples above the river water level did not exceed 2 m. Relevés were taken 0–22 m away from the riverbed, within a range of the natural potential vegetation units *Carici elongatae-Alnetum* or *Fraxino-Alnetum*, occasionally the *Stellario-Carpinetum*. Soils were mineral, more seldom mineral-organic and organic; neutral, slightly acidic, or acidic; fresh or moist, classified as loamy sands, slightly loamy sands, or sandy loams. The dominant land use forms were deciduous forests, meadows and pastures, or shrubs. On the river side, vegetation samples adjoined aquatic communities, rushes (*Phragmitetum australis*, *Phalaridetum arundinaceae*, and *Glycerietum maximae*), and more seldom with the *Alnus glutinosa* community. Landward they were in contact with meadows, and less frequently alder carrs. **Distribution in northwestern Poland:** Valleys of the rivers Ina, Myśla, Łeba, Reda, Piaśnica, Wda, Stobnica, Prusina, Reczyca, and Oder.

Fig. 21 *Urtico-Convolvuletum sepium aegopodietosum* in Łeba valley (photo M. Myśliwy, 2010-08-17).

4.2.9. *Soncho palustris-Archangelicetum litoralis* Tx. 1937 (SA) (Fig. 22)

Syn.: *Convolvulo-Archangelicetum* Pass. 1964, *Archangelico-Calystegietum sepium* Passarge 1976. Incl.: *Convolvulus-Archangelica*-Gesellschaft Passarge 1959.

Floristic composition, physiognomy, and structure. This vegetation unit consisted of 12–27 plant species per sample (mean number exceeded 18). The shrub and moss layers were seldom present, but when there, they were composed of *Salix fragilis* and *Fraxinus excelsior*, and *Brachythecium rutabulum*, *B. rivulare*, *Cirriphyllum piliferum*, and *Plagiomnium affine*, respectively. The herb layer covered 80–100% of the sample area, and formed two or three sublayers. The samples were dominated by *Angelica archangelica* subsp. *litoralis*, growing to the height of 170–250 cm, and frequently accompanied by codominants *Urtica dioica* and *Calystegia sepium*. Other most frequent taxa included *Phalaris arundinacea* and *Carduus crispus* in the highest herb sublayer, and *Poa palustris*, *Stachys palustris*, *Humulus lupulus*, *Symphytum officinale*, *Filipendula ulmaria*, and *Mentha aquatica* in the middle herb sublayer. *Glechoma hederacea*, *Galium aparine*, *Cirsium arvense*, *Anthriscus sylvestris*, *Elymus repens*, *Poa trivialis*, and *Galeopsis speciosa* were frequent components of the unit as well (SA in Tab. 3).

Conditions of occurrence. The community occurred on sunny or slightly shaded, and sporadically on strongly shaded sites. The riverbanks were often tilted (to 75°), facing north, northeast, and other directions. The elevation of vegetation samples above the river water level usually did not exceed 1 m. Relevés were taken 0–25 m (average 3.8 m) away from the

Fig. 22 *Soncho palustris-Archangelicetum litoralis* in Łeba valley (photo M. Myśliwy, 2010-08-17).

riverbed, within a range of the natural potential vegetation unit *Fraxino-Alnetum*, and more seldom the *Stellario-Carpinetum* or other natural potential vegetation units. Soils were most often mineral and mineral-organic; slightly acidic, neutral, and less frequently acidic; fresh or moist, classified as loamy, slightly loamy, or loose sands. The dominant land use forms were most often meadows and pastures or shrubs. Riverward the vegetation samples were in contact with aquatic communities, rushes (*Phragmitetum australis*, *Glycerietum maximae*), and more seldom *Salix viminalis*, *S. cinerea*, and *Alnus glutinosa* shrubberies, whereas landward they adjoined meadows, and less frequently alder or willow cars, and others.

Distribution in northwest Poland. Valleys of the rivers Łeba, Parsęta, Reda, Piaśnica, Ina, Krąpiel, Piława, and Oder, and the Szczecin Lagoon.

4.2.10. *Epilobio hirsuti-Convolvuletum sepium* Hilbig et al. 1972 (EC) (Fig. 23)

Syn.: *Epilobietum hirsuti* Westhoff et Den Held 1969, *Calystegio-Epilobietum hirsuti* sensu auct.

Floristic composition, physiognomy, and structure. This vegetation unit was one of the most common riparian tall herb fringe communities in the study area. Vegetation samples contained on average 15 plant species (range 10–26). More than 30% of relevés possessed a shrub layer, its cover ranging 5–15%. It was composed of *Salix fragilis*, *S. cinerea*, *S. caprea*,

Fig. 23 *Epilobio hirsuti-Convolvuletum sepium* in Reda valley (photo M. Myśliwy, 2009-08-10).

Alnus glutinosa, *Fraxinus excelsior*, *Corylus avellana*, *Sambucus nigra*, or *Ribes nigrum*. More than 40% of vegetation samples contained a moss layer, most frequently covering 10–40% of the area, and sporadically as high as 70%. The moss layer included, inter alia, *Brachythecium rutabulum*, *B. oedipodium*, *Plagiomnium undulatum*, *Eurhynchium schleicheri*, *Kindbergia praelonga*, and *Lophocolea bidentata*. The dominant species, *Epilobium hirsutum*, was accompanied by *Urtica dioica* and *Galium aparine* covering substantial proportions of the relevé surface areas. The relevés also contained *Phalaris arundinacea*, *Carex acutiformis*, *Phragmites australis*, *Cirsium arvense*, *Vicia cracca*, and *Poa trivialis* (EC in Tab. 3). Almost 50% of samples contained *Calystegia sepium*, whereas *Filipendula ulmaria*, *Cirsium oleraceum*, *Lysimachia vulgaris*, *Lythrum salicaria*, *Dactylis glomerata*, and other species typical of moist meadows featured prominently in the remaining samples.

Conditions of occurrence. The community occurred on sunny or slightly shaded, or sporadically on strongly shaded sites. The riverbanks were flat or tilted (10–70°), facing different directions. The average elevation of vegetation samples above the river water level was 0.5 m. Relevés were taken 0–25 m (average 3.6 m) away from the riverbed, within a range of the natural potential vegetation unit *Fraxino-Alnetum*, and more seldom the *Carici elongatae-Alnetum*, *Stellario-Carpinetum*, or other natural potential vegetation units. Soils were mineral, more seldom mineral-organic or organic; neutral or slightly acidic; fresh or moist, classified as loamy, slightly loamy, and loose sands or sandy loams. The dominant land use forms were meadows and pastures. Riverward, vegetation samples were in contact with aquatic communities, rushes (*Sparganietum erecti*, *Phalaridetum arundinaceae*, *Typhetum latifoliae*, *Caricetum acutiformis*, and *Glycerietum maximae*), and more seldom with *Salix cinerea* or *Alnus glutinosa* shrubs, summer therophytes of the class *Bidentetea*, and others, whereas landward they adjoined wet meadows, and less frequently alder carrs and others.

Distribution in northwestern Poland. Valleys of the rivers Ina, Łupawa, Piaśnica, Reda, Łeba, Słupia, Płutnica, Wda, Drawa, Korytnica, Piława, Bielica, and Oder, and the Szczecin Lagoon.

4.2.11. *Eupatorietum cannabini* Tx. 1937 (Eu)

Syn.: *Eupatorio-Convolvuletum* (Oberd. et al. 1967) Görs 1974.

Floristic composition, physiognomy, and structure. This vegetation unit was very common in northwestern Poland and contained 9–31 plant species per sample (the mean species richness exceeded 17). The shrub layer, composed of *Salix cinerea*, *Betula pubescens*, *Frangula alnus*, and *Rhamnus cathartica*, was sporadic. The moss layer was present in 50% of samples, and sometimes covered 60–65% of the relevé area, and included inter alia: *Plagiomnium undulatum*, *P. ellipticum*, *Brachythecium rivulare*, *B. rutabulum*, *B. oedipodium*, *Eurhynchium hians*, and *Kindbergia praelonga*. The herb layer covered 95–100% of the relevé area and was divided into two or three sublayers. The species dominant in the highest sublayer (up to a mean average height of 170 cm) was *Eupatorium cannabinum*, accompanied by *Urtica dioica* and *Galium aparine*, and less frequently by *Calystegia sepium*. The samples often contained rush taxa, such as *Carex acutiformis*, *Phragmites australis*, *Phalaris arundinacea*, as well as the taxa typical of moist meadows, including *Cirsium oleraceum*, *Lysimachia vulgaris*, *Filipendula ulmaria*, *Scirpus sylvaticus*, and *Poa trivialis*. The association was divided into three subassociations (Eut, Eua, and Euc in Tab. 3):

- ***Eupatorietum cannabini*** Tx. 1937 ***typicum*** Görs 1974 (Eut) (Fig. 24). The typical subassociation exhibited the fairly frequent presence of *Calamagrostis epigejos*, *Deschampsia caespitosa*, *Galeopsis bifida*, *G. speciosa*, *Galium mollugo*, *Holcus lanatus*, *Symphytum officinale*, and *Vicia cracca* (Eut in Tab. 3). **Conditions of occurrence:** The community occurred on sunny or slightly shaded sites. The riverbanks were flat or tilted (to 40°), usually lower than 1 m, and facing different directions (mostly east, northeast, and south). Vegetation samples were collected 0–14 m away from the riverbed, within a range of the natural potential vegetation unit *Fraxino-Alnetum*, and more seldom the *Carici elongatae-Alnetum* or *Fago-Quercetum* unit. Soils were mineral or mineral-organic, neutral or slightly acidic, fresh or moist, classified as loose sands or slightly loamy sands. The dominant land use forms were meadows and pastures. Riverward the samples most often adjoined rushes (*Phragmitetum australis*, *Caricetum acutiformis*, *Glycerietum maximae*, and *Phalaridetum arundinaceae*), whereas landward they were in contact with rushes, meadows, or ruderal communities. **Distribution in northwestern Poland:** Valleys of the rivers Piaśnica, Drawa, Łupawa, Ina, and Reda, and the Szczecin Lagoon.
- ***Eupatorietum cannabini*** Tx. 1937 ***aegopodietosum*** Görs 1974 (Eua) (Fig. 25). This subassociation was distinct in that it contained *Aegopodium podagraria*, *Lamium maculatum*, *Heracleum sphondylium* subsp. *sibiricum*, and *Stellaria nemorum* (Eua in Tab. 3). **Conditions of occurrence:** The vegetation unit occurred on flat banks or tilted (10–75°) slopes, facing different directions (mostly south, southeast, and southwest), and experienced varying

Fig. 24 *Eupatorietum cannabini typicum* in Łupawa valley (photo M. Myśliwy, 2010-08-18).

Fig. 25 *Eupatorietum cannabini aegopodietosum* in Ina valley (photo M. Myśliwy, 2009-09-19).

degrees of shading. Vegetation samples were most often elevated less than 0.5 m above the river water level. Relevés were taken 0–8 m away from the riverbed, within a range of the natural potential vegetation unit *Carici elongatae-Alnetum*, and more seldom the *Stellario-Carpinetum* or *Fraxino-Alnetum* unit. Soils were mineral or mineral-organic, less frequently organic; slightly acidic or neutral; fresh, moist, or wet, and being loamy, slightly loamy, or loose sands. The dominant land use forms were forests (both deciduous and coniferous), shrubs or meadows and pastures. Riverward the samples were in contact with aquatic communities, rushes (*Glycerietum maximae*, *Phragmitetum australis*, and *Caricetum acutiformis*), and other tall herb fringe communities, whereas landward they adjoined, inter alia, rushes, meadows, alder carrs, riparian woodland, or *Salix cinerea* shrubbery. **Distribution in northwestern Poland:** Valleys of the rivers Ina, Wda, Drawa, Słupia, Łupawa, and Korytnica.

- ***Eupatorietum cannabini*** Tx. 1937 ***cardaminetosum amarae*** Myśliwy **subass. nov. hoc loco** (Euc) (Fig. 26). **Type:** Tab. 6, Relevé 4 holotypus hoc loco. **Differential species of subassociation:** *Geranium robertianum*, *Scirpus sylvaticus*, *Galium palustre*, *Myosotis palustris*, *Crepis paludosa*, *Climacium dendroides*, *Valeriana dioica*, *Cardamine amara*, *Chrysosplenium alternifolium*. Vegetation samples representing this new subassociation were distinct in that they contained numerous hygrophilous plants, such as the diagnostic species mentioned above, as well as *Mentha aquatica*, *Epilobium palustre*, *Plagiomnium undulatum*, and *Stellaria nemorum* (Tab. 6). **Conditions of occurrence:** The community was recorded on heavily shaded sites. Riverbanks were flat or sloping (10–20°), lower than 0.5 m, facing different directions. Vegetation samples were collected 3–15 m away from the riverbed, in close proximity to discharges of head waters, within a range of the natural potential vegetation unit *Ficario-Ulmetum chrysosplenietosum*. Soils were organic, slightly acidic, wet, more seldom mineral-organic, and classified as loose sands. The dominant land use forms were deciduous forests. The community was found in gaps between tree stands of well-developed riparian woodland and headwater carrs, usually unaffected by human activities. **Distribution in northwestern Poland:** The relevés were taken in valleys of the rivers Piaśnica and Łeba, but similar vegetation types were also observed by the Wda and Ina rivers.

4.2.12. *Cirsium arvense* community (*Archangelicion litoralis*) (Ci)

Two vegetation samples (Ci in Tab. 5) found in the valleys of the Łeba and Radew rivers were characterized by the dominance of *Cirsium arvense*, accompanied by species such as *Galium aparine*, *Glechoma hederacea*, *Urtica dioica*, *Aegopodium podagraria*, *Equisetum arvense*, *Filipendula ulmaria*, and *Phragmites australis*. Floristically, the samples were similar to the *Urtico-Convolvuletum sepium*, but they lacked *Calystegia sepium*. The vertical structure of the community lacked the shrub and moss layers, whereas the herb layer grew to a height of 150 cm to cover 100% of the relevé area and form three sublayers. The samples were collected on sunny sites, close to the riverbed, within a range of the natural potential vegetation unit *Fraxino-Alnetum*. Soils were mineral, neutral or very acidic, dry or fresh, and classified as loose or slightly loamy sands. The dominant land use forms were meadows and pastures. Riverward vegetation samples were in contact with aquatic communities or tall herbs, whereas landward they were in contact with meadows.

Fig. 26 *Eupatorietum cannabini cardaminetosum amarae* subass. nov. in Łeba valley (photo M. Myśliwy, 2009-08-12).

4.2.13. *Carduus crispus* community (*Archangelicion litoralis*) (Ca)

Two vegetation samples (Ca in Tab. 5) found in the valleys of the Łeba and Prostynia rivers were characterized by dominance of *Carduus crispus*. They were species-poor and exhibited similarity to the *Urtico-Convolvuletum sepium*, but they lacked *Calystegia sepium*. The vertical structure of the community lacked the shrub and moss layers, and the herb layer grew to a height of 120–150 cm to cover 100% of the relevé area and form two sublayers. The relevés contained the following species: *Urtica dioica*, *Elymus repens*, *Galium aparine*, *Anthriscus sylvestris*, *Fallopia dumetorum*, *Galeopsis speciosa*, *Myosoton aquaticum*, *Bromus inermis*, and others. The samples were collected on sunny or slightly shaded sites, which were elevated 1–2 m above the river water level and located 0.5 and 4 m away from the riverbed, within a range of the natural potential vegetation unit *Fraxino-Alnetum*. Soils were fresh, mineral and slightly acidic, and being slightly loamy sands, or were organic and very acidic. The dominant land use forms were meadows and pastures. From the river side the samples were adjacent to aquatic communities or rushes, whereas landward they were adjacent to meadows.

4.2.14. *Urtica dioica* community (*Archangelicion litoralis*) (Ur) (Fig. 27)

Floristic composition, physiognomy, and structure. This vegetation unit belongs to species-poor tall herb fringe communities (9–23 plant species per sample, average 15), and was very common in the study area. The shrub layer, with a maximum of 15% cover, was present in 25% of the samples. It was composed of *Salix cinerea*, *S. viminalis*, *Sambucus nigra*, or *Viburnum opulus*. The moss layer was present in 50% of relevés, covering 5–30% of the area. It was formed by species such as *Plagiomnium undulatum*, *Brachythecium rutabulum*, *B. oedipodium*, and *Eurhynchium hians*. The herb layer covered 80–100% of the sample area, and reached a mean maximum height of 140 cm. The layer was composed of dense aggregations of *Urtica dioica*, with numerous *Galium aparine*, and occasionally *Humulus lupulus*. In addition, the following species were most often recorded: *Poa palustris*, *Filipendula ulmaria*, *Carex acutiformis*, *Phalaris arundinacea*, *Phragmites australis*, *Solanum dulcamara*, *Elymus repens*, *Equisetum arvense*, *Artemisia vulgaris*, *Cirsium arvense*, *Galeopsis tetrachit*, and *Glechoma hederacea*. Following species from the *Aegopodion* alliance were fairly common: *Aegopodium podagraria*, *Lamium maculatum*, *Anthriscus sylvestris*, as well as *Stellaria nemorum* (Ur in Tab. 3).

Conditions of occurrence. The community occurred on slightly or strongly shaded sites. The riverbanks were flat or tilted (10–60°), usually lower than 1 m, facing different directions (mostly south, southwest, and west). Vegetation samples were collected 0–5 m away from the riverbed, within a range of the natural potential vegetation units *Fraxino-Alnetum* or *Ficario-Ulmetum chrysosplenietosum*, and less frequently the *Carici elongatae-Alnetum* and other natural potential vegetation units. Soils were mineral or mineral-organic; slightly

Fig. 27 *Urtica dioica* community in Wda valley (photo M. Myśliwy, 2008-07-17).

acidic or neutral; moist, fresh, or dry, and usually classified as loamy or slightly loamy sands. The dominant land use forms were deciduous forests or meadows and pastures. Riverward vegetation samples were most often in contact with aquatic communities, reed rushes, or alder forests, whereas landward they adjoined ash-alder or elm-ash riparian woodlands, alder cars, pine monocultures, ruderal communities, and others.

Distribution in northwestern Poland. Valleys of the rivers Piaśnica, Wda, Ina, Drawa, Łupawa, and Radew.

4.2.15. *Impatiens glandulifera* community (*Archangelicion litoralis*) (Im) (Fig. 28)

Floristic composition, physiognomy, and structure. This vegetation unit contained from 8 to 22 plant species (average number exceeded 16). The shrub layer was rare and poorly compacted. More than 50% of relevés had a moss layer covering 5–30% of the area. It was composed of *Eurhynchium hians*, *Cirriphyllum piliferum*, and *Brachythecium oedipodium*. The herb layer covered 100% of the sample area and consisted of three sublayers. The dominant species, *Impatiens glandulifera*, grew to, on average, 180 cm, but occasionally it was taller than 2 m. In addition, the vegetation samples contained *Calystegia sepium*, *Humulus lupulus*, *Cuscuta europaea*, *Rubus caesius*, *Stachys palustris*, *Phragmites australis*, *Eupatorium cannabinum*, *Epilobium hirsutum*, *Galium aparine*, *Glechoma hederacea*, and *Aegopodium podagraria* (Im in Tab. 3).

Fig. 28 *Impatiens glandulifera* community in Łupawa valley (photo J. Myśliwy, 2010-08-19).

Conditions of occurrence. The community occurred on slightly shaded, flat, and low banks, facing different directions. Relevés were taken 2–5 m away from the riverbed (6–50 m from the banks of the Szczecin Lagoon), within a range of the natural potential vegetation unit *Salici-Populetum* (at the Szczecin Lagoon) or the *Fraxino-Alnetum* (at rivers). Soils were mineral, alkaline (at the Szczecin Lagoon), or slightly acidic, fresh, and usually classified as loose sands. The dominant land use forms were deciduous forests, and less frequently shrubs. Riverward vegetation samples were most often in contact with rushes of *Phragmitetum australis*, whereas landward they most often were in contact with willow, poplar, or alder carrs.

Distribution in northwestern Poland. The Szczecin Lagoon and valleys of the Słupia and Łupawa rivers.

4.2.16. *Helianthus tuberosus* community (*Archangelicion litoralis*) (He)

Two species-poor vegetation samples (He in Tab. 5), found in the Ina River valley, were characterized by the dominance of *Helianthus tuberosus*. The relevés were taken 1.5 m away from the riverbed, approximately 2 m above the river water level, on somewhat sloping (10–20°) northeast-facing banks, within a range of the natural potential vegetation unit *Carici elongatae-Alnetum*. Soils were mineral, neutral or alkaline, fresh, and classified as loamy and slightly loamy sands. Riverward the samples were adjacent to *Phragmitetum australis*, whereas landward they were adjacent to crops. In addition to the dominant species that grew up to 250–300 cm, the samples contained, inter alia, *Calystegia sepium*, *Galium aparine*, *Phragmites australis*, *Galeopsis speciosa*, *Chenopodium album*, *Urtica dioica*, *Aegopodium podagraria*, and *Stellaria nemorum*.

4.2.17. *Reynoutria japonica* community (*Convolvuletalia sepium*) (Rj) (Fig. 29)

Two floristically different vegetation samples (Rj in Tab. 5) were characterized by the dominance of *Reynoutria japonica*. The first was found 25 m away from the Ina riverbank, on a north-facing slope tilted to 30°. It was in contact with wet alder woodland and newly planted *Robinia pseudoacacia*, within a range of the natural potential vegetation unit *Fraxino-Alnetum*. Soil was mineral, slightly acidic, moist, and being sandy loams. The sample was extremely species-poor (it contained five plant species), as the lush stems of the dominant species grew to 300 cm and were highly compact. The second sample was taken from a very steep (70°), fairly high, north-facing shore of the Szczecin Lagoon. It was in contact with ruderal communities growing at the sides of a nearby road, within a range of the natural potential vegetation unit *Salici-Populetum*. The soil was mineral, alkaline, fresh, and classified as loamy sands. The neophyte's stems were lower and clearly less compact, and the species were accompanied by, inter alia, *Calystegia sepium*, *Rubus caesius*, *Petasites spurius*, *Phalaris arundinacea*, and *Equisetum arvense*.

Fig. 29 *Reynoutria japonica* community by the Szczecin Lagoon (photo M. Myśliwy, 2011-07-03).

4.2.18. *Rubus idaeus* community (*Convolvuletalia sepium*) (Ri) (Fig. 30)

Floristic composition, physiognomy, and structure. This vegetation unit was species-poor and consisted of 8–21 plant species (average 15). In the vertical structure, the shrub layer (except for the raspberry) was rare, and its cover, when it occurred, was poor. The moss layer was present in more than 70% of samples. It covered up to 30% of the sample area, and was composed of such species as *Plagiomnium undulatum*, *Brachythecium rutabulum*, *Cirriphyllum piliferum*, and *Atrichum undulatum*. The herb layer (including *Rubus idaeus*) covered 70–100% of the sample area and was divided into two or three sublayers. The dominant species was most often accompanied by *Urtica dioica*, *Glechoma hederacea*, *Carex acutiformis*, *Phalaris arundinacea*, *Lysimachia vulgaris*, *Elymus repens*, *Deschampsia caespitosa*, *Holcus lanatus*, and the taxa belonging to the alliance *Aegopodion*, which included *Aegopodium podagraria* and *Lamium maculatum*, as well as *Stellaria nemorum*. Creepers were represented by *Humulus lupulus*, *Galium aparine*, *Calystegia sepium*, and *Fallopia dumetorum* (Ri in Tab. 3).

Conditions of occurrence. The community occurred on strongly or slightly shaded sites. The riverbanks were flat and low, facing northeast or north. Vegetation samples were taken 0–8 m away from the riverbed, within a range of the natural potential vegetation units *Fraxino-Alnetum* or *Ficario-Ulmetum chrysosplenietosum*. The soils were mineral or organic, very acidic or acidic, fresh, and classified as slightly loamy or loose sands. The dominant land use forms were forests (both deciduous and coniferous), and less frequently meadows or pastures, shrubs, and others. Riverward the samples were in contact with aquatic communities, rushes,

Fig. 30 *Rubus idaeus* community in Słupia valley (photo M. Myśliwy, 2010-08-21).

tall herbs, or *Salix cinerea* shrubberies, whereas landward they were adjacent to ash-alder or elm-ash riparian woodlands, wet meadows, and less frequently to pine monocultures or ruderal communities.

Distribution in northwestern Poland. Valleys of the Piaśnica, Łeba, Słupia, Prostynia, and Prusina rivers.

4.2.19. *Galeopsis speciosa* community (*Convolvuletalia sepium*) (Gs) (Fig. 31)

Floristic composition, physiognomy, and structure. This vegetation unit was species-poor and consisted of 8–19 plant species (average 13). The shrub and moss layers were absent. The herb layer covered 95–100% of the sample area and was divided into two or three sublayers. The dominant species *Galeopsis speciosa* was accompanied in the middle sublayer by *Lysimachia vulgaris*, *Stellaria nemorum*, *Aegopodium podagraria*, *Lamium maculatum*, *Ranunculus repens*, *Agrostis stolonifera*, *Galeopsis bifida*, and *Carex acutiformis*. The highest sublayer was composed of *Phragmites australis*, *Elymus repens*, and *Holcus mollis*. Creepers were represented by *Humulus lupulus*, *Galium aparine*, *Fallopia dumetorum*, and *Calystegia sepium* (Gs in Tab. 3).

Conditions of occurrence. The community occurred most often on slightly shaded, flat, and low riverbanks, facing northeast or southwest. Vegetation samples were collected, on average, 7 m away from the riverbed, within a range of the natural potential vegetation units

Fig. 31 *Galeopsis speciosa* community in Łeba valley (photo M. Myśliwy, 2009-08-12).

Fraxino-Alnetum or *Ficario-Ulmetum chrysosplenietosum*. Soils were mineral, and more seldom organic or mineral-organic, very acidic to acidic, fresh, and classified as loamy or slightly loamy sands. The dominant land use forms were meadows and pastures, deciduous forests, less frequently shrubs. Riverward the samples were in contact with moist alder forests, alder cars, or reed rushes, whereas landward they were in contact with *Salix cinerea* shrubs, wet meadows, and less frequently pine monocultures or alder carrs.

Distribution in northwestern Poland. Valleys of the rivers Piaśnica, Łeba, Łupawa, and Słupia.

Tab. 3 The synoptic table of the riparian tall herb fringe communities of the order *Convolvuletalia sepium* Tx. ex Moor 1958 in NW Poland.

	Syntaxa*																		
	Se	FC	So	CCh	CCt	CCa	Rc	AC	UCt	UCa	SA	EC	Eut	Eua	Euc	Im	Ur	Gs	Ri
Number of relevés	9	9	9	15	20	19	5	21	12	33	23	31	14	18	7	7	16	7	15
Characteristic and dominant species																			
Senecio fluviatilis	100^{2-3}	11^{1}	22^{1}	.	.	.	20^{+}	.	.	.	.	.	.	.	.	.	.	.	.
Cucubalus baccifer	22^{1-2}	100^{2-4}	44^{+-2}	7^{+}	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solidago gigantea	78^{1-4}	78^{+-2}	100^{4-5}	80^{+-2}	5^{+}	.	20^{1}	.	.	.	.	.	.	.	.	.	.	.	.
Cuscuta europaea	33^{+-1}	67^{1-3}	22^{+}	93^{1-3}	65^{1-3}	84^{+-3}	.	52^{1-3}	.	.	13^{+-1}	3^{+}	.	.	.	43^{+}	.	.	.
Rubus caesius	100^{+-3}	100^{2-4}	78^{1-2}	93^{+-3}	65^{+-4}	32^{+-3}	100^{4-5}	76^{+-4}	.	6^{+-1}	17^{+-1}	13^{+-2}	7^{1}	6^{+}	.	43^{+-2}	6^{+}	.	.
Cuscuta lupuliformis	.	11^{+}	.	20^{+-1}	5^{+}	.	.	86^{+-3}	.	.	.	.	.	.	.	.	.	.	.
Achillea salicifolia	.	.	.	.	.	.	.	43^{r-4}	.	.	.	.	.	.	.	.	.	.	.
Calystegia sepium	67^{1-2}	44^{1}	44^{+-2}	67^{1-3}	95^{+-4}	84^{+-4}	80^{1-3}	100^{1-3}	100^{+-4}	100^{+-4}	61^{+-4}	45^{1-4}	36^{+-4}	50^{+-3}	.	86^{+-2}	.	14^{+}	7^{2}
Urtica dioica	89^{+-2}	89^{+-2}	89^{+-1}	93^{+-3}	100^{+-4}	100^{2-5}	80^{+-1}	100^{+-4}	100^{+-5}	100^{1-5}	100^{+-4}	97^{+-4}	93^{+-2}	83^{+-4}	43^{r-1}	100^{+-3}	100^{3-5}	71^{+-1}	80^{+-3}
Angelica archangelica subsp. *litoralis*	.	.	.	.	.	11^{1}	.	.	.	.	100^{2-5}	.	7^{+}	.	.	.	6^{+}	.	.
Epilobium hirsutum	.	.	11^{+}	.	.	21^{+-2}	.	.	.	18^{r-1}	13^{+-1}	100^{3-5}	21^{+}	11^{+}	.	14^{2}	.	.	7^{+}
Eupatorium cannabinum	.	.	11^{+}	.	.	11^{+-1}	20^{+}	.	17^{+}	6^{+-1}	13^{+}	13^{+-3}	100^{3-5}	100^{2-5}	100^{4-5}	14^{+}	6^{1}	.	13^{1}
Impatiens glandulifera	.	.	.	.	.	.	.	.	.	3^{2}	.	3^{3}	7^{3}	11^{3}	.	100^{3-5}	.	.	.
Galeopsis speciosa	.	.	11^{1}	.	15^{+-2}	47^{+-3}	.	5^{1}	25^{1-3}	45^{+-3}	30^{+-1}	29^{+-2}	36^{+}	.	.	43^{+-2}	19^{+-2}	100^{4-5}	60^{r-2}
Rubus idaeus	.	.	.	.	.	.	.	.	8^{+}	3^{+}	4^{1}	3^{+}	.	.	.	.	6^{1}	57^{+-1}	100^{3-5}
Differential species of Ass and Subass																			
Chaerophyllum bulbosum	33^{+-2}	67^{+-3}	22^{+}	100^{1-4}	.	11^{+}	.	.	.	.	.	.	.	.	.	.	.	.	.
Acer negundo c**	22^{+-1}	.	.	47^{+-1}	10^{+}	.	.	5^{+}	.	3^{+}	.	.	.	.	.	.	.	.	.
Rumex confertus	11^{+}	.	11^{+}	20^{+}	5^{+}	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aegopodium podagraria	33^{+-1}	22^{+}	33^{+-1}	13^{+}	.	47^{+-2}	.	.	.	61^{+-2}	22^{+-1}	23^{+-2}	.	61^{+-2}	.	43^{+-1}	56^{+-3}	43^{+-1}	60^{+-3}

Tab. 3 Continued

	Syntaxa*																		
	Se	FC	So	CCh	CCt	CCa	Rc	AC	UCt	UCa	SA	EC	Eut	Eua	Euc	Im	Ur	Gs	Ri
Stellaria nemorum	.	.	22^{2-3}	.	.	47^{+-2}	.	.	.	61^{+-4}	9^{+-2}	13^{+-2}	.	50^{r-2}	71^{+-2}	57^{1-2}	56^{+-4}	86^{+-3}	60^{+-3}
Heracleum sphondylium subsp. *sibiricum*	.	.	.	7^{+}	5^{+}	21^{+}	20^{+}	5^{+}	.	9^{+-1}	13^{+-2}	6^{+}	.	17^{+-1}	.	.	19^{+-1}	.	7^{+}
Lamium maculatum	.	.	.	.	.	74^{+-1}	.	.	.	55^{+-3}	13^{+}	23^{+}	.	17^{+-1}	.	14^{+}	25^{r-+}	57^{r-1}	33^{+}
Echinocystis lobata	.	.	.	7^{+}	30^{+-2}	5^{+}	20^{2}	67^{+-2}	.	12^{+-1}	17^{+-3}	.	.	.	.	.	.	.	.
Bidens frondosa	.	.	.	20^{r-+}	20^{+-1}	.	.	62^{+-2}	.	.	.	3^{+}	7^{+}	.	.	.	.	.	.
Petasites spurius	11^{+}	.	11^{+}	.	.	.	.	19^{1-3}	.	.	.	.	.	.	.	.	.	.	.
Galium elongatum	.	.	.	.	5^{+}	.	.	24^{+}	.	.	.	3^{+}	.	.	.	.	.	.	.
Veronica longifolia	.	.	.	7^{+}	5^{2}	.	.	14^{1-3}	.	.	.	.	.	.	.	.	.	.	.
Rorippa palustris	.	.	.	.	.	.	.	24^{+}	.	.	.	.	.	.	.	.	.	.	.
Scirpus sylvaticus	.	.	.	.	.	5^{1}	.	.	.	3^{1}	4^{+}	10^{+-1}	14^{+}	28^{+-1}	71^{+-1}	.	6^{+}	14^{2}	7^{2}
Geranium robertianum	.	.	.	.	.	.	.	.	8^{+}	.	9^{+-1}	.	.	.	86^{+-1}	.	19^{+}	.	20^{+}
Myosotis palustris	.	.	.	.	.	.	.	.	.	.	4^{+}	3^{+}	.	11^{+}	57^{+}	.	6^{+}	.	.
Galium palustre	.	.	.	.	.	5^{+}	.	.	.	.	4^{+}	.	.	11^{+}	71^{+-1}	.	.	.	.
Crepis paludosa	.	.	.	.	.	.	.	.	.	.	4^{+}	6^{+-1}	.	.	57^{+}	.	6^{+}	.	.
Cardamine amara	.	.	.	.	.	.	.	.	.	.	4^{+}	3^{1}	.	6^{+}	43^{+-1}	.	.	.	.
Chrysosplenium alternifolium	.	.	.	.	.	.	.	.	.	6^{+}	.	.	.	17^{+}	43^{+}	.	25^{+}	.	.
Valeriana dioica	.	.	.	.	.	.	.	.	.	.	.	.	.	.	57^{+-2}	.	.	.	.
Climacium dendroides d**	.	.	.	.	.	.	.	.	.	.	.	.	.	.	57^{2-3}	.	.	.	.
Senecionion fluviatilis																			
Calamagrostis epigejos	22^{+}	44^{+}	67^{+-2}	40^{+-1}	25^{+-1}	5^{+}	40^{+-1}	24^{+-1}	8^{+}	3^{r}	9^{+}	6^{+-1}	29^{+}	6^{+}	.	.	.	.	.
Bromus inermis	44^{+-1}	33^{1-2}	22^{+}	33^{+-1}	35^{+-1}	5^{+}	.	14^{1}	17^{+}	9^{+-1}	13^{+}	6^{+-2}	.	.	.	.	.	.	7^{+}
Erysimum cheiranthoides	22^{+}	44^{+-1}	33^{r-+}	33^{+}	45^{+-1}	5^{+}	20^{1}	29^{+-1}	.	.	.	.	.	.	.	29^{+}	6^{+}	.	.
Tanacetum vulgare	33^{+}	.	22^{+}	13^{+}	.	.	20^{+}	19^{r-+}	8^{+}	.	.	3^{+}	.	.	.	.	6^{+}	.	.

Tab. 3 Continued

	Syntaxa*																		
	Se	FC	So	CCh	CCt	CCa	Rc	AC	UCt	UCa	SA	EC	Eut	Eua	Euc	Im	Ur	Gs	Ri
Lactuca serriola	.	11^{+}	.	7^{+}	20^{+}	5^{+}	20^{+}	10^{+-1}	.	.	.	.	.	.	.	.	.	.	.
Atriplex prostrata subsp. *latifolia*	.	11^{+}	.	.	45^{+-2}	5^{+}	20^{+}	67^{+-2}	8^{+}	.	.	.	.	.	.	.	.	.	.
Chenopodium album	.	33^{+}	.	13^{+}	45^{+-1}	.	20^{1}	10^{+}	.	.	.	.	.	.	.	14^{+}	.	.	.
Rorippa sylvestris	.	11^{+}	.	7^{+}	15^{+-1}	.	20^{+}	5^{+}	.	.	.	.	.	.	.	.	.	.	.
Archangelicion litoralis																			
Filipendula ulmaria	.	.	22^{+}	.	5^{1}	32^{+-1}	.	.	42^{+-2}	21^{r-1}	30^{+-1}	42^{+-2}	14^{+}	33^{r-+}	71^{+}	14^{1}	19^{r-+}	14^{1}	7^{+}
Carex acutiformis	.	.	.	.	.	16^{+-1}	20^{3}	.	.	27^{+-2}	22^{+-1}	39^{+-3}	64^{+-3}	44^{+-2}	71^{+-1}	14^{+}	19^{+-3}	29^{+-2}	53^{+-2}
Brachythecium rutabulum d**	.	.	.	.	.	5^{2}	20^{1}	.	8^{2}	12^{1-2}	9^{+-2}	16^{1-3}	7^{1}	22^{1}	14^{2}	.	25^{1-2}	.	33^{+-2}
Deschampsia caespitosa	.	.	11^{+}	.	.	.	.	.	17^{+}	15^{+}	17^{+-1}	10^{+-2}	36^{+-1}	22^{+}	.	.	25^{+}	14^{1}	33^{+-2}
Cirsium oleraceum	.	.	.	.	.	32^{+-2}	.	.	8^{+}	18^{+-1}	.	23^{r-1}	.	44^{+-1}	29^{1}	.	6^{+}	14^{+}	7^{+}
Scrophularia umbrosa	.	.	11^{+}	.	.	5^{+}	.	.	17^{1}	12^{+-1}	22^{+}	23^{+-2}	36^{+}	33^{+}	.	29^{+-2}	.	.	.
Equisetum palustre	.	.	11^{+}	.	.	5^{1}	.	.	.	.	22^{+-1}	23^{+-1}	21^{+-2}	22^{+-1}	29^{+-1}	.	.	.	13^{+-1}
Rumex thyrsiflorus	.	.	.	.	.	.	.	.	8^{+}	.	4^{+}	.	7^{+}	17^{+-1}	29^{+}	.	13^{+}	14^{+}	.
Plagiomnum undulatum d**	.	.	.	.	.	.	.	.	.	21^{+-1}	.	10^{1-2}	.	22^{+-4}	86^{1-3}	.	38^{+-2}	.	33^{+-2}
Mentha aquatica	.	.	.	.	5^{1}	.	.	.	8^{+}	.	30^{+-2}	10^{+-1}	.	11^{+-1}	86^{+-2}	.	.	.	.
Lythrum salicaria	.	.	.	.	.	.	.	.	8^{+}	.	13^{+}	19^{+-1}	21^{+-1}	28^{+}	.	.	.	.	13^{r-+}
Convolvuletalia sepium																			
Phalaris arundinacea	78^{+-2}	78^{+-2}	44^{+-2}	67^{+-2}	60^{+-2}	58^{+-1}	60^{1-3}	71^{+-2}	33^{+-2}	19^{+-2}	65^{+-2}	71^{+-3}	43^{+-2}	33^{+-2}	.	29^{+-1}	13^{+}	14^{+}	47^{+-2}
Lysimachia vulgaris	11^{+}	.	11^{+}	13^{+}	15^{+-3}	11^{+-1}	60^{+}	24^{+-2}	17^{+}	6^{+}	13^{+-1}	19^{+-1}	29^{+-1}	17^{+-1}	57^{+}	.	6^{+}	43^{+}	40^{+-2}
Vicia cracca	44^{+-2}	22^{+}	67^{+}	53^{r-+}	30^{+}	37^{+-2}	80^{+}	43^{r-1}	50^{+-3}	15^{+}	30^{r-2}	52^{+-1}	57^{+-2}	6^{+}	.	.	13^{+}	.	13^{+}
Poa palustris	67^{+-1}	22^{1}	56^{+-1}	20^{1}	40^{+-1}	11^{1}	20^{+}	19^{1}	.	9^{+-1}	43^{+-2}	26^{+-2}	29^{+-1}	22^{+-1}	.	29^{+-1}	39^{+-2}	.	7^{1}
Stachys palustris	22^{+}	22^{+-1}	22^{+-1}	40^{+-2}	60^{+-3}	11^{+}	20^{+}	86^{+-3}	.	9^{+-1}	39^{+-1}	10^{+-1}	14^{+-1}	11^{+}	.	43^{+}	.	.	.
Phragmites australis	.	.	.	.	40^{+-2}	32^{+-2}	60^{+-1}	24^{+-2}	83^{+-3}	42^{+-3}	26^{1-2}	26^{+-2}	50^{1-3}	22^{1-2}	.	71^{+-2}	13^{+-2}	29^{1-2}	7^{1}

Tab. 3 Continued

	Syntaxa*																		
	Se	FC	So	CCh	CCt	CCa	Rc	AC	UCt	UCa	SA	EC	Eut	Eua	Euc	Im	Ur	Gs	Ri
Solanum dulcamara	.	.	22^{+}	13^{+}	.	11^{+}	20^{1}	14^{+}	.	.	17^{+-1}	29^{+-2}	14^{+}	17^{+}	43^{+-3}	.	13^{+}	.	.
Thalictrum flavum	.	.	.	.	5^{1}	5^{+}	.	10^{+}	.	6^{r-+}	4^{1}	3^{r}	7^{+}	.	.	.	.	.	.
Epilobietea angustifolii																			
Galium aparine	67^{+-2}	44^{+-1}	78^{+-1}	60^{+-3}	55^{+-2}	84^{+-2}	60^{+-1}	48^{+-2}	75^{1-3}	88^{+-3}	74^{+-3}	81^{+-3}	79^{+-2}	72^{+-3}	43^{1-2}	86^{+-1}	94^{+-4}	43^{1}	60^{r-2}
Glechoma hederacea	33^{2-3}	67^{+-2}	89^{+-2}	73^{+-3}	85^{+-3}	58^{+-2}	40^{+-1}	43^{+-2}	50^{+-2}	27^{+-2}	65^{+-2}	19^{+-2}	14^{+-1}	22^{+}	.	71^{+-1}	25^{+-4}	14^{1}	47^{r-2}
Humulus lupulus	56^{+-2}	67^{+-2}	89^{+-3}	80^{+-3}	35^{1-3}	47^{+-4}	60^{+-3}	14^{+-3}	8^{3}	27^{+-2}	35^{+-2}	16^{+}	14^{+-1}	22^{r-2}	.	57^{1-2}	38^{r-3}	43^{+-1}	33^{+-4}
Carduus crispus	44^{1-2}	56^{+}	11^{+}	67^{+-2}	55^{+-3}	53^{+-4}	20^{1}	29^{+-2}	8^{1}	24^{1-4}	39^{+-2}	23^{+-2}	.	6^{+}	43^{+}	14^{+}	6^{+}	.	20^{+-1}
Galeopsis bifida	11^{+}	11^{+}	.	20^{+}	35^{+-2}	5^{2}	20^{+}	24^{+-1}	8^{+}	6^{+}	17^{+}	16^{+-3}	36^{+-1}	6^{+}	.	29^{+}	6^{2}	29^{+-1}	27^{+}
Symphytum officinale	44^{+-2}	11^{1}	11^{+}	40^{+-1}	25^{+-2}	16^{+}	40^{+}	10^{+}	33^{+-1}	18^{+-1}	30^{+-1}	23^{+}	36^{+-2}	6^{+}	.	.	6^{r}	.	.
Myosoton aquaticum	11^{+}	.	22^{+}	.	40^{+-4}	32^{r-2}	20^{+}	24^{+-1}	33^{r-1}	12^{+-2}	13^{r-+}	6^{1-2}	14^{+}	.	.	14^{+}	6^{+}	.	.
Anthriscus sylvestris	.	.	.	.	20^{+-2}	16^{+}	.	5^{+}	50^{+-1}	21^{+-2}	43^{r-1}	19^{+-1}	7^{+}	11^{+}	.	14^{+}	38^{+-2}	14^{+}	7^{+}
Angelica sylvestris	.	.	.	.	.	11^{+}	20^{1}	.	17^{+}	6^{+}	9^{+-1}	6^{1}	14^{+-1}	6^{+}	.	.	6^{+}	14^{+}	7^{+}
Impatiens parviflora	.	.	11^{+}	.	25^{+-2}	11^{+}	20^{+}	.	.	6^{+}	22^{+-1}	10^{+-2}	14^{+}	6^{+}	.	29^{+}	.	.	7^{1}
Fallopia dumetorum	.	11^{+}	.	20^{+-1}	20^{+-3}	16^{+}	.	33^{+-3}	8^{2}	.	.	.	.	6^{r}	.	14^{1}	.	14^{1}	7^{1}
Geum urbanum	.	.	.	.	.	5^{+}	20^{+}	.	8^{+}	3^{+}	9^{+-1}	6^{+}	.	6^{+}	.	.	25^{+}	.	13^{+}
Galeopsis tetrahit	.	.	.	.	5^{+}	.	.	.	25^{+-1}	3^{+}	4^{+}	.	.	.	.	14^{+}	13^{+-2}	.	.
Torilis japonica	.	.	.	.	.	.	.	.	25^{+}	3^{+}	.	3^{2}	14^{+}	.	.	.	6^{+}	.	7^{r}
Chelidonium majus	.	.	.	.	.	.	.	.	.	3^{+}	9^{+}	.	.	6^{+}	.	14^{+}	.	14^{r}	.
Valeriana officinalis	.	.	.	.	.	5^{+}	.	.	.	.	9^{+}	.	14^{+}	11^{+}	.	.	6^{r}	.	.
Impatiens noli-tangere	.	.	.	.	.	.	.	.	8^{1}	6^{+-3}	.	.	.	.	14^{+}	.	19^{+}	.	7^{+}
Molinio-Arrhenatheretea																			
Agrostis stolonifera	.	.	11^{1}	.	5^{+}	21^{+-1}	20^{+}	5^{1}	25^{+-1}	12^{+}	17^{+-1}	6^{+-1}	14^{+}	33^{+-1}	14^{+}	14^{+}	6^{+}	57^{+-1}	20^{+-1}
Poa trivialis	.	.	11^{+}	.	35^{+-2}	5^{1}	20^{1}	14^{+-1}	42^{+-1}	39^{+-1}	35^{+-1}	42^{+-1}	14^{+-1}	44^{+-1}	86^{+-1}	.	31^{+-2}	29^{r-+}	20^{+-1}

Tab. 3 Continued

	Syntaxa*																		
	Se	FC	So	CCh	CCt	CCa	Rc	AC	UCt	UCa	SA	EC	Eut	Eua	Euc	Im	Ur	Gs	Ri
Ranunculus repens	.	11^{+}	.	.	15^{+-1}	11^{+}	20^{+}	5^{+}	.	6^{+}	26^{+}	3^{r}	.	22^{+}	.	29^{+}	13^{+-1}	43^{+}	20^{+}
Alopecurus pratensis	.	.	.	7^{+}	15^{+-1}	16^{+-1}	20^{+}	10^{+-1}	8^{+}	9^{+}	22^{+-1}	6^{+-1}	.	.	.	.	6^{+}	14^{+}	7^{+}
Dactylis glomerata	.	.	11^{+}	.	.	32^{+}	60^{+}	.	42^{+}	12^{+}	26^{+-1}	16^{+}	7^{+}	17^{+}	.	.	25^{+}	29^{+}	20^{+-1}
Arrhenatherum elatius	.	.	.	.	.	16^{+-2}	20^{1}	5^{+}	33^{+}	18^{+-2}	9^{+-1}	16^{+-1}	7^{1}	.	.	.	19^{+-1}	14^{+}	.
Lathyrus pratensis	.	.	.	.	5^{+}	11^{+-1}	20^{+}	.	33^{+}	.	4^{+}	3^{+}	7^{+}	11^{+}	.	.	6^{2}	.	7^{+}
Veronica chamaedrys	.	.	11^{+}	.	.	5^{+}	.	.	8^{+}	6^{+}	.	.	.	6^{1}	.	14^{+}	6^{+}	14^{+}	7^{+}
Galium mollugo	.	.	.	13^{+}	.	.	.	.	8^{+}	.	13^{+}	10^{+}	36^{+-1}	6^{+}	.	.	6^{+}	.	13^{+}
Holcus lanatus	.	.	.	.	.	5^{+}	.	.	.	3^{+}	4^{+}	6^{1}	29^{+-1}	.	.	.	19^{+-1}	29^{1}	33^{r-+}
Poa pratensis	.	.	11^{+}	.	.	11^{+}	.	.	.	6^{+}	4^{+}	.	14^{+}	.	.	.	13^{+}	.	7^{+}
Juncus effusus	.	.	11^{+}	.	.	.	.	.	.	.	4^{+}	3^{+}	7^{+}	17^{+}	.	.	6^{+}	.	13^{+}
Carex hirta	.	.	.	.	.	.	.	10^{+}	17^{+}	.	9^{+}	6^{+}	7^{+}	.	.	.	13^{+}	.	13^{+}
Achillea millefolium	.	.	.	.	.	5^{+}	.	.	8^{+}	.	4^{+}	.	7^{+}	6^{+}	.	.	6^{+}	.	.
Potentilla anserina	.	.	.	.	.	5^{+}	.	5^{+}	.	.	4^{+}	3^{+}	14^{+-1}	.	.	.	.	.	7^{+}
Geum rivale	.	.	.	.	.	.	.	.	.	.	4^{+}	10^{1-2}	14^{+}	6^{+}	.	.	13^{+}	.	.
Other species, in at least five units																			
Salix fragilis b**	.	11^{+}	.	.	20^{1-2}	5^{1}	.	14^{2-3}	.	3^{1}	4^{3}	6^{1-2}	.	.	.	.	.	.	.
Salix viminalis b**	11^{+}	.	.	7^{2}	.	16^{+-1}	.	19^{1-2}	8^{+}	.	.	.	.	.	.	.	6^{2}	.	.
Ulmus laevis b**	.	11^{+}	11^{+}	7^{+}	5^{+}	.	.	14^{1-2}	.	.	.	.	.	.	.	.	.	.	.
Salix cinerea b**	.	.	.	.	.	.	.	.	.	3^{2}	.	6^{1}	14^{+-1}	.	.	.	6^{1}	.	7^{1}
Cirsium arvense	89^{+-2}	44^{+-1}	44^{+-2}	67^{+-1}	45^{+-3}	53^{+-1}	40^{+}	29^{+-1}	83^{+-4}	30^{+-3}	48^{+}	52^{+-2}	64^{+-1}	28^{r-1}	.	43^{+-3}	19^{r-+}	14^{+}	7^{1}
Artemisia vulgaris	22^{+}	22^{+}	33^{+}	33^{+-1}	35^{+-2}	26^{+-1}	20^{+}	38^{+-1}	17^{+-2}	9^{+-2}	13^{r-+}	3^{+}	7^{+}	11^{+}	.	43^{+}	25^{+}	14^{+}	.
Elymus repens	89^{+-1}	56^{+-1}	56^{+-2}	67^{r-1}	30^{+-1}	47^{+-1}	20^{+}	71^{+-2}	.	33^{+-2}	43^{+-2}	10^{1}	21^{+}	11^{+}	.	14^{+}	38^{+-2}	29^{+-1}	33^{+-1}
Equisetum arvense	.	11^{+}	11^{+}	7^{+}	10^{+}	37^{+-1}	.	19^{+}	8^{+}	9^{+-1}	13^{+-1}	6^{+}	7^{+}	6^{+}	.	57^{+-1}	38^{+-1}	29^{+-1}	7^{+}

Tab. 3 Continued

	Syntaxa*																		
	Se	FC	So	CCh	CCt	CCa	Rc	AC	UCt	UCa	SA	EC	Eut	Eua	Euc	Im	Ur	Gs	Ri
Scrophularia nodosa	56^{+-1}	11^{+}	44^{+-1}	20^{+}	10^{+}	16^{+}	20^{+}	5^{+}	25^{+-1}	3^{+}	17^{+}	6^{+}	7^{3}	11^{+}	.	.	13^{+}	.	.
Polygonum amphibium f. *terrestre*	.	.	11^{+}	.	5^{+}	16^{+}	.	14^{+}	17^{+-1}	3^{+}	30^{r-+}	13^{+}	14^{+}	.	.	.	19^{+}	14^{+}	.
Iris pseudacorus	.	.	.	7^{r}	5^{+}	.	20^{+}	5^{+}	25^{+}	3^{+}	22^{+-1}	6^{+}	29^{+}	6^{+}	.	.	.	.	7^{+}
Scutellaria galericulata	.	.	.	7^{+}	.	.	20^{+}	5^{+}	17^{+}	.	4^{+}	3^{+}	7^{+}	22^{+}	43^{+}	.	.	.	7^{+}
Holcus mollis	.	.	.	.	.	5^{+}	.	.	8^{+}	.	4^{+}	6^{+}	7^{+}	17^{+-1}	14^{+}	.	25^{+}	71^{+-2}	20^{+-1}
Convolvulus arvensis	.	11^{+}	11^{+}	13^{+}	5^{+}	.	.	.	17^{+}	.	4^{+}	3^{1}	14^{+}	.	.	.	13^{+-1}	.	.
Lycopus europaeus	.	.	11^{+}	.	.	.	.	5^{+}	8^{+}	3^{+}	13^{+}	13^{+-1}	.	22^{+}	.	.	19^{r-+}	.	.
Brachythecium oedipodium d**	.	.	.	.	.	11^{1}	.	.	.	6^{1}	.	10^{1-2}	7^{1}	11^{1-2}	.	14^{1}	13^{1}	.	7^{1}
Elymus caninus	.	.	.	.	.	16^{+-1}	.	.	.	15^{+-1}	.	6^{+}	.	17^{+-2}	.	.	6^{+}	14^{2}	7^{+}
Glyceria maxima	.	.	.	.	.	.	.	.	8^{+}	.	26^{+-1}	10^{+-1}	7^{+}	17^{+-1}	.	14^{1}	.	.	7^{1}
Eurhynchium hians d**	.	.	.	.	.	5^{1}	.	.	.	15^{+-2}	.	.	7^{1}	6^{1}	14^{1}	29^{1-3}	19^{+-2}	.	.
Rumex obtusifolius	.	.	11^{+}	.	.	16^{+}	.	.	8^{+}	.	13^{+}	.	.	.	.	.	6^{+}	14^{+}	.
Silene alba	.	.	.	.	20^{+-1}	11^{+}	20^{+}	5^{+}	8^{+}	.	4^{+}	.	.	.	.	.	6^{+}	.	.
Brachythecium rivulare d**	.	.	.	.	.	16^{1-2}	.	.	.	6^{1-2}	4^{2}	.	.	6^{1}	29^{1-3}	.	6^{1}	.	.
Fallopia convolvulus	.	11^{+}	.	13^{+}	25^{+-2}	.	.	10^{+-3}	.	.	.	.	.	.	.	.	13^{r-1}	.	.
Festuca gigantea	.	.	.	.	.	.	.	.	.	6^{+}	.	.	7^{+}	17^{+}	29^{+}	.	.	.	20^{r-+}
Cirriphyllum piliferum d**	.	.	.	.	.	.	.	.	.	6^{+}	4^{3}	3^{2}	.	.	.	14^{2}	.	.	13^{+-2}

* Complete names of syntaxa: Se – *Senecionetum fluviatilis*; FC – *Fallopio-Cucubaletum bacciferi*; So – *Solidago gigantea-community*; CCh – *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* subass. nov.; CCt – *Convolvulo sepium-Cuscutetum europaeae typicum*; CCa – *Convolvulo sepium-Cuscutetum europaeae aegopodietosum*; Rc – *Rubus caesius* community; AC – *Achilleo salicifoliae-Cuscutetum lupuliformis*; UCt – *Urtico-Convolvuletum sepium typicum*; UCa – *Urtico-Convolvuletum sepium aegopodietosum*; SA – *Soncho palustris-Archangelicetum litoralis*; EC – *Epilobio hirsuti-Convolvuletum sepium*; Eut – *Eupatorietum cannabini typicum*; Eua – *Eupatorietum cannabini aegopodietosum*; Euc – *Eupatorietum cannabini cardaminetosum amarae* subass. nov.; Im – *Impatiens glandulifera* community; Ur – *Urtica dioica* community; Gs – *Galeopsis speciosa* community; Ri – *Rubus idaeus* community.

** The lowercase letters b, c, and d after species names indicate shrub, herb, and moss layer, respectively.

The percentage frequency of the occurrence of species in relevés are given as well as the range of cover-abundance values (superscript numbers). Diagnostic species of particular syntaxa are marked in gray.

Tab. 4 The relevé table of *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* Myśliwy subass. nov. hoc loco (holotypus Relevé 6).

	Successive number															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	
	Field number*															
	CCh592Wi	CCh600Wi	CCh603Wi	CCh604Wi	CCh605Wi	CCh606Wi	CCh599Wi	CCh634Wi	CCh619Wi	CCh624Wi	CCh586Wi	CCh588Wi	CCh585Wi	CCh594Wi	CCh609Wi	%
Date	2012-07-01	2012-07-01	2012-07-02	2012-07-02	2012-07-02	2012-07-02	2012-07-01	2012-07-05	2012-07-03	2012-07-04	2012-06-30	2012-06-30	2012-06-30	2012-07-01	2012-07-02	
Locality**	Ko	Ko	Sw	Sw	Sw	ND	Ko	Op	Ch	Dr	Cr	Cr	Cr	Ko	ND	
Relevé area (m^2)	20	14	10	25	16	12	18	18	12	18	10	20	20	20	25	
Slope in degrees	0	20	0	0	0	0	0	0	0	20	0	0	0	0	0	
Aspect	SE	NW	SE	SE	SE	NW	SE	E	SE	N	E	E	SE	SE	NW	
Cover of shrub layer (%)	0	0	0	0	0	0	0	0	0	0	5	0	0	0	10	
Cover of herb layer (%)	100	100	100	100	100	100	100	100	100	95	100	100	100	100	100	
Cover of moss layer (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Max height of herb layer (cm)	180	190	180	180	200	200	140	200	150	190	200	190	170	140	200	
Number of species	14	15	20	22	16	16	12	23	21	12	17	16	18	25	17	
Characteristic species of Ass and differential species of Subass																
Cuscuta europaea	2	3	2	2	3	1	3	1	1	2	2	2	3	2	.	93
Chaerophyllum bulbosum	2	2	3	3	2	2	1	2	2	4	2	3	2	1	2	100
Acer negundo c***	1	.	+	.	.	.	.	+	+	.	+	.	+	1	.	47
Rumex confertus	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	20

Tab. 4 Continued

	Successive number															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	Field number*															
	CCh592Wi	CCh600Wi	CCh603Wi	CCh604Wi	CCh605Wi	CCh606Wi	CCh599Wi	CCh634Wi	CCh619Wi	CCh624Wi	CCh586Wi	CCh588Wi	CCh585Wi	CCh594Wi	CCh609Wi	%
Senecionion fluviatilis																
Rubus caesius	2	2	2	3	3	3	2	3	+	.	2	2	2	2	3	93
Solidago gigantea	2	2	2	+	.	2	2	1	2	+	.	2	+	1	.	80
Calamagrostis epigejos	.	+	.	+	.	+	+	+	1	.	.	.	.	.	.	40
Bromus inermis	.	.	.	.	.	1	+	.	+	.	+	.	.	+	.	33
Erysimum cheiranthoides	.	.	.	.	.	+	.	+	.	.	+	.	+	.	+	33
Cuscuta lupuliformis	.	.	.	.	.	.	.	.	.	.	.	.	1	+	1	20
Bidens frondosa	.	.	+	.	.	.	.	r	+	.	.	.	.	.	.	20
Tanacetum vulgare	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	13
Chenopodium album	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	13
Cucubalus baccifer	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	7
Echinocystis lobata	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	7
Veronica longifolia	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	7
Rorippa sylvestris	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	7
Lactuca serriola	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	7
Convolvuletalia sepium																
Phalaris arundinacea	2	.	+	1	+	+	+	.	.	.	1	2	+	+	.	67

Tab. 4 Continued

	Successive number															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	Field number*															
	CCh592Wi	CCh600Wi	CCh603Wi	CCh604Wi	CCh605Wi	CCh606Wi	CCh599Wi	CCh634Wi	CCh619Wi	CCh624Wi	CCh586Wi	CCh588Wi	CCh585Wi	CCh594Wi	CCh609Wi	%
Vicia cracca	+	+	+	+	r	.	.	+	.	.	.	.	.	+	+	53
Stachys palustris	.	.	+	2	1	.	.	2	.	.	.	+	.	+	.	40
Poa palustris	.	.	1	.	.	.	.	1	.	.	.	.	.	.	1	20
Lysimachia vulgaris	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	13
Solanum dulcamara	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	13
Epilobietea angustifolii																
Urtica dioica	2	1	1	+	1	1	2	+	+	+	2	+	2	3	.	93
Humulus lupulus	2	3	.	2	1	.	+	1	3	2	2	1	1	+	.	80
Glechoma hederacea	.	+	2	1	.	1	.	1	1	3	2	1	+	2	.	73
Calystegia sepium	2	1	1	.	3	2	.	.	.	.	1	1	1	3	2	67
Carduus crispus	.	1	1	.	1	1	.	2	.	1	+	+	1	.	+	67
Galium aparine	.	.	.	+	+	.	.	2	+	.	+	1	+	1	3	60
Symphytum officinale	.	+	.	.	.	.	.	.	.	.	1	1	1	1	+	40
Galeopsis bifida	.	.	.	+	+	.	.	.	.	.	.	.	.	.	+	20
Fallopia dumetorum	.	.	.	+	.	.	.	.	+	1	.	.	.	.	.	20
Aegopodium podagraria	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	13
Barbarea stricta	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	13

Tab. 4 Continued

	Successive number															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	Field number*															
	CCh592Wi	CCh600Wi	CCh603Wi	CCh604Wi	CCh605Wi	CCh606Wi	CCh599Wi	CCh634Wi	CCh619Wi	CCh624Wi	CCh586Wi	CCh588Wi	CCh585Wi	CCh594Wi	CCh609Wi	%
Other species																
Elymus repens	1	1	1	1	r	+	+	.	1	+	.	.	.	.	+	67
Cirsium vulgare	1	.	.	.	.	+	+	+	1	+	+	1	1	+	.	67
Artemisia vulgaris	.	.	1	.	.	1	.	+	1	.	.	.	.	+	.	33
Scrophularia nodosa	.	+	.	.	.	.	.	.	+	.	.	.	.	+	.	20
Arctium lappa	.	.	.	.	.	.	.	.	.	.	2	.	2	.	.	13
Equisetum hyemale	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	13
Linaria vulgaris	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	13
Galium mollugo	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	13
Fallopia convolvulus	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	13
Convolvulus arvensis	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	13
Allium scorodoprasum	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	13

Sporadic species: *Salix viminalis* b*** 15 (2), *Viburnum opulus* b*** 11 (1), *Alopecurus pratensis* 15 (+), *Anchusa officinalis* 14 (+), *Cardaminopsis arenosa* 8 (+), *Cornus sanguinea* c*** 4 (+), *Equisetum arvense* 4 (+), *Euphorbia esula* subsp. *esula* 4 (+), *Heracleum sphondylium* subsp. *sibiricum* 14 (+), *Iris pseudacorus* 1 (r), *Prunus spinosa* c*** 10 (1), *Scutellaria galericulata* 14 (+), *Ulmus laevis* c*** 9 (+).

* Geographical coordinates for relevés: CCh585Wi – N53.31651, E18.32822; CCh586Wi – N53.31683, E18.32848; CCh588Wi – N53.31777, E18.32913; CCh592Wi – N53.33834, E18.35114; CCh594Wi – N53.33711, E18.34945; CCh599Wi – N53.34812, E18.36511; CCh600Wi – N53.34718, E18.36377; CCh603Wi – N53.37394, E18.43235; CCh604Wi – N53.37479, E18.43349; CCh605Wi – N53.37558, E18.43545; CCh606Wi – N53.37881, E18.4514; CCh609Wi – N53.38123, E18.45575; CCh619Wi – N53.22254, E18.20379; CCh624Wi – N53.50791, E18.7466; CCh634Wi – N53.74471, E18.85465.
** Locality: Ch – Chełmszczanka; Cr – Chrystkowo; Dr – Dragacz; Ko – Kosowo; ND – Nowe Dobra; Op – Opalenie; Sw – Świecie.
*** The lowercase letters b and c after species names indicate shrub and herb layer, respectively.

Tab. 5 The relevé table of the riparian tall herb fringe communities of the order *Convolvuletalia sepium* represented by few samples and not included in the synoptic table.

	Successive number									
	1	2	3	4	5	6	7	8	9	10
	Syntaxa*									
	Fa		Ca		Ci		He		Rj	
Field number**	FH622Wi	FH626Wi	Ca122Po	Ca346Le	Ci99Le	Ci188Ra	He139In	He140In	Rj417Za	Rj132In
Date	2012-07-04	2012-07-04	2009-09-12	2010-08-17	2009-08-12	2010-07-08	2009-09-19	2009-09-19	2011-07-03	2009-09-13
Locality***	Dr	Dr	Pr	Go	Pa	Bi	Re	Re	Wa	Ry
Relevé area (m^2)	18	18	6	10	6	14	6	6	9	8
Slope in degrees	0	0	0	0	0	30	20	10	75	30
Aspect	E	E	S	NE	SW	NW	NE	NE	N	N
Cover of shrub layer (%)	0	0	0	0	0	0	0	0	0	0
Cover of herb layer (%)	85	100	100	100	100	100	100	100	100	100
Cover of moss layer (%)	0	0	0	0	0	0	1	0	5	5
Max height of herb layer (cm)	40	120	120	150	150	150	250	300	180	300
Number of species	14	16	10	9	16	16	16	11	26	5
Dominant species										
Fallopia dumetorum	4	4	3	.	.	.	.	.	.	.
Humulus lupulus	2	4	.	.	.	.	.	.	.	.
Carduus crispus	1	1	4	4	.	.	.	.	.	.
Cirsium arvense	.	.	.	.	4	3	.	.	.	.
Helianthus tuberosus	.	.	.	.	.	.	5	5	1	.
Reynoutria japonica	.	.	.	.	.	.	.	.	5	5
Senecionion fluviatilis										
Chenopodium album	+	+	.	.	.	.	+	+	.	.
Erysimum cheiranthoides	+	+	.	.	.	.	.	.	+	.
Bromus inermis	+	.	.	1	.	.	.	.	.	.
Convolvuletalia sepium										
Phragmites australis	.	.	.	.	.	2	+	+	+	.
Vicia cracca	.	.	r	.	.	.	+	.	+	.
Poa palustris	.	+	.	.	.	1	.	.	.	.
Phalaris arundinacea	.	.	.	.	.	2	.	.	1	.

Tab. 5 Continued

	Successive number									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Syntaxa*									
	Fa		**Ca**		**Ci**		**He**		**Rj**	
Epilobietea angustifolii										
Urtica dioica	.	1	3	1	+	+	r	+	+	1
Galium aparine	.	1	2	+	2	2	2	1	+	.
Aegopodium podagraria	.	1	.	.	2	4	+	r	+	2
Glechoma hederacea	+	.	r	.	2	1	.	.	.	.
Galeopsis speciosa	.	.	.	1	+	.	+	1	.	.
Galeopsis bifida	+	+	.	.	.	1	.	.	.	.
Calystegia sepium	.	.	.	.	.	.	1	2	2	.
Lamium maculatum	.	+	.	+	.	.	.	.	.	.
Anthriscus sylvestris	.	.	2	+	.	.	.	.	.	.
Other species										
Equisetum arvense	+	.	r	.	1	+	.	.	1	.
Elymus repens	.	.	1	2	.	+	.	.	+	.
Conyza canadensis	+	+	.	.	+	.	.	.	.	.
Artemisia vulgaris	1	+	.	.	.	.	.	.	+	.
Elymus caninus	.	.	.	.	2	.	+	+	.	.
Scrophularia nodosa	.	1	.	.	.	.	+	.	.	.
Dactylis glomerata	.	.	.	.	.	+	.	.	+	.
Eurhynchium hians d****	.	.	.	.	.	.	.	.	1	+
Saponaria officinalis	.	.	.	.	.	.	1	.	+	.
Stellaria nemorum	.	.	.	.	.	.	+	1	.	.

Sporadic species: *Achillea millefolium* 9 (+), *Alopecurus pratensis* 6 (+), *Arrhenatherum elatius* 9 (+), *Calamagrostis epigejos* 9 (+), *Capsella bursa-pastoris* 2 (+), *Carex acutiformis* 8 (1), *Ceratodon purpuraeus* d**** 9 (+), *Convolvulus arvensis* 9 (+), *Cornus sanguinea* c**** 1 (+), *Deschampsia caespitosa* 5 (+), *Equisetum palustre* 7 (+), *Fallopia convolvulus* 1 (+), *Filipendula ulmaria* 5 (+), *Fraxinus excelsior* c**** 5 (+), *Galeopsis pubescens* 3 (+), *Holcus mollis* 6 (+), *Lapsana communis* 5 (+), *Myosoton aquaticum* 4 (+), *Petasites spurius* 9 (2), *Physcomitrium pyriforme* d**** 7 (r), *Pimpinella major* 6 (+), *Plagiomnium undulatum* d**** 10 (1), *Pohlia wahlenbergii* d**** 7 (r), *Potentilla reptans* 9 (+), *Ranunculus acris* 6 (+), *Rorippa palustris* 2 (+), *Rubus caesius* 9 (1), *Rumex thyrsiflorus* 5 (+), *Silene alba* 1 (+), *Sisymbrium loeselii* 9 (+), *Tanacetum vulgare* 9 (+), *Taraxacum* sect. *Taraxacum* 5 (+), *Valeriana sambucifolia* 5 (2).

* Complete names of syntaxa: Fa – *Fallopia dumetorum* community; Ca – *Carduus crispus* community; Ci – *Cirsium arvense* community; He – *Helianthus tuberosus* community; Rj – *Reynoutria japonica* community.
** Geographical coordinates for relevés: FH622Wi – N53.50981, E18.7474; FH626Wi – N53.50587, E18.74548; Ca122Po – N53.30894, E15.77752; Ca346Le – N54.55279, E17.56514; Ci99Le – N54.54544, E18.02107; Ci188Ra – N54.09405, E16.08621; He139In – N53.25771, E15.53566; He140In – N53.25728, E15.53542; Rj417Za – N53.70639, E14.35566; Rj132In – N53.29184, E15.54686.
*** Locality: Bi – Białogórzyno; Dr – Dragacz; Go – Górzyno; Pa – Paraszyno; Pr – Prostynia; Re – Recz; Ry – Rybaki; Wa – Warnołęka.
**** The lowercase letters c and d after species names indicate herb and moss layer, respectively.
Diagnostic species of particular syntaxa are marked in gray.

Tab. 6 The relevé table of *Eupatorietum cannabini cardaminetosum amarae* Myśliwy subass. nov. hoc loco (holotypus Relevé 4).

	Successive number							
	1	2	3	4	5	6	7	
	Field number*							
	Euc53Ps	Euc109Le	Euc61Ps	Euc62Ps	Euc57Ps	Euc55Ps	Euc52Ps	%
Date	2009-08-08	2009-08-12	2009-08-08	2009-08-08	2009-08-08	2009-08-08	2009-08-08	
Locality**	PW	Pa	PW	PW	PW	PW	PW	
Relevé area (m²)	8	6	10	10	12	12	8	
Slope in degrees	20	0	0	0	10	20	0	
Aspect	S	NW	S	N	N	SW	S	
Cover of shrub layer (%)	0	0	0	0	0	0	0	
Cover of herb layer (%)	95	95	95	100	100	95	95	
Cover of moss layer (%)	60	40	65	40	50	15	60	
Max height of herb layer (cm)	150	150	150	160	150	140	150	
Number of species	21	13	20	24	22	19	21	
Characteristic species of Ass and differential species of Subass								
Eupatorium cannabinum	4	5	4	5	4	5	4	100
Geranium robertianum	1	+	.	+	+	+	+	86
Scirpus sylvaticus	.	.	1	1	+	+	+	71
Galium palustre	.	.	1	+	+	+	+	71
Myosotis palustris	+	+	+	.	.	.	+	57
Crepis paludosa	.	.	+	+	.	+	+	57
Climacium dendroides d***	.	.	.	2	3	2	3	57
Valeriana dioica	2	.	.	.	+	1	1	57
Cardamine amara	+	1	.	+	.	.	.	43
Chrysosplenium alternifolium	.	.	+	+	.	.	+	43
Archangelicion litoralis								
Mentha aquatica	2	+	.	+	+	+	+	86
Plagiomnium undulatum d***	3	.	3	2	2	1	2	86
Filipendula ulmaria	.	.	+	+	+	+	+	71
Carex acutiformis	.	.	1	+	1	1	+	71
Cirsium oleraceum	.	.	1	.	.	1	.	29
Equisetum palustre	.	.	.	.	+	.	1	29

Tab. 6 Continued

	Successive number							
	1	2	3	4	5	6	7	
	Field number							
	Euc53Ps	Euc109Le	Euc61Ps	Euc62Ps	Euc57Ps	Euc55Ps	Euc52Ps	%
Rumex thyrsiflorus	.	+	.	+	.	.	.	29
Brachythecium rutabulum d***	.	.	2	.	.	.	.	14
Convolvuletalia sepium								
Lysimachia vulgaris	.	.	.	+	+	+	+	57
Solanum dulcamara	.	.	3	+	.	.	1	43
Epilobietea angustifolii								
Urtica dioica	.	+	.	r	1	.	.	43
Carduus crispus	+	.	.	+	.	.	+	43
Galium aparine	.	.	1	1	2	.	.	43
Impatiens noli-tangere	.	.	.	.	.	+	.	14
Other species								
Poa trivialis	.	+	1	1	1	1	1	86
Stellaria nemorum	.	1	+	+	2	1	.	71
Scutellaria galericulata	+	.	.	.	.	+	+	43
Athyrium filix-femina	.	.	.	+	+	+	.	43
Brachythecium rivulare d***	.	3	1	.	.	.	.	29
Festuca gigantea	+	.	+	.	.	.	.	29
Euonymus europaeus c***	.	.	.	+	+	.	.	29
Epilobium palustre	.	.	.	+	+	.	.	29
Calliergonella cuspidata d***	+	.	.	.	.	.	+	29

Sporadic species: *Agrostis stolonifera* 1 (+), *Caltha palustris* 5 (+), *Carex paniculata* 7 (+), *Cratoneuron filicinum* d*** 1 (1), *Dryopteris carthusiana* 1 (+), *Epilobium adenocaulon* 1 (+), *E. obscurum* 2 (+), *Equisetum fluviatile* 5 (+), *Eurhynchium hians* d*** 3 (1), *Glyceria nemoralis* 1 (+), *Holcus mollis* 2 (+), *Juncus bulbosus* 1 (+), *Lychnis flos-cuculi* 5 (+), *Lysimachia nummularia* 1 (+), *Mercurialis perennis* 3 (+), *Mnium hornum* d*** 1 (2), *Oxalis acetosella* 4 (+), *Rhizomnium punctatum* d*** 1 (+), *Stellaria uliginosa* 2 (2), *Trichocolea tomentella* d*** 3 (1), *Veronica beccabunga* 1 (+), *Viola palustris* 6 (+).

* Geographical coordinates for relevés: Euc52Ps – N54.6868, E18.18514; Euc53Ps – N54.68689, E18.18434; Euc55Ps – N54.68666, E18.18317; Euc57Ps – N54.68652, E18.18306; Euc61Ps – N54.68781, E18.16425; Euc62Ps – N54.68773, E18.165; Euc109Le – N54.54303, E18.01876.
** Locality: PW – Piaśnica Wielka; Pa – Paraszyno.
*** The lowercase letters c and d after species names indicate herb and moss layer, respectively.

4.3. Environmental characteristics of the riparian tall herb fringe vegetation

More than 64% of the relevés were obtained on the flat banks of the rivers, whereas almost 36% (107 relevés) were from bank slopes. The slope angle in almost 30% of the relevés ranged 10–45° (Fig. 32A, Tab. S1). The exposure type (aspect) in the dataset analyzed was slightly dominated by south- and northeast facing slopes. Vegetation samples on flat banks were dominated by the east facing, followed by south facing ones (Fig. 32B).

More than 65% of the tall herb fringe vegetation samples occurred 0–5 m away from the riverbank, including more than 30% occurred no farther than 1 m away from the bank. In 17% of the relevés, the distance between the vegetation sample and the riverbed amounted to 5–10 m, the greater distance was recorded in 18% of the relevés (Fig. 32C, Tab. S1). The distance was weekly correlated with various factors, with the strongest correlation being that with river size and riverbed width (Tab. S2).

Approximately 45% of the tall herb fringe vegetation samples were obtained from low banks, 50 cm above the water level at most. The bank heights of 50–100 cm were recorded in 25% of the relevés. More than 14% of samples occurred on 1–2 m high banks (Fig. 32D, Tab. S1). The sample elevation above the river water level was significantly, albeit weakly or moderately, correlated with all the factors, except the slope angle, aspect, and C/N ratio (Tab. S2).

Almost half of the relevés (47%) experienced full light, more than 38% light shading, and strong shading was experienced by less than 15%. The latter were most frequently encountered in gaps of tree stands or at the forest fringe, and more seldom were found in the shadow of solitary trees. The degree of shading was weakly correlated with various factors, including the riverbed width and river size (Tab. S2).

The most frequent river flow rate encountered in the vicinity of the riparian tall herb vegetation samples was either rippled flow (more than 51% of the relevés) or smooth flow (more than 46%) (Fig. 32E). The flow rate was weakly correlated with various factors, with a moderate correlation occurring with river size and riverbed width (Tab. S2).

A total of 4% of the relevés, taken in the valleys of small rivers, were located near drainage ditches. In small river valleys, approximately 4% of vegetation samples were taken in the vicinity of headwater seeps. Conversely, the relevés taken in localities with distinct traces of summer floods were typical of large rivers and the Szczecin Lagoon (more than 4% of the relevés).

Collected soil samples showed a highly variable organic matter content (Fig. 32F). Approximately 69% of the samples represented mineral soils, 20% being assigned to mineral-organic soils, whereas only 11% were classified as organic soils. The loss on ignition (LOI) values in organic soil samples ranged widely, from over 20 to more than 85% (Tab. S1). The LOI was strongly correlated with the humus, organic carbon (C_{org}), total nitrogen (N_{tot}), bioavailable calcium (CaO), and magnesium (MgO) contents, and the silt fraction (Tab. S2).

Granulometric categories represented by the mineral and mineral-organic soil samples (a total of 267 samples) were dominated by loamy sands (more than 36% of samples), as well as slightly loamy and loose sands (23.6% and 19.1%, respectively). Approximately 13.5% of soil samples were classified as sandy loams, and the remaining granulometric categories were represented by only a few samples each (Fig. 32G).

The mineral and mineral-organic soils represented four weight categories: very light (more than 42% of the samples), light (almost 37%), medium-weight (about 18%), and heavy soils (more than 2%). The heavy and the medium-weight soil samples were collected (only and mostly, respectively) in large river valleys.

The skeletal percentage of soil samples exhibited domination of skeleton-less formations, and the coarsest fraction was not found in 47% of soil samples. Two groups, consisting of 30% and 16% of soil samples, were very poorly skeletal formations (containing up to 5% of the skeletal fraction) and poorly skeletal formations (5–15% of the skeletal fraction), respectively. Moderately skeletal formations (15–35% of skeletal fraction contribution) were represented by 7.3% of samples (Fig. 32H, Tab. S1). The weight percentage of the soil skeleton was weakly correlated with various factors, with a moderate, negative correlation produced with the riverbed width and the clay fraction (Tab. S2).

More than 90% of mineral and mineral-organic soil samples contained 70–100% sand. In the case of silts, more than 68% of samples had a silt contribution ranging from 0% to 15%, with 15–25% silts being found in approximately 23% of the samples. The contribution of the clay fraction in more than 90% of samples ranged 0–8% and did not exceed 20% (Fig. 32I–K, Tab. S1). The percent contribution of sand was strongly negatively correlated with the contributions of silt and clay, as well as with the contents of available magnesium (MgO), phosphorus (P_2O_5), and potassium (K_2O). The silt fraction contribution was strongly positively correlated with the MgO and P_2O_5 contents, as well as with the N_{tot}, C_{org}, and humus contents, LOI, and the clay fraction contribution. The clay fraction contribution was strongly positively correlated with potassium content, with the other correlations being weaker (Tab. S2).

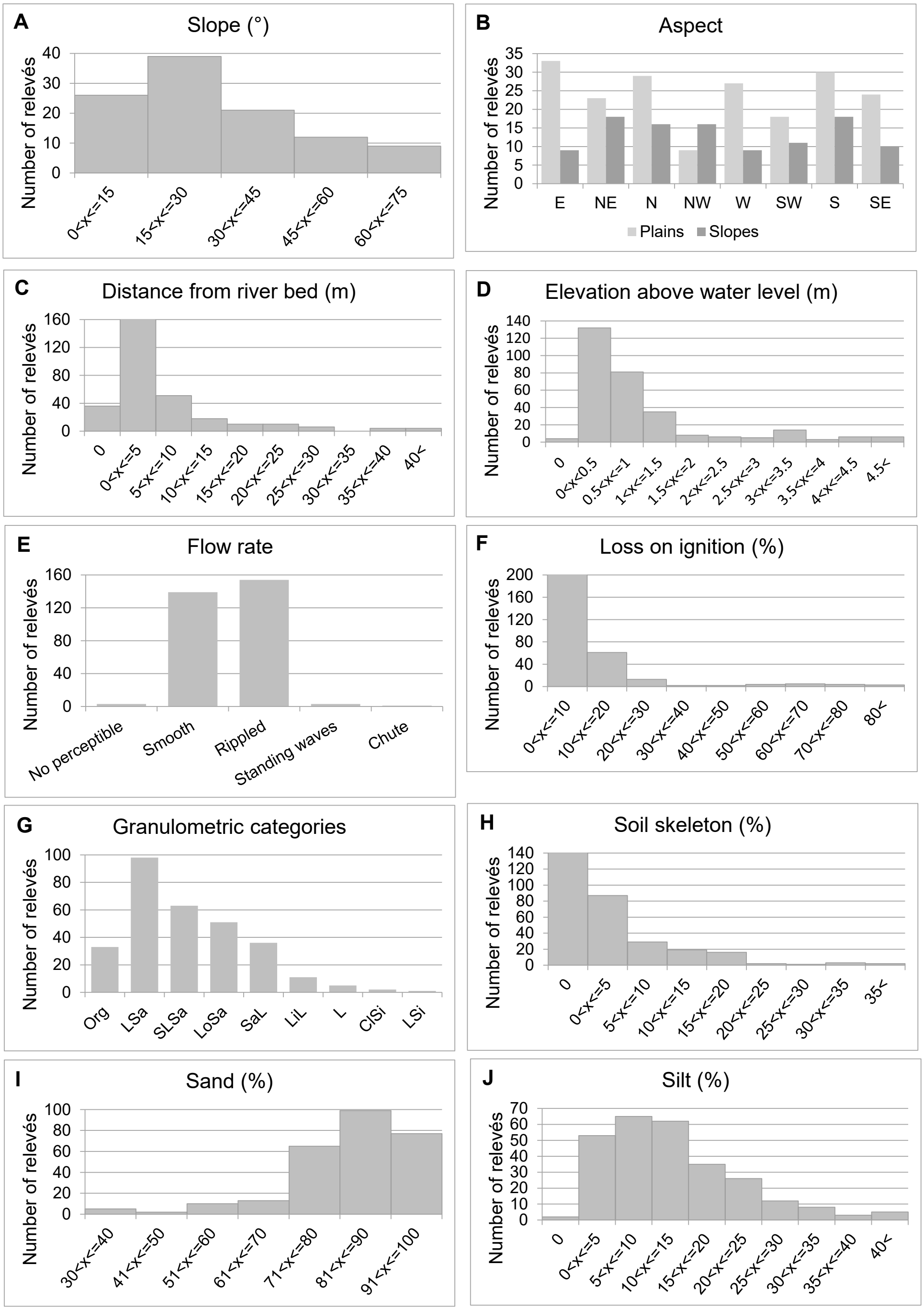
The soil pH ranged widely from very acidic to alkaline, with a median of 6.6 (Tab. S1). Most samples were characterized as neutral (pH 6.6–7.2) or slightly acidic pH (5.6–6.5) (Fig. 32L). The soil pH was significantly correlated with most environmental factors, with the strongest correlations with calcium carbonate ($CaCO_3$) content and river size (Tab. S2).

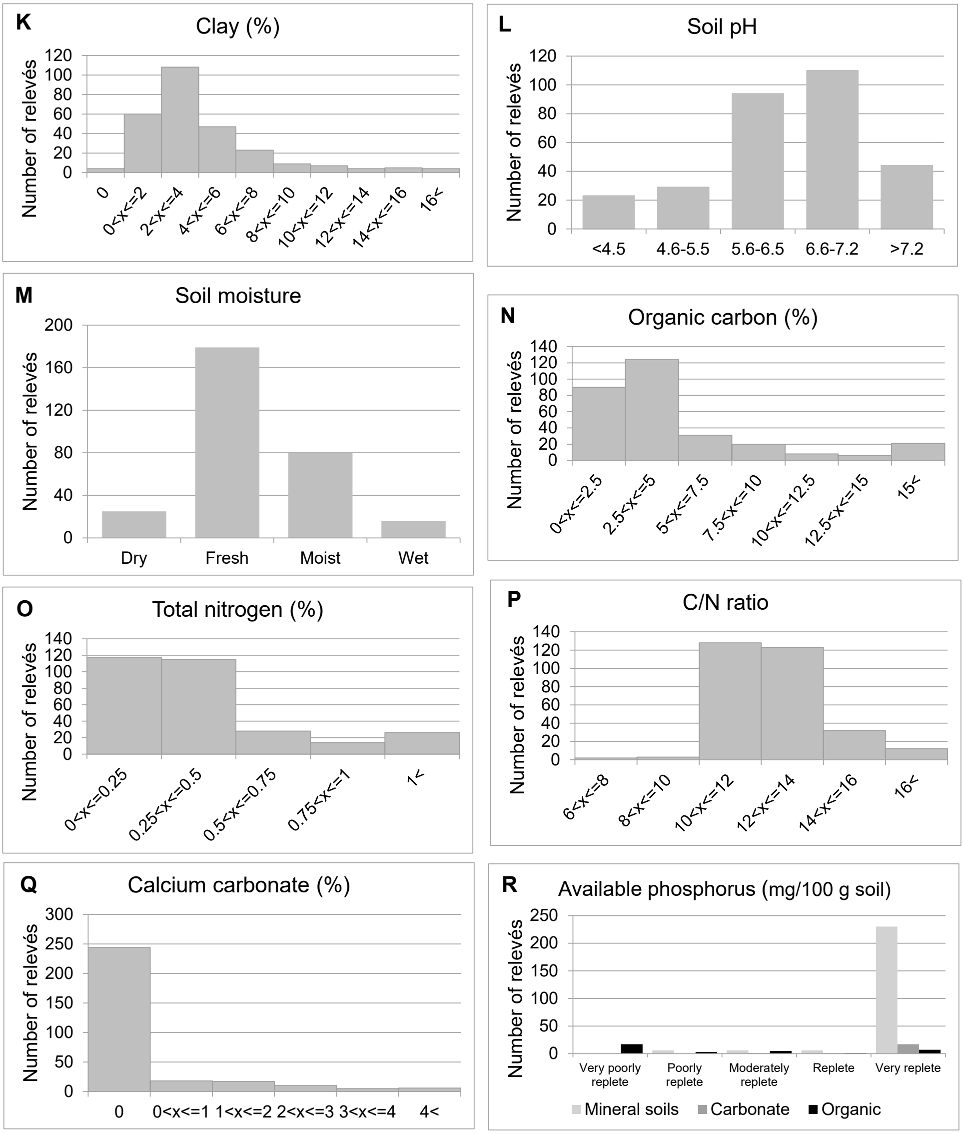
Hand-felt soil moisture assessment was primarily that of fresh (almost 60% of samples) and moist soils (more than 26%) (Fig. 32M). Wet soils occurred in the lowest-lying and most shaded locations. Dry soils supporting patches dominated by nettle occurred most often in meadow and pasture complexes. Moisture was weakly correlated with various factors, including the sand and silt fractions (Tab. S2).

More than 70% of soil samples had organic carbon (C_{org}) contents lower than 5%. All these samples represented mineral and mineral-organic soils. Organic carbon contents ranging within 5–10% were found in 17% of samples, with all classified as mineral-organic. The organic soils had the highest C_{org} content. The median value of humus content in soil samples was approximately 6%, and 75% of samples had a humus content lower than 10%. In 77% of soil samples, the total nitrogen (N_{tot}) content was lower than 0.5%. N_{tot} contents higher than 1% were found in less than 9% of soil samples and were only typical of organic soils (Fig. 32N,O, Tab. S2). The C_{org}, humus, and N_{tot} contents were strongly positively intercorrelated, and strongly positively correlated with the LOI, contents of CaO and MgO, and the silt fraction (Tab. S2).

The median value of the C/N ratio exceeded 12 (Tab. S1). In 84% of soil samples, it ranged within 10–14 (Fig. 32P). The C/N ratio was weakly correlated with various factors and had a moderate correlation with longitude and $CaCO_3$ content (Tab. S2).

Among all the numerical variables, $CaCO_3$ content showed the highest coefficient of variation (Tab. S1). Carbonates were detected in less than 20% of samples, including 20 samples (almost 7%) with contents higher than 2%, which were regarded as carbonate soils (Fig. 32Q). The $CaCO_3$ content was weakly correlated with many factors, and the strongest correlation was with soil pH (Tab. S2).


A
Slope (°)
Number of relevés
0<x<=15
15<x<=30
30<x<=45
45<x<=60
60<x<=75
B
Aspect
Number of relevés
E
NE
N
NW
W
SW
S
SE
Plains
Slopes
C
Distance from river bed (m)
Number of relevés
0
0<x<=5
5<x<=10
10<x<=15
15<x<=20
20<x<=25
25<x<=30
30<x<=35
35<x<=40
40<
D
Elevation above water level (m)
Number of relevés
0
0<x<0.5
0.5<x<=1
1<x<=1.5
1.5<x<=2
2<x<=2.5
2.5<x<=3
3<x<=3.5
3.5<x<=4
4<x<=4.5
4.5<
E
Flow rate
Number of relevés
No perceptible
Smooth
Rippled
Standing waves
Chute
F
Loss on ignition (%)
Number of relevés
0<x<=10
10<x<=20
20<x<=30
30<x<=40
40<x<=50
50<x<=60
60<x<=70
70<x<=80
80<
G
Granulometric categories
Number of relevés
Org
LSa
SLSa
LoSa
SaL
LiL
L
ClSi
LSi
H
Soil skeleton (%)
Number of relevés
0
0<x<=5
5<x<=10
10<x<=15
15<x<=20
20<x<=25
25<x<=30
30<x<=35
35<
I
Sand (%)
Number of relevés
30<x<=40
41<x<=50
51<x<=60
61<x<=70
71<x<=80
81<x<=90
91<x<=100
J
Silt (%)
Number of relevés
0
0<x<=5
5<x<=10
10<x<=15
15<x<=20
20<x<=25
25<x<=30
30<x<=35
35<x<=40
40<


K
Clay (%)
Number of relevés
120
100
80
60
40
20
0
0
0<x<=2
2<x<=4
4<x<=6
6<x<=8
8<x<=10
10<x<=12
12<x<=14
14<x<=16
16<
L
Soil pH
Number of relevés
120
100
80
60
40
20
0
<4.5
4.6-5.5
5.6-6.5
6.6-7.2
>7.2
M
Soil moisture
Number of relevés
200
160
120
80
40
0
Dry
Fresh
Moist
Wet
N
Organic carbon (%)
Number of relevés
140
120
100
80
60
40
20
0
0<x<=2.5
2.5<x<=5
5<x<=7.5
7.5<x<=10
10<x<=12.5
12.5<x<=15
15<
O
Total nitrogen (%)
Number of relevés
140
120
100
80
60
40
20
0
0<x<=0.25
0.25<x<=0.5
0.5<x<=0.75
0.75<x<=1
1<
P
C/N ratio
Number of relevés
140
120
100
80
60
40
20
0
6<x<=8
8<x<=10
10<x<=12
12<x<=14
14<x<=16
16<
Q
Calcium carbonate (%)
Number of relevés
300
250
200
150
100
50
0
0
0<x<=1
1<x<=2
2<x<=3
3<x<=4
4<
R
Available phosphorus (mg/100 g soil)
Number of relevés
250
200
150
100
50
0
Very poorly replete
Poorly replete
Moderately replete
Replete
Very replete
Mineral soils
Carbonate
Organic

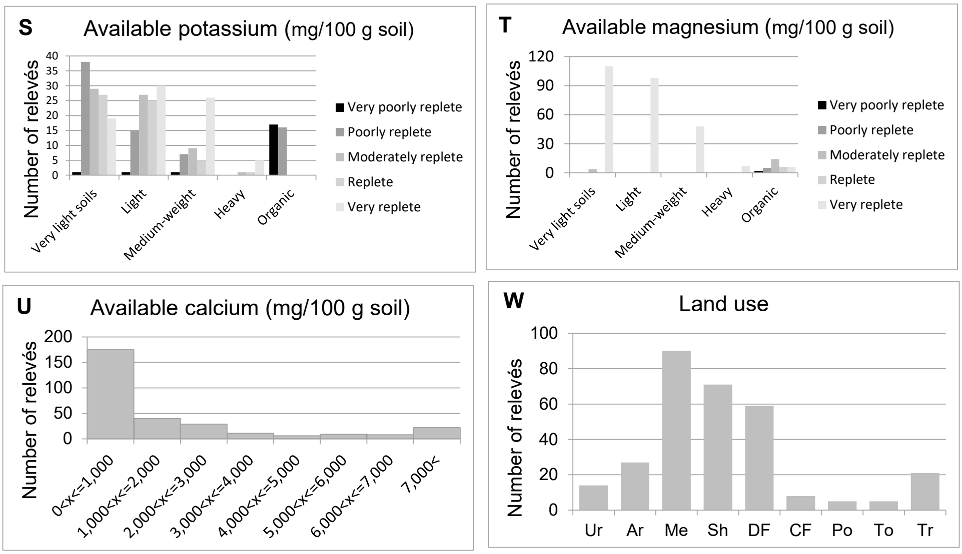


Fig. 32 Frequency distributions of selected variables. Abbreviations denoting granulometric categories: Org – organic soil; LSa – loamy sand; SLSa – slightly loamy sand; LoSa – loose sand; SaL – sandy loam; LiL – light loam; L – loam; ClSi – clayey silt; LSi – loamy silt. Abbreviations denoting land use type: Ur – urban areas; Ar – arable land; Me – meadows and pastures; Sh – shrubs; DF – deciduous forest; CF – coniferous forest; Po – fish culture ponds; To – tourism; Tr – transportation.

The median phosphorus (P_2O_5) content in the soil samples was 71.9 mg/100 g soil (Tab. S1). Based on the official reference standards, more than 92%, 89%, and 21% of the mineral, carbonate, and organic soil samples, respectively, could be regarded as phosphorus-replete (Fig. 32R). The P_2O_5 content was strongly positively correlated with the soil silt fraction, and a strong negative correlation occurred with the sand fraction and latitude (Tab. S2).

The median potassium (K_2O) content in the soil samples was 16 mg/100 g soil (Tab. S1). According to the reference standards, organic soils were potassium poor. Poorly or moderately potassium-replete soils were also very light soils (almost 60% of samples). In contrast, heavy soil samples exhibited very high potassium content (71% of samples). Soils that were highly replete and replete in potassium were medium-weight soils (54% and 10% of samples, respectively). Among light soil samples, almost 31% exhibited very high K_2O contents, and 25.5% exhibited high contents (Fig. 32S). The K_2O content was strongly correlated with the magnesium content and with individual grain size fractions (Tab. S2).

The median magnesium (MgO) content in the soil samples was 35 mg/100 g soil (Tab. S1). According to the reference standards, almost all the mineral and mineral-organic samples indicated highly magnesium-replete soils. Organic soil samples were dominated by soils moderately magnesium-replete (more than 42% of samples) and replete or highly replete (18% each) (Fig. 32T). The MgO content was strongly positively correlated with silt, and negatively correlated with sand fractions. Strong significant correlations were also found with CaO and K_2O contents, as well as the LOI, and the N_{tot}, C_{org}, and humus contents (Tab. S2).

The median calcium (CaO) content was 647.4 mg/100 g soil (Tab. S1). The dominant range covered 0–5,000 mg/100 g soil (Fig. 32U). The CaO content was strongly positively correlated with the content of MgO, humus, C_{org}, N_{tot}, and LOI (all the correlation coefficients exceeded 0.5 at $p < 0.05$), with the other relationships being moderate or weak (Tab. S2).

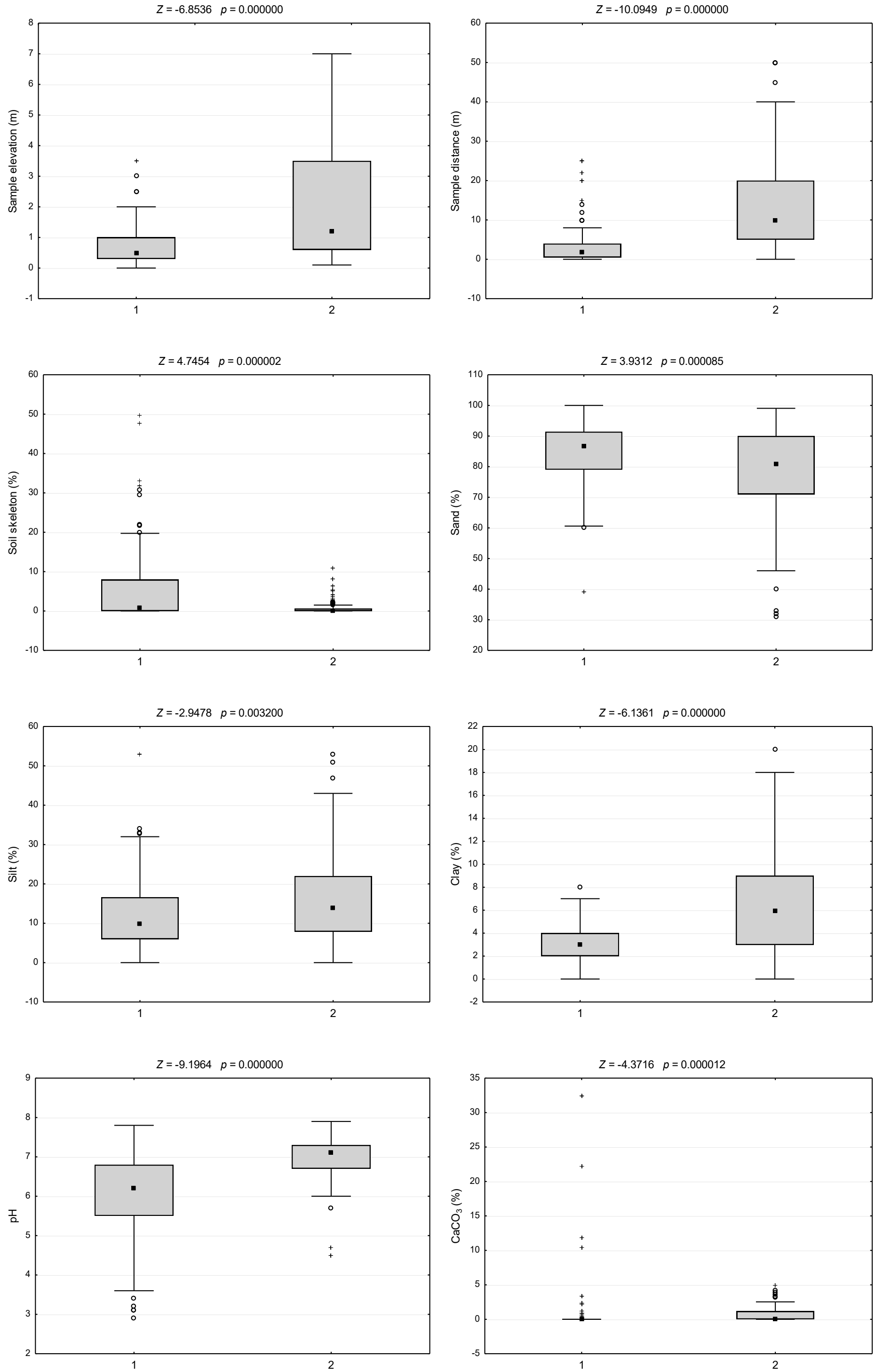
4.4. Characteristics of river size-related environmental conditions

The riparian tall herb fringe vegetation samples collected along rivers of various size differed significantly in terms of most environmental factors (Fig. 33). A very strong positive correlation was found between river size and its channel width ($r = 0.82$) (Tab. S2) and a statistically significant between-group difference occurred for river channel width ($p < 0.05$). Statistical significance also occurred for the correlation between river size and the distance of vegetation sample from the channel and sample elevation above the river water level. These two characteristics were significantly different between samples from small and large rivers. Water flow rate in small rivers was lower than that in large rivers and the difference was significant. A significant difference occurred for the degree of shading of the riparian tall herb fringe vegetation on large rivers, with substantially deforested valleys and those on small rivers, which more often occur in woodlands. No significant differences occurred between sample groups in regard to slope angle and aspect.

The soil samples collected along large rivers were significantly different from those from small rivers in terms of numerous soil parameters (Fig. 33). Differences in the proportions of all grain size fractions were significant. The highest median clay and silt proportions were typical of large-river samples; in contrast, those samples showed the lowest median sand and skeletal percentages (Tab. S1, Fig. 33).

Soil samples from large-river riparian tall herb fringe communities exhibited high pH values, which were significantly different from that of soil samples from small rivers. A comparison between medians of bioavailable phosphorus (P_2O_5), potassium (K_2O), and magnesium (MgO) contents in the samples revealed significant differences between large river valleys (with higher medians) and small rivers (with lower medians). Soil calcium (CaO) content was also significantly different between small rivers and large rivers, with the median CaO content in large-river soil samples being lower. However, the median carbonate ($CaCO_3$) content in the large river samples and in the small ones was equal to 0.0; nonetheless, the difference between these groups was significant (Tab. S1, Fig. 33).

The fertility of the small-river soils was higher and significantly different from that of large-river soils. This effect was caused by higher median total nitrogen, organic carbon, and humus contents, as well as higher LOI values in small-river soils (Tab. S1, Fig. 33). The soil samples from small river valleys were significantly different in terms of their C/N ratio from samples collected from large rivers, which had a higher median value. Among all the soil parameters studied, only the difference in soil moisture content between the groups was not statistically significant.


Z = -6.8536 p = 0.000000
Sample elevation (m)
Z = -10.0949 p = 0.000000
Sample distance (m)
Z = 4.7454 p = 0.000002
Soil skeleton (%)
Z = 3.9312 p = 0.000085
Sand (%)
Z = -2.9478 p = 0.003200
Silt (%)
Z = -6.1361 p = 0.000000
Clay (%)
Z = -9.1964 p = 0.000000
pH
Z = -4.3716 p = 0.000012
CaCO3 (%)
1
2

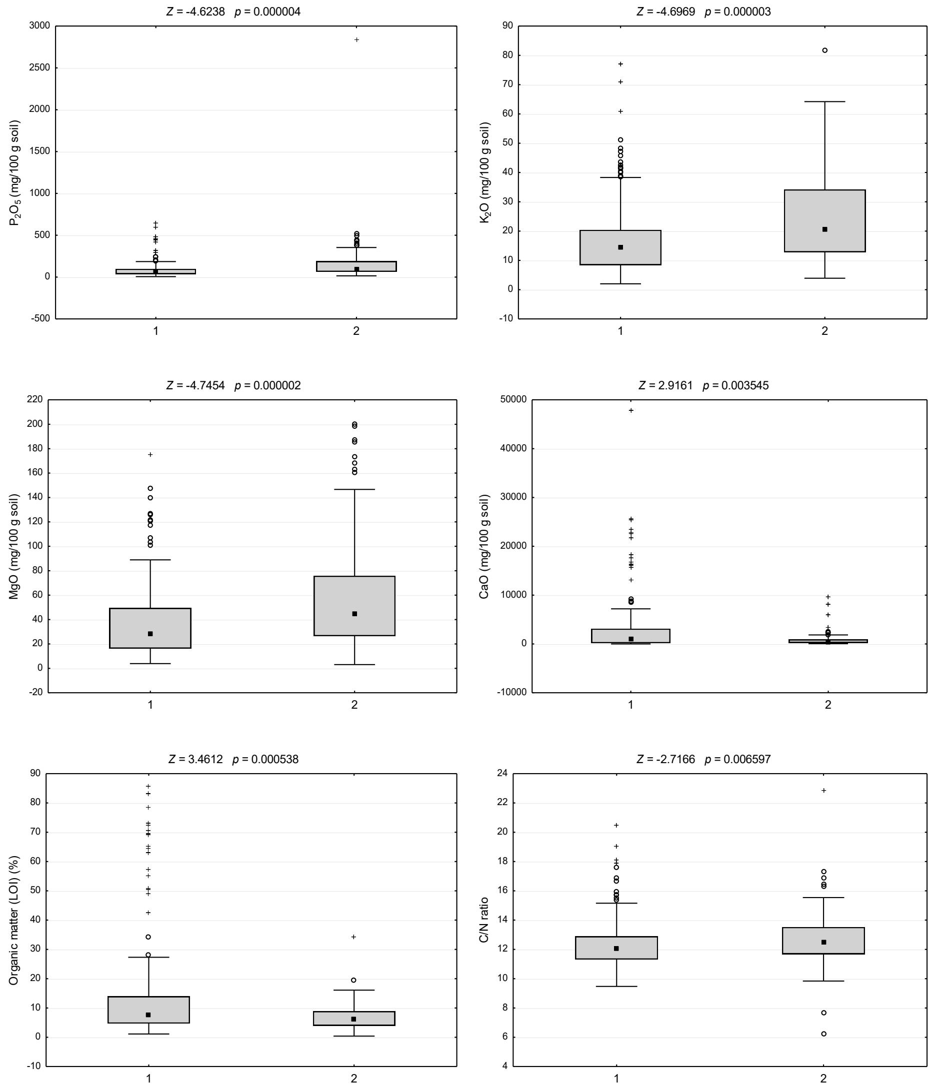


Fig. 33 Box and whisker plots of selected environmental variables for riparian tall herb fringe communities of the order *Convolvuletalia sepium* in NW Poland: comparison of small (1) and large (2) rivers. The box length is the interquartile range; small squares indicate the median; circles represent outlier values; crosses reflect extreme values. Results of Mann–Whitney *U* (*Z* and *p* values) test are given.

4.5. Relationships between riparian tall herb fringe communities and natural potential vegetation

The riparian tall herb fringe vegetation samples were assigned to 10 natural potential vegetation cartographic units. The most common unit was the *Fraxino-Alnetum*, which supported 39% of vegetation samples, with the majority occurring in the vicinity of small rivers, particularly in the coastal zone. The *Salici-Populetum* supported 28% of vegetation samples, primarily occurring close to large rivers, including the Szczecin Lagoon. The *Carici elongatae-Alnetum* supported 14% of vegetation samples, and was recorded in small river valleys. Distinctly rarer was the *Ficario-Ulmetum chrysosplenietosum* with approximately 7% of vegetation samples and occurring on small rivers. Further rare were the poor and rich *Stellario-Carpinetum* with 3% and more than 3% of vegetation samples, respectively, with both recorded on small river valleys. The other potential vegetation units (the *Ficario-Ulmetum typicum*, *Fago-Quercetum*, *Galio odorati-Fagetum*, *Empetro nigri-Pinetum*, and *Leucobryo-Pinetum*) were recorded sporadically.

4.6. Vegetation mosaic and landscape heterogeneity

Almost 25% of the riparian tall herb fringe vegetation samples were recorded at the very edge of the riverbank, directly adjoining aquatic communities representing the classes *Potamogetonetea* and *Lemnetea*. More than 40% of vegetation samples were separated from the water by the *Phragmito-Magnocaricetea* communities, including the most common associations: *Phragmitetum australis*, *Phalaridetum arundinaceae*, *Glycerietum maximae*, *Caricetum acutiformis*, and *Sparganietum erecti*. Rushes were adjacent, on the landward side, to 14% of the riparian tall herb fringe vegetation samples.

In 24% of vegetation samples, the fringe communities occurred in gaps between alder carr stands. A total of 34% of the riparian tall herb fringe vegetation samples were, at least landward, adjacent to forest or shrub communities of the classes *Salicetea purpureae*, *Alno glutinosae-Populetea albae*, *Carpino-Fagetea sylvaticae*, and *Alnetea glutinosae*. They were most often represented by the associations *Salicetum albae*, *Salicetum fragilis*, *Salicetum triandrae*, *Stellario nemorum-Alnetum glutinosae*, *Ficario vernae-Ulmetum campestris*, *Carici acutiformis-Alnetum glutinosae*, and the pussy willow-dominated *Salicetum pentandro-auritae*.

More than 28% of vegetation samples were neighboring, on the landward side, meadow communities of the class *Molinio-Arrhenatheretea* (primarily representing the alliances *Deschampsion cespitosae* and *Calthion palustris*, and less frequently *Arrhenatherion elatioris* or *Molinion caeruleae*). Approximately 12% of vegetation samples adjoined other tall herb communities, most often those representing the order *Convolvuletalia sepium*, and less frequently the alliances *Filipendulion ulmariae*, *Geo urbani-Alliarion officinalis*, or *Aegopodion podagrariae*. Ten percent of all the tall herb fringe vegetation samples directly neighboring ruderal (class *Artemisietea vulgaris*) and segetal communities were on both small and large rivers.

In the vicinity of the riparian tall herb fringe communities studied in river valleys, three dominant forms of land use were the most common: meadows and pastures (30% of vegetation samples), shrubs (23%), and deciduous forests (19%) (Fig. 32W).

4.7. Differences in conditions prevalent in habitats supporting particular vegetation units

Various riparian tall herb fringe communities were associated with rivers of different size (Tab. 7). Statistically significant differences in river size were observed between the *Senecionetum fluviatilis* (Se), *Fallopio-Cucubaletum bacciferi* (FC), *Achilleo salicifoliae-Cuscutetum lupuliformis* (AC), *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* (CCh), and *Convolvulo sepium-Cuscutetum europaeae typicum* (CCt) occurring exclusively (the latter almost exclusively) on large rivers and the *Convolvulo sepium-Cuscutetum europaeae aegopodietosum* (CCa), *Urtico-Convolvuletum sepium aegopodietosum* (UCa), *Soncho palustris-Archangelicetum litoralis* (SA), *Epilobio hirsuti-Convolvuletum sepium* (EC), *Eupatorietum cannabini typicum* (Eut) (except for Se and FC), *Eupatorietum cannabini aegopodietosum* (Eua), *Eupatorietum cannabini cardaminetosum amarae* (Euc) (except for Se, FC, and CCt), *Urtica dioica* community (Ur), *Rubus idaeus* community (Ri), and *Galeopsis speciosa* community (Gs) (except for Se, FC, and CCt) typical of small rivers. No significant differences were observed for *Solidago gigantea* community (So), *Rubus caesius* community (Rc), *Impatiens glandulifera* community (Im), and *Urtico-Convolvuletum sepium typicum* (UCt).

River size largely determined environmental conditions of tall herb fringe vegetation (cf. chapter “Characteristics of river size-related environmental conditions”). The highest elevation of samples above the river water level was typical for Se, FC, CCh, and So, and was significantly different between these vegetation units and the tall herb fringe communities occurring in valleys of small rivers. Conversely, the elevation of samples from AC and CCt, also typical of large rivers, were similar to the elevation characteristic of plant communities from small rivers. In terms of the distance of vegetation samples from the riverbed, significant differences were observed between the vegetation units occurring on large rivers (except for FC) and the communities typical of small rivers (except for UCt, UCa, Eut, Euc, and Gs) (Tab. S3, Fig. 34).

The most heavily shaded sites were occupied by Euc and Ri, the communities present on small rivers, which were significantly different in terms of shading from the AC, CCh, and CCt from valleys of large rivers; moreover, they were also significantly different from the UCt and Eut, associated with small rivers. A significant difference in the degree of shading was also observed between Ur and CCt. No significant differences between samples from particular plant communities were found regarding their slope angle or aspect (Tab. S3).

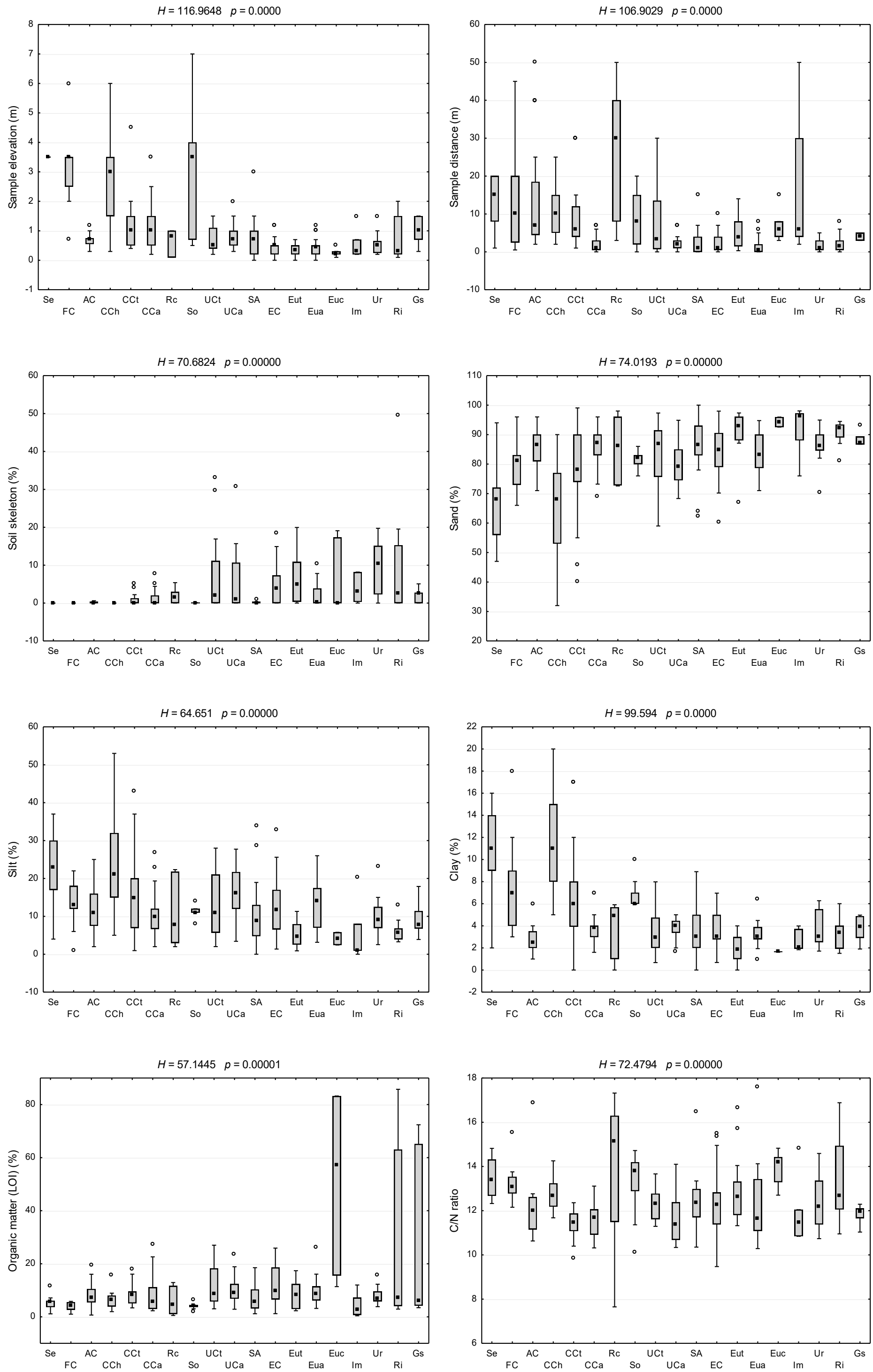
The highest median contribution of the silt fraction was typical of soils supporting the Se and CCh communities, and significant differences occurred between these and some tall herb fringe communities from small river valleys, namely Eut, Ri, and SA, as well as the Im community occurring on small rivers and by the Szczecin Lagoon. Soil samples representing sites supporting Se and CCh also exhibited the lowest median sand fraction contribution. However, significant differences were visible not only in comparison with samples from

Tab. 7 Proportion of relevés assigned to particular tall herb fringe communities recorded along small and large rivers in NW Poland.

Plant community	Number of relevés	Small rivers (%)	Large rivers (%)
Senecionetum fluviatilis (Se)	9	-	100
Fallopio-Cucubaletum bacciferi (FC)	9	-	100
Achilleo salicifoliae-Cuscutetum lupuliformis (AC)	21	-	100
Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi (CCh)	15	-	100
Convolvulo sepium-Cuscutetum europaeae typicum (CCt)	20	9	91
Rubus caesius community (Rc)	5	20	80
Solidago gigantea community (So)	9	33	67
Impatiens glandulifera community (Im)	7	43	57
Urtico-Convolvuletum sepium typicum (UCt)	12	67	33
Eupatorietum cannabini typicum (Eut)	14	86	14
Soncho palustris-Archangelicetum litoralis (SA)	23	87	13
Epilobio hirsuti-Convolvuletum sepium (EC)	31	94	6
Urtico-Convolvuletum sepium aegopodietosum (UCa)	33	94	6
Convolvulo sepium-Cuscutetum europaeae aegopodietosum (CCa)	19	100	-
Eupatorietum cannabini aegopodietosum (Eua)	18	100	-
Eupatorietum cannabini cardaminetosum amarae (Euc)	7	100	-
Urtica dioica community (Ur)	16	100	-
Rubus idaeus community (Ri)	15	100	-
Galeopsis speciosa community (Gs)	7	100	-

small rivers, but also with respect to samples representing the AC. The contribution of both soil fractions significantly differentiated the soils supporting Eut from those with UCa, both communities occurring by small rivers. Still more significant differences between the communities were detected with respect to the percent contribution of clay. The community CCh, typical of large rivers, was significantly different in this respect from all vegetation units associated with small rivers (except for Gs), and differed significantly from AC, which was exclusively associated with large rivers. Moreover, AC was significantly different in terms of clay contribution of its soils from Se and FC (Tab. S3, Fig. 34).

In terms of soil fertility (i.e., LOI, humus, C_{org}, and N_{tot} contents), the sites supporting individual tall herb fringe communities were not significantly different, except for that supporting Euc, the community growing on the most fertile sites and exhibiting significant differences


H = 116.9648 p = 0.0000
Sample elevation (m)
H = 106.9029 p = 0.0000
Sample distance (m)
H = 70.6824 p = 0.00000
Soil skeleton (%)
H = 74.0193 p = 0.00000
Sand (%)
H = 64.651 p = 0.00000
Silt (%)
H = 99.594 p = 0.0000
Clay (%)
H = 57.1445 p = 0.00001
Organic matter (LOI) (%)
H = 72.4794 p = 0.00000
C/N ratio
Se FC AC CCh CCt CCa Rc So UCt UCa SA EC Eut Eua Euc Im Ur Ri Gs

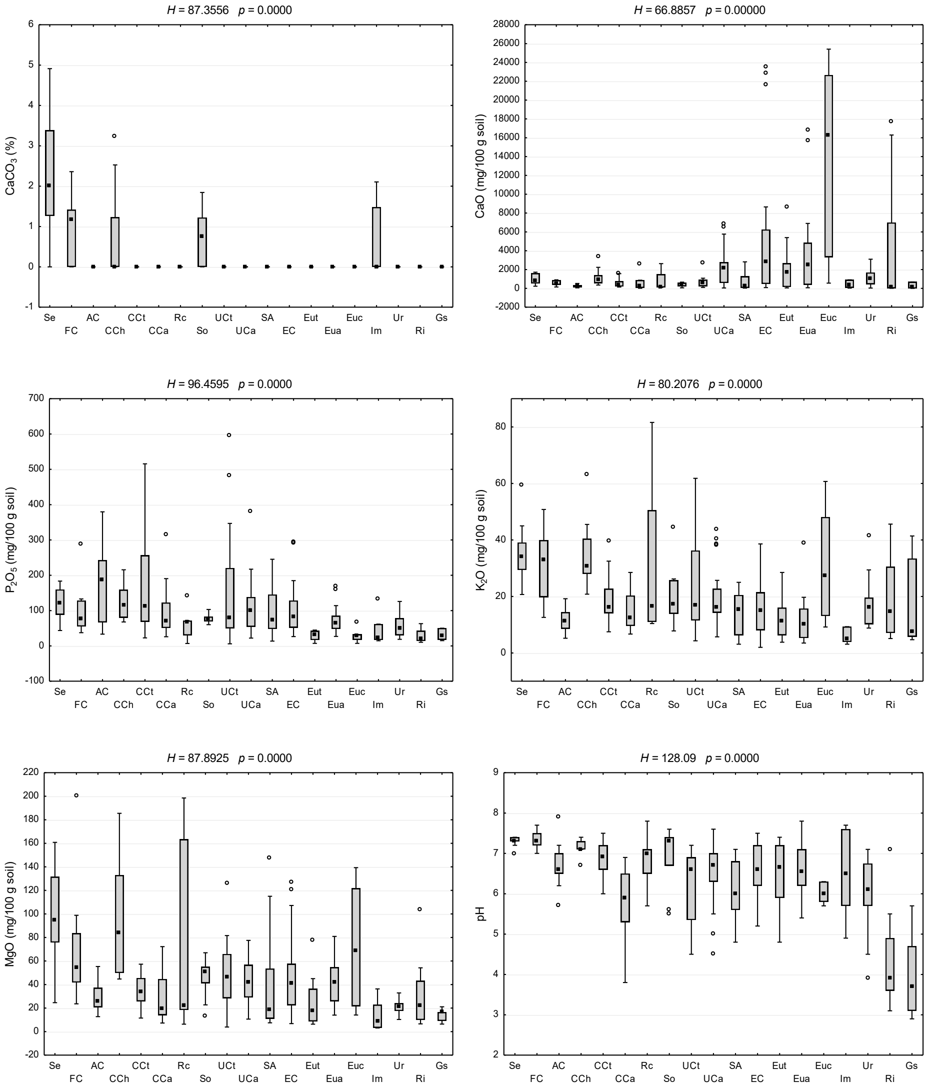


Fig. 34 Box and whisker plots of selected environmental variables for the commonest riparian tall herb fringe communities of the order *Convolvuletalia sepium* in NW Poland. The box length is the interquartile range; small squares indicate the median; circles represent outlier values. Results of Kruskal–Wallis (*H* and *p* values) test are given. Complete names of plant communities are given in Tab. 7.

with respect to the Se, FC, CCa, So, SA, and Im communities. Soils supporting Se and Euc differed significantly in their C/N ratio from soils typically occupied by CCt, CCa, and UCa. A significant difference in this parameter were also observed between soils supporting FC and CCt (Tab. S3, Fig. 34).

The highest soil carbonate content was found in soils supporting Se. It was significantly different from soils at sites with tall herb fringe communities typical of small rivers, i.e., the CCa, UCa, SA, Ur, Ri. On the other hand, the highest soil CaO content was typical in the soil at sites with Euc and significantly different from those supporting SA, CCa, and AC. The last of the units listed were significantly different in terms of soil CaO content from that of UCa and EC (Tab. S3, Fig. 34).

Numerous significant differences between the vegetation units were observed with respect to the soil content of available phosphorus (P_2O_5), potassium (K_2O), and magnesium (MgO). With respect to the P_2O_5 content, the large river communities were significantly different from those associated with small rivers, but significant differences were also evident within the small river communities, i.e., between the Eut and UCa, as well as between the Ri and UCa, SA, and EC. The soil contents of K_2O and MgO were highest at the sites occupied by communities associated with large rivers and significantly different from the units occurring by small rivers. An exception was observed for AC, soils containing low levels of available forms of K and Mg, which was significantly different from those of Se and CCh (in the K content) and CCh (in the Mg content) (Tab. S3, Fig. 34).

Appropriate soil moisture is indispensable for all the riparian tall herb fringe communities. A significantly moister soil was found at the sites supporting Euc associated with head water areas. On the other hand, the soil pH was significantly different between most plant communities studied. This variable was nonsignificant only with respect to three communities: Rc, UCt, and Im (Tab. S3, Fig. 34).

4.8. Patterns of species and sample distribution

The first ordination axis in the DCA run on the entire dataset was 4.874 *SD* long, which indicated that the set contained species that exhibited a clear unimodal response along the gradient. The high eigenvalue of the first axis (0.517) confirmed that the environmental gradient it represented significantly distinguished between the samples and species in the dataset. The remaining ordination axes were distinctly less important. The value of the total vegetation variation (total inertia) was 14.508. The first ordination axis accounts for 3.6% of the variation, the four axes combined accounting for 9.3% (Tab. 8).

The analyses revealed 60 species present in a single vegetation sample out of the 300 examined. Removal of the singletons from the DCA resulted in a decrease in the total variation to 12.058, and in a slight increase in the explained variation (4.2% and 10.6% for the first axis and four axes combined, respectively). However, the eigenvalues of the ordination axes were reduced (Tab. 8). The majority of the sporadic species recorded represented plants typical of forests (e.g., *Acer platanoides*, *Atrichum undulatum*, *Corylus avellana*, *Ranunculus lanuginosus*, *Rumex sanguineus*, and *Trichocolea tomentella*), rushes (e.g., *Acorus calamus*, *Lysimachia thyrsiflora*, *Veronica anagallis-aquatica*, and *V. beccabunga*), meadows (e.g.,

Tab. 8 Summary of DCA for 300 samples of riparian tall herb fringe communities: DCA1 – analysis performed with all 282 species; DCA2 – analysis performed without 60 sporadic species.

	DCA 1				DCA 2			
	Axis 1	**Axis 2**	**Axis 3**	**Axis 4**	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
Eigenvalues of axes	0.517	0.32	0.274	0.231	0.504	0.305	0.261	0.205
Length of gradient	4.874	4.116	2.876	3.056	4.417	3.908	2.785	2.592
Percent variation explained (cumulative)	3.6	5.8	7.7	9.3	4.2	6.7	8.9	10.6
Total inertia	14.508				12.058			

Festuca pratensis, *Geranium pratense*, and *Lychnis flos-cuculi*), and mud deposits (e.g., *Bidens tripartita*, *Polygonum minus*, and *Rumex maritimus*). Fewer species were representative of peat bogs, headwaters, and sandy soil grasslands. Owing to the specificity of the communities studied that occurred in the ecotone and were characterized by frequent presence of species migrating from the adjacent assemblages, it was decided not to remove the sporadic species from the ordination analyses because the presence of such species may be indicative of special microhabitat conditions at the sites they inhabit.

The arrangement of the species in the DCA ordination space corresponded to their occurrence in valleys of rivers of differing size (Tab. 9, Fig. 35). Those species associated with valleys of large rivers (e.g., *Cucubalus baccifer*, *Senecio fluviatilis*, *Chaerophyllum bulbosum*, *Cuscuta lupuliformis*, *Achillea salicifolia*, and *Solidago gigantea*) were concentrated in the right-hand part of the ordination diagram. The species encountered mostly on small rivers (e.g., *Myosotis palustris*, *Scirpus sylvaticus*, *Eupatorium cannabinum*, *Rubus idaeus*, *Filipendula ulmaria*, *Carex acutiformis*, and *Epilobium hirsutum*) aggregated in the left-hand part of the diagram.

The left-hand part of the DCA diagram showed a sample distribution that contained relevés representing the *Eupatorietum cannabini cardaminetosum amarae* (Euc), *Eupatorietum cannabini aegopodietosum* (Eua), *Rubus idaeus* community (Ri), and *Urtica dioica* community (Ur), which occur in valleys of small rivers (Tab. 7, Fig. 36). The central part of the diagram depicts an aggregation of samples representing riparian tall herb fringe communities typical of small rivers, but also appearing sporadically on large rivers or on the Szczecin Lagoon [e.g., the *Epilobio hirsuti-Convolvuletum sepium* (EC), *Soncho palustris-Archangelicetum litoralis* (SA), and *Urtico-Convolvuletum sepium aegopodietosum* (UCa)]. Farther to the right are relevés of the *Convolvulo sepium-Cuscutetum europaeae typicum* (CCt), found on large rivers, but exceptionally also on small rivers, whereas the extreme right-hand part of the diagram contains an aggregation of samples representing riparian tall herb fringe communities found on large rivers only: the *Achilleo salicifoliae-Cuscutetum lupuliformis* (AC), *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* (CCh), *Senecionetum fluviatilis* (Se), and *Fallopio-Cucubaletum bacciferi* (FC). Ecological interpretation of the second ordination axis is difficult. It could be said that the axis is related to a gradient likely responsible for internal differentiation of the communities examined.

Tab. 9 Proportion of occurrences of particular species recorded in tall herb fringe communities along small and large rivers in NW Poland.

Species	Number of records	Small rivers (%)	Large rivers (%)
Senecio fluviatilis (Senflu)	13	-	100
Cucubalus baccifer (Cucbac)	16	-	100
Achillea salicifolia (Achsal)	9	-	100
Cuscuta lupuliformis (Cuslup)	23	-	100
Rumex confertus (Rumcon)	6	-	100
Bidens frondosa (Bidfro)	22	5	95
Erysimum cheiranthoides (Eryche)	37	5	95
Chaerophyllum bulbosum (Chabul)	29	7	93
Acer negundo (Aceneg)	13	8	92
Solidago gigantea (Solgig)	37	8	92
Calamagrostis epigejos (Calepi)	43	16	84
Rubus caesius (Rubcae)	96	20	80
Tanacetum vulgare (Tanvul)	16	25	75
Bromus inermis (Broine)	38	29	71
Cuscuta europaea (Cuseur)	72	33	67
Echinocystis lobata (Echlob)	31	35	65
Calystegia sepium (Calsep)	182	55	45
Impatiens glandulifera (Impgla)	12	58	42
Impatiens parviflora (Impparv)	25	64	36
Helianthus tuberosus (Heltub)	6	67	33
Angelica archangelica subsp. *litoralis* (Anglit)	27	85	15
Epilobium hirsutum (Epihir)	52	90	10
Carex acutiformis (Caracti)	67	94	6
Filipendula ulmaria (Filulm)	61	95	5
Rubus idaeus (Rubida)	24	96	4
Eupatorium cannabinum (Eupcan)	58	97	3
Cirsium oleraceum (Cirole)	33	97	3
Deschampsia caespitosa (Descae)	35	97	3
Lamium maculatum (Lammac)	61	98	2
Scirpus sylvaticus (Scisyl)	21	100	-
Lythrum salicaria (Lytsal)	20	100	-
Myosotis palustris (Myopal)	9	100	-
Galium palustre (Galpal)	9	100	-

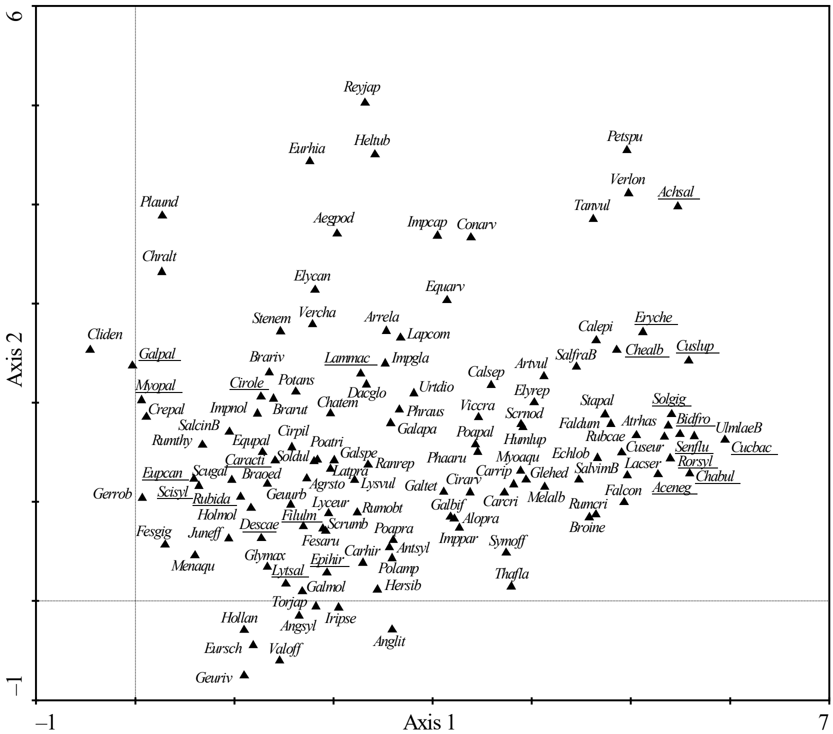


Fig. 35 DCA ordination plot with species (black triangles), based on the whole dataset of 300 relevés and 282 species (only 133 species with at least 1% weight range are shown). Abbreviated species names consist of the first three letters of the genus Latin name and the species epithet. Species typical of small rivers (left side) and large rivers (right side) are underlined (cf. Tab. 9).

All environmental variables included in the CCA explained 28% of the total variation in vegetation (Tab. 10). The *p* values for significance tests for the first canonical axis and for all canonical axes were less than 0.05. Thus, the relationships between the species and the environmental variables selected were statistically significant.

The forward selection and the permutation test revealed 28 factors that significantly differentiated the vegetation and explained 19% of the variation in the dataset (Tab. 11). The relatively high eigenvalue of Axis I (0.453) compared to the clearly lower eigenvalues of the remaining axes (Tab. 10) indicated the main reasons why the vegetation differed. Along the gradient represented by Axis I, the highest correlation between the sample position and environmental variables (the interset correlation) was typical of one of the 10 natural potential vegetation cartographic units, namely the *Salici-Populetum* ($r = -0.785$). This variable was most closely related to species diversity of the samples, and the amount of variation it explained (Lambda A) was 0.37, which with a total variation of 14.508 represented 2.55% of the variation being explained. The second most important variable in the model was the "headwater seeps," most closely correlated with Axis II ($r = 0.635$), and explained an additional 1.65% of the total variation in the vegetation. River size, latitude, sample elevation, riverbed

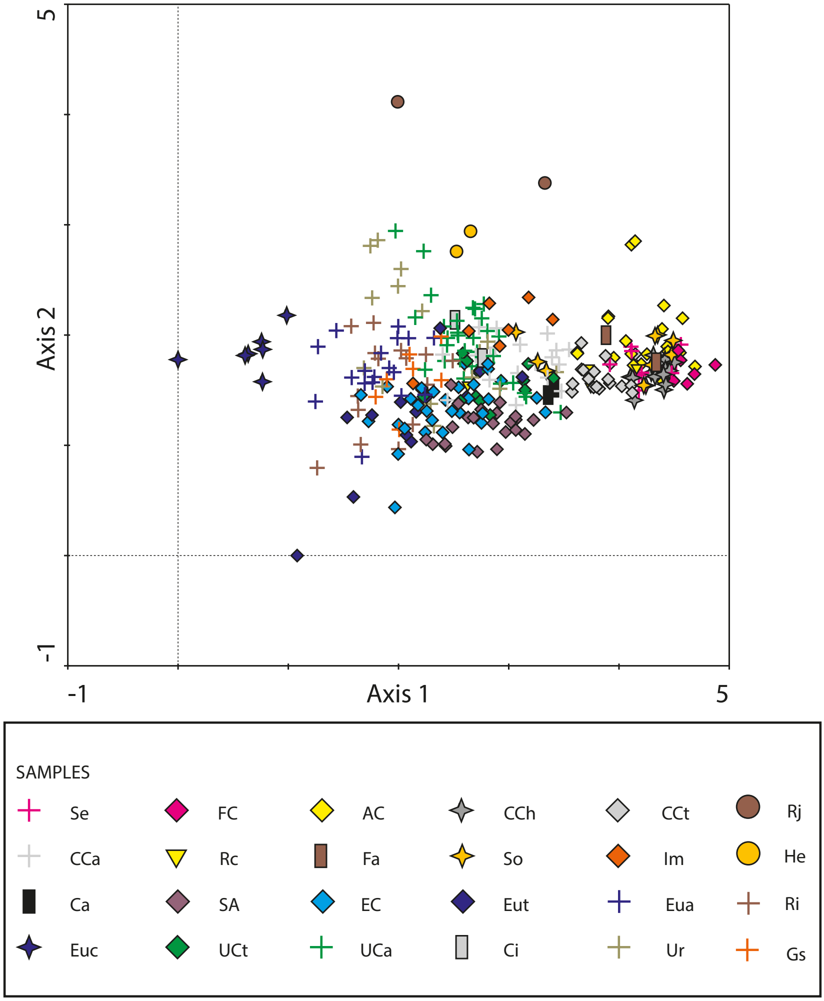


Fig. 36 DCA ordination plot with samples, based on the whole dataset of 300 relevés and 282 species. Explanations: Se – *Senecionetum fluviatilis*; FC – *Fallopio-Cucubaletum bacciferi*; AC – *Achilleo salicifoliae-Cuscutetum lupuliformis*; CCh – *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi*; CCt – *Convolvulo sepium-Cuscutetum europaeae typicum*; CCa – *Convolvulo sepium-Cuscutetum europaeae aegopodietosum*; Rc – *Rubus caesius* community; Fa – *Fallopia dumetorum* community; So – *Solidago gigantea* community; Im – *Impatiens glandulifera* community; Ca – *Carduus crispus* community; SA – *Soncho palustris-Archangelicetum litoralis*; EC – *Epilobio hirsuti-Convolvuletum sepium*; Eut – *Eupatorietum cannabini typicum*; Eua – *Eupatorietum cannabini aegopodietosum*; Euc – *Eupatorietum cannabini cardaminetosum amarae*; UCt – *Urtico-Convolvuletum sepium typicum*; UCa – *Urtico-Convolvuletum sepium aegopodietosum*; Ci – *Cirsium arvense* community; Ur – *Urtica dioica* community; Rj – *Reynoutria japonica* community; He – *Helianthus tuberosus* community; Ri – *Rubus idaeus* community; Gs – *Galeopsis speciosa* community.

Tab. 10 Results of CCA and DCCA for 300 samples of riparian tall herb fringe communities and 282 species.

		CCA*	CCA1	CCA2	CCA3	CCA4	DCCA
Eigenvalues of axes	Axis 1	0.453	0.150	0.114	0.100	0.130	0.453
	Axis 2	0.261	0.125	0.103	0.089	0.074	0.218
	Axis 3	0.218	0.106	0.090	0.079	0.061	0.187
	Axis 4	0.194	0.089	0.087	0.074	0.058	0.137
Total inertia		14.508					
Sum of all canonical values		4.067	0.970	1.035	0.857	0.496	4.067
% variation explained		28.033	6.686	7.134	5.907	3.419	28.033

CCA* – analysis with all 58 environmental variables; CCA1 – analysis with 13 hydrogeomorphological variables and the rest 45 variables – as covariables; CCA2 – analysis with 19 soil parameters and the rest 39 variables – as covariables; CCA3 – analysis with 17 variables of potential and actual vegetation and the rest 41 variables – as covariables; CCA4 – analysis with nine variables of land use form and the rest 49 variables – as covariables.

width, soil pH, and deciduous forest were also highly important (all correlated with Axis I), as well as the soil moisture content and the natural potential vegetation unit *Ficario-Ulmetum chrysosplenietosum* (correlated with Axis II) (Tab. 11).

Analysis of variation partitioning between the four groups of factors (Tab. 3) showed that the largest part of variation was explained by soil parameters (7.1%), followed by hydrogeomorphic variables (6.7%), potential and actual vegetation (5.9%), and land use (3.4%). On the other hand, 4.9% of the total variation was explained jointly by the four groups of aforementioned variables (Fig. 37).

As shown by the CCA ordination diagram (Fig. 38), *Senecio fluviatilis*, *Cucubalus baccifer*, *Solidago gigantea*, *Rorippa sylvestris*, *Acer negundo*, *Chaerophyllum bulbosum*, *Erysimum cheiranthoides*, *Chenopodium album*, *Achillea salicifolia*, and other species were associated with large rivers, with sites within a range of the natural potential vegetation unit *Salici-Populetum*, with soils most enriched with available Mg and K, as well as having the highest pH. In its turn, *Climacium dendroides*, as well as the sporadically occurring species not shown on the diagram (*Cratoneuron filicinum*, *Mnium hornum*, *Valeriana dioica*, *Viola palustris*, *Juncus bulbosus*, and *Veronica beccabunga*) were associated with the presence of headwater seeps, small rivers, the most shaded sites, sites with the highest soil moisture and organic matter content, and low pH. An array of taxa was associated with sites that were humid and shaded, with acidic and organic matter-rich soils, located within a range of the natural potential vegetation unit *Ficario-Ulmetum chrysosplenietosum*, which includes *Crepis paludosa*, *Galium palustre*, *Geranium robertianum*, *Chrysosplenium alternifolium*, *Myosotis palustris*, and *Plagiomnium undulatum*. Sites with equally low pH but featuring less humid and fertile soils support species such as *Rubus idaeus*, *Brachythecium rutabulum*, *Juncus effusus*, *Cirriphyllum piliferum*, *Holcus mollis*, *H. lanatus*, *Deschampsia caespitosa*, and *Galeopsis speciosa* (Fig. 38).

Tab. 11 Results of CCA forward selection of 58 environmental variables and the Monte Carlo permutation test as well as correlation between sample location and variables along gradients represented by four ordination axes of CCA.

		Conditional effects			Marginal effects	Inter set correlations of variables with axes			
No.	Variable	*p* value	Lambda A	% variance explained	Lambda 1	Axis 1	Axis 2	Axis 3	Axis 4
1	Sa-Po*	0.002	0.37	2.55	0.37	**−0.785**	0.346	0.009	0.064
2	Seeps*	0.002	0.24	1.65	0.26	0.430	**0.635**	−0.183	−0.115
3	CF*	0.002	0.16	1.10	0.17	0.221	0.022	0.266	**0.435**
4	Long*	0.002	0.16	1.10	0.16	0.133	0.264	**0.498**	−0.082
5	DF*	0.002	0.12	0.83	0.19	0.447	0.179	0.044	−0.078
6	Latit*	0.002	0.12	0.83	0.23	**0.551**	−0.093	0.214	−0.118
7	pH*	0.002	0.12	0.87	0.21	−0.451	0.196	−0.197	−0.359
8	LSi	0.102	0.10	0.69	0.10	0.056	0.005	−0.093	−0.123
9	SElev*	0.002	0.10	0.69	0.24	**−0.539**	0.247	**0.439**	−0.158
10	skelet*	0.002	0.09	0.62	0.13	0.322	−0.113	0.050	0.037
11	RW*	0.002	0.09	0.62	0.21	−0.477	0.143	0.157	−0.249
12	Fi-Uch*	0.002	0.09	0.62	0.20	0.422	**0.415**	0.052	0.100
13	RS*	0.002	0.09	0.62	0.36	**−0.783**	0.285	−0.025	0.042
14	Flood*	0.004	0.08	0.55	0.09	−0.021	−0.122	−0.015	−0.173
15	LOI*	0.004	0.07	0.48	0.17	0.418	0.230	−0.008	0.106
16	Ca-Al*	0.002	0.08	0.55	0.11	0.154	−0.166	−0.116	−0.190
17	P_2O_5	0.122	0.07	0.48	0.11	−0.247	0.035	−0.252	0.184
18	K_2O*	0.002	0.07	0.48	0.10	−0.156	0.207	0.225	−0.153

Tab. 11 Continued

		Conditional effects			Marginal effects	Inter set correlations of variables with axes			
No.	**Variable**	***p* value**	**Lambda A**	**% variance explained**	**Lambda 1**	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
19	Fa-Qu	0.056	0.08	0.55	0.08	0.082	−0.032	−0.021	−0.098
20	SDist*	0.004	0.07	0.48	0.14	−0.353	0.119	−0.031	−0.082
21	Em-Pi	0.114	0.07	0.48	0.07	0.025	−0.051	−0.017	0.021
22	Slope*	0.002	0.06	0.41	0.09	0.024	−0.111	−0.191	−0.143
23	C/N*	0.016	0.07	0.48	0.08	0.062	0.180	0.148	0.018
24	Tr*	0.014	0.06	0.41	0.07	0.001	−0.124	−0.075	−0.048
25	Shad*	0.006	0.06	0.41	0.16	0.392	0.221	0.207	0.092
26	LoSa*	0.010	0.05	0.34	0.09	0.113	0.007	−0.124	0.010
27	MgO*	0.006	0.06	0.41	0.10	−0.215	0.260	0.101	−0.132
28	Moist*	0.010	0.06	0.41	0.14	0.241	**0.432**	−0.029	−0.178
29	St-Ca*	0.020	0.06	0.41	0.07	0.072	−0.087	−0.042	−0.069
30	To	0.190	0.05	0.34	0.06	0.046	−0.046	0.038	0.008
31	Asp*	0.008	0.06	0.41	0.06	−0.025	0.017	−0.030	−0.085
32	segetal	0.110	0.05	0.34	0.09	−0.188	0.116	0.255	−0.169
33	rushes*	0.008	0.06	0.41	0.09	−0.160	−0.121	−0.308	0.075
34	Po	0.184	0.05	0.34	0.07	0.074	−0.047	−0.092	−0.084
35	Le-Pi	0.242	0.06	0.41	0.06	0.047	−0.087	0.063	0.075
36	SLSa*	0.042	0.05	0.34	0.05	0.053	−0.124	−0.034	0.103
37	ruderal	0.118	0.05	0.34	0.07	−0.007	−0.091	−0.066	−0.033

Tab. 11 Continued

No.	Variable	Conditional effects			Marginal effects	Inter set correlations of variables with axes			
		p value	Lambda A	% variance explained	Lambda 1	Axis 1	Axis 2	Axis 3	Axis 4
38	Ur	0.140	0.05	0.34	0.06	−0.020	−0.004	−0.123	0.076
39	Flow	0.090	0.05	0.34	0.09	−0.188	0.212	0.158	−0.048
40	Fi-Utp	0.248	0.05	0.34	0.04	−0.071	−0.015	−0.096	0.046
41	CaO	0.210	0.05	0.34	0.14	0.362	0.205	−0.070	−0.100
42	aquatic	0.078	0.05	0.34	0.08	0.217	−0.153	0.120	0.021
43	Ar	0.290	0.05	0.34	0.12	−0.267	0.143	0.304	−0.238
44	Org	0.336	0.04	0.28	0.14	0.388	0.158	0.044	0.107
45	herbs	0.292	0.05	0.34	0.05	−0.012	−0.051	0.067	−0.043
46	Fr-Al	0.466	0.04	0.28	0.17	0.368	−0.350	0.078	0.054
47	LSa	0.556	0.04	0.28	0.06	−0.108	−0.110	−0.036	−0.038
48	$CaCO_3$	0.440	0.04	0.28	0.04	−0.046	0.024	0.017	−0.101
49	grasses	0.702	0.04	0.28	0.07	−0.011	−0.184	0.024	0.020
50	Me	0.782	0.04	0.28	0.07	−0.006	−0.216	−0.153	0.026
51	L	0.678	0.04	0.28	0.06	−0.166	0.098	0.056	0.002
52	Ditch	0.854	0.03	0.21	0.04	0.110	−0.101	0.037	0.029
53	ClSi	0.732	0.03	0.21	0.04	−0.110	0.060	0.012	0.012
54	SaL	1.000	0.03	0.21	0.06	−0.206	0.050	0.087	−0.110
55	forest	-	-	-	0.10	0.081	0.378	0.114	−0.014
56	Sh	-	-	-	0.09	−0.331	0.073	−0.050	0.046

Tab. 11 Continued

		Conditional effects			Marginal effects	Inter set correlations of variables with axes			
No.	**Variable**	***p* value**	**Lambda A**	**% variance explained**	**Lambda 1**	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
57	LiL	-	-	-	0.06	−0.204	0.091	0.179	−0.111
58	Me-Fa	-	-	-	0.04	−0.008	−0.032	−0.003	−0.015

Statistically significant factors are indicated with asterix. The highest correlations of variables with axes are in bold. A complete list of environmental variables is as follows. Hydrogeomorphic variables: Long – longitude; Latit – latitude; Slope – slope angle; Asp – aspect; RS – river size; RW – river bed width; SDist – river bed-sample distance; SElev – relative sample elevation; Shad – degree of shading; Seeps – headwater seeps; Flood – summer flooding; Ditch – drainage dithes; Flow – flow rate. Soil variables: LOI – loss on ignition; skelet – soil skeleton; Org – organic soil; LSa – loamy sand; SLSa – slightly loamy sand; LoSa – loose sand; SaL – sandy loam; LiL – light loam; L – loam; ClSi – clayey silt; LSi – loamy silt; pH – soil pH; Moist – soil moisture content; C/N – C/N ratio; $CaCO_3$ – calcium carbonate; P_2O_5 – available phosphorus; K_2O – available potassium; MgO – available magnesium; CaO – available calcium. Adjacent phytocoenoses: aquatic – aquatic communities; rushes – rushes; grasses – meadows and grasses; herbs – tall herbs; forest – forests and shrubs; ruderal – ruderal assemblages; segetal – segetal assemblages. Natural potential vegetation: Sa-Po – *Salici-Populetum*; Fr-Al – *Fraxino-Alnetum*; Ca-Al – *Carici elongatae-Alnetum*; Fi-Utp – *Ficario-Ulmetum typicum*; Fi-Uch – *Ficario-Ulmetum chrysosplenietosum*; St-Ca – *Stellario-Carpinetum*; Fa-Qu – *Fago-Quercetum*; Me-Fa – *Melico-Fagetum*; Le-Pi – *Leucobryo-Pinetum*; Em-Pi – *Empetro-Pinetum*; Land use: Ur – urban areas; Ar – arable land; Me – meadows and pastures; Sh – shrubs; DF – deciduous forest; CF – coniferous forest; Po – fish culture ponds; To – tourism; Tr – transportation.

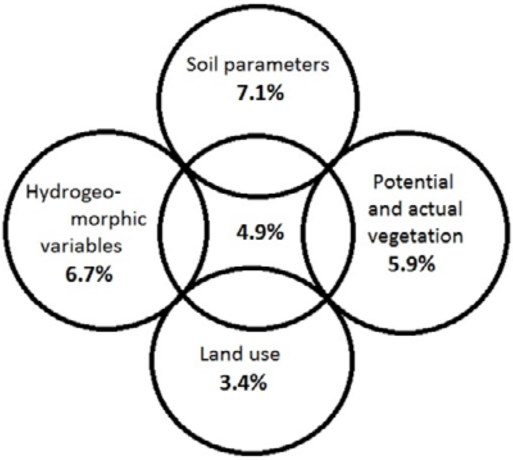


Fig. 37 Partitioning of vegetation variance explained by four categories of variables: hydrogeomorphic variables, soil parameters, potential and actual vegetation and land use.

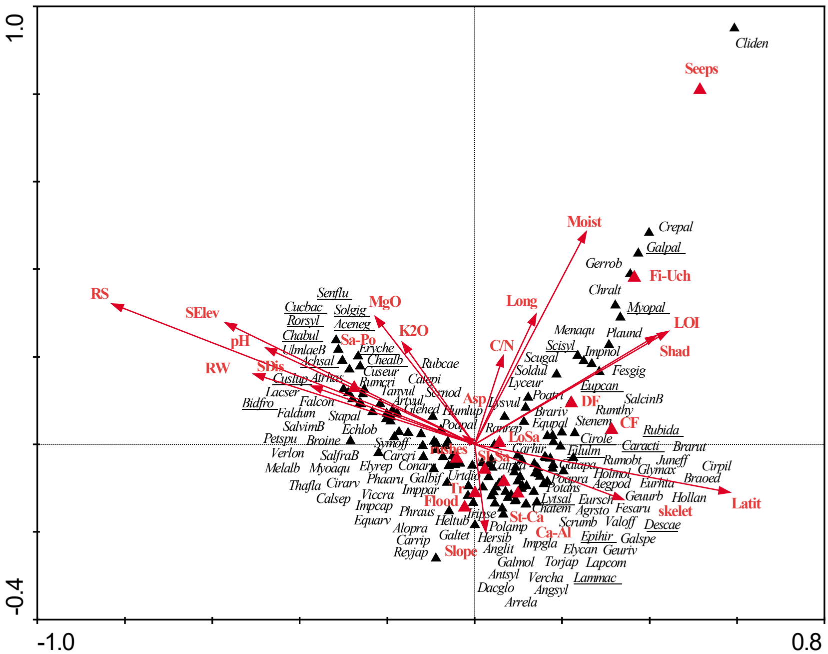


Fig. 38 CCA ordination plot with species (black triangles) and environmental variables (red arrows for numerical, red triangles for nominal), based on the whole dataset of 300 relevés, 282 species, and 58 variables (only 133 species with at least 1% weight range and only 28 significant variables are shown). Abbreviated species names consist of the first three letters of the genus Latin name and the species epithet. Species typical of large rivers (left side) and small rivers (right side) are underlined (cf. Tab. 9). Abbreviations denoting environmental variables are explained in Tab. 11.

The distribution of samples on the resultant CCA diagram was clearly clustered (Fig. 39). The upper right-hand corner of the diagram contained a group of relevés primarily related to the subassociation Euc. These relevés were taken in the most shaded, fertile, and humid sites, associated with headwater seeps, and located within a range of the natural potential vegetation unit *Ficario-Ulmetum chrysosplenietosum*. The upper left-hand quarter of the diagram contained relevés from the Vistula valley (large river), with vegetation samples located relatively high above the water level in the river, frequently at some distance from the riverbed, within a range of the natural potential vegetation unit *Salici-Populetum*. All the patches representing the three vegetation units FC, Se, and CCh were found here. In addition, almost all the patches of the community So belong here as well. The left-hand side of the diagram, albeit lower than the group just described, was also the location of the relevés representing the AC and CCt, where the first was recorded only for large rivers, and the latter also on small ones. The cloud of points in the lower part of the diagram represents relevés taken mainly on small rivers with the communities SA, EC, Eut, UCt, UCa, and CCa. Somewhat higher and in the right-hand part of the diagram are the strongly shaded patches dominated by *Rubus idaeus* or *Galeopsis speciosa* (Fig. 39).

Results of DCCA proved that the previously performed CCA did not seriously suffer from a visible "arch effect." The DCCA eigenvalues of ordination Axes II–IV were slightly lower (Tab. 10), and the correlation of variables probably responsible for the "arch effect" (headwater seeps, moisture, *Ficario-Ulmetum chrysosplenietosum*) with Axis II also lower and switched to negative. However, both analyses show similar general vegetation patterns (Fig. 40).

The results of the CVA showed that riparian tall herb fringe communities were significantly differentiated by 25 environmental factors (Tab. 12). The most important differentiating variable was the natural potential vegetation unit *Salici-Populetum*, followed by headwater seeps, soil pH, and sample elevation, which explained 3.6%, 2.2%, 1.9%, and 1.8% of the vegetation variation, respectively. All the statistically significant variables explained 24% of the variation, whereas all the variables included in the CVA explained 33%. These results were consistent with the results of the CCA previously performed.

Distribution of the vegetation units in the CVA ordination space (Fig. 41) differentiated between two groups of tall herb fringe communities. These were the Se, FC, CCh, and So located in the upper right-hand quarter of the plot, and the AC, CCt, and Rc in the lower right-hand quarter. Both groups occurred by large rivers, at sites within a range of the natural potential vegetation unit *Salici-Populetum*, and on high pH soils. However, the sites occupied by the first group were more elevated, their soils moister and richer in K_2O, had higher C/N ratios, and more frequently adjoined with communities of segetal weeds. On the other hand, the sites occupied by the other group were lower, in sunnier areas, had lower soil moisture, lower soil K_2O, and a lower C/N ratio. They were more frequently located in the proximity of rushes.

Two other groups could be distinguished to the left of the plot (Fig. 41). They consisted of communities occurring on small rivers with low banks, lower soil pH, within a range of the natural potential vegetation units *Fraxino-Alnetum*, *Ficario-Ulmetum chrysosplenietosum*, or *Carici elongatae-Alnetum*. The first group, located in the upper left-hand quarter of the plot, consisted of the Euc, Ri, Gs, and Ur (i.e., plant communities associated with the most shaded sites occupying moist and wet soils, and sometimes near headwater seeps). The second group was comprised of UCa, Eua, CCa, UCt, EC, Eut, Im, and SA (i.e., the communities associated with less shaded riverbanks, soils with a relatively lower content of K_2O, lower moisture,

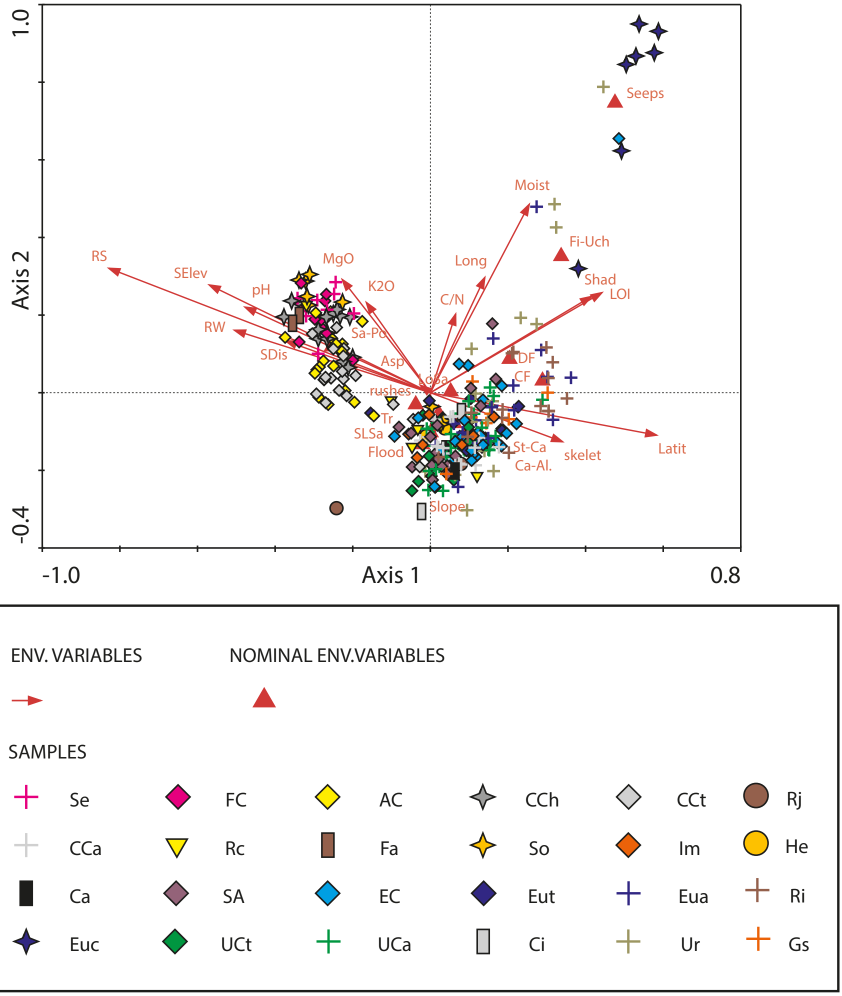


Fig. 39 CCA ordination plot with samples and environmental variables (red arrows for numerical, red triangles for nominal), based on the whole dataset of 300 relevés, 282 species, and 58 variables (only 28 significant variables are shown). Abbreviations denoting environmental variables are explained in Tab. 11. Abbreviations denoting plant communities are explained in Fig. 36.

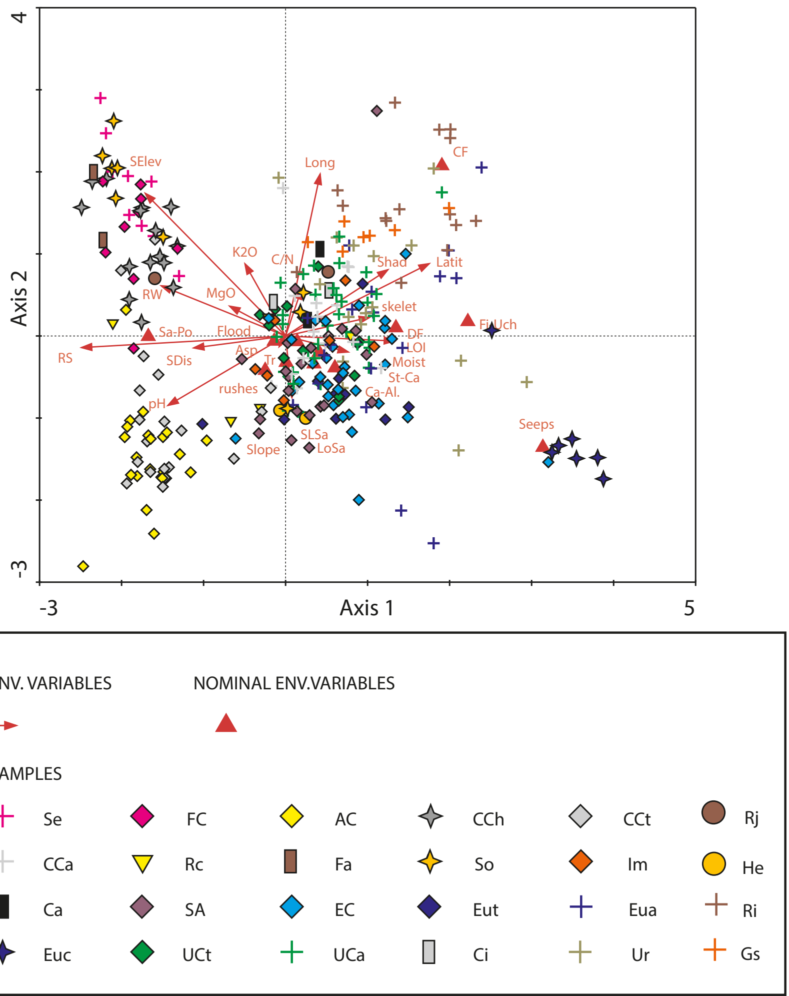


Fig. 40 DCCA ordination plot with samples and environmental variables (red arrows for numerical, red triangles for nominal), based on the whole dataset of 300 relevés, 282 species, and 58 variables (only 28 significant variables are shown). Abbreviations denoting environmental variables are explained in Tab. 11. Abbreviations denoting plant communities are explained in Fig. 36.

Tab. 12 Results of CVA forward selection of 58 environmental variables and the Monte Carlo permutation test as well as correlation between sample location and variables along gradients represented by four ordination axes of CVA.

		Conditional effects			Marginal effects	Inter set correlations of variables with axes			
No.	Variable	*p* value	Lambda A	% variance explained	Lambda 1	Axis 1	Axis 2	Axis 3	Axis 4
1	Sa-Po*	0.002	0.82	3.57	0.82	**0.872**	0.117	0.068	0.003
2	Seeps*	0.002	0.50	2.17	0.51	−0.191	0.079	**0.566**	−0.353
3	pH*	0.002	0.44	1.91	0.53	0.458	0.009	−0.235	**−0.461**
4	SElev*	0.002	0.41	1.78	0.57	0.497	**0.512**	−0.114	0.033
5	RW*	0.002	0.25	1.09	0.44	0.432	0.242	−0.129	−0.140
6	RS*	0.002	0.31	1.35	0.74	**0.829**	0.040	0.016	−0.049
7	Long*	0.002	0.25	1.09	0.42	−0.011	**0.591**	0.145	−0.006
8	Latit*	0.102	0.25	1.09	0.47	−0.558	0.208	0.116	0.020
9	Flood*	0.006	0.18	0.78	0.23	−0.067	−0.067	−0.150	−0.187
10	Shad*	0.002	0.17	0.74	0.32	−0.317	0.178	0.314	0.037
11	Ar*	0.002	0.16	0.70	0.33	0.239	0.373	−0.089	−0.104
12	segetal*	0.002	0.18	0.78	0.21	0.145	0.269	−0.024	−0.026
13	K_2O*	0.002	0.16	0.70	0.27	0.158	0.317	0.042	−0.143
14	CaO*	0.042	0.15	0.65	0.25	−0.223	0.019	0.236	−0.214
15	Slope*	0.002	0.15	0.65	0.18	−0.087	−0.177	−0.085	−0.111
16	skelet*	0.010	0.14	0.61	0.18	−0.327	0.002	0.043	0.034
17	Asp*	0.002	0.13	0.57	0.12	0.030	−0.029	0.021	−0.076
18	Fi-Uch*	0.024	0.12	0.52	0.43	−0.269	0.153	**0.563**	0.044

Tab. 12 Continued

No.	Variable	Conditional effects			Marginal effects	Inter set correlations of variables with axes			
		p value	Lambda A	% variance explained	Lambda 1	Axis 1	Axis 2	Axis 3	Axis 4
19	rushes*	0.018	0.12	0.52	0.24	0.154	−0.311	−0.107	−0.009
20	Sh*	0.014	0.12	0.52	0.21	0.330	−0.003	−0.072	0.042
21	Flow*	0.024	0.11	0.48	0.20	0.231	0.182	0.087	0.031
22	Moist*	0.018	0.11	0.48	0.25	−0.045	0.137	0.242	−0.283
23	C/N*	0.036	0.11	0.48	0.16	−0.001	0.227	0.081	−0.045
24	Em-Pi	0.060	0.13	0.57	0.12	0.001	−0.051	−0.060	−0.103
25	herbs*	0.042	0.10	0.43	0.13	0.012	0.108	−0.062	0.055
26	Ca-Al*	0.024	0.11	0.48	0.28	−0.241	−0.058	−0.219	−0.068
27	LiL	0.080	0.10	0.43	0.19	0.237	0.177	−0.033	−0.055
28	Le-Pi	0.118	0.09	0.39	0.12	−0.067	0.035	0.091	−0.016
29	DF	0.090	0.10	0.43	0.31	−0.351	0.048	0.229	−0.093
30	aquatic	0.110	0.08	0.35	0.16	−0.247	0.046	−0.087	0.045
31	Fi-Utp	0.160	0.09	0.39	0.04	0.136	−0.132	0.057	0.038
32	Me-Fa	0.156	0.09	0.39	0.03	0.021	−0.080	−0.012	−0.029
33	LSa	0.152	0.08	0.35	0.14	0.017	−0.032	−0.120	−0.003
34	LOI	0.154	0.08	0.35	0.32	−0.276	0.041	0.396	0.015
35	LoSa	0.232	0.08	0.35	0.17	−0.085	−0.068	0.010	−0.033
36	CF	0.250	0.08	0.35	0.13	−0.124	0.044	0.057	0.120
37	To	0.198	0.07	0.30	0.10	−0.010	0.017	−0.023	0.001

Tab. 12 Continued

		Conditional effects			Marginal effects	Inter set correlations of variables with axes			
No.	Variable	*p* value	Lambda A	% variance explained	Lambda 1	Axis 1	Axis 2	Axis 3	Axis 4
38	Fa-Qu	0.224	0.07	0.30	0.07	−0.049	0.006	−0.061	−0.022
39	Me	0.180	0.08	0.35	0.13	−0.063	−0.192	−0.093	0.089
40	L	0.294	0.07	0.30	0.10	0.205	0.075	0.005	−0.027
41	ruderal	0.258	0.07	0.30	0.10	0.003	−0.092	−0.070	−0.078
42	SDist	0.286	0.07	0.30	0.30	0.371	−0.025	0.015	−0.114
43	Fr-Al	0.370	0.07	0.30	0.28	−0.428	−0.094	−0.150	0.065
44	SLSa	0.492	0.06	0.26	0.10	−0.061	−0.154	0.012	0.141
45	MgO	0.296	0.07	0.30	0.28	0.273	0.245	−0.004	−0.250
46	Org	0.620	0.06	0.26	0.22	−0.274	0.060	0.271	0.022
47	LSi	0.478	0.05	0.22	0.05	−0.036	−0.003	−0.028	−0.030
48	grasses	0.770	0.04	0.17	0.09	−0.059	−0.018	−0.089	0.097
49	$CaCO_3$	0.620	0.05	0.22	0.08	0.054	0.055	−0.059	−0.073
50	Po	0.664	0.05	0.22	0.07	−0.084	−0.019	−0.008	−0.077
51	Ditch	0.782	0.04	0.17	0.08	−0.134	−0.011	−0.016	0.074
52	P_2O_5	0.788	0.04	0.17	0.12	0.220	−0.201	−0.009	0.031
53	Ur	0.898	0.04	0.17	0.06	0.037	−0.097	0.026	0.010
54	SaL	0.940	0.03	0.13	0.10	0.170	0.092	−0.087	−0.100
55	forest	-	-	-	0.22	0.008	0.170	0.289	−0.083
56	Tr	-	-	-	0.10	−0.064	−0.091	−0.012	−0.014

Tab. 12 Continued

		Conditional effects			Marginal effects	Inter set correlations of variables with axes			
No.	Variable	*p* value	Lambda A	% variance explained	Lambda 1	Axis 1	Axis 2	Axis 3	Axis 4
57	ClSi	-	-	-	0.08	0.127	0.145	−0.023	−0.028
58	St-Ca	-	-	-	0.07	−0.128	−0.031	−0.106	−0.034

Statistically significant factors are indicated with asterisks. The highest correlations of variables with axes are in bold. Complete names of environmental variables are given in Tab. 11.

and lower C/N ratio). The location of the communities with *Fallopia dumetorum*, *Reynoutria japonica*, *Carduus crispus*, *Cirsium arvense*, and *Helianthus tuberosus* could have been random, as they are each represented by a very low number of samples.

4.9. Level of invasion

Of the 27 alien species recorded in the riparian tall herb fringe communities in northwestern Poland, 14 were considered invasive aliens (all recorded neophytes, except for *Acorus calamus* and *Sisymbrium loeselii*, both species recorded only once). The most frequently recorded invasive alien species included *Solidago gigantea* (37 relevés), *Echinocystis lobata* (31), *Impatiens parviflora* (25), *Bidens frondosa* (22), *Acer negundo* (13), and *Impatiens glandulifera* (12). The highest cover-abundance was ascribed to *Solidago gigantea*, *Impatiens glandulifera*, *Reynoutria japonica*, and *Helianthus tuberosus*. All the invasive alien species occurred in a total of 115 vegetation samples (accounting for 38% of all the relevés), producing a total of 167 records.

Invasive aliens were markedly more frequent on large rivers (116 records, 73 samples, 63.5% of all samples containing alien invasive plants, 71.6% of all samples from large rivers) than on small ones (51 records, 42 samples, 36.5% of all samples containing alien invasive plants, 21.2% of all samples from small rivers). Large and small rivers were significantly different ($p < 0.001$) in terms of the invasive species richness and percentage of invasive flora, and both measures of the level of invasion were strongly correlated with river size. Moderate correlations with river width, soil pH, sample elevation, and $CaCO_3$ occurred, with other correlations being weaker (Tab. S2). The invasive alien species distinctly associated with valleys of large rivers included *Solidago gigantea*, *Bidens frondosa*, *Acer negundo*, *Rumex confertus*, and *Echinocystis lobata* (Tab. 9, Fig. 19, Fig. 42,

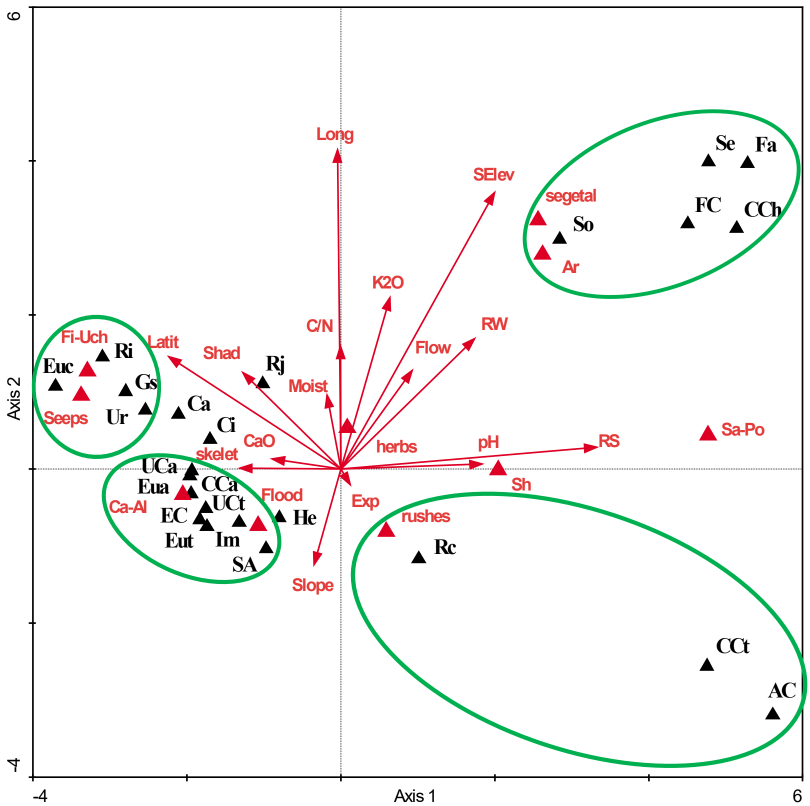


Fig. 41 CVA ordination plot with particular riparian tall herb fringe communities (black triangles) and the best discriminating significant variables (red arrows for numerical, red triangles for nominal). Plant communities similar in terms of their response to environmental variables are grouped within green circles. Abbreviations denoting environmental variables are explained in Tab. 11. Abbreviations denoting plant communities are explained in Fig. 36.

Fig. 43). More frequent on small rivers were *Impatiens glandulifera*, *I. parviflora*, *Helianthus tuberosus*, and *Epilobium adenocaulon*. The remaining invasive species were recorded only one–three times.

Particular tall herb fringe communities differed in their invasive species richness and percentage of invasive flora. Significant differences were observed between the *Achilleo salicifoliae-Cuscutetum lupuliformis* (AC) associated with large rivers and *Urtico-Convolvuletum sepium* (UC), *Eupatorietum cannabini* (Eu), *Epilobio hirsuti-Convolvuletum sepium* (EC), *Rubus idaeus* community (Ri), and *Urtica dioica* community (Ur), which occur primarily on small rivers. A significant difference in the invasive species richness also occurred between *Convolvulo sepium-Cuscutetum europaeae* (CC) and *Urtico-Convolvuletum sepium* (UC). As many as 17 out of 21 relevés of *Achilleo salicifoliae-Cuscutetum lupuliformis* (AC) were found to contain invasive species. In the case of the *Convolvulo sepium-Cuscutetum europaeae* (CC), invasive species were identified in 30 out of the 54 samples. The highest ratio between the number of invasive species-containing relevés and the total number of relevés (14/15) occurred

Fig. 42 *Acer negundo* in riparian tall herb fringe vegetation in Vistula valley (photo M. Myśliwy, 2012-07-04).

Fig. 43 *Rumex confertus* in riparian tall herb fringe vegetation in Vistula valley (photo M. Myśliwy, 2012-07-05).

for the subassociation *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* (CCh) that was closely associated with large rivers, the lowest ratio (3/19) occurred for the subassociation *Convolvulo sepium-Cuscutetum europaeae aegopodietosum* (CCa) occurring exclusively on small rivers. By definition, the communities built by invasive species contained them in each sample, for which reason significant differences in the invasive species richness and percentage of invasive flora were revealed also between the *Impatiens glandulifera* community (Im) and the *Urtico-Convolvuletum sepium* (UC), *Eupatorietum cannabini* (Eu), *Epilobio hirsuti-Convolvuletum sepium* (EC), *Rubus idaeus* community (Ri) and *Urtica dioica* community (Ur), as well as between the *Solidago gigantea* community (So) and the *Urtico-Convolvuletum sepium* (UC) and *Urtica dioica* community (Ur).

Certain invasive species were markedly more frequent in some communities than in others. *Solidago gigantea* most frequently occurred in *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* (CCh) (12 records), *Senecionetum fluviatilis* (Se) (seven records), *Fallopio-Cucubaletum bacciferi* (FC) (seven records), and often formed its own communities (nine records). *Acer negundo* was most often recorded in *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* (CCh) (seven records), whereas *Bidens frondosa* and *Echinocystis lobata* occurred in the *Achilleo salicifoliae-Cuscutetum lupuliformis* (AC) (13 and 14 records, respectively). The largest generalist was *Impatiens parviflora*, recorded in 11 vegetation units.

5. Discussion

5.1. Environmental underpinnings of variability in riparian tall herb fringe communities

Rivers vary in size. Furthermore, their habitat characteristics involve four dimensions: longitudinal (down the river), lateral (river-floodplain), vertical (river-groundwater), and temporal [171]. Swanson et al. [172] suggested that the "spatial variation of riparian characteristics takes place along the continuum of increasing stream size from small headwater streams to large rivers". The results of the present study showed that river size is one of the most important variables differentiating riparian tall herb fringe communities of the order *Convolvuletalia sepium*. River size was significantly correlated with almost all the hydrogeomorphic and soil characteristics of the sites examined, with the strongest correlation observed for riverbed width, sample distance from the riverbed, soil pH, sample elevation above the river water level, clay fraction contribution, and $CaCO_3$ content in the soil.

Valleys of large rivers in northwestern Poland supported 13 vegetation units, four of which (*Senecionetum fluviatilis*, *Fallopio-Cucubaletum bacciferi*, *Achilleo salicifoliae-Cuscutetum lupuliformis*, and *Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* subass. nov.) were restricted to large rivers, and three others (*Convolvulo sepium-Cuscutetum europaeae typicum*, *Rubus caesius* community, and *Solidago gigantea* community) were mostly associated with them. A significant contribution of specialist species in plant communities growing in valleys of large rivers is caused by the sorting of species along gradients created by water table depth and stream power [173]. For example, the river corridor plants, e.g., *Achillea salicifolia*, *Chaerophyllum bulbosum*, *Cucubalus baccifer*, *Cuscuta europaea*, *C. lupuliformis*, *Senecio fluviatilis*, and *Petasites spurius*, were frequent components of the tall herb fringe communities examined. The main drivers responsible for their distribution patterns included the regular disturbance by flooding, constant water availability and nutrient supply [15], and higher temperature and soil pH in the valleys of large rivers compared to that of adjacent areas [16], or the fact that river corridor plants are not capable of taking advantage of more benign conditions outside stressful habitats [174].

In contrast, the riparian tall herb fringe communities studied in valleys of small rivers were mainly composed of generalist species, not restricted to river corridors, but inhabiting other systems (ditches, meadows, forest clearings) as well, e.g., *Epilobium hirsutum*, *Eupatorium cannabinum*, *Calystegia sepium*, *Filipendula ulmaria*, and *Galeopsis speciosa*. This was caused by the fact that small rivers produce narrow floodplains with restricted geomorphic development, which causes weaker species sorting along the hydrologic gradient [23] and requires fewer specific adaptations to the aquatic/terrestrial transition zone [7]. Furthermore, the floristic composition of plant communities growing on narrow floodplains of small (low-order) rivers is more strongly influenced by adjacent assemblages than that of communities found on large (higher-order) rivers [23]. As demonstrated in this study, and as summarized in the synoptic table provided, plant communities associated with small rivers (*Eupatorietum cannabini*, *Epilobio hirsuti-Convolvuletum sepium*, *Soncho palustris-Archangelicetum litoralis*, *Urtico-Convolvuletum sepium*, *Convolvulo sepium-Cuscutetum europaeae aegopodietosum*, *Urtica dioica* community, *Galeopsis speciosa* community, and *Rubus idaeus* community) are rich in meadow, forest, and mesic fringe species, e.g., *Filipendula ulmaria*, *Stellaria nemorum*, and *Anthriscus sylvestris*, respectively. Matthews et al. [23] and Pielech [31] likewise found that stream order (an indication of river size) was a strong factor differentiating among various forest vegetation types on alluvia. A close relationship between riparian vegetation (the number of plant communities) and stream size was also reported by Dunn et al. [175] and Dybkjær et al. [19].

Elevation above the river water level and distance from the riverbed were important explanatory factors of variation in the riparian tall herb fringe communities of the order *Convolvuletalia sepium*. Moreover, the present study demonstrated that the variables were significantly correlated with river size. The latter in turn determines flow and flood regimes and may serve as a proxy of flooding disturbance. The elevation and distance themselves have a close relationship with flooding frequency. Annual water-level variation in large rivers may span several meters; therefore, the tall herb fringe communities studied in valleys of large rivers were found even at the relative altitude of several meters and tens of meters away from the riverbed, whereas the communities associated with small rivers occurred relatively close to the river and only at low altitudes. Simple indicators of the flood regime, such as the distance to the main channel, relative elevation, and position relative to levees, are as informative as detailed and expensive hydrologic modelling [26]. Significant correlations between riparian vegetation patterns and sample elevation above or the distance away from the river channel were reported also by van Coller et al. [176], Hrivnák [177], Bufková and Prach [178], and Yang et al. [10], whereas Menges and Waller [179] showed that relative elevation influences the distribution of floodplain herbs.

The data in this study showed the riparian tall herb fringe communities of the order *Convolvuletalia sepium* to be photophilous. The tall herb fringe communities on sunny riverbanks showed the highest species richness (an average of 16.6 plant species per sample), whereas the vegetation samples subjected to low and strong shading were more species-poor (an average of 15.9 and 15.2 species per sample, respectively). Moreover, the degree of shading was found to be significantly different between the communities developing on large and small rivers. Swanson et al. [172] also demonstrated that availability of sunlight changes with the increase in stream size. Small headwater floodplains are dominated by forests. A dense canopy produces heavy shading, which suppresses the development of herbs. On the other hand, the canopy along medium-sized and large rivers is at least partially open, which allows light-demanding plants to establish. Menges and Waller [179] suggested that the combination of low light and frequent flooding disturbance strongly reduces plant growth. This is also in agreement with the suggestion by Grime [180] that the combined effects of high stress (here the light) and severe disturbance (here the inundation) preclude plant adaptation and prevent the recovery of destroyed vegetation.

Van Coller et al. [176] stressed that, for geomorphologically complex rivers, a simple gradient approach does not deal successfully with the complexity of the patch mosaic structure. Therefore, to describe vegetation patterns, they used the main riparian gradients (elevation above and horizontal distance away from the active channel) in combination with a geomorphic patch hierarchy framework (channel type, morphologic units, and surface substratum type). The patch perspective (although without the hierarchy) was incorporated into the present study in the form of granulometric soil groups (substratum type), as well as land use forms and the natural potential vegetation cartographic units. The latter in particular turned out to be a very important factor explaining the riparian tall herb fringe community distribution pattern. The natural potential vegetation unit *Salici-Populetum* produced the highest inter-set correlation along the first CCA axis, whereas the unit *Ficario-Ulmetum chrysosplenietosum* was strongly correlated with the second CCA axis. The integration of gradient and patch perspectives significantly improved the comprehension of the riparian vegetation pattern, because these two perspectives underpin different processes shaping the vegetation [176]. It should be emphasized that the variable "natural potential vegetation unit," represented in this study by 10 categories, has a very complex nature and comprises a number of factors, both microclimatic and edaphic. Similarly, the land use form, e.g., arable land, may, on the one hand, affect chemical parameters of the soil adjacent to an arable field, and on the other, could enhance weed growth in tall herb communities and even be associated with mechanical destruction of those communities by agrotechnical practices. The complex nature of the patchiness at different spatial and temporal scales was also referred to by van Coller et al. [176], because an individual patch reflects the interaction of hydrological and fluvial processes with geology and topography.

Evaluation, based on a wide range of factors, of major gradients shaping variation of the vegetation, as conducted in the present study, provides a framework for the holistic understanding of riparian ecosystem structure and functioning. The four selected groups of variables can be arranged in the following order of their relative importance, determined by the decomposition of variance: soil parameters, hydrogeomorphic variables, actual and potential vegetation, and land use form (a proxy of disturbance level). Although the land use form explained the smallest part of riparian tall herb fringe vegetation variation, which is in agreement with results reported by Turner et al. [26] and Douda [29], it should be considered in studies of riparian vegetation responses to environmental variables because of the widespread human influence on river valleys [29]. The simultaneous analysis of numerous environmental variables such that a broader environmental context may be achieved also has been postulated by Turner et al. [26] and Lyon and Gross [28].

The environmental data used in this study allowed for the conclusion that the tall herb fringe communities associated with large rivers differ significantly, with respect to their habitat conditions, from the plant communities occurring along small rivers. The important differences between large and small river sites include the degree of shading, proportion of all grain size fractions in the soil, contents of organic matter, humus, organic carbon, and total nitrogen, available phosphorus, potassium, magnesium, and calcium, soil pH, and C/N ratio. The differences in environmental characteristics of particular plant communities were demonstrated as well. The variables which best discriminated between riparian tall herb fringe communities included pH, the contents of K_2O and CaO, the C/N ratio, and moisture. The clay, silt, and sand percentages in the soil were also significantly different between the communities examined in the present study. The variation observed in the soil chemistry and texture was related both to large and small rivers, as significant differences were revealed not only between the communities of large and small rivers, but also between the communities within the same group. This is in contrast to the results reported by Matthews et al. [23] who attributed the differences between forest communities associated with smaller rivers primarily to soil chemistry (nutrients and pH), while relating the soil texture gradient to variation within larger floodplain forests.

The present study showed that the contents of bioavailable phosphorus, potassium, and magnesium were significantly higher at large river sites than at those situated on small rivers.

This finding is in agreement with results reported by Spink et al. [2], who concluded that larger rivers tended to have more nutrient-rich floodplains. However, regarding the contents of organic carbon, humus, and total nitrogen, the present data showed them to be significantly higher in small river soils. Although riparian habitats are considered to be very productive, surprisingly few data on floodplain nutrient dynamics are available [2,181,182]. Pinay et al. [181] stressed the importance of geomorphic patterns, which directly control the C, N, and P accumulation in riparian soils through erosion/sedimentation processes, and that can completely change as the channel evolves. However, Spink et al. [2] demonstrated factors other than soil fertility (e.g., high or low temperature, drought, flooding) to be extremely important in valleys of large rivers where the supply of bearing sediments is so large that nutrients are no longer limiting. This highlights the complexity of river-floodplain systems and poses some important questions about processes underlying soil nutrient dynamics and the interactions between various factors affecting riparian vegetation that need to be explored [2].

5.2. A syntaxonomic approach to the plant communities studied

The results of this study confirm that the riparian tall herb fringe communities in Central Europe are correctly divided into two groups (alliances) and for the first time provide clear evidence that they are significantly floristically and ecologically distinct, depending on the river size: (***i***) communities associated with large rivers should be assigned to the *Senecionion fluviatilis* alliance, (***ii***) communities occurring on small rivers and other water bodies represent the *Archangelicion litoralis*. In the first group, are important specialist plant species with characteristic distribution patterns, i.e., river corridor plants. In the second group are important species with a broad habitat spectrum that are frequently common, with the exception of *Angelica archangelica*, a species occurring in the tall herb fringe communities near the sea shore and included in the list of river corridor plants [15,16].

The river valleys of northwestern Poland supported a total of 24 vegetation units representing tall herb fringe communities from the order *Convolvuletalia sepium*. Two subassociations (*Convolvulo sepium-Cuscutetum europaeae chaerophylletosum bulbosi* subass. nov., *Eupatorietum cannabini cardaminetosum amarae* subass. nov.) are described here for the first time, whereas six others (*Convolvulo sepium-Cuscutetum europaeae typicum* and *aegopodietosum*, *Eupatorietum cannabini typicum* and *aegopodietosum*, and *Urtico-Convolvuletum sepium typicum* and *aegopodietosum*) have not been previously reported from Poland. No phytosociological documentation on rare and endangered associations (*Senecionetum fluviatilis*) has been published to date in Poland or only single phytosociological relevés (*Fallopio-Cucubaletum bacciferi*) have been available.

The data summarized in the synoptic table indicate that the species diagnostic for the different plant communities should be revised on the supra-regional scale. For example: (***i***) in the opinion of Müller [71] and Matuszkiewicz [37], *Thalictrum flavum* and *Valeriana officinalis* belong to the species differential for the *Senecionetum fluviatilis*, but this is not confirmed by the results of this study. (***ii***) According to Brzeg and Wojterska [61], the differential species of the *Achilleo salicifoliae-Cuscutetum lupuliformis* include *Calamagrostis epigejos*, *Thalictrum flavum*, and *Veronica longifolia*. However, in northwestern Poland, the first two species are not bound to the association; in turn, besides *Veronica longifolia*, also *Petasites spurius*, *Galium elongatum*, *Rorippa palustris*, *Echinocystis lobata*, and *Bidens frondosa* may be regarded as differential species. It is worth noting that the relevés of the *Achilleo salicifoliae-Cuscutetum lupuliformis* taken on the Noteć River could be referred to as the subcontinental variety with *Petasites spurius*, as described by Passarge [147]. (***iii***) The species characteristic of the *Convolvulo sepium-Cuscutetum europaeae* include: *Cuscuta europaea*, *C. lupuliformis*, and *C. gronovii* [36]; *C. europaea* together with the American species of the genus *Aster* (e.g., *A. lanceolatus*, *A. novi-belgii*, *A.* × *salignus*) [37]; or only *C. europaea* [61,68]. The latter approach was applied in this study. (***iv***) Matuszkiewicz [37] considers *Epilobium hirsutum*, *E. parviflorum*, *E. roseum*, and *Scrophularia umbrosa* as the species characteristic of *Epilobio hirsuti-Convolvuletum sepium*. The last species of those listed occurs in northwest Poland equally frequently in other herb communities on small rivers. On the other hand, Brzeg and Wojterska [61] consider *Sonchus arvensis* subsp. *uliginosus* and *S. palustris*, in addition to the *Epilobium* species, as characteristic of the community, but both species are rare in tall herb fringe communities in northwestern Poland and are found in different communities. Brzeg and Wojterska [61] regard *Filipendula ulmaria*, *Rumex hydrolapathum*, *Scrophularia umbrosa*, *Typha latifolia*, and *Phragmites australis* as the differential species, whereas, perhaps except for the rarely encountered *Rumex hydrolapathum*, they are not diagnostic of this community in northwestern Poland.

The large heterogeneity of habitats occupied by the *Convolvulo sepium-Cuscutetum europaeae* in the area of study resulted in significant floristic diversity and structure, which made it possible to distinguish three subassociations: a typical one, a subassociation with *Aegopodium podagraria*, and a newly described subassociation with *Chaerophyllum bulbosum*. The latter is similar to the subcontinental race described by Görs and Müller [149], and clearly differs from the *Chaerophylletum bulbosi* Tx. 1937, most often assigned to the alliance *Aegopodion podagrariae* and containing a set of plant species diagnostic of this group of mesic fringe assemblages (cf. [71]). Even the phytocoenoses described as the *Chaerophylletum bulbosi cuscutetosum* [63,71,154] differ in their floristic composition from the new vegetation unit presented in this study. Furthermore, distinguishing a separate association with *Chaerophyllum bulbosum* has been criticized several times as unjustified [57,149], and the community with the species as a dominant has been assigned to a number of different alliances, and even orders (cf. [69,147,148]). All this renders the diagnostic value of *Chaerophyllum bulbosum* questionable as a species diagnostic of its own association [149].

Some vegetation samples representing the *Convolvulo sepium-Cuscutetum europaeae typicum* in northwestern Poland were missing dodder (*Cuscuta europaea*). The German literature has widely discussed the problem of *Cuscuta europaea* disappearance from riparian tall herb fringe communities (e.g. [57,59,64,147]). The prevailing view, adopted also in the present study on the basis of author's observations, holds that the lack of *C. europaea* cannot be the sole reason for qualifying herb assemblages as a separate community, the *Urtico-Convolvuletum sepium*.

The vegetation samples of the *Convolvulo sepium-Cuscutetum europaeae aegopodietosum* from northwestern Poland miss some species, diagnostic for the subassociation in the opinion of Müller [71], including *Alliaria petiolata*, *Ficaria verna*, *Lamium album*, and *Melandrium rubrum*. On the other hand, fairly frequent were *Galeopsis speciosa*, *Stellaria nemorum*, *Cirsium oleraceum*, and *Filipendula ulmaria*, i.e., the species typical of the communities occurring in valleys of small rivers. It was on small rivers that the subassociation was recorded in this study, which renders the community intermediate between the alliances *Senecionion fluviatilis* and *Archangelicion litoralis*.

In the original diagnosis, the *Urtico-Convolvuletum sepium* was described as an "incomplete community" (Rumpfgesellschaft) characterized by the lack of species diagnostic for the alliance *Senecionion fluviatilis* [149]. In the opinion of Brzeg [36], the community differs from the *Convolvulo sepium-Cuscutetum europaeae* by the absence of dodder and by the presence of species from the alliance *Aegopodion podagrariae*, as well as by the occurrence in valleys of small rivers. Differentiation between the two associations is, however, not easy, as evidenced by the results presented in this work, i.e., the presence of the *Convolvulo sepium-Cuscutetum europaeae aegopodietosum*, with both *Cuscuta europaea* and species from the alliance *Aegopodion podagrariae*, as well as the *Convolvulo sepium-Cuscutetum europaeae typicum* lacking dodder.

Some authors regard the *Urtico-Convolvuletum sepium* as unjustified [57,69,159], and usually combine it with the *Convolvulo sepium-Cuscutetum europaeae*. However, the CVA conducted in this study showed that, although the *Convolvulo sepium-Cuscutetum europaeae aegopodietosum* was located in the ordination space close to the *Urtico-Convolvuletum sepium typicum* and *aegopodietosum*, the opposite part of the plot featured the *Convolvulo sepium-Cuscutetum europaeae typicum* and *chaerophylletosum bulbosi* subass. nov. Both subassociations of *Convolvulo sepium-Cuscutetum europaeae* occur on large rivers, in the range of the natural potential vegetation unit *Salici-Populetum*, on soils with higher pH. In addition, the sites of the subassociation with *Chaerophyllum bulbosum* were more elevated, and the soils were moister and richer in K_2O. Instead, the *Urtico-Convolvuletum sepium* was associated with small rivers, the range of the natural potential vegetation units *Fraxino-Alnetum, Ficario-Ulmetum*, or *Carici elongatae-Alnetum* and with soils of lower pH, that were richer in CaO and the skeletal fraction. Siedentopf [63] also found the combination of the two associations to be very problematic, as they occur at differing sites. The absence of diagnostic species for the *Senecionion fluviatilis* in phytocoenoses of the *Urtico-Convolvuletum sepium* becomes obvious when the association is assigned to the *Archangelicion litoralis*, as clearly indicated by the results of this work. The association *Urtico-Convolvuletum sepium* was primarily defined by the absence of positive diagnostic species; therefore, it may be called the "central association" of the alliance *Archangelicion litoralis*, as postulated by, inter alia, Koska [62].

The phytosociological literature lists two herb communities with *Angelica archangelica* subsp. *litoralis*. The first described by Tüxen [141], is the subhalophilous *Soncho palustris-Archangelicetum litoralis* and the other, described by Passarge [144,183], is the nonhalophilous *Convolvulo-Archangelicetum*. The discussion of the syntaxonomic position and relationships between the two communities has been very lively (e.g., [63,82,150,154,184]). However, because of the lack of their own characteristic species, or even good differential species, it is not justified to keep the two associations. A broad approach to *Soncho palustris-Archangelicetum litoralis* (incl. *Convolvulo-Archangelicetum*) has been postulated by Brzeg and Wojterska [61], Matuszkiewicz [37], Koska [62], Ratyńska et al. [68], and Zgrabczyńska and Brzeg [82]. The subassociations and variants of the *Soncho palustris-Archangelicetum litoralis* described in Poland to date [82] are not consistent with the internal variability of the community as observed in this study. A final decision regarding the community division into lower syntaxonomic units will be possible only after relevés from Central Europe have been analyzed.

The phytosociological literature considers the *Eupatorietum cannabini*, described by Tüxen [141], as a forest clearing community of the class *Epilobietea angustifolii*, whereas the

Eupatorio-Convolvuletum was described by Görs [59], as different from the previous one and assigned to the order *Convolvuletalia sepium* in the class *Artemisietea vulgaris*. However, good diagnostic species characteristic for both associations cannot be defined in this case either. According to Müller [71], Tüxen's clearing community should not be retained, because, although *Eupatorium cannabinum* can be differential for various forest clearing assemblages, the species occurs predominantly in riparian tall herb communities. Other authors maintain that the species has two clear ecological optima: one in riparian tall herb communities and the other in the natural gaps in tree stands and on clearings produced by the removal of fertile alder carrs and riparian woodland [36,147,185,186]. The problem with the classification of communities dominated by *Eupatorium cannabinum* is resolved by the broad approach to the class *Epilobietea angustifolii* proposed by Mucina et al. [70]. The present work proposes setting off a single association dominated by *Eupatorium cannabinum* with its original Tüxen's name *Eupatorietum cannabini* and assigning to it both the phytocoenoses typical of riparian tall herb fringe communities (subassociations *Eupatorietum cannabini typicum* and *aegopodietosum*) and those developing in gaps in alder carrs and head water tree stands (*Eupatorietum cannabini cardaminetosum amarae* subass. nov.). Koska [62] regarded the name *Eupatorietum cannabini* as nomen dubium. This opinion is not shared by the author of this study, because Tüxen's [141] synoptic table based on relevés serving as the nomenclatural type cannot be treated as so complex as to preclude assigning them to the community discussed (cf. Art. 37 ICPN [99]). Tüxen [65] himself pointed out that the phytosociological affinity of *Eupatorietum cannabini* he described requires further study, because the floristic composition deviates from typical clearing communities.

A point for a new approach to the class *Epilobietea angustifolii* [70] is also provided by the herb fringe communities, documented from northwestern Poland and dominated by *Galeopsis speciosa* and *Rubus idaeus*, their nature being clearly intermediate between the riparian and clearing herb communities. These species occur most frequently in forest clearings, but their communities were distinctly associated with river channels, and their floristic composition feature characteristic and differential species of communities from the order *Convolvuletalia sepium* (e.g., *Galium aparine*, *Humulus lupulus*, *Carex acutiformis*, *Lysimachia vulgaris*, *Carduus crispus*, *Eupatorium cannabinum*, *Phalaris arundinacea*, *Calystegia sepium*, and *Fallopia dumetorum*). The presence of both plant communities in the Piaśnica River valley had already been reported by Myśliwy [187]. No description of a similar community with *Rubus idaeus* is in the available literature, except for the floristically different, typical clearing community *Rubetum idaei* Pfeiffer 1936 em. Oberd. 1973 [37,67]. On the other hand, Mucina [69] described a more ruderal assemblage with *Galeopsis speciosa*, featuring *Urtica dioica*, *Mentha longifolia*, and *Rubus fruticosus* agg. and growing on the fringes of forests and roads.

5.3. Plant invasions in river valley communities

Riparian habitats are extremely rich in alien invasive plants, which can find appropriate ecological niches in the riparian zone [11,43,47,188–190]. Many of these plants spread along watercourses and exhibit river corridor distribution patterns, at least at the early stage of their invasion history [15]. Probably the main reasons for such distribution patterns include hydrochory and availability of open sites created by destructive flooding events [15,191]. Of the aliens recorded in tall herb fringe communities in northwestern Poland, *Bidens frondosa* was included in Burkart's [15] river corridor plants list. According to Tokarska-Guzik [192], *Acer negundo*, *Echinocystis lobata*, *Rumex confertus*, *Solidago canadensis*, and *S. gigantea* are also associated with river valleys. *Solidago canadensis* was sporadically recorded in the riparian tall herb fringe communities in the area of study, whereas *S. gigantea* was clearly linked with rivers. According to Szymura and Szymura [193], this can be the effect of early colonization patterns (priority effect), rather than the result of differences in habitat preferences of both *Solidago* species. Both species show no differences with respect to moisture, as expressed by topographic wetness index, or the composition of the co-occurring vascular plant species [193]. However, in the opinion of Nobis and Skórka [16], alien plants should not be included in the list of river corridor plants at all.

Results of this study indicate that the establishment of alien invasive species in riparian tall herb fringe communities is more common in valleys of large rivers and the Szczecin Lagoon than in the valleys of small rivers. Large river floodplains are subjected to regular inundation events producing new niches available for colonization. In addition, valleys of large rivers are often anthropogenically transformed and deforested, hence they receive a higher supply of diaspores of alien species. The riverbed width, directly related to the size of the river, also emerged as an important predictor of the level of plant invasion in the study of Liendo et al. [194]. The distribution patterns of alien plants shown by Planty-Tabacchi et al. [195] and confirmed by studies of Truscott et al. [196], point to a longitudinal trend along the river, whereby the number of aliens, relatively low in headwaters, increases consistently down river. Planty-Tabacchi et al. [195] list three main reasons for the high abundance of aliens in downstream river reaches: a greater share of specialized plants because of the disturbance flood regime, a milder climate, and a greater human effect. In addition, anthropogenic river regulation was indicated as an important factor increasing the susceptibility of riparian vegetation to invasion [197,198].

Differences in propagule pressure among various land use forms clearly influence the level of invasion: in the present study, approximately 60–70% of vegetation samples taken in the vicinity of buildings and arable land contained alien invasive species, whereas they were present in only 25% of samples collected near meadows and forests. Agricultural intensification and urbanization are among the most important land-use drivers affecting the incidence of alien invasive species [199]. A higher invasion level at sites subjected to a high level of anthropogenic pressure was also reported by Lambdon et al. [200], Liendo et al. [194,201], and Myśliwy [202].

The present results showed no significant differences between the *Solidago gigantea* or *Impatiens glandulifera* communities and the other riparian tall herb fringe communities examined regarding the number of species, Shannon's diversity, and evenness. Moreover, the original floristic composition of native communities was recognizable in some samples with a relatively high contribution of the two alien species, because the species diagnostic for the original communities were still present. This confirms that although some alien plant species significantly affect the composition and structure of native plant communities, other invaders produce very little or no effect on species richness and diversity [203,204]. According to Hejda et al. [205], *Reynoutria japonica* belongs to the former group, *Impatiens glandulifera* to the latter, whereas *Helianthus tuberosus* and *Solidago gigantea* appear to be intermediate in terms of their effect. In addition, wetland plant diversity is considered low, regardless of the dominant being a native or an alien species [206], which is indeed the case in the riparian tall herb fringe communities.

Neophyte dominated phytocoenoses have been treated in publications as separate associations or as plant communities without any syntaxonomic rank (e.g., [37,61,67,69,157,159]). Because of the wide ecological amplitude of numerous alien species, they can penetrate ruderal, seminatural, and natural communities representing different alliances (*Senecionion fluviatilis*, *Aegopodion podagrariae*, *Arction lappae*, *Dauco-Melilotion*). While considering the presence of typically ruderal and typically riparian communities dominated by particular alien species, it was decided for the purpose of the present study not to assign them any rank.

It is often possible to identify a native plant community penetrated by a given neophyte. Passarge [147] treated such synusia with different alien species as facies. In this study, various intermediate forms between phytocoenoses dominated by *Solidago gigantea* and *Senecionetum fluviatilis* or *Fallopio-Cucubaletum bacciferi*, as well as between phytocoenoses dominated by *Impatiens glandulifera* and *Eupatorietum cannabini* or *Epilobio hirsuti-Convolvuletum sepium* were observed. Each vegetation sample with the contribution of alien invasive species was identified with the particular native association as long as its floristic composition was recognizable.

6. Conclusions

Quantitative description and classification of alluvial vegetation are very important for conservation and restoration purposes. The results presented provide a comprehensive description of riparian tall herb fringe communities representing the order *Convolvuletalia sepium* in northwestern Poland, including their environmental settings. A total of 24 vegetation units were documented, and the key underlying gradients and major environmental factors that influence the vegetation patterns observed were identified. The study shows that:

- Floristic and ecological differences between communities occurring in valleys of large rivers and in small rivers (e.g., plant species richness, moss layer cover, contribution of river corridor plants, influence of adjacent plant communities on the floristic composition, relative elevation and distance away from the riverbed, degree of shading, soil texture and pH, and contents of nutrients) justify their division into two alliances: *Senecionion fluviatilis* associated with large rivers, and *Archangelicion litoralis* associated with small rivers and other water bodies.
- Significant differences in environmental characteristics of the particular tall herb fringe communities, as well as an array of factors significantly discriminated between them (e.g., the natural potential vegetation, soil pH, sample elevation, river size, flooding, degree of shading, soil moisture content, K_2O and CaO contents, C/N ratio) showed that most vegetation units examined were well defined.
- The understanding of riparian vegetation patterns can be significantly improved when the evaluation of variation in the vegetation is based on a wide range of factors (e.g., hydrogeomorphic and soil characteristics), and when the main riparian gradients are integrated with the patch perspective (e.g., natural potential vegetation units, land use forms).
- The tall herb fringe communities of the order *Convolvuletalia sepium* are multilayered and floristically diverse assemblages that occur in ecotone systems and are therefore frequently penetrated by species from adjacent plant communities. Such sporadic species may be indicative of special microhabitat conditions (e.g., species typical of headwaters, forests, and meadows); thus, it is advisable to include them in the analyses.
- The high floristic variability and the dominance of different species in the particular tall herb assemblages are the main reason to distinguish between numerous individual associations, subassociations, variants, and facies, the diagnostic species of which are frequently of only local or regional importance. A final decision regarding the association division into lower syntaxonomic units and identification of diagnostic species of supraregional importance will be possible only after a comprehensive numerical analysis of the Central European relevés.
- The inclusion of the order *Convolvuletalia sepium* to the class *Epilobietea angustifolii* resolves the problem of classifying the community dominated by *Eupatorium cannabinum*, a species showing two ecological optima: one in riparian tall herb communities and the other in natural gaps of the tree stands and clearings of fertile alder carrs and riparian woodlands, as well as the problem of classifying the communities dominated by *Galeopsis speciosa* and *Rubus idaeus*, intermediate between riparian tall herb and clearing communities.
- The tall herb fringe communities occurring along large rivers showed a higher level of invasion compared with the communities from small rivers. Alien invasive plants enter

different native associations, depending on the river size. *Solidago gigantea* and *Impatiens glandulifera* produced a low effect on the species richness and diversity of the riparian tall herb fringe communities examined. While considering the presence of typically riparian or typically ruderal communities dominated by alien species, it is more appropriate to leave them without any syntaxonomic rank and to assign them to a recognized alliance or order.

The documentation collected in this study contributes to the knowledge on the distribution and diversity of riparian tall herb fringe communities and may serve as a reference for management of the vegetation in river valleys and to promote their conservation. It will be also essential for any future syntaxonomic revision of riparian tall herb fringe communities at a larger geographical extent.

7. References

1. Neiman RJ, Decamps H, McClain ME. Riparia: ecology, conservation, and management of streamside communities. Burlington: Elsevier Academic Press; 2005.
2. Spink A, Sparks RE, van Oorschot M, Verhoeven JTA. Nutrient dynamics of large river floodplains. Regulated Rivers: Research and Management. 1998;14:203–216. https://doi.org/10.1002/(SICI)1099-1646(199803/04)14:2<203::AID-RRR498>3.0.CO;2-7
3. Thorp JH, Thoms MC, Delong MD. The riverine ecosystem synthesis: biocomplexity in river networks across space and time. River Res Appl. 2006;22:123–147. https://doi.org/10.1002/rra.901
4. Vannote RL, Minshall GW, Cummins KW, Sedell JR, Cushing CE. The river continuum concept. Can J Fish Aquat Sci. 1980;37:130–137. https://doi.org/10.1139/f80-017
5. Tabacchi E, Planty-Tabacchi AM, Salinas MJ, Décamps H. Landscape structure and diversity in riparian plant communities: a longitudinal comparative study. Regulated Rivers: Research and Management. 1996;12:367–390. https://doi.org/10.1002/(SICI)1099-1646(199607)12:4/5<367::AID-RRR424>3.0.CO;2-X
6. Montgomery DR. Process domains and the river continuum. Journal of the American Water Resources Association. 1999;35(2):397–410. https://doi.org/10.1111/j.1752-1688.1999.tb03598.x
7. Junk JW, Bayley PB, Sparks RE. The flood pulse concept in river-floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences. 1989;106:110–127.
8. Poff NL, Allan JD, Bain MB, Karr JR, Prestegaard KL, Richter BD, et al. The natural flow regime. A paradigm for river conservation and restoration. BioScience. 1997;47:769–784. https://doi.org/10.2307/1313099
9. Wassen MJ, Peeters WHM, Venterink HO. Patterns in vegetation, hydrology, and nutrient availability in an undisturbed river floodplain in Poland. Plant Ecol. 2002;165:27–43. https://doi.org/10.1023/A:1021493327180
10. Yang J, Dilts TE, Condon LA, Turner PL, Weisberg PJ. Longitudinal- and transverse-scale environmental influences on riparian vegetation across multiple levels of ecological organization. Landsc Ecol. 2011;26:381–395. https://doi.org/10.1007/s10980-010-9565-z
11. Tabacchi E, Correll DL, Hauer R, Pinay G, Planty-Tabacchi AM, Wissmar RC. Development, maintenance and role of riparian vegetation in the river landscape. Freshw Biol. 1998;40:497–516. https://doi.org/10.1046/j.1365-2427.1998.00381.x
12. Tockner K, Malard F, Ward JV. An extension of the flood pulse concept. Hydrol Process. 2000;14:2861–2883. https://doi.org/10.1002/1099-1085(200011/12)14:16/17<2861::AID-HYP124>3.0.CO;2-F
13. Wu J, Loucks OL. From balance of nature to hierarchical patch dynamics: a paradigm shift in ecology. Q Rev Biol. 1995;70(4):439–466. https://doi.org/10.1086/419172
14. Ward JV, Tockner K, Schiemer F. Biodiversity of floodplain river ecosystems: ecotones and connectivity. Regulated Rivers: Research and Management. 1999;15:125–139. https://doi.org/10.1002/(SICI)1099-1646(199901/06)15:1/3<125::AID-RRR523>3.0.CO;2-E
15. Burkart M. River corridor plants (Stromtalpflanzen) in Central European lowland: a review of a poorly understood plant distribution pattern. Global Ecology and Biogeography. 2001;10:449–468. https://doi.org/10.1046/j.1466-822x.2001.00270.x

16. Nobis A, Skórka P. River corridor plants revised: what drives their unique distribution patterns? Plant Biosyst. 2016;150(2):244–253. https://doi.org/10.1080/11263504.2014.972999
17. van Looy K, Honnay O, Bossuyt B, Hermy M. The effect of river embankment and forest fragmentation on the plant species richness and composition of floodplain forests in the Meuse valley, Belgium. Belg J Bot. 2003;136:97–108.
18. Leyer I. Predicting plant species' responses to river regulation. The role of water level fluctuations. J Appl Ecol. 2005;42:239–250. https://doi.org/10.1111/j.1365-2664.2005.01009.x
19. Dybkjær JB, Baattrup-Pedersen A, Kronvang B, Thodsen H. Diversity and distribution of riparian plant communities in relation to stream size and eutrophication. J Environ Qual. 2012;41:348–354. https://doi.org/10.2134/jeq2010.0422
20. Szoszkiewicz K. Vegetation as an indicator of trophic status of running waters based on rivers of Great Britain and Northern Ireland. Roczniki AR w Poznaniu, Rozprawy Naukowe. 2004;349:3–116.
21. Giller S. River restoration: seeking ecological standards. Editor's introduction. J Appl Ecol. 2005;42:201–207. https://doi.org/10.1111/j.1365-2664.2005.01020.x
22. Härdtle W, Redecker B, Assmann T, Meyer H. Vegetation responses to environmental conditions in floodplain grasslands: prerequisites for preserving plant species diversity. Basic Appl Ecol. 2006;7:280–288. https://doi.org/10.1016/j.baae.2005.09.003
23. Matthews ER, Peet RK, Weakley AS. Classification and description of alluvial plant communities of the Piedemont region, North Carolina, USA. Appl Veg Sci. 2011;14:485–505. https://doi.org/10.1111/j.1654-109X.2011.01150.x
24. Ellenberg H. Vegetation ecology of Central Europe. 4th ed. Cambridge: Cambridge University Press; 2009.
25. Kucharczyk M. Distribution atlas of vascular plants in the middle Vistula River Valley. Lublin: Maria Curie-Skłodowska University Press; 2001.
26. Turner MG, Gergel SE, Dixon MD, Miller JR. Distribution and abundance of trees in floodplain forests of the Winsconsin River: environmental influences at different scales. J Veg Sci. 2004;15:729–738. https://doi.org/10.1658/1100-9233(2004)015[0729:DAAOTI]2.0.CO;2
27. Hérault B, Honnay O. The relative importance of local, regional and historical factors determining the distribution of plants in fragmented riverine forests: an emergent group approach. J Biogeogr. 2005;32:2069–2081. https://doi.org/10.1111/j.1365-2699.2005.01351.x
28. Lyon J, Gross NM. Patterns of plant diversity and plant-environmental relationships across three riparian corridors. For Ecol Manage. 2005;204:267–278. https://doi.org/10.1016/j.foreco.2004.09.019
29. Douda J. The role of landscape configuration in plant composition of floodplain forests across different physiographic areas. J Veg Sci. 2010;21:1110–1124. https://doi.org/10.1111/j.1654-1103.2010.01213.x
30. Goebel PC, Palik BJ, Pregitzer KS. Structure and composition of riparian forests in an old-growth northern hardwood-hemlock watershed. For Ecol Manage. 2012;280:52–61. https://doi.org/10.1016/j.foreco.2012.05.037
31. Pielech R. Formalised classification and environmental controls of riparian forest communities in the Sudetes (SW Poland). Tuexenia. 2015;35:155–176. https://doi.org/10.14471/2015.35.003
32. Pielech R, Anioł-Kwiatkowska J, Szczęśniak E. Landscape-scale factors driving plant species composition in mountain streamside and spring riparian forests. For Ecol Manage. 2015;347:217–227. https://doi.org/10.1016/j.foreco.2015.03.038

33. Dwire KA, Kauffman JB, Baham JE. Plant species distribution in relation to water-table depth and soil redox potential in montane riparian meadows. Wetlands. 2006;26(1):131–146. https://doi.org/10.1672/0277-5212(2006)26[131:PSDIRT]2.0.CO;2
34. Ludewig K, Korell L, Löffler F, Scholz M, Mosner E, Jensen K. Vegetation patterns of floodplain meadows along the climatic gradient at the Middle Elbe River. Flora. 2014;209:446–455. https://doi.org/10.1016/j.flora.2014.04.006
35. Kopecký K. Společenstva řádu *Convolvuletalia sepium* a svazu *Convolvulion sepium* v Československu. Preslia. 1985;57:235–246.
36. Brzeg A. Przegląd systematyczny zbiorowisk okrajkowych dotąd stwierdzonych i mogących występować w Polsce. Fragmenta Floristica et Geobotanica. 1989;34(3–4):385–423.
37. Matuszkiewicz W. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Warszawa: WN PWN; 2002. (Vademecum Geobotanicum; vol 3).
38. Rodwell JS, Dring JC, Averis ABG, Proctor MCF, Malloch AJC, Schaminée JHJ, et al. Review of coverage of the National Vegetation Classification. Peterborough: JNCC; 2000. (Joint Nature Conservation Council Report; vol 302).
39. Mróz W. Ziołorośla górskie (*Adenostylion alliariae*) i ziołorośla nadrzeczne (*Convolvuletalia sepium*). In: Herbich J, editor. Murawy, łąki, ziołorośla, wrzosowiska, zarośla. Poradniki ochrony siedlisk i gatunków Natura 2000 – podręcznik metodyczny; vol. 3. Warszawa: Ministerstwo Środowiska; 2004. p. 171–184.
40. Lonsdale WM. Global patterns of plant invasions and the concept of invisibility. Ecology. 1999;80:1522–1536. https://doi.org/10.1890/0012-9658(1999)080[1522:GPOPIA]2.0.CO;2
41. Richardson DM, Pyšek P. Plant invasions: merging the concepts of species invasiveness and community invisibility. Prog Phys Geogr. 2006;30(3):409–431. https://doi.org/10.1191/0309133306pp490pr
42. Tokarska-Guzik B. Habitat preferences of some alien plants (kenophytes) occurring in Poland. In: Zając A, Zając M, Zemanek B, editors. Phytogeographical problems of synanthropic plants. Cracow: Jagiellonian University; 2003. p. 75–83.
43. Chytrý M, Pyšek P, Tichý L, Knollová I, Danihelka J. Invasions by alien plants in the Czech Republic: a quantitative assessment across habitats. Preslia. 2005;77:339–354.
44. Botta-Dukát Z. Invasion of alien species to Hungarian (semi-)natural habitats. Acta Bot Hung. 2008;50(suppl):219–227. https://doi.org/10.1556/ABot.50.2008.Suppl.11
45. Stępień E. Kenophytes in the Cedynia Landscape Park. In: Holeksa J, Babczyńska-Sendek B, Wika S, editors. The role of geobotany in biodiversity conservation. Katowice: University of Silesia; 2009. p. 309–317.
46. Sîrbu C, Oprea A, Samuil C, Tănase C. Neophyte invasion in Moldavia (eastern Romania) in different habitat types. Folia Geobot. 2012;47:215–229. https://doi.org/10.1007/s12224-011-9112-y
47. Myśliwy M. Habitat preferences of some neophytes, with a reference to habitat disturbances. Pol J Ecol. 2014;63:509–524. https://doi.org/10.3161/104.062.0311
48. Dajdok Z, Anioł-Kwiatkowska J. Wstępne wyniki badań nad ekspansją niecierpka gruczołowatego (*Impatiens glandulifera* Royle) w Dolinie Odry. Badania Fizjograficzne nad Polską Zachodnią, Seria B – Botanika. 1998;47:195–204.
49. Zaliberová M, Jarolímek I. Distribution of the plant communities of the order *Convolvuletalia sepium* in Slovakia. In: Zając A, Zając M, Zemanek B, editors. Phytogeographical problems of synanthropic plants. Cracow: Institute of Botany, Jagiellonian University; 2003. p. 283–291.

50. Kompała-Bąba A, Błońska A. Plant communities with *Helianthus tuberosus* L. in the towns of the Upper Silesian Industrial Region (southern Poland). Biodivers Res Conserv. 2008;11–12:57–64.

51. Śliwiński M. Występowanie *Reynoutria japonica* Houtt., *Reynoutria sachalinensis* (F. Schmidt) Nakai i *Impatiens glandulifera* Royle wzdłuż strumieni Gór Sowich w okolicach Bielawy. Acta Botanica Silesiaca. 2009;4:91–106.

52. Medvecká J, Jarolímek I, Zaliberová M. Ruderal vegetation of the Horná Orava Region 2. *Galio-Urticetea*, *Epilobietea angustifolii*. Thaiszia. 2010;20:17–52.

53. Chmura D, Tokarska-Guzik B, Nowak T, Woźniak G, Bzdęga K, Koszela K, et al. The influence of invasive *Fallopia* taxa on resident plant species in two river valleys (southern Poland). Acta Soc Bot Pol. 2015;84(1):23–33. https://doi.org/10.5586/asbp.2015.008

54. Pattison Z, Minderman J, Boon PJ, Willby N. Twenty years of change in riverside vegetation: what role have invasive plants played? Appl Veg Sci. 2017;20(3):422–434. https://doi.org/10.1111/avsc.12297

55. Moor M. Pflanzengesellschaften schweizerischer Flußauen. Mitteilungen Schweizerische Anstalt für das Forstliche Versuchswesen. 158;34(4):221–360.

56. Kopecký K. Die flussbegleitende Neophytengesellschaft *Impatienti-Solidaginetum* in Mittelmähren. Preslia. 1967;39(2):15l-166.

57. Hilbig W, Heinrich W, Niemann E. Übersicht über die Pflanzengesellschaften des südlischen Teiles der DDR. 4. Die nitrophilen Saumgesellschaften. Hercynia NF Leipzig. 1972;9:229–270.

58. Anioł-Kwiatkowska J. Flora i zbiorowiska synantropijne Legnicy, Lubina i Polkowic. Wrocław: Wydawnictwo Uniwersyteckie; 1974. (Acta Universitatis Wratislaviensis, Prace Botaniczne; vol 19).

59. Görs S. Nitrophile Saumgesellschaften im Gebiet des Taubergiessen. In: Landesstelle für Naturschutz und Landschaftspflege Baden-Württemberg, editors. Das Taubergießengebiet – eine Rheinauenlandschaft. Ludwigsburg: Landesstelle für Naturschutz und Landschaftspflege Baden-Württemberg; 1975. p. 325–354. (Natur- und Landschaftsschutzgebiete Baden-Württembergs; vol 7).

60. Fijałkowski D. Synantropy roślinne Lubelszczyzny. Warszawa: PWN; 1978.

61. Brzeg A, Wojterska M. Zespoły roślinne Wielkopolski, ich stan poznania i zagrożenie. In: Wojterska M, editor. Szata roślinna Wielkopolski i Pojezierza Południowopomorskiego. Przewodnik sesji terenowych 52. Zjazdu PTB; 2001 Sep 24–28; Poznań, Poland. Poznań: Bogucki Wydawnictwo Naukowe; 2001. p. 39–110.

62. Koska I. Klasse: *Phragmito-Magno-Caricetea* Klika in Klika & V. Novák 1941 – Röhrichte, Großseggenriede und Feuchtstaudenfluren nährstoffreicher Standorte. In: Berg C, Dengler J, Abdank A, Isermann M, editors. Die Pflanzengesellschaften Mecklenburg-Vorpommerns und ihre Gefährdung – Textband. Herausgegeben vom Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern. Jena: Weissdorn-Verlag; 2004. p. 196–224.

63. Siedentopf YM. Vegetationsökologie von Stromtalpflanzengesellschaften (*Senecion fliviatilis*) an der Elbe. Technischen Universität Carolo-Wilhelmina [Internet]. 2005 [cited 2018 Jan 20]. Available from: https://publikationsserver.tu-braunschweig.de/receive/dbbs_mods_00001776

64. Tüxen R. Der Pflanzensozologische Garten in Hannover und seine bisherige Entwicklung. Jahresber Naturhist Ges Hannover. 1947;94–98:113–288.

65. Tüxen R. Grundriß einer Systematik der nitrophilen Unkratgesellschaften in der Eurosibirischen Region Europas. Mitt Florist-Soziol Arbeitsgem NF. 1950;2:94–175.

66. Oberdorfer E, Görs S, Korneck D, Lohmeyer W, Müller T, Philippi G, et al. Systematische Übersicht der westdeutschen Phanerogamen- und Gefäßkryptogamen-Gesellschaften. Schriftenreihe für Vegetationskunde. 1967;2:7–62.
67. Pott R. Die Pflanzengesellschaften Deutschlands. Stuttgart: Verlag Eugen Ulmer; 1992.
68. Ratyńska H, Wojterska M, Brzeg A. Multimedialna encyklopedia zbiorowisk roślinnych Polski [CD-ROM]. Warszawa: Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej w Warszawie; 2010. CD 1–2.
69. Mucina L. *Galio-Urticetea*. In: Mucina L, Grabherr G, Ellmauer T, editors. Die Pflanzengesellschaften Österreichs. I. Anthropogene Vegetation. Jena: Fisher; 1993. p. 203–251.
70. Mucina L, Bültmann H, Dierßen K, Theurillat JP, Raus T, Čarni A, et al. Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Appl Veg Sci. 2016;19(1 suppl):3–264. https://doi.org/10.1111/avsc.12257
71. Müller T. Klasse: *Artemisietea vulgaris* Lohm., Prsg. et Tx. in Tx. 50. In: Oberdorfer E, editor. Süddeutsche Pflanzengesellschaften, vol. 3. Stuttgart: Gustav Fischer Verlag; 1983. p. 135–177.
72. Kuzyarin AT. The syntaxonomy of ruderal vegetation of flood plain ecosystems in the Western Bug River basin. Proceedings of the State Natural History Museum (Lviv). 2005;21:29–52.
73. Dengler J, Koska I, Timmermann T, Berg C, Clausnitzer U, Isermann M, et al. New descriptions and typifications of syntaxa within the project "Plant communities of Mecklenburg-Vorpommern and their vulnerability" Part II. Feddes Repert. 2004;115(3–4):343–392. https://doi.org/10.1002/fedr.200411043
74. van't Veer R, Schaminée JHJ, Weeda EJ. *Convolvulo-Filipenduletea*. In: Stortelder AHF, Schaminée JHJ, Hommel PWFM, editors. De Vegetatie von Nederland. Deel 5. Plantengemeenschappen van ruigten, struwelen en bossen. Upsala: Opulus; 1999. p. 13–40.
75. Kępczyński K, Rutkowski L. Zbiorowiska wodne, szuwarowe i zaroślowe w dolinie Wisły na odcinku Nebrowo Wielkie-Jarzębina. Studia Societatis Scientiarum Torunensis Sectio D (Botanica). 1981;11(3):3–35.
76. Borysiak J, Wiszniewska K. Zbiorowiska z *Convolvulion sepium* Tx. (1947) 1950 na aluwiach Warty między Santokiem a Świerkocinem (Kotlina Gorzowska). Badania Fizjograficzne nad Polską Zachodnią seria B – Botanika. 1990;40:153–163.
77. Rutkowski L, Kaźmierczak E. Zbiorowiska okrajkowe zagłębień śródpolnych w okolicach Chełmży na Pojezierzu Chełmińskim. Acta Universitatis Nicolai Copernici, Biologia, Nauki Matematyczno-Przyrodnicze. 1993;89:153–162.
78. Borysiak J. Struktura aluwialnej roślinności lądowej środkowego i dolnego biegu Warty. Poznań: WN UAM; 1994. (Seria Biologia; vol 52).
79. Ratyńska H. Roślinność poznańskiego przełomu Warty i jej antropogeniczne przemiany. Bydgoszcz: Wydawnictwo Akademii Bydgoskiej im. K. Wielkiego; 2001.
80. Ejankowski W. Ciepłolubne i nitrofilne zbiorowiska okrajkowe w Górznieńsko-Lidzbarskim Parku Krajobrazowym. Parki Narodowe i Rezerwaty Przyrody. 2005;24:3–29.
81. Bosiacka B. Roślinność nitrofilnych okrajków wokół śródpolnych oczek wodnych w północno-zachodniej Polsce. Badania Fizjograficzne nad Polską Zachodnią seria B – Botanika. 2008;57:7–26.
82. Zgrabczyńska M, Brzeg A. Występowanie w Wielkopolsce oraz charakterystyka zespołu mlecza błotnego i arcydzięgla nadbrzeżnego *Sonchus palustris-Archangelica litoralis* R. Tx. 1937. Badania Fizjograficzne seria B – Botanika. 2010;59:97–112.
83. Szafer W, Zarzycki K. Szata roślinna Polski, vol. 1. 3rd ed. Warszawa: PWN; 1977.

84. Brzeg A, Wojterska M. Przegląd systematyczny zbiorowisk roślinnych Wielkopolski wraz z oceną stopnia ich zagrożenia. Badania Fizjograficzne nad Polską Zachodnią seria B – Botanika. 1996;45:7–40.

85. Matuszkiewicz JM. Geobotanical regionalization of Poland [Internet]. Warszawa: IGiPZ PAN. 2008 [cited 2017 Oct 21]. Available from: https://www.igipz.pan.pl/Regiony-geobotaniczne-zgik.html

86. Kondracki J. Geografia regionalna Polski. Warszawa: Wydawnictwo Naukowe PWN; 2000.

87. Prusinkiewicz Z, Bednarek R. Gleby. In: Starkel L, editor. Geografia Polski. Środowisko przyrodnicze. Warszawa: Wydawnictwo Naukowe PWN; 1999. p. 373–396.

88. Borówka RK. Środowisko geograficzne. In: Borówka RK, Friedrich S, Heese T, Jasnowska J, Kochanowska R, Opęchowski M, et al, editors. Przyroda Pomorza Zachodniego. Szczecin: Oficyna In Plus; 2002. p. 6–105.

89. Koźmiński C, Michalska B, editors. Atlas of climatic risk to crop cultivation in Poland. Szczecin: Akademia Rolnicza w Szczecinie, Uniwersytet Szczeciński; 2001.

90. Ewert A. Zagadnienie kontynentalizmu termicznego klimatu Polski i Europy na tle kontynentalizmu kuli ziemskiej. Prace i Studia Instytutu Geograficznego Uniwersytetu Warszawskiego, Klimatologia. 1973;6:9–17.

91. Kożuchowski K, Wilbig J. Kontynentalizm pluwialny w Polsce: zróżnicowanie geograficzne i zmiany wieloletnie. Acta Geographica Lodziensia. 1988;55:3–102.

92. Dynowska I, Pociask-Karteczka J. Obieg wody. In: Starkel L, editor. Geografia Polski. Środowisko przyrodnicze. Warszawa: Wydawnictwo Naukowe PWN; 1999. p. 343–373.

93. Gutry-Korycka M. Geneza i ewolucja den dolin rzecznych i sieci rzecznej. In: Richling A, Ostaszewska K, editors. Geografia fizyczna Polski. Warszawa: Wydawnictwo Naukowe PWN; 2006. p. 151–154.

94. Bajkiewicz-Grabowska E, Mikulski Z. Hydrologia ogólna. 4th ed. Warszawa: Wydawnictwo Naukowe PWN; 2010.

95. Braun-Blanquet J. Pflanzensoziologie. Grundzüge der Vegetationskunde. Berlin: Springer; 1928. https://doi.org/10.1007/978-3-662-02056-2

96. Dzwonko Z. Przewodnik do badań fitosocjologicznych. Poznań: Sorus; 2007. (Vademecum Geobotanicum; vol 6).

97. Hennekens SM, Schaminée JHJ. TURBOVEG, a comprehensive data base management system for vegetation data. J Veg Sci. 2001;12:589–591. https://doi.org/10.2307/3237010

98. Kącki Z, Śliwiński M. The Polish Vegetation Database: structure, resources and development. Acta Soc Bot Pol. 2012;81(2):75–79. https://doi.org/10.5586/asbp.2012.014

99. Weber HE, Moravec J, Theurillat JP. International code of phytosociological nomenclature. 3rd ed. J Veg Sci. 2000;11:739–768. https://doi.org/10.2307/3236580

100. Chytrý M, editor. Vegetation of the Czech Republic. 1. Grassland and heathland vegetation. Praha: Academia; 2007.

101. Chytrý M, editor. Vegetation of the Czech Republic. 2. Ruderal, weed, rock and scree vegetation. Praha: Academia; 2009.

102. Chytrý M, editor. Vegetation of the Czech Republic. 3. Aquatic and wetland vegetation. Praha: Academia; 2011.

103. Chytrý M, editor. Vegetation of the Czech Republic. 4. Forest and scrub vegetation. Praha: Academia; 2013.

104. Mirek Z, Piękoś-Mirkowa H, Zając A, Zając M, editors. Flowering plants and pteridophytes of Poland – a checklist. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2002. (Biodiversity of Poland; vol 1).

105. Szweykowski J. An annotated checklist of Polish liverworts and hornworts. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2006.

106. Ochyra R, Żarnowiec J, Bednarek-Ochyra H. Census catalogue of Polish mosses. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2003. (Biodiversity of Poland; vol 3).

107. Tokarska-Guzik B, Dajdok Z, Zając M, Zając A, Urbisz A, Danielewicz W, et al. Rośliny obcego pochodzenia w Polsce ze szczególnym uwzględnieniem gatunków inwazyjnych. Warszawa: Generalna Dyrekcja Ochrony Środowiska; 2012.

108. Jusik S, Szoszkiewicz K, Kupiec JM, Lewin I, Samecka-Cymerman A. Development of comprehensive river typology based on macrophytes in the mountain-lowland gradient of different Central European ecoregions. Hydrobiologia. 2015;745:241–262. https://doi.org/10.1007/s10750-014-2111-2

109. Matuszkiewicz JM. Potential natural vegetation of Poland [Internet]. Warszawa: IGiPZ PAN; 2008 [cited 2017 Oct 21]. Available from: https://www.igipz.pan.pl/Roslinnosc-potencjalna-zgik.html

110. Bednarek R, Dziadowiec H, Pokojska U, Prusinkiewicz Z. Badania ekologiczno-gleboznawcze. Warszawa: Wydawnictwo Naukowe PWN; 2011.

111. PSSS. Particle size distribution and textural classes of soils and mineral materials – classification of Polish Society of Soil Science 2008. Roczniki Gleboznawcze. 2009;60(2):5–16.

112. Polski Komitet Normalizacyjny. Analiza chemiczno-rolnicza gleby. Oznaczanie zawartości przyswajalnego magnezu w glebach mineralnych PN-R-04020:1994. Warszawa: Polski Komitet Normalizacyjny; 1994.

113. Polski Komitet Normalizacyjny. Analiza chemiczno-rolnicza gleby. Oznaczanie zawartości przyswajalnego potasu w glebach mineralnych PN-R-04022:1996. Warszawa: Polski Komitet Normalizacyjny; 1996.

114. Polski Komitet Normalizacyjny. Analiza chemiczno-rolnicza gleby. Oznaczanie zawartości przyswajalnego fosforu w glebach mineralnych PN-R-04023:1996. Warszawa: Polski Komitet Normalizacyjny; 1996.

115. Polski Komitet Normalizacyjny. Analiza chemiczno-rolnicza gleby. Oznaczanie zawartości przyswajalnego fosforu, potasu, magnezu i manganu w glebach organicznych PN-R-04024:1997. Warszawa: Polski Komitet Normalizacyjny; 1997.

116. Kącki Z, Czarniecka M, Swacha G. Statistical determination of diagnostic, constant and dominant species of the higher vegetation units of Poland. Łódź: Polish Botanical Society; 2013. (Monographiae Botanicae; vol 103). https://doi.org/10.5586/mb.2013.001

117. Jasnowski M. Budowa i roślinność torfowisk Pomorza Szczecińskiego. Szczecin: Szczecińskie Towarzystwo Naukowe; 1962. (Szczecińskie Towarzystwo Naukowe, Wydział Nauk Przyrodniczo-Rolniczych; vol 10).

118. Piotrowska H. Nadmorskie zespoły solniskowe w Polsce i problemy ich ochrony. Ochrona Przyrody. 1974;39:7–63.

119. Święs F. Roślinność ruderalna Dęblina. Annales Universitatis Mariae Curie-Skłodowska, Sectio C. 1986;41(7):89–100.

120. Święs F. Roślinność synantropijna Tarnowa. Annales Universitatis Mariae Curie-Skłodowska, Sectio C. 1989;44(15):236–270.

121. Kępczyński K, Rutkowski L. Interesujące zbiorowiska roślinne w Dolinie Dolnej Wisły na odcinku Nowe–Gniew. Acta Universitatis Nicolai Copernici, Biologia, Nauki Matematyczno-Przyrodnicze. 1992;79:187–204.

122. Jutrzenka-Trzebiatowski A. Dotychczasowe wyniki badań nad zbiorowiskami ziołoroślowymi Żuław Wiślanych. Acta Botanica Cassubica. 2005;5:7–37.

123. Dajdok Z, Anioł-Kwiatkowska J, Kącki Z. *Impatiens glandulifera* Royle in the floodplain vegetation of the Odra River (West Poland). In: Starfinger U, Edwards K, Kowarik I, Williamson M, editors. Plant invasions: ecological mechanisms and human responses. Leiden: Backhuys Publishers; 1998. p. 161–168.

124. Dajdok Z, Anioł-Kwiatkowska J, Kącki Z. Distribution of *Impatiens glandulifera* along the Odra river. In: Zając A, Zając M, Zemanek B, editors. Phytogeographical problems of synantropic plants. Cracow: Institute of Botany, Jagiellonian University; 2003. p. 137–146.

125. Borysiak J. Plant cover of the Lower Oder River Valley Landscape Park. Poznań: UAM; 2004. (Biologia; vol 70).

126. Kordus-Walankiewicz B. Zbiorowiska roślinne jezior przemęckich. Badania Fizjograficzne nad Polską Zachodnią seria B – Botanika. 1977;30:111–132.

127. Stachnowicz W, Nagengast B. Roślinność strefy przybrzeżnej mezotroficznego Jeziora Powidzkiego w warunkach wzrastającej presji osadniczej i rekreacyjnej: stan aktualny oraz ocena wartości dla ochrony przyrody. Badania Fizjograficzne nad Polską Zachodnią seria B – Botanika. 2010;59:7–41.

128. Kaźmierczak E. The vegetation of kettle-holes in central Poland. Uppsala: Svenska Växtgeografiska Sällskapet; 1997. (Acta Phytogeographica Suecica; vol 83).

129. Faliński JB, Falińska K. Szata roślinna rezerwatu krajobrazowego "Dolina Rzeki Wałszy" (Wzniesienia Górowskie). Materiały Zakładu Fitosocjologii Stosowanej UW. 1965;7:3–83.

130. Załuski T. Zbiorowiska roślinne projektowanego rezerwatu "Olszyny Bobrowe". Acta Universitatis Nicolai Copernici, Biologia, Nauki Matematyczno-Przyrodnicze. 1992;79:205–234.

131. Macicka-Pawlik T, Wilczyńska W. Szata roślinna projektowanego rezerwatu "Uroczysko-Wrzosy" koło Wołowa (studium florystyczno-fitosocjologiczne). Acta Universitatis Wratislaviensis, Prace Botaniczne. 1995;64:121–195.

132. Antkowiak W, Stefanek-Pańczuk W. Flora i roślinność planowanego rezerwatu "Papiernia" w zachodniej Wielkopolsce. Badania Fizjograficzne nad Polską Zachodnią seria B – Botanika. 2000;49:113–140.

133. Fijałkowski D. Szata roślinna Parku Krajobrazowego "Lasy Janowskie". Lublin: Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej; 1997.

134. Celiński F, Tobolski M. Stanowiska rzadszych roślin w okolicy Stepnicy nad Zalewem Szczecińskim. Badania Fizjograficzne nad Polską Zachodnią. 1961;8:237–242.

135. Slavik B. Verbreitung von *Cucubalus baccifer* in der Tschechoslowakei. Preslia. 1980;52(2):127–154.

136. Brzeg A. Zbiorowiska okrajkowe okolic Rakowa i Ramieszowa na północ od Wrocławia. Badania Fizjograficzne nad Polską Zachodnią seria B – Botanika. 1983;34:145–163.

137. Rutkowski L. Zbiorowiska okrajkowe w południowo-wschodniej części Puszczy Boreckiej. Acta Universitatis Nicolai Copernici, Biologia, Nauki Matematyczno-Przyrodnicze. 1992;79:171–185.

138. Szczęśniak E. Szata roślinna północno-zachodniej części Pogórza Wałbrzyskiego. III. Zbiorowiska nieleśne. Acta Universitatis Wratislaviensis, Prace Botaniczne. 1998;74:9–37.

139. Torbé M. Występowanie niecierpka gruczołowatego (*Impatiens glandulifera* Royle Walpers) i niecierpka pomarańczowego (*Impatiens capensis* Meerb.) na południowo-zachodnim brzegu Zalewu Szczecińskiego. Folia Universitatis Agriculturae Stetinensis, Agricultura. 2000;85:193–202.

140. Wojterska M. Struktura krajobrazów roślinnych Pojezierza Międzychodzko-Sierakowskiego. Poznań: Bogucki Wydawnictwo Naukowe; 2003.

141. Tüxen R. Die Pflanzengesellschaften Nordwestdeutschlands. Mitteilungen der Floristisch-soziologischen Arbeitsgemeinschaft in Niedersachsen. 1937;3:1–170.

142. Lohmeyer W. Über die Herkunft Einiger Nitrophiler Unkräuter Mitteleuropas. Plant Ecol. 1953;5–6(1):63–65. https://doi.org/10.1007/BF00299554

143. Lohmeyer W. Über flussbegleitende nitrophile Hochstaudenfluren am Mittel- und Niderrhein. Schriftenreihe für Vegetationskunde. 1975;8:79–98.

144. Passarge H. Pflanzengesellschaften zwischen Trebel, Grenz-Bach und Peene (O-Mecklenburg). Berlin: Akademie Verlag; 1959. (Feddes Repertorium Sperierum Novarum Regi Vegetabilis Beiheft; vol 135).

145. Passarge H. Über einige interessante Stromtalgesellschaften der Elbe unterhalb von Magdeburg. Abhandlungen und Berichte für Naturkunde und Vorgeschichte/Museum für Kulturgeschichte Magdeburg. 1965;11:83–93.

146. Passarge H. Über Saumgesellschaften im nordostdeutschen Flachland. Feddes Repert. 1967;74:145–158. https://doi.org/10.1002/fedr.19670740303

147. Passarge H. Über Schleier- und Staudengesellschaften mitteleuropäischer Ufersäume. Folia Geobotanica and Phytotaxonomica. 1976;11:137–162. https://doi.org/10.1007/BF02854756

148. Kopecký K. Zur Syntaxonomie der natürlichen nitrophilen Saumgesellschaften in der Tschechoslowakei und zur Gliederung der Klasse *Galio-Urticetea*. Folia Geobotanica and Phytotaxonomica. 1969;4:235–259. https://doi.org/10.1007/BF02854746

149. Görs S, Müller T. Beitrag zur Kenntnis der nitrophilen Saumgesellschaften Südwestdeutschlands. Mitteilungen der Floristisch-soziologischen Arbeitsgemeinschaft. 1969;14:153–168.

150. Dierschke H, Jackel G, Brandes D. Das *Calystegio-Archangelicetum litoralis* Pass. (1957) 1959 in Nordwest-Deutschland. Mitteilungen der Floristisch-soziologischen Arbeitsgemeinschaft. 1977;19–20:115–124.

151. Zahlheimer WA. Vegetationsstudien in den Donauauen zwischen Regensburg und Straubing als Grundlage für den Naturschutz. Hoppea. 1979;38:3–398.

152. Jackowiak B, Grabherr G. Zur Ausbreitung von *Angelica archangelica* L. an der Donau in Wien. Verh Zool Bot Ges Österr. 1990;127:113–122.

153. Géhu JM, Géhu-Franck J. Groupements arbustifs el mégaphorbiaies du Haut Jura français. Quelques aspects particuliers. Lazaroa. 1987;7:25–35.

154. Brandes D. Ruderal and skirt communities of Oker Valley (Lower Saxony). Braunschweiger Naturkundliche Schriften. 1992;4(1):143–165.

155. Brandes D, Oppermann FW. Die Uferflora der oberen Weser. Braunschweiger Naturkundliche Schriften. 1994;4(3):575–607.

156. Dierßen K. Vegetation Nordeuropas. Stuttgart: Eugen Ulmer; 1996.

157. Jarolímek I, Zaliberowá M. *Convolvuletalia sepum*. In: Valachovič M, editor. Plant communities of Slovakia. 3. Wetland vegetation. Bratislava: Veda Publisher House; 2001. p. 21–49.

158. Siedentopf YM, Brandes D. *Cucubalus baccifer* L. 1753 als Stromtalpflanze ou der mittelerewn Elbe. Brauschweiger Naturkuntliche Schriften. 2001;6(2):485–500.

159. Láníková D, Kočí M, Sádlo J, Šumberová K, Hájková P, Hájek M, et al. Nitrofilní vytrvalá vegetace vlhkývh a mezických stanovišť (*Galio-Urticetea*). In: Chytrý M, editor. Vegetation of the Czech Republic. 2. Ruderal, weed, rock and scree vegetation. Praha: Academia; 2009. p. 289–378.

160. de Foucault B. Contribution au prodrome des végétations de France: les *Filipendulo ulmariae-Convolvuletea sepium* Géhu et Géhu-Franck 1987. Journal de Botanique de la Société Botanique de France. 2011;53:73–137.

161. van der Maarel E. Transformation of cover-abundance values in phytosociology and its effects on community similarity. Vegetatio. 1979;39:97–114. https://doi.org/10.1007/BF00052021

162. Kovach WL. MVSP – A MultiVariate Statistical Package for Windows. Version 3.2. Users' manual. Pentraeth: Kovach Computing Services; 2010.

163. Jongman RHG, ter Braak CJF, van Tongeren OFR, editors. Data analysis in community and landscape ecology. Cambridge: Cambridge University Press; 1995. https://doi.org/10.1017/CBO9780511525575

164. Dzwonko Z, Loster S. Vegetation differentiation and secondary succession on a limestone hill in southern Poland. J Veg Sci. 1990;1:615–622. https://doi.org/10.2307/3235567

165. Stanisz A. Przystępny kurs statystyki z zastosowaniem Statistica PL na przykładach z medycyny. Vol 1. Statystyki podstawowe. Kraków: StatSoft; 2006.

166. StatSoft. Statistica 10 – data analysis software system [software]. 2010 [cited 2017 Oct 10]. Available from: https://www.statsoft.com/

167. ter Braak CJF, Šmilauer P. CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination (version 4.5). Ithaca, NY: Microcomputer Power; 2002.

168. Lepš J, Šmilauer P. Multivariate analysis of ecological data using CANOCO. Cambridge: Cambridge University Press; 2003. https://doi.org/10.1017/CBO9780511615146

169. ter Braak CJF. The analysis of vegetation–environment relationship by canonical correspondence analysis. Vegetatio. 1987;69:69–77. https://doi.org/10.1007/BF00038688

170. ter Braak CJF. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology. 1986;67:1167–1179. https://doi.org/10.2307/1938672

171. Ward JV. The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society. 1989;8(1):2–8. https://doi.org/10.2307/1467397

172. Swanson FJ, Gregory SV, Sedell JR, Campbell AG. Land-water interactions: the riparian zone. In: Edmonds RL, editor. Analysis of coniferous forest ecosystems in the Western United States. Stroudsburg, PA: Hutchinson and Ross; 1982. p. 267–291. (US IBP Synthesis Series; vol 14).

173. Bendix J, Hupp CR. Hydrological and geomorphological impacts on riparian plant communities. Hydrol Process. 2000;14:2977–2990. https://doi.org/10.1002/1099-1085(200011/12)14:16/17<2977::AID-HYP130>3.0.CO;2-4

174. Fischer M, Burkart M, Pasqualetto V, van Kleunen M. Experiment meets biogeography: plants of river corridor distribution are not more stress tolerant but benefit less from more benign conditions elsewhere. J Plant Ecol. 2010;3(3):149–155. https://doi.org/10.1093/jpe/rtq013

175. Dunn WC, Milne BT, Mantilla R, Gupta VK. Scaling relations between riparian vegetation and stream order in the Whitewater River network, Kansas, USA. Landsc Ecol. 2011;26:983–997. https://doi.org/10.1007/s10980-011-9622-2

176. van Coller AL, Rogers KH, Heritage GL. Riparian vegetation–environment relationships: complimentarity of gradients versus patch hierarchy approaches. J Veg Sci. 2000;11:337–350. https://doi.org/10.2307/3236626

177. Hrivnák R. Effect of ecological factors on the zonation of wetland vegetation. Acta Soc Bot Pol. 2005;74(1):73–81. https://doi.org/10.5586/asbp.2005.011

178. Bufková I, Prach K. Linking vegetation pattern to hydrology and hydrochemistry in a montane river floodplain, the Šumava National Park, Central Europe. Wetl Ecol Manag. 2006;14:317–327. https://doi.org/10.1007/s11273-005-3817-8

179. Menges ES, Waller DM. Plant strategies in relation to elevation and light in floodplain herbs. Am Nat. 1983;122(4):454–473. https://doi.org/10.1086/284149

180. Grime JP. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. Am Nat. 1977;111(982):1169–1194. https://doi.org/10.1086/283244

181. Pinay G, Fabre A, Vervier P, Gazelle F. Control of C, N, P distribution in soils of riparian forests. Landsc Ecol. 1992;6(3):121–132. https://doi.org/10.1007/BF00130025

182. Baldwin DS, Mitchel AM. The effects of drying and re-flooding on the sediment and soil nutrient dynamics of lowland river-floodplain systems: a synthesis. Regulated Rivers: Research and Management. 2000;16:457–467. https://doi.org/10.1002/1099-1646(200009/10)16:5<457::AID-RRR597>3.0.CO;2-B

183. Passarge H. Pflanzengesellschaften des nordostdeutschen Flachlandes I. Pflanzensoziologie. 1964;13:1–324.

184. Zaharias D. Das *Sonchetum palustris* (Vlieger et Zinderen Bakker 1942) van Donselaar 1961 im östlichen Niedersachsen. Tuxenia. 1987;7:101–111.

185. Michálková D, Zaliberová M. Synantropizácia prirodzenej vegetácie na vrchu Rohatín v Strážovských vrchoch. Bulletin Slovenskej Botanickej Spoločnosti. 2006;28:211–222.

186. Jarolímek I, Šibík J, Hegedüšová K, Janišová M, Kliment J, Kučera P, et al. A list of vegetation units of Slovakia. In: Jarolímek I, Šibík J, editors. Diagnostic, constant and dominant species of the higher vegetation units of Slovakia. Bratislava: Veda; 2008. p. 295–329.

187. Myśliwy M. Riparian tall herb fringe communities in a small lowland river valley: species-environment interactions. Natura Montenegrina. 2010;9(3):403–415.

188. Richardson DM, Holmes PM, Esler KJ, Galatowitsch SM, Stromberg JC, Kirkman SP, et al. Riparian vegetation: degradation, alien plant invasions, and restoration prospects. Divers Distrib. 2007;13:126–139. https://doi.org/10.1111/j.1366-9516.2006.00314.x

189. Cushman JH, Gaffney KA. Community-level consequences of invasion: impacts of exotic clonal plants on riparian vegetation. Biol Invasions. 2010;12:2765–2776. https://doi.org/10.1007/s10530-009-9682-2

190. Campos JA, Biurrun I, García-Mijangos I, Loidi J, Herrera M. Assessing the level of plant invasion: a multi-scale approach based on vegetation plots. Plant Biosyst. 2013;147(4):1148–1162. https://doi.org/10.1080/11263504.2013.861538

191. Pyšek P, Prach K. How important are rivers for supporting plant invasions? In: de Waal LC, Child LE, Wade PM, Brock JH, editors. Ecology and management of invasive riverside plants. Chichester: John Wiley & Sons; 1994. p. 19–26.

192. Tokarska-Guzik B. The establishment and spread of alien plant species (kenophytes) in the flora of Poland. Katowice: Wydawnictwo Uniwersytetu Śląskiego; 2005.

193. Szymura M, Szymura TH. Historical contingency and spatial processes rather than ecological

niche differentiation explain the distribution of invasive goldenrods (*Solidago* and *Euthamia*). Plant Ecol. 2016;217(5):565–582. https://doi.org/10.1007/s11258-016-0601-1

194. Liendo D, García-Mijangos I, Campos JA, López-Munian U, Biurrun I. Drives of plant invasion at broad and fine scale in short temperate streams. River Res Appl. 2016;32:1730–1739. https://doi.org/10.1002/rra.3024
195. Planty-Tabacchi AM, Tabacchi E, Naiman RJ, Deferrai C, Décamps H. Invasibility of species-rich communities in riparian zones. Conserv Biol. 1996;10(2):598–607. https://doi.org/10.1046/j.1523-1739.1996.10020598.x
196. Truscott AM, Palmer SCF, Soulsby C, Hulme PE. Assessing the vulnerability of riparian vegetation to invasion by *Mimulus guttatus*: relative importance of biotic and abiotic variables in determining species occurrence and abundance. Divers Distrib. 2008;14:412–421. https://doi.org/10.1111/j.1472-4642.2007.00449.x
197. Catford JA, Downes BJ, Gippel CJ, Vesk PA. Flow regulation reduces native plant cover and facilitates exotic invasion in riparian wetlands. J Appl Ecol. 2011;48:432–442. https://doi.org/10.1111/j.1365-2664.2010.01945.x
198. Greet J, Cousens RD, Webb JA. More exotic and fewer native plant species: riverine vegetation patterns associated with altered seasonal flow patterns. River Res Appl. 2013;29:686–706. https://doi.org/10.1002/rra.2571
199. Vilà M, Ibáñez I. Plant invasions in the landscape. Landsc Ecol. 2011;26:461–472. https://doi.org/10.1007/s10980-011-9585-3
200. Lambdon PW, Pyšek P, Basnou C, Hejda M, Arianoutsou M, Essl F, et al. Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs. Preslia. 2008;80(2):101–149.
201. Liendo D, Biurrun I, Campos JA, Herrera M, Loidi J, García-Mijangos I. Invasion patterns in riparian habitats: the role of anthropogenic pressure in temperate streams. Plant Biosyst. 2013;149:289–297. https://doi.org/10.1080/11263504.2013.822434
202. Myśliwy M. Plant invasions across different habitat types at floristic survey. Appl Ecol Environ Res. 2014;12(1):193–207. https://doi.org/10.15666/aeer/1201_193207
203. Vilà M, Espinar JL, Hejda M, Hulme PE, Jarošík V, Maron JL, et al. Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. Ecol Lett. 2011;14:702–708. https://doi.org./10.1111/j.1461-0248.2011.01628.x
204. Pyšek P, Jarošík V, Hulme PE, Pergl J, Hejda M, Schaffner U, et al. A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. Glob Chang Biol. 2012;18(5):1725–1737. https://doi.org/10.1111/j.1365-2486.2011.02636.x
205. Hejda M, Pyšek P, Jarošík V. Impact of invasive plants on the species richness, diversity and composition of invaded communities. J Ecol. 2009;97(3):393–403. https://doi.org/10.1111/j.1365-2745.2009.01480.x
206. Hejda M, Pyšek P. What is the impact of *Impatiens glandulifera* on species diversity of invaded riparian vegetation? Biol Conserv. 2006;132(2):142–152. https://doi.org/10.1016/j.biocon.2006.03.025

8. Appendix 1. Lists of diagnostic species (characteristic and differential) for riparian tall herb fringe communities of the order *Convolvuletalia sepium* based on literature sources

***Senecionetum fluviatilis* T. Müller ex Straka in Mucina 1993**
Characteristic species. *Senecio fluviatilis* (transgr., dom.), *Cucubalus baccifer*.
Differential species. *Thalictrum flavum*, *Valeriana officinalis*.

***Fallopio-Cucubaletum bacciferi* Passarge 1976**
Characteristic species. *Cucubalus baccifer* (opt.), *Fallopia dumetorum* (loc.).

***Achilleo salicifoliae-Cuscutetum lupuliformis* Tx. ex Passarge 1993**
Characteristic species. *Achillea salicifolia*, *Cuscuta lupuliformis*, *Euphorbia palustris*, *Senecio paludosus*.
Differential species. *Calamagrostis epigejos*, *Rorippa amphibia*, *Thalictrum flavum*, *Veronica longifolia*.

***Convolvulo sepium-Cuscutetum europaeae* Tx. ex Lohmeyer 1953**
Characteristic species. *Cuscuta europaea* (opt.), *C. gronovii* (loc.), *Aster* div. spec.
Differential species. *Brassica nigra*.

***Convolvulo sepium-Cuscutetum europaeae aegopodietosum* Lohmeyer 1975**
Differential species. *Lamium maculatum*, *Aegopodium podagraria*, *Heracleum sphondylium*, *Ficaria verna*, *Alliaria petiolata*, *Melandrium rubrum*, *Cruciata laevipes*, *Lamium album*, *Chaerophyllum aureum*.

***Convolvulo sepium-Asperuletum aparine* Tx. ex Faliński 1966**
Characteristic species. *Galium rivale* (= *Asperula aparine*).

***Fallopio-Humuletum lupuli* Brzeg ex Brzeg et Wojterska 2001**
Characteristic species. *Fallopia dumetorum* (opt.), *Humulus lupulus* (opt., dom., subdom.).
Differential species. *Alnus glutinosa*, *Cornus sanguinea*, *Sambucus nigra*, *Ulmus minor*, *U. laevis*.

***Carduo crispi-Rubetum caesii* Brzeg in Brzeg et Wojterska 2001**
Characteristic species. *Carduus crispus* (opt.), *Rubus caesius* (opt.).

***Sicyo angulatae-Echinocystietum lobatae* Fijałkowski ex Brzeg et Wojterska 2001**
Characteristic species. *Bryonia alba* (loc.), *Echinocystis lobata* (dom., subdom.), *Sicyos angulata* (loc.).

***Rudbeckio-Solidaginetum* Tx. et Raabe 1950**
Characteristic species. (?)*Rudbeckia hirta*, *R. laciniata*, *Solidago canadensis* (opt.), *S. gigantea*, *S. graminifolia*.

***Helianthetum decapetali* (Moor 1958) Morariu 1967**
Characteristic species. *Halianthus tuberosus*, *H. decapetalus*, et al. (dom.).

***Impatienti glanduliferae-Convolvuletum sepium* Hilbig 1972**
Characteristic species. *Impatiens glandulifera* (opt.).

***Polygonetum cuspidati* Görs et Müller in Görs 1975**
Characteristic species. *Reynoutria japonica* (dom.).

***Asteretum lanceolati* Holzner et al. 1978**
Characteristic species. *Aster lanceolatus* et div. spec. (dom.).

***Urtico-Convolvuletum sepium* Görs et T. Müller 1969**
Characteristic species. *Calystegia sepium*, *Myosoton aquaticum*, *Symphytum officinale*, et al. (loc.).
Differential species. *Galium aparine*, *Urtica dioica* (dom.), *Anthriscus sylvestris*, *Dactylis glomerata*.

***Urtico-Convolvuletum sepium aegopodietosum* Görs 1974**
Differential species. *Lamium maculatum*, *Aegopodium podagraria*, *Heracleum sphondylium*, *Ficaria verna*, *Alliaria petiolata*, *Melandrium rubrum*, *Cruciata laevipes*, *Lamium album*, *Chaerophyllum aureum*.

***Soncho palustris-Archangelicetum litoralis* Tx. 1937**
Characteristic species. *Angelica archangelica* subsp. *litoralis* (subdom.), *Sonchus palustris* (transgr., loc.).
Differential species. *Oenanthe lachenalii*, *Phragmites australis*.

***Soncho palustris-Archangelicetum litoralis phragmitetosum* Zgrabczyńska et Brzeg 2010**
Differential species. *Carex acutiformis*, *Cirsium oleraceum*, *Phragmites australis*.

***Soncho palustris-Archangelicetum litoralis tanacetetosum* Zgrabczyńska et Brzeg 2010**
Differential species. *Achillea millefolium*, *A. salicifolia*, *Agrostis stolonifera*, *Artemisia vulgaris*, *Rumex acetosa*, *Tanacetum vulgare*, *Thalictrum flavum*.

***Epilobio hirsuti-Convolvuletum sepium* Hilbig et al. 1972**
Characteristic species. *Epilobium hirsutum* (opt., dom.), *E. parviflorum* (opt.), *E. roseum* (transgr.), *Sonchus arvensis* subsp. *uliginosus* (opt.), *S. palustris* (loc.).
Differential species. *Filipendula ulmaria*, *Rumex hydrolapathum*, *Scrophularia umbrosa*, *Typaha latifolia*, *Phragmites australis* (subdom.).

Eupatorietum cannabini Tx. 1937

Characteristic species. *Eupatorium cannabinum* (opt., dom.).
Differential species. *Brachypodium sylvaticum*, *Carex acutiformis*, *Cirsium oleraceum*, *Filipendula ulmaria*, *Deschampsia caespitosa*, *Festuca gigantea*, *Geum rivale*, *Holcus lanatus*, *Rubus idaeus*, *Veronica chamaedrys*.

Eupatorietum cannabini aegopodietosum Görs 1974

Differential species. *Lamium maculatum*, *Aegopodium podagraria*, *Heracleum sphondylium*, *Ficaria verna*, *Alliaria petiolata*, *Melandrium rubrum*, *Cruciata laevipes*, *Lamium album*, *Chaerophyllum aureum*.

Literature sources

[36,37,61,68,69,71,82]

9. Supplementary material

The following supplementary material for this work is available at http://pbsociety.org.pl/journals/index.php/mb/rt/suppFiles/mb.2019.001/0:

Fig. S1 The division of subclusters A2 and A3 into plant communities, based on the comparison of two dendrograms obtained as a result of cluster analysis, according to the strict consensus partitioning rule.

Fig. S2 The division of subcluster A1 into plant communities, based on the comparison of two dendrograms obtained as a result of cluster analysis, according to the strict consensus partitioning rule.

Fig. S3 The division of subcluster B1a into plant communities, based on the comparison of two dendrograms obtained as a result of cluster analysis, according to the strict consensus partitioning rule.

Fig. S4 The division of the subclasters B1b and B1c into plant communities based on the comparison of two dendrograms obtained as a result of cluster analysis, according to the strict consensus partitioning rule.

Fig. S5 The division of subcluster B2 into plant communities, based on the comparison of two dendrograms obtained as a result of cluster analysis, according to the strict consensus partitioning rule.

Fig. S6 The division of subcluster C1 into plant communities, based on the comparison of two dendrograms obtained as a result of cluster analysis, according to the strict consensus partitioning rule.

Tab. S1 Descriptive statistics of hydrogeomorphic variables and soil parameters, calculated for the entire data set of riparian tall herb fringe communities in NW Poland as well as for small and large rivers.

Tab. S2 Spearman rank correlations between environmental variables.

Tab. S3 Descriptive statistics of hydrogeomorphic variables and soil parameters for plant communities of the order *Convolvuletalia sepium* in NW Poland.