DOI: 10.2478/frp-2018-0019
Available online: www.lesne-prace-badawcze.pl

Leśne Prace Badawcze / *Forest Research Papers*
Czerwiec / June 2018, Vol. 79 (2): 181–197

ORIGINAL RESEARCH ARTICLE

e-ISSN 2082-8926

Plant communities of the Czerwona Woda River Valley (Stołowe Mountains National Park)

Remigiusz Pielech,[1] Marek Malicki,[2] Michał Smoczyk,[3] Andrzej M. Jagodziński,[4] Marcin K. Dyderski,[4] Paweł Horodecki,[4] Sylwia Wierzcholska,[5] Maciej Skorupski,[6] Jacek Kamczyc,[6] Izabela Kałucka,[7,8] Mariusz Hachułka,[7] Anna Gazda[1]*

[1]University of Agriculture in Kraków, Faculty of Forestry, Institute of Forest Ecology and Silviculture, Department of Forest Biodiversity, al. 29-Listopada 46, 31–425 Kraków, Poland; [2]University of Wrocław, Faculty of Biological Sciences, Institute of Environmental Biology, Department of Botany, ul. Kanonia 6/8, 50–328 Wrocław, Poland; [3]ul. Wojska Polskiego 30/5, 69–110 Rzepin, Poland; [4]The Institute of Dendrology, Polish Academy of Sciences, ul. Parkowa 5, 62–035 Kórnik, Poland; [5]University of Opole, Faculty of Natural Sciences and Technology, Chair of Biosystematics, ul. Oleska 22, 45–052 Opole, Poland; [6]Poznań University of Life Sciences, Faculty of Forestry, Department of Game Management and Forest Protection, ul. Wojska Polskiego71c, 60–625 Poznań, Poland; [7]University of Łódź, Faculty of Biology and Environmental Protection, Laboratory of Algology and Mycology, ul. Banacha 12/16, 90–237 Łódź, Poland; [8]University of Łódź, Institute of Forest Sciences, Branch in Tomaszów Mazowiecki, ul. Konstytucji 3 Maja 65/67, 97–200 Tomaszów Mazowiecki, Poland

*Tel. +48 12 6625117, e-mail: rlgazda@cyf-kr.edu.pl

Abstract. The Czerwona Woda River is the main watercourse in the Stołowe Mountains National Park and drains the major part of the Stołowe Mts. It was regulated in the past, but its channel has been spontaneously naturalised. Now, managed spruce forests grow along almost the entire length of this small mountain stream. The aims of the present study were to investigate diversity of plant communities connected with the Czerwona Woda stream and to prepare detailed vegetation maps. The results obtained can potentially be a reference for future restoration projects implemented in the Stołowe Mountains National Park.

As a result of vegetation mapping, there were distinguished 20 plant communities representative of the current vegetation and 3 communities representative of the potential vegetation. Phytosociological data on the vegetation was documented by making 62 phytosociological relevés. Based on these, 9 forest communities were distinguished, of which 3 were classified into associations, 1 – into alliance, 5 – into secondary forest communities. Furthermore, there were distinguished 14 non-forest communities, of which 10 were classified into associations. Several of the phytosociological classes distinguished have been reported for the first time in the Stołowe Mountains National Park.

Keywords: river valley, riparian vegetation, plant communities, Stołowe Mountains, Central Sudetes

1. Introduction

The vegetation along watercourses is a key element of riverine ecosystems, used as an indicator of their condition (Johansen et al. 2008; Macfarlane et al. 2017). River valley ecosystems are extremely valuable due to the numerous ecosystem services they provide (Sweeney et al. 2004; Gundersen et al. 2010; Van Looy et al. 2017). Unfortunately, they are also among the most transformed ecosystems (González et al. 2017), mainly through the regulation of rivers (Nilsson, Berggren 2000; Nilsson et al. 2005; Greet et al. 2013; Foster, Rood 2017), various forms of use (Allan 2004; González et al. 2017) and invasions of alien species (Richardson et al. 2007; Catford et al. 2011; Dyderski et al. 2015; Wagner et al. 2017).

The situation is similar in the area of the Sudetes Mountains. Riverside forests, especially those associated with the upper sections of mountain rivers, are characterised by higher than average floristic richness (Pielech 2015). However, the intensive use of the forest, lasting until the 18th century, led to an almost total deforestation of the Sudetes (Wilczkiewicz 1982). This also occurred in river valleys, which, already transformed

Received: 14.02.2018, reviewed: 21.05.2018 accepted: 4.06.2018.

as a result of the development of settlements, were used to raft wood (KRNAP 2012). The development of "modern" forestry in the beginning of the 19th century, however, was associated with the elimination of deciduous species and the mass introduction of spruce in the region under discussion (Barzdajn et al. 1999). This led to further, far-reaching changes in vegetation, the effects of which are observed to this day. Many river valleys in the Sudetes are deprived of the natural riparian forest communities that had occurred here in the past, with artificially introduced spruce monocultures taking their place. Riparian forests have been preserved only in the form of small fragments. Despite their invaluable role in the environment, these forests are still subject to the negative impact of anachronistic concepts of flood protection, further building development in river valleys or use that is incompatible with the requirements of protecting the resources of the natural environment (Pielech, Kisiel 2010; Pielech et al. 2017).

Czerwona Woda in the Stołowe Mountains is an example of a river that perfectly matches the above description. The small mountain stream is now surrounded along almost its entire length by managed spruce forests. The hydromorphological features of the Czerwona Woda stream are typical of unregulated rivers (Witek 2013), however, a more accurate inspection of the area reveals traces of modification of hydrological regimes, including drainage meliorations, regulation and sectional bedding, dams that cross the river and modify water flow and others. Such a high degree of transformation of the riverside ecosystems has affected both water resources and the biodiversity of this area. Due to problems relating to a very low water level in recent years, the Stołowe Mountains National Park is considering plans to restore the Czerwona Woda River. However, this requires very detailed knowledge of the current vegetation.

This paper presents the results of the research aimed at obtaining a detailed identification and mapping of plant communities associated with the Czerwona Woda River in the Stołowe Mountains, in particular: (1) to determine the diversity of the plant communities, (2) to map the currently existing vegetation and (3) to develop a map of the potential vegetation.

2. Materials and methods

2.1. Characteristics of the study site

Czerwona Woda is the longest watercourse in the Stołowe Mountains National Park (13.45 km) and drains the greater part of the Stołowe Mountains massif (Adynkiewicz-Piragas et al. 2011). Sources of the stream are located on the slopes of Skalniak, at an altitude of about 798 m a.s.l. It initially flows in a poorly delineated valley in the area of the spring (Witek 2013), but below Karłów, it forms a well-developed valley over ten meters deep within a narrow tectonic ditch – the Czerwona Woda Depression (Migoń et al. 2011). The geological substrate is made up of Turonian marls and sandstones, which is reflected in the morphology of the valley in the form of sections of gorges typical of Stołowe Mountain streams (Migoń et al. 2011), for example, the Cygański Gorge above Batorów. A very characteristic feature is the brown-red color of the water in the stream (hence the name[1]), which is the result of the draining of peatlands located nearby, such as the Great Batorowski Peatbog, Niknącej Łąki and Zmrozowisko. In its upper and middle reaches, the stream's channel and the processes shaping it are more varied (lateral erosion and accumulation, bottom erosion). A different situation applies to the entire valley of the Czerwona Woda, where as a result of long-term transformations, mainly relating to draining in order to intensify forestry activities and road construction, the water conditions are permanently anthropogenically disturbed. Most of the area of the Czerwona Woda valley is covered with forests (afforestation of the basin reaches 90%). Most of the forests are spruce plantations; larger non-forest enclaves are occupied by the villages of Karłów and Batorów. Peaty-gleysols and alluvial soils dominate in the immediate vicinity of the stream bed, cambisols and luvisols at the foot of the slopes within floodplains, as well as podzolic soils in places (Kabała et al. 2002b).

The boundaries of the study area were precisely determined based on a model of the terrain. In places where the valley expands considerably, the research area was limited to a 100 m zone in each direction from the axis of the Czerwona Woda water channel (Figure 1). Defined in this way, the study site covered an area of 91.2 ha.

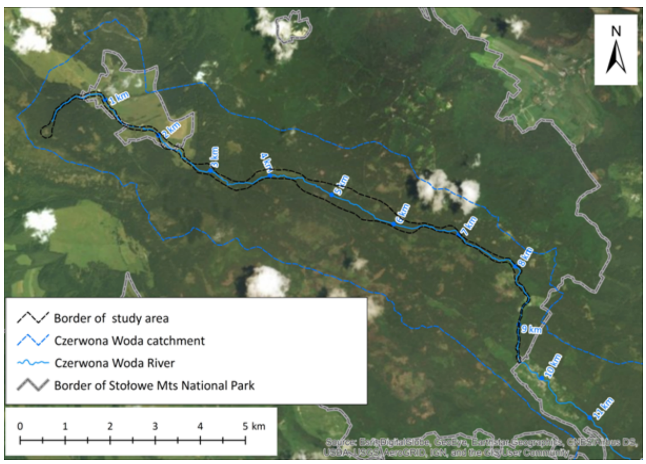

Figure 1. Study area overlied by Czerwona Woda river catchment; river kilometrage is given for reference

2.2. Geobotanical reconnaissance of the study area

The vegetation of the Czerwona Woda valley has not yet been studied in detail. There is no accurate information on the vascular plant species found there, nor on the diversity of its plant communities. However, the area of the Stołowe Mountains was often the subject of geobotanical research. The first reliable data is found in the work of the pre-war botanists (e.g., Fiek 1881; Schube 1903, 1906; Pax 1915). Unfortunately, the sites of individual plants noted in the aforementioned works can only be identified to more generally defined areas due to the lack of accurate information about their locations. Similarly, after the Second World War, the Stołowe Mountains enjoyed the attention of botanists and phytosociologists. In addition to many botanical notes and remarks on the diversity of vegetation, a detailed list of these works can be found in the study of Świerksz et al. (2008); the comprehensive geobotanical analysis of the Stołowe Mountains (Świerksz 1998; Wierzcholska et al. 2018)) deserves attention. Unfortunately, due to the large area covered by the research in question, the data included in the afore-mentioned botanical-phytosociological reports as well as in the detailed geobotanical study do not allow us to precisely assign the enumerated plant sites to the Czerwona Woda valley. In turn, the most recent reports (after 2008) containing the precise locations describe only sites located outside the area covered by this study (e.g., Wójcik 2017).

2.3. Field work

Field studies were conducted in August and September 2017. The basic unit of actual vegetation distinguished during mapping was a plant association. In exceptional cases, where there were no characteristic species or the community had transitional character, the given patch of vegetation was assigned to the level of alliance. The current hierarchical system of syntaxonomic units developed for Europe (Mucina et al. 2016) was adopted to analyze the diversity of the vegetation. However, plant associations were distinguished according to the approach used in the Czech Republic (Chytrý 2007, 2009, 2011, 2015) as the one best characterizing the diversity of vegetation in the Sudetes. The research included both forest vegetation and non-forest plant communities. In addition to the natural and semi-natural communities, secondary forest communities were also distinguished. The guidelines of distinguishing and naming secondary forest communities were adopted from the Instructions for Forest Management (PGL LP 2012). The boundaries of the distinguished vegetation patches of communities were determined in the field by means of a precise GIS class GPS receiver (the average estimated accuracy under a tree stand canopy is ± 5–10 m). It was assumed that the minimum area of a distinguished vegetation patches on the map is 0.1 ha. In the case of wetland habitats (springs, seeps, reed beds, riparian forests, coniferous bogs), when possible, smaller patches were also charted. The actual vegetation map was made in the field with the Collector for ArcGIS application, and the result of the work is a polygon layer containing the assigned phytosociological diagnoses as one of the attributes.

The map of potential vegetation was produced on the basis of the previously made map of actual vegetation, using knowledge about the dynamics of the communities and the vegetation diversity of the Sudetes, as well as with a scanned and geographically referenced soil map of Stołowe Mountains National Park (Kabała et al. 2002a, b). Then, for each of the polygons representing a map of actual vegetation, another phytosociological diagnosis was made of the potential vegetation, but the potential vegetation was determined only to the level of an alliance.

Most of the distinguished natural and semi-natural vegetation patches were documented by making a phytosociological relevé. The size of the relevés was adopted in accordance with the recommendations of Otypkova and Chytrý (2006). In most cases, the relevés were square-shaped and oriented according to the earth's directions. The share of particular species of vascular plants was estimated using the Braun-Blanquet scale of abundance (Dzwonko 2007). The relevés also include the most common species of bryophytes having a diagnostic value for the distinguished unit. The names of bryophytes are consistent with the works of Ochyra et al. (2003) and Szweykowski (2006). The phytosociological relevés of the forest communities made as part of this research are stored in the Forest Database of Southern Poland (Pielech et al. 2018). In order to present the differences among the distinguished syntaxa, phytosociological tables of the communities were made, which were documented by at least three phytosociological relevés. Diagnostic species of individual associations were distinguished in the relevés in accordance with the studies by Chytrý et al. (2007, 2009, 2011, 2015). Diagnostic regional species were distinguished on the basis of juxtaposed tables and knowledge about the diversity of the vegetation in the Sudetes. Providing the diagnostic species of higher-ranking units was abandoned. In addition, a detailed description of the distinguished communities was made that included information on their structure, conservation status and distribution in the study area.

3. Results

3.1. Maps of actual and potential vegetation

The actual vegetation map includes/presents 20 types of communities (Table 1), while the potential vegetation map distinguishes three types of communities (Table 2). A total of 62 phytosociological relevés were made during the field work. In ordering the phytosociological relevés, nine forest

Table 1. List of plant communities distinguished on the map of current vegetation

No.	Plant community	Area (ha)
1	community *Picea abies-Deschampsia flexuosa*	51.8
2	*Vaccinio uliginosi-Piceetum abietis*	14.8
3	*Angelico sylvestris-Cirsietum oleracei*	2.3
4	*Juncetum squarrosi*	1.7
5	community within the association *Calthion palustris*	1.3
6	*Geranio sylvatici-Trisetetum flavescentis*	1.0
7	mosaic of the communities *Magno-Caricion gracilis/Alnion incanae*	0.9
8	*Phalaridetum arundinaceae*	0.8
9	the pool of water	0.7
10	coniferous forest	0.6
11	*Equiseto sylvatici-Piceetum abietis*	0.4
12	community from the class *Artemisietea vulgaris*	0.3
13	community within the association *Alnion incanae*	0.2
14	community with *Alnus incana*	0.1
15	community with *Carex brizoides*	0.1
16	*Stellario nemorum-Alnetum glutinosae*	< 0.1
17	mosaic of the communities *Magno-Caricion gracilis*	< 0.1
18	community within the association *Caricion canescenti-nigrae*	< 0.1
19	*Scirpetum sylvatici*	< 0.1
20	community *Acer pseudoplatanus-Rubus* sp.	< 0.1

communities were distinguished, three of which were assigned to associations, one to an alliance, and the remaining five are secondary forest communities. In addition, 14 types of non-forest communities were identified, 10 of which were described to the level of association. Below is a list of all the distinguished units in the hierarchical systemic order.

Forest communities:

Class: *Alno glutinosae-Populetea albae* P. Fukarek et Fabijanić 1968

Order: *Alno-Fraxinetalia excelsioris* Passarge 1968

Alliance: *Alnion incanae* Pawłowski et al. 1928

1. *Stellario nemorum-Alnetum glutinosae* Lohmeyer 1957
2. Community within the *Alnion incanae* association

Class: *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939

Order: *Piceetalia excelsae* Pawłowski et al. 1928

Alliance: *Piceion excelsae* Pawłowski et al. 1928

3. *Equiseto sylvatici-Piceetum abietis* Šmarda 1950

Order: *Vaccinio uliginosi-Pinetalia sylvestris* Passarge 1968

Table 2. List of plant communities distinguished on the map of potential vegetation

No.	Plant community	Area (ha)
1	*Luzulo-Fagion sylvaticae*	36.2
2	*Alnion incanae*	27.1
3	*Eriophoro-Piceion abietis*	17.1

Alliance: *Eriophoro-Piceion abietis* Passarge 1968

4. *Vaccinio uliginosi-Piceetum abietis* Schubert 1972

Secondary forest communities:

5. *Picea abies-Deschampsia flexuosa* community
6. *Picea abies-Molinia caerulea* community
7. *Picea abies-Carex brizoides* community
8. *Acer pseudoplatanus-Rubus* sp. community
9. Community with *Alnus incana*

Non-forest communities:
Class: *Molinio-Arrhenatheretea* Tx. 1937
Order: *Poo alpinae-Trisetetalia* Ellmauer et Mucina 1993
Alliance: *Triseto flavescentis-Polygonion bistortae* Br.-Bl. et Tx. ex Marschall 1947
1. *Geranio sylvatici-Trisetetum flavescentis* Knapp ex Oberdorfer 1957
Order: *Molinietalia caeruleae* Koch 1926
Alliance: *Calthion palustris* Tx. 1937
2. *Angelico sylvestris-Cirsietum oleracei* Tüxen 1937
3. *Cirsietum rivularis* Nowiński 1927
4. *Scirpetum sylvatici* Ralski 1931
5. Community within the *Calthion palustris* association
6. Community with *Carex brizoides*
Class: *Nardetea strictae* Rivas Goday et Borja Carbonell in Rivas Goday et Mayor López 1966
Order: *Nardetalia strictae* Preising 1950
Alliance: *Nardo-Juncion squarrosi* (Oberd. 1957) Passarge 1964
7. *Juncetum squarrosi* Oberdorfer 1934
Class: *Artemisietea vulgaris* Lohmeyer et al. in Tx. ex von Rochow 1951
8. Community within the *Artemisietea vulgaris* class
Class: *Phragmito-Magnocaricetea* Klika in Klika et Novák 1941
Order: *Phragmitetalia* Koch 1926
Alliance: *Phragmition communis* Koch 1926
9. *Typhetum angustifoliae* Pignatti 1953
10. *Typhetum latifoliae* Nowiński 1930
11. *Phragmitetum australis* Savič 1926
Order: *Magnocaricetalia* Pignatti 1953
Alliance: *Magnocaricion elatae* Koch 1926
12. *Equiseto fluviatilis-Caricetum rostratae* Zumpfe 1929
Alliance: *Magnocaricion gracilis* Géhu 1961
13. *Phalaridetum arundinaceae* Libbert 1931
Class: *Scheuchzerio palustris-Caricetea fuscae* Tx. 1937
Order: *Caricetalia fuscae* Koch 1926
Alliance: *Caricion fuscae* Koch 1926
14. Community within the *Caricion fuscae* association

3.2. Detailed characteristics of the distinguished communities

Equiseto sylvatici-Piceetum abietis Šmarda 1950 (Table 3)

Spruce forest growing in the vicinity of local springs and seeps. Norway spruce dominates in the forest stand. The shrub layer is usually poorly developed. The forest floor, in addition to species typical of coniferous forests, contains large group of species associated with springs, including *Crepis paludosa, Equisetum sylvaticum, Glyceria fluitans, Carex remota, Dactylorhiza fuchsii* and *Viola palustris*. In addition, the moss layer is very well developed, reaching up to 80% of coverage, consisting mainly of *Polytrichastrum formosum, Polytrichum commune, Sphagnum girgensohnii* and *S. squarrosum*. The *Equiseto sylvatici-Piceetum abietis* association was reported at several seeps in the upper reaches of Czerwona Woda. This community has not been reported from the Stołowe Mountains, its few occurrences in the Central Sudetes are known, among others, from the Bystrzyckie and Orlické Mountains, as well as from the Śnieżnik Massif in the Eastern Sudetes.

Vaccinio uliginosi-Piceetum abietis Schubert 1972 (Table 3, Fig. 2)

The *Vaccinio uliginosi-Piceetum abietis* association occurs most frequently in the middle course of Czerwona Woda (mainly in the area where the Great Batorowski Peatbog is located), in places where the valley expands significantly and has a flat bottom. This part of the valley has alluvial soils at the very edge of the river, which is a potential riparian habitat; while a little further from the riverbed, large areas of spruce swamp forests of the *Vaccinio uliginosi-Piceetum abietis* association developed on the peat-silt soils. Numerous trenches suggest that in the past, it was a much more extensively boggy area. Currently, a poorer form of the association is observed here, lacking, as a result of past drainage activities, in several peat bog species typical of this type of community; for example, *Eriophorum vaginatum, Oxycoccus palustris* or *Vaccinium uliginosum*. Given the current overgrowth occurring in the former ditches and the renewed in view of the overgrowth occurring in the old ditches and the renewed formation of bogs, the spruce swamp forest is slowly regenerating. The stand consists only of spruce, and the shrub layer, where it has developed, is made up of spruce saplings. The herbaceous layer is dominated by coniferous forest species (*Calamagrostis villosa, Vaccinium myrtillus, Deschampsia flexuosa*). A characteristic feature is the strongly developed moss layer with a high proportion of sphagnum (*Sphagnum girgenoshnii, S. russowii* and *S. capillifolium*) and other acidophilic bryophytes (*Bazzania trilobata, Leucobryum glaucum* and *Dicranodontium denudatum*). Spruce swamp forests occur locally and are scattered in the Stołowe Mountains, their largest areas are located in the vicinity of the Great Batorowski Peatbog (Potocka 1999; Pender 2008). This community is also known for its neighboring Sudetes ranges: Bystrzyckie Mountains, Kamienne Mountains and the Śnieżnik Massif (M. Smoczyk – own observations).

The *Picea abies-Deschampsia flexuosa* community (Table 4, Fig. 3)

The secondary community of spruce stands is mainly found in the poor habitat of acidic beech forests. It also occurs at the riverbed itself, occupying part of potential riparian habitat. This community was established as a managed forest when spruce

Table 3. Phytosociological table presenting *Equiseto sylvatici-Piceetum abietis* (Es-Pa) Šmarda 1950 and *Vaccinio uliginosi-Piceetum abietis* (Vu-Pa) Schubert 1972 associations. Regionally diagnostic species are marked by light grey colour.

Consecutive no.		1	2	3	4	5	6	7	8	Constancy Es-Pa (%)	Constancy Vu-Pa (%)
Relevé no.		7	11	12	38	43	45	49	59		
Date		2017 08 28	2017 08 29	2017 08 29	2017 08 30	2017 08 30	2017 08 30	2017 08 31	2017 09 07		
Plot area [m²]		200	200	200	200	200	200	200	200		
Cover of tree layer		70	40	25	60	60	20	40	70		
Cover of shrub layer		1	1	30	35	5	1	5	10		
Cover of herb layer		40	40	40	40	35	50	60	40		
Cover of moss layer		40	80	80	80	70	50	60	50		
Number of species		26	30	36	17	14	16	12	19		
		Equiseto sylvatici-Piceetum abietis			*Vaccinio uliginosi-Piceetum abietis*						
Picea abies	a	4	3	2	4	4	.	3	4		
Picea abies	b	+	+	3	.	1	+	1	2	100	100
Picea abies	c	1	+	+	+	1	2	2	1		
Calamagrostis villosa	c	2	2	1	2	2	2	2	3	100	100
Polytrichastrum formosum	d	2	2	+	1	1	2	1	2	100	100
Sphagnum girgensohnii	d	2	2	2	4	4	3	3	3	100	100
Vaccinium myrtillus	c	2	2	1	.	+	1	3	+	100	80
Cardamine amara	c	.	.	+	.	.	.	.	.	33	0
Chaerophyllum hirsutum	c	.	1	1	.	.	.	.	.	67	0
Circaea alpina	c	+	.	+	.	.	.	.	.	67	0
Crepis paludosa	c	1	1	+	.	.	.	.	.	100	0
Dryopteris dilatata	c	.	.	+	.	.	.	.	.	33	0
Equisetum sylvaticum	c	+	+	+	.	.	.	.	+	100	20
Stellaria nemorum	c	.	.	+	.	.	.	.	.	33	0
Dicranodontium denudatum	d	+	.	.	.	.	.	+	.	33	20
Polytrichum commune	d	.	2	2	+	.	.	.	.	67	20
Sphagnum palustre	d	.	+	.	.	.	.	.	.	33	0
Sphagnum squarrosum	d	.	.	2	.	.	.	.	.	33	0
Ranunculus repens	c	+	+	+	.	.	.	.	.	100	0
Athyrium filix-femina	c	+	+	1	.	.	.	.	.	100	0
Glyceria fluitans	c	+	2	2	.	.	.	.	.	100	0
Juncus effusus	c	.	+	+	.	.	+	.	.	67	20
Lysimachia nemorum	c	r	+	1	.	.	.	.	.	100	0
Carex remota	c	.	+	+	.	.	.	.	.	67	0
Dactylorhiza fuchsii	c	.	r	+	.	.	.	.	.	67	0

Deschampsia caespitosa	c	r	.	+	.	.	.	.	.	67	0
Viola palustris	c	.	+	+	.	.	.	.	.	67	0
Senecio ovatus	c	+	.	+	.	.	.	.	.	67	0
Sphagnum russowii	d	.	.	1	.	.	1	+	.	33	40
Hypnum cupressiforme	d	.	.	.	+	+	.	.	1	0	60
Pleurozium schreberi	d	.	.	.	.	.	1	1	1	0	60
Galium saxatile	c	.	.	.	+	+	.	.	.	0	40
Deschampsia flexuosa	c	1	1	.	1	2	1	2	2	67	100
Dryopteris carthusiana	c	+	+	+	+	1	+	.	+	100	80
Oxalis acetosella	c	2	+	+	2	+	+	.	2	100	80
Dicranum scoparium	d	1	1	.	1	+	.	2	.	67	60
Maianthemum bifolium	c	+	+	.	+	+	.	.	+	67	60
Sorbus aucuparia	c	+	+	.	+	+	.	.	.	67	40
Betula pendula	b	.	.	r	2	.	.	.	r	33	40
Fagus sylvatica	c	1	+	.	1	.	.	.	.	67	20
Trientalis europaea	c	.	+	.	.	+	.	.	+	33	40
Betula pendula	c	.	.	.	.	.	+	2	.	0	40
Carex echinata	c	.	.	+	.	.	+	.	.	33	20
Fagus sylvatica	b	+	.	.	2	.	.	.	.	33	20
Leucobryum glaucum	d	.	.	.	r	.	.	+	.	0	40
Sphagnum fallax	d	1	.	.	.	.	2	.	.	33	20
Sphagnum sp.	d	.	2	2	.	.	.	.	.	67	0

Rare species: b *Rubus idaeus* 3.+, c *Carex brizoides* 8.1, c *C. nigra* 6.2, c *C. sylvatica* 1.+, c *Epilobium palustre* 3.+, c *Equisetum palustre* 3.+, c *Galium palustre* 3.1, c *Gymnocarpium dryopteris* 1.1, c *Homogyne alpina* 2.+, c *Hypericum perforatum* 2.+, c *Lysimachia vulgaris* 8.+, c *Melampyrum pratense* 1.+, c *Molinia caerulea* 6.+, c *Myosotis palustris* 3.+, c *Polygonatum verticillatum* 8.+, c *Potentilla erecta* 2.r, c *Rubus idaeus* 3.+, c *Tussilago farfara* 3.+, c *Veratrum lobelianum* 8.+, d *Mnium hornum* 8.2, d *Plagiomnium undulatum* 4.+

plantations were introduced in the deciduous and mixed forest habitats. The forest floor has species of acidophilic plants, among others: *Vaccinium myrtillus, Calamagrostis villosa, Deschampsia flexuosa, Maianthemum bifolium* or *Oxalis acetosella*. The moss layer reaches 40% of coverage and mainly consists of *Polytrichastrum formosum, Dicranum scoparium* and *Pleurozium schreberii*. In slightly wetter places, *Sphagnum girgensohnii* also appears. The *Picea abies-Deschampsia flexuosa* community definitely dominates the landscape of the Czerwona Woda valley, being its most widespread plant community. It also occurs both in the Stołowe Mountains and in the adjacent mountain ranges of the Sudetes.

The remaining forest communities

In the lower reaches of Czerwona Woda, a patch of riparian forest represented by the *Stellario nemorum-Alnetum glutinosae* association was identified in the village of Batorów near the border of the National Park. The stand is made up of sycamore and Norway maples with an admixture of spruce. The shrub layer is not very dense, but it consists of as many as five species: *Acer pseudoplatanus, Lonicera nigra, Ribes rubrum, Ribes uva-crispa* and *Sambucus nigra*. The lush forest floor is dominated by typical riparian species, including *Impatiens noli-tangere, Cirsium oleraceum, Petasites albus, Phalaris arundinacea, Rubus idaeus, Stellaria nemorum, Thalictrum aquilegiifolium, Urtica dioica* and *Senecio ovatus* (Fig. 4). In addition, several plots of riparian forest communities were identified that did not have a set of characteristic species allowing us to determine their more precise syntaxonomic affiliation other than to the *Alnion incanae* alliance. There are several places of the Czerwona Woda valley where communities are formed by the grey alder, in which there are no riparian species on the forest floor, but mainly species from the neighboring forest communities or previous succession stages (e.g., meadows). Such phytocoenoses were referred to as a community with *Alnus incana*. In turn, on the outskirts of Batorów, an intermediate phytocoenosis was identified, in between the type of coniferous forest found on slopes from the *Acerion pseudoplatani* alliance and the riparian forest from the *Alnion incanae* alliance. The number of species of herbaceous plants was limited due to the expansion of brambles, making it more difficult to determine the phytosociological affiliation, which is why the phytocoenosis was defined as *Acer pseudoplatanus-Rubus* sp.

In addition to those mentioned above, two more communities were found that are forms of a degenerated spruce swamp forest. The *Picea abies-Molinia caerulea* community is a spruce forest on desiccated peat, clearly dominated by *Molinia caerulea* in the ground cover. In turn, the *Picea abies-Carex brizoides* community is a spruce forest with a massive share of the expansive sedge *Carex brizoides*. Both communities occur in very small areas in the middle part of the Czerwona Woda valley and were documented by single phytosociological relevés.

Non-forest communities

Six types of meadow communities were found in the study area. The most common were wet meadows of the *Calthion palustris* alliance, represented mainly by *Angelico sylves-*

Figure 2. Association *Vaccinio uliginosi-Piceetum abietis* with well-developed moss layer

Figure 3. Community *Picea abies-Deschampsia flexuosa*

Table 4. Phytosociological table presenting community *Picea abies-Deschampsia flexuosa*

Consecutive no.		1	2	3	4	5	Constancy (%)
Relevé no.		35	37	42	55	56	
Date		2017 08 30	2017 08 30	2017 08 30	2017 09 07	2017 09 07	
Plot area [m^2]		200	200	200	200	200	
Cover of tree layer		40	60	60	75	80	
Cover of shrub layer		10	30	10	1	0	
Cover of herb layer		60	60	40	2	1	
Cover of moss layer		40	20	20	30	20	
Number of species		15	23	16	13	13	
Picea abies	a	3	4	4	3	5	
Picea abies	b	2	2	.	.	.	100
Picea abies	c	1	1	+	.	+	

Fagus sylvatica	b	.	2	2	+	.	60
Fagus sylvatica	c	.	1	1	.	.	
Calamagrostis villosa	c	1	1	2	+	+	100
Deschampsia flexuosa	c	2	3	2	r	+	100
Dryopteris carthusiana	c	+	+	+	r	r	100
Vaccinium myrtillus	c	2	1	1	+	+	100
Polytrichastrum formosum	d	1	1	2	1	1	100
Dicranum scoparium	d	2	.	+	+	+	80
Maianthemum bifolium	c	+	+	+	.	.	60
Oxalis acetosella	c	+	1	2	.	.	60
Sorbus aucuparia	c	+	+	+	.	.	60
Pleurozium schreberi	d	+	1	.	2	.	60
Sphagnum girgensohnii	d	2	1	1	.	.	60
Luzula pilosa	c	.	r	+	.	.	40
Bazzania trilobata	d	+	.	.	.	+	40
Dicranodontium denudatum	d	+	.	.	.	+	40
Hypnum cupressiforme	d	.	.	.	+	+	40
Abies alba	a	.	.	.	2	.	20
Larix decidua	a	.	.	.	2	.	20
Athyrium filix-femina	c	.	+	.	.	.	20
Calamagrostis arundinacea	c	.	.	r	.	.	20
Dryopteris dilatata	c	.	r	.	.	.	20
Galium saxatile	c	.	+	.	.	.	20
Homogyne alpina	c	.	+	.	.	.	20
Lysimachia nemorum	c	.	+	.	.	.	20
Polygonatum verticillatum	c	.	.	+	.	.	20
Prenanthes purpurea	c	.	.	.	.	+	20
Rubus idaeus	c	.	r	.	.	.	20
Senecio ovatus	c	.	r	.	.	.	20
Stellaria nemorum	c	.	+	.	.	.	20
Thelypteris phegopteris	c	.	.	+	.	.	20
Dicranella heteromalla	d	.	.	.	.	+	20
Dicranum polysetum	d	.	.	.	2	.	20
Leucobryum glaucum	d	.	.	.	.	+	20
Mnium hornum	d	.	1	.	.	.	20
Polytrichum commune	d	1	.	.	.	.	20
Sphagnum fallax	d	.	+	.	.	.	20

tris-Cirsietum oleracei thistle meadows with cabbage thistle (Table 5, Fig. 5). Communities representing the *Scirpetum sylvatici* association of forest rushes are found in their complexes in small and dispersed areas. Small patch of thistle meadows were also identified, with *Cirsium rivulare* . The Czerwona Woda valley also has a characteristic community dominated by the sedge *Carex brizoides*. It is a typical community associated with peat bogs decaying because of desiccation. A similar community is sometimes distinguished within the *Calthion palustris* alliance, characterised, in addition to *Carex brizoides*, by the presence of meadow species of the *Scirpo sylvatici-Caricetum brizoidis* association Kučera et al. 1994. For this reason, the *Carex brizoides* community occurring in the Czerwona Woda valley was included in the group of meadow communities. Trisetum grass meadows representing the *Geranio sylvatici-Trisetetum flavescentis* association are found on moderately moist soils in areas slightly above groundwater level (Table 5). They are characterised by the presence of poor grassland species (e.g., *Agrostis capillaris, Nardus stricta, Campanula rotundifolia, Potentilla erecta*) and mountain herbaceous species (including *Cirsium helenioides, Chaerophyllum aromaticum, Angelica sylvestris, Polygonum bistorta, Senecio nemorensis* s.l.) adjacent to each other. All these meadow communities are a frequent element of the vegetation occurring both in the Stołowe Mountains and the neighboring Sudetes mountain ranges. In moist and peat-boggy areas, characterised by a low trophic level, wet *Nardus* grasslands representing the *Juncetum squarrosi* association also developed (Fig. 6, Table 5). Although there is relatively little *Juncus squarrosus* here, the association is well defined by the presence of other characteristic species, including *Nardus stricta, Potentilla erecta, Galium saxatile, Luzula campestris* and *Carex nigra*. Wet mat-grass sward communities are rare in the Stołowe Mountains (Pender 2008), uncommon in the Central Sudetes, and also rarely occur in the other mountain ranges of the Kłodzko region: Bystrzyckie Mountains and the Śnieżnik Massif (M. Smoczyk – own observations).

The high water level and the presence of several water reservoirs fosters a large diversity of rush communities. The most common of them is the reed canary grass *Phalaridetum arundinaceae* association (Table 6). Patches of this association formed in the wettest areas of the Czerwona Woda channel, and sometimes also occur in a mosaic with wet meadows and willow shrubs. Next to the communities dominated by reed canary grass, the rush communities representing four additional associations were also recognised: narrowleaf cattail *Typhetum angustifoliae*, bulrush *Typhetum latifoliae,* common reed *Phragmitetum australis* and bottle sedge *Equiseto fluviatilis-Caricetum rostratae* associations. Rush communities in mountain areas are rarely recorded and de-

Figure 4. Association *Stellario nemorum-Alnetum glutinosae*

Figure 5. Wet meadow with cabbage thistle (association *Angelico sylvestris-Cirsietum oleracei*)

Figure 6. Wet grasslands of *Juncus squarrosus* and *Nardus stricta* (association *Juncetum squarrosi*)

Table 5. Phytosociological table presenting *Geranio sylvatici-Trisetetum flavescentis* (Gs-Tt) Knapp ex Oberdorfer 1957, *Angelico sylvestris-Cirsietum oleracei* (As-Co) Tüxen 1937 and *Juncetum squarrosi* (Js) Oberdorfer 1934 associations. Regionally diagnostic species are marked by light grey colour.

Consecutive no.		1	2	3	4	5	6	7	8	9	10	11	12	Constancy (Gs-Tf) (%)	Constancy (As-Co) (%)	Constancy (Js) (%)
Relevé no.		21	22	28	33	15	18	25	30	34	39	40	41			
Date		2017 08 29	2017 08 29	2017 08 29	2017 08 30	2017 08 29	2017 08 29	2017 08 29	2017 08 29	2017 08 30	2017 08 30	2017 08 30	2017 08 30			
Plot area [m²]		25	25	25	25	25	25	25	25	25	25	25	25			
Cover of herb layer		90	90	95	90	95	100	100	100	85	90	80	90			
Cover of moss layer		0	0	0	0	0	0	0	0	0	0	5	1			
Number of species		31	33	31	26	32	28	18	33	19	13	20	19			
		Molinio-Arrhenatheretea								*Calluno-Ulicetea*						
		Geranio sylvatici-Trisetetum flavescentis				*Angelico sylvestris-Cirsietum oleracei*				*Juncetum squarrosi*						
Alopecurus pratensis	c	.	.	+	+	+	+	.	1	.	.	.	.	50	75	0
Lathyrus pratensis	c	.	.	+	+	.	+	1	1	.	.	.	.	50	75	0
Rumex acetosa	c	+	.	+	+	+	.	.	+	+	+	+	.	75	50	75
Ranunculus acris	c	+	.	+	.	+	.	.	.	+	.	.	.	50	25	25
Dactylis glomerata	c	+	3	2	1	2	2	2	2	+	.	.	.	100	100	25
Achillea millefolium	c	+	1	+	+	.	.	+	+	1	.	.	.	100	50	25
Alchemilla sp.	c	+	+	+	.	1	.	+	+	.	.	.	.	75	75	0
Veronica chamaedrys	c	+	.	+	1	1	+	+	+	1	.	.	.	75	100	25
Phleum pratense	c	1	.	.	+	1	1	.	+	.	.	.	.	50	75	0
Agrostis capillaris	c	3	2	3	3	2	+	.	+	2	1	+	.	100	75	75
Hypericum maculatum	c	2	2	2	2	.	.	.	.	2	.	.	.	100	0	25
Vicia cracca	c	+	+	1	+	.	.	.	+	+	.	.	.	100	25	25
Campanula rotundifolia	c	+	+	.	+	+	.	.	.	+	.	+	+	75	25	75
Cardaminopsis halleri	c	+	+	.	+	+	.	.	+	.	.	.	.	75	50	0
Cirsium helenioides	c	+	+	2	2	.	.	.	.	.	.	1	.	100	0	25
Chaerophyllum aromaticum	c	+	+	+	.	.	.	1	.	.	.	.	.	75	25	0
Cirsium oleraceum	c	.	+	.	.	3	3	2	3	.	.	.	.	25	100	0
Angelica sylvestris	c	+	1	1	.	1	+	r	1	.	.	.	.	75	100	0
Filipendula ulmaria	c	.	.	.	.	.	.	+	1	.	.	.	.	0	50	0
Scirpus sylvaticus	c	.	.	.	.	.	+	.	.	.	2	.	1	0	25	50

Phalaris arundinacea	c	.	.	.	+	.	+	2	2	.	.	.	.	25	75	0
Chaerophyllum hirsutum	c	.	.	.	.	+	.	1	+	.	.	.	.	0	75	0
Hypericum perforatum	c	.	.	.	.	+	+	.	2	.	.	+	.	0	75	25
Poa trivialis	c	.	.	.	.	+	+	.	.	.	.	.	.	0	50	0
Nardus stricta	c	1	.	.	.	.	.	.	.	3	2	2	2	25	0	100
Potentilla erecta	c	+	+	.	.	.	.	.	.	1	1	1	1	50	0	100
Deschampsia flexuosa	c	.	.	.	.	.	.	.	.	1	.	2	2	0	0	75
Galium saxatile	c	.	.	.	.	.	.	.	.	.	2	4	4	0	0	75
Carex nigra	c	.	.	+	.	.	+	.	.	.	1	1	2	25	25	75
Luzula campestris	c	.	.	.	.	.	.	.	.	+	+	1	.	0	0	75
Deschampsia caespitosa	c	1	+	+	1	2	1	.	+	.	2	+	+	100	75	75
Festuca rubra	c	2	2	+	2	2	+	.	+	.	1	+	+	100	75	75
Stellaria graminea	c	+	+	+	+	+	+	.	+	.	+	+	+	100	75	75
Holcus mollis	c	1	1	1	1	.	+	.	.	1	+	.	+	100	25	75
Polygonum bistorta	c	2	1	.	+	+	2	.	1	+	.	.	+	75	75	50
Senecio nemorensis s.l.	c	+	1	1	+	.	+	2	1	.	.	.	.	100	75	0
Poa pratensis	c	+	.	+	+	.	.	.	.	+	.	.	+	75	0	50
Vicia sepium	c	.	+	+	+	+	.	+	.	.	.	.	.	75	50	0
Campanula patula	c	.	+	+	+	.	.	.	+	.	.	.	.	75	25	0
Galeopsis pubescens	c	+	.	+	.	.	.	+	+	.	.	.	.	50	50	0
Juncus conglomeratus	c	.	.	.	.	.	2	.	.	.	1	+	+	0	25	75
Knautia arvensis	c	+	+	.	.	+	.	.	.	+	.	.	.	50	25	25
Ranunculus repens	c	r	+	.	+	1	.	.	.	.	.	.	.	75	25	0
Sanguisorba officinalis	c	.	.	+	.	+	1	.	+	.	.	.	.	25	75	0
Briza media	c	+	+	.	.	.	.	.	.	+	.	.	.	50	0	25
Heracleum sphondylium	c	.	+	+	.	+	.	.	.	.	.	.	.	50	25	0
Pimpinella major	c	.	+	.	.	+	.	.	+	.	.	.	.	25	50	0
Rumex obtusifolius	c	.	.	r	.	.	+	+	.	.	.	.	.	25	50	0
Aegopodium podagraria	c	.	+	.	+	.	.	.	.	.	.	.	.	50	0	0
Carex pallescens	c	.	.	.	.	.	.	.	.	.	.	+	+	0	0	50
Carex pilulifera	c	.	.	.	.	.	.	.	.	.	.	r	+	0	0	50
Geum rivale	c	.	.	.	.	+	.	.	+	.	.	.	.	0	50	0
Pleurozium schreberi	d	.	.	.	.	.	.	.	.	.	.	+	+	0	0	50

Polytrichastrum formosum	d	.	.	.	.	.	.	.	.	.	.	1	+	0	0	50
Stellaria nemorum	c	.	.	.	.	+	.	.	+	.	.	.	.	0	50	0
Urtica dioica	c	.	.	.	.	.	.	1	+	.	.	.	.	0	50	0

Rare species: c *Acer pseudoplatanus* 1.r, c *Agrostis canina* 6.1, c *Carex ovalis* 6.+, c *Cerastium holosteoides* 4.+, c *Cirsium palustre* 3.+, c *C. rivulare* 6.1, c *Crepis paludosa* 5.+, c *Elymus caninus* 6.+, c *Epilobium palustre* 6.+, c *Epilobium* sp. 2.+, c *Equisetum arvense* 9.r, c *E. palustre* 8.r, c *Festuca gigantea* 5.+, c *Galeopsis tetrahit* 5.+, c *Galium aparine* 7.+, c *G. mollugo* 1.+, c *G. palustre* 8.+, c *G. uliginosum* 2.r, c *Holcus lanatus* 5.+, c *Hypochoeris radicata* 2.r, c *Juncus effusus* 6.+, c *Leontodon hispidus* 2.+, c *Lupinus polyphyllus* 1.r, c *Lysimachia nemorum* 8.+, c *Plantago lanceolata* 2.+, c *Rubus idaeus* 7.2, c *Rumex hydrolapathum* 8.r, c *Rumex* sp. 5.+, c *Stachys sylvatica* 2.+, c *Trifolium hybridum* 3.+, c *T. repens* 3.+, c *Veronica officinalis* 11.+, c *Vicia sativa* 3.r, d *Rhytidiadelphus squarrosus* 12.+

velop mainly as the result of anthropogenic transformations of river valleys, such as the construction of artificial water reservoirs. This also applies to the Czerwona Woda valley − these communities were found near a retention reservoir in the forest. In the upper reaches of Czerwona Woda, communities characteristic of acidic seeps have formed. Their syntaxonomic affiliation was only determined to the *Caricion canescenti-nigrae* alliance (Table 6).

4. Discussion

Despite its very strong transformation, there are a large number of natural and semi-natural plant communities in the natural environment of the Czerwona Woda valley. Some of the identified associations have never been reported from the Stołowe Mountain region, for example, the *Equiseto sylvatici-Piceetum abietis* association of spruce swamp forests growing by springs and seeps.

The ecosystems of the Czerwona Woda valley are places where rare species occur, including plants in danger of extinction in the region and in Poland. The meadows near Karłów contain the globeflower *Trollius europaeus* and melancholy thistle *Cirsium helenioides*. In the neighboring grasslands near Karłów, the common lousewort *Pedicularis sylvatica* (Wójcik 2017) was recently found, a species in danger of extinction in Poland in the VU category (Kaźmierczakowa et al. 2016). The locations of this species are several hundred meters away from the study area and it is very likely that it will be found in the Czerwona Woda valley in the future, where there are well-preserved habitats suitable for this species – wet seeps. The locations mentioned above emphasize the importance of open areas for the preservation of local biodiversity. Unfortunately, a large part of the valuable meadows near Karłów are located outside the National Park and may be threatened by changes in their use or by abandonment. During field work, we observed rush species; among them was the reed canary grass *Phalaris arundinacea*, encroaching in parts of the local wet meadows that are no longer being used. In the spruce swamp forests, stag's-horn clubmoss *Lycopodium clavatum* was found − a species near threatened in Poland. In addition, the presence of many taxa deserve attention, such as wavy cotton moss *Bukiella undulata* or alpine coltsfoot *Homogyne alpina*. These species are considered to be characteristic of high-mountain spruce forests (Matuszkiewicz 2001; Chytrý 2015). In the study area, they were recorded both in spruce swamp forests and secondary forest communities with spruce stands, even at an altitude of less than 700 m a.s.l. This may indicate the specific climatic conditions that prevail in the Czerwona Woda valley. Masses of cool air flow from higher mountainous locations down the mountain valleys (Pypker et al. 2007; Wang et al. 2015), which in turn increase altitudinal range of mountain plants by downward shifts of the lower range limits.

The small proportion of alien species in the plant communities of the Czerwona Woda valley is somewhat surprising. The vegetation of river valleys is susceptible to invasions of alien plants (Planty-Tabacchi et al. 1996; Richardson et al. 2007; Wagner et al. 2017), which are additionally positively correlated with the intensity of human pressure (Nilsson, Berggren 2000; Mortenson, Weisberg 2010; Dyderski et al. 2015). Meanwhile, there are only three species of invasive plants in the Czerwona Woda valley (*Impatiens glandulifera, I. parviflora, Lupinus polyphyllus*), and their populations are very small. *Impatiens gladulifera* probably escaped from home gardens in the area of Karłów. On the other hand, the spread of *I. parviflora* in the forest communities is probably restrained by the low trophism of forest habitats in the Czerwona Woda valley. Although these plants do not have a significant negative impact on the riverside ecosystems, their populations should be regularly monitored. This is particularly important in the face of potential work to re-naturalize the Czerwona Woda; it also provides an opportunity to plan the total elimination of species with the greatest invasive potential.

The destruction of wetland habitats is a serious problem. In addition to the importance of preserving biodiversity, these habitats are primarily responsible for the protection

Table 6. Phytosociological table presenting *Phalaridetum arundinaceae* (Pa) Libbert 1931 association and community of *Caricion canescenti-nigrae* (Cc-n) alliance. Regionally diagnostic species are marked by light grey colour.

Consecutive no.		1	2	3	4	5	6	Constancy (Pa) (%)	Constancy (association and community of the alliance Cc-n) (%)
Relevé no.		23	24	31	8	9	10		
Date		2017 08 29	2017 08 29	2017 08 29	2017 08 28	2017 08 28	2017 08 28		
Plot area [m^2]		25	25	25	25	25	25		
Cover of herb layer		100	100	100	40	55	55		
Cover of moss layer		0	0	0	75	80	80		
Number of species		5	9	5	22	15	13		
		Phalaridetum arundinaceae			association and community of the alliance *Caricion canescenti-nigrae*				
Phalaris arundinacea	c	5	5	5	.	.	.	100.0	0.0
Carex echinata	c	.	.	.	+	+	+	0.0	100.0
Carex nigra	c	.	.	.	+	1	.	0.0	66.7
Carex curta	c	.	.	.	+	.	.	0.0	33.3
Juncus filiformis	c	.	.	.	1	1	2	0.0	100.0
Urtica dioica	c	2	2	2	.	.	.	100.0	0.0
Filipendula ulmaria	c	+	r	+	.	.	.	100.0	0.0
Stellaria nemorum	c	.	2	2	+	.	.	66.7	33.3
Cirsium oleraceum	c	+	.	.	.	.	.	33.3	0.0
Deschampsia caespitosa	c	+	.	.	.	.	.	33.3	0.0
Chaerophyllum hirsutum	c	.	2	.	.	.	.	33.3	0.0
Lathyrus pratensis	c	.	r	.	.	.	.	33.3	0.0
Galeopsis sp.	c	.	r	.	.	.	.	33.3	0.0
Senecio nemorensis s.l.	c	.	1	.	.	.	.	33.3	0.0
Polygonum bistorta	c	.	.	+	.	.	.	33.3	0.0
Juncus effusus	c	.	.	.	1	1	+	0.0	100.0
Polytrichum commune	d	.	.	.	4	4	3	0.0	100.0
Sphagnum fallax	d	.	.	.	+	2	3	0.0	100.0
Equisetum palustre	c	.	r	.	+	+	+	33.3	100.0
Athyrium filix-femina	c	.	.	.	+	r	.	0.0	66.7
Calamagrostis epigeios	c	.	.	.	2	+	.	0.0	66.7
Carex ovalis	c	.	.	.	+	+	.	0.0	66.7

Dryopteris carthusiana	c	.	.	.	+	.	+	0.0	66.7
Galium palustre	c	.	.	.	+	+	.	0.0	66.7
Glyceria fluitans	c	.	.	.	1	.	2	0.0	66.7
Holcus mollis	c	.	.	.	+	2	.	0.0	66.7
Calamagrostis villosa	c	.	.	.	.	2	2	0.0	66.7
Sphagnum girgensohnii	d	.	.	.	.	2	3	0.0	66.7

Rare species: c *Agrostis capillaris* 6.2, c *Carex remota* 4.+, c *Epilobium palustre* 4.+, c *Equisetum sylvaticum* 5.+, c *Hypericum perforatum* 4.+, c *Ranunculus repens* 4.+, c *Rubus idaeus* 4.r, c *Sorbus aucuparia* 6.r, c *Vaccinium myrtillus* 6.+, d *Sphagnum* sp. 4.1

of water resources (Malanson 1993; Richter et al. 2003; Naiman et al. 2005). There are numerous evidence of drainage activities in the Czerwona Woda valley. Although partially overgrown, these ditches still accelerate the outflow of huge amounts of water that could be retained by wetland ecosystems. Considering the problems with the water supply of nearby towns (including Batorów), activities aimed at stopping the outflow of water and restoring natural retention capabilities should be an absolute priority if plans to re-naturalize the Czerwona Woda valley are being considered.

In the case of planned restoration, the habitat conditions presented in this study should be taken into account. Attempts to improve the ecological condition of the ecosystems undertaken to date, for example, the methods used to reconstruct the spruce stands, do not seem to be very effective. In the course of the field work, for example, we observed beech saplings planted in a swamp forest under a canopy of spruce, with not the slightest hope of growth and development in such conditions. It seems that the comprehensive habitat reconnaissance prepared within the framework of this study, as well as the map of potential vegetation, will enable possible projects to be more precisely adjusted to the conditions of the natural environment.

Conflict of interest

The authors declare no potential conflicts of interest.

Acknowledgment and source of funding

The research was financed from the Forest Fund (General Directorate of State Forests in Warsaw) as part of a research project entitled "Recognition and assessment of the current status of natural habitats in the area adjacent to the Czerwona Woda River", implemented on the basis of an agreement between Stołowe Mountains National Park and the Institute of Dendrology of the Polish Academy of Sciences, and partly from a grant from the Ministry of Science and Higher Education for the statutory activities of the Forestry Faculty of the H. Kołłątaj University of Agriculture in Kraków (DS 3421/ZBL).

References

Adynkiewicz-Piragas M., Bogusz A., Chudzik B., Garncarz-Wilk B., Lejcuś I., Malicka J., Mordalska H., Pasiecznik A., Tokarczyk T. 2011. Warunki hydrologiczne Gór Stołowych, w: Chodak T., Kabała C., Kaszubkiewicz J., Migoń P., Wojewoda J. (red.), Geoekologiczne warunki środowiska przyrodniczego Parku Narodowego Gór Stołowych (monografia). WIND, Wrocław, 169–182.

Allan J. D. 2004. Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems. *Annual Review of Ecology, Evolution and Systematics* 35(1): 257–284. DOI 10.1146/annurev.ecolsys.35.120202.110122.

Barzdajn W., Ceitel J., Danielewicz W., Zientarski J. 1999. Leśnictwo proekologiczne. Wydawnictwo Akademii Rolniczej im. Augusta Cieszkowskiego w Poznaniu, Poznań, 106 s. ISBN 83-7160-182-4.

Catford J.A., Downes B.J., Gippel C.J., Vesk P.A. 2011. Flow regulation reduces native plant cover and facilitates exotic invasion in riparian wetlands. *Journal of Applied Ecology* 48(2): 432–442. DOI 10.1111/j.1365-2664.2010.01945.x.

Chytrý M. 2007. Grassland and Heathland Vegetation. Vegetation of the Czech Republic. 1. Academia, Praha. ISBN 978-80-200-1462-7.

Chytrý M. 2009. Ruderal, Weed, Rock and Scree Vegetation. Vegetation of the Czech Republic. 2. Academia, Praha. ISBN 978-80-200-1769-7.

Chytrý M. 2011. Aquatic and Wetland Vegetation. Vegetation of the Czech Republic. 3. Academia, Praha. ISBN 978-80-200-1918-9.

Chytrý M. 2015. Forest and Scrub Vegetation. Vegetation of the Czech Republic. 4. Academia, Praha. ISBN 978-80-200-2299-8.

Dyderski M.K., Gdula A.K., Jagodziński A.M. 2015. "The rich get richer" concept in riparian woody species – A case study of the Warta River Valley (Poznań, Poland). *Urban Forestry & Urban Greening* 14(1): 107–114. DOI 10.1016/j.ufug.2014.12.003.

Dzwonko Z. 2007. Przewodnik do badań fitosocjologicznych. Vademecum Geobotanicum. Sorus, Instytut Botaniki UJ, Poznań -Kraków. ISBN 978-83-899-23-3.

Fiek E. 1881. Flora von Schlesien preussischen und österreichischen Antheils, enthaltend die wildwachsenden, verwilderten und angebauten Phanerogamen und Gefäss-Cryptogamen. J. U. Kern's Verlag, Breslau.

Foster S.G., Rood S.B. 2017. River regulation and riparian woodlands: Cottonwood conservation with an environmental flow regime along the Waterton River, Alberta. *River Research and Applications* 33(7): 1088–1097. DOI 10.1002/rra.3156.

González E., Felipe-Lucia M.R., Bourgeois B., Boz B., Nilsson C., Palmer G., Sher A.A. 2017. Integrative conservation of riparian zones. *Biological Conservation* 211(Part B): 20–29. DOI 10.1016/j.biocon.2016.10.035.

Greet J., Cousens R., Webb J.A. 2013. Seasonal timing of inundation affects riparian plant growth and flowering: implications for riparian vegetation composition. *Plant Ecology* 214(1): 87–101. DOI 10.1007/s11258-012-0148-8.

Gundersen P., Laurén A., Finér L., Ring E., Koivusalo H., Sætersdal M., Weslien J.-O., Sigurdsson B., Högbom L., Laine J., Hansen K. 2010. Environmental Services Provided from Riparian Forests in the Nordic Countries. *Ambio* 39(8): 555–566. DOI 10.1007/s13280-010-0073-9.

Johansen K., Phinn S., Lowry J., Douglas M. 2008. Quantifying indicators of riparian condition in Australian tropical savannas: integrating high spatial resolution imagery and field survey data. *International Journal of Remote Sensing* 29(23): 7003–7028. DOI 10.1080/01431160802220201.

Kabała C., Szerszeń L., Wicik B. 2002a. Geneza, właściwości i systematyka gleb Parku Narodowego Gór Stołowych. *Szczeliniec* 6: 21–94.

Kabała C., Szerszeń L., Wicik B. 2002b. Mapa gleb Parku Narodowego Gór Stołowych. *Szczeliniec* 6.

Kaźmierczakowa R., Bloch-Orłowska J., Celka Z., Cwener A., Dajdok Z., Michalska-Hejduk D., Pawlikowski P., Szczęśniak E., Ziarnek K. 2016. Polska czerwona lista paprotników i roślin kwiatowych. Instytut Ochrony Przyrody PAN, Kraków. ISBN 978-83-61191-88-9.

KRNAP 2012. Historia lasu - dziewięć stuleci puszczy karkonoskich. Správa Krkonošského národního parku, Vrchlabí. ISBN 978-80-86418-96-4.

Macfarlane W. W., Gilbert J. T., Jensen M. L., Gilbert J. D., Hough-Snee N., Mchugh P. A., Wheaton J. M., Bennett S. N. 2017. Riparian vegetation as an indicator of riparian condition: Detecting departures from historic condition across the North American West. *Journal of Environmental Management* 202(Part 2): 447–460. DOI 10.1016/j.jenvman.2016.10.054.

Malanson G. P. 1993. Riparian landscapes. Cambridge University Press, Cambridge, 296 s. ISBN 9780521566834.

Matuszkiewicz J. M. 2001. Zespoły leśne Polski. Wydawnictwo Naukowe PWN, Warszawa, 357 s. ISBN 9788301134013.

Migoń P., Latocha A., Parzóch K., Kasprzak M., Owczarek P., Witek M., Pawlik Ł. 2011. Współczesny system morfogenetyczny Gór Stołowych, w: Chodak T., Kabała C., Kaszubkiewicz J., Migoń P., Wojewoda J. (red.), Geoekologiczne warunki środowiska przyrodniczego Parku Narodowego Gór Stołowych (monografia). WIND, Wrocław, 1–52. ISBN 9788392233046.

Mortenson S.G., Weisberg P.J. 2010. Does river regulation increase the dominance of invasive woody species in riparian landscapes? *Global Ecology and Biogeography* 19(4): 562–574. DOI 10.1111/j.1466-8238.2010.00533.x.

Mucina L., Bültmann H., Dierßen K., Theurillat J.-P., Raus T., Čarni A., Šumberová K., Willner W., Dengler J., García R.G., Chytrý M., Hájek M., Di Pietro R., Iakushenko D., Pallas J., Daniëls F.J.A., Bergmeier E., Santos Guerra A., Ermakov N., Valachovič M., Schaminée J.H.J., Lysenko T., Didukh Y.P., Pignatti S., Rodwell J.S., Capelo J., Weber H.E., Solomeshch A., Dimopoulos P., Aguiar C., Hennekens S. M., Tichý L. 2016. Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Applied Vegetation Science* 19: 3–264. DOI 10.1111/avsc.12257.

Naiman R.J., Décamps H., Mcclain M.E. 2005. Riparia: Ecology, Conservation and Management of Streamside Communities. Elsevier, Burlington. ISBN 9781493301980.

Nilsson C., Berggren K. 2000. Alterations of Riparian Ecosystems Caused by River Regulation. *BioScience* 50(9): 783–792.

Nilsson C., Reidy C.A., Dynesius M., Revenga C. 2005. Fragmentation and Flow Regulation of the World's Large River Systems. *Science* 308(5720): 405–408. DOI 10.1126/science.1107887.

Ochyra R., Żarnowiec J., Bednarek-Ochyra H. 2003. Census catalogue of Polish Moses. Biodiversity of Poland. 3. Szafer Institute of Botany, Polish Academy of Sciences, Kraków. ISBN 83-85444-84-X.

Otypková Z., Chytrý M. 2006. Effects of plot size on the ordination of vegetation samples. *Journal of Vegetation Science* 17(4): 465–472. DOI 10.1111/j.1654-1103.2006.tb02467.x.

Pax F. 1915. Schlesiens Pflanzenwelt. Eine pflanzengeographische Schilderung der Provinz. Verlag von Gustav Fischer, Jena.

Pender K. 2008. Zbiorowiska roślinne, w: Witkowski A., Pokryszko B.M., Ciężkowski W. (red.), Przyroda Parku Narodowego Gór Stołowych. Park Narodowy Gór Stołowych, Kudowa-Zdrój, 182–193.

PGL LP 2012. Instrukcja urządzania lasu. Część II. Instrukcja wyróżniania i kartowania w Lasach Państwowych typów siedliskowych lasu oraz zbiorowisk roślinnych. Centrum Informacyjne Lasów Państwowych, Warszawa.

Pielech R. 2015. Formalised classification and environmental controls of riparian forest communities in the Sudetes (SW Poland). *Tuexenia: Mitteilungen der Floristisch-Soziologischen Arbeitsgemeinschaft* 35: 155–176. DOI 10.14471/2015.35.003.

Pielech R., Kisiel P. 2010. Prace utrzymaniowe jako zagrożenie dla osiągnięcia środowiskowych celów Ramowej Dyrektywy Wodnej oraz dla funkcjonowania sieci ekologicznej Natura 2000 w Polsce. WWF Polska, Wrocław-Warszawa, 71 s.

Pielech R., Bodziarczyk J., Gazda A., Malicki M., Szwagrzyk J. 2017. Łęgi w źródliskach i przy drobnych ciekach wodnych; jak identyfikować, kartować i chronić te zbiorowiska? *Studia i Materiały CEPL* 19(51): 93–102.

Pielech R., Baran J., Bodziarczyk J., Kucharzyk S., Malicki M., Smoczyk M., Wilczek Z., Zarzycki W., Zięba A. 2018. Forest Database of Southern Poland. *Phytocoenologia*: (in press). DOI 10.1127/phyto/2018/0237.

Planty-Tabacchi A.-M., Tabacchi E., Naiman R.J., Deferrari C., Décamps H. 1996. Invasibility of Species-Rich Communities in Riparian Zones. *Conservation Biology* 10(2): 598–607. DOI 10.1046/j.1523-1739.1996.10020598.x.

Potocka J. 1999. Współczesna szata roślinna Wielkiego Torfowiska Batorowskiego. *Szczeliniec* 3: 49–99.

Pypker T.G., Unsworth M.H., Lamb B., Allwine E., Edburg S., Sulzman E., Mix A.C., Bond B.J. 2007. Cold air drainage in a forested valley: Investigating the feasibility of monitoring ecosystem metabolism. *Agricultural and Forest Meteorology* 145(3): 149–166. DOI 10.1016/j.agrformet.2007.04.016.

Richardson D.M., Holmes P.M., Esler K.J., Galatowitsch S.M., Stromberg J.C., Kirkman S.P., Pyšek P., Hobbs R. J. 2007. Riparian vegetation: degradation, alien plant invasions, and restoration prospects. *Diversity and Distributions* 13(1): 126–139. DOI 10.1111/j.1366-9516.2006.00314.x.

Richter B.D., Mathews R., Harrison D.L., Wigington R. 2003. Ecologically sustainable water management: Managing river flows for ecological integrity. *Ecological Applications* 13(1): 206–224. DOI 10.1890/1051-0761(2003)013[0206:ESWMMR]2.0.CO;2.

Schube T. 1903. Die Verbreitung der Gefässpflanzen in Schlesien preussischen und österreichischen Antheils. Druck von R. Nischowsky, Breslau.

Schube T. 1906. Waldbuch von Schlesien: Nachweis der beachtenswerten und zu schützenden Bäume und Sträucher Schlesiens nebst einer Charakteristik seiner wichtigsten Holzgewächse. G.T. Korn, Breslau.

Sweeney B.W., Bott T.L., Jackson J.K., Kaplan L.A., Newbold J.D., Standley L.J., Hession W.C., Horwitz R.J. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. *Proceedings of the National Academy of Sciences* 101(39): 14132–14137. DOI 10.1073/pnas.0405895101.

Szweykowski J. 2006. An annotated checklist of Polish liverworts and hornworts. Biodiversity of Poland. vol. 4. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków. ISBN 8389648334

Świerkosz K. 1998. Analiza geobotaniczna Gór Stołowych. Wydział Nauk Przyrodniczych, Uniwersytet Wrocławski. Praca doktorska. Wydział Nauk Przyrodniczych Uniwersytetu Wrocławskiego, tom 1: 225 s., tom 2: 408 s.

Świerkosz K., Smoczyk M., Gołąb Z. 2008. Flora naczyniowa Gór Stołowych, w: Witkowski A., Pokryszko M.B., Ciężkowski W. (red.) Przyroda Parku Narodowego Gór Stołowych. PNGS, Kudowa-Zdrój, 174–181.

Van Looy K., Tormos T., Souchon Y., Gilvear D. 2017. Analyzing riparian zone ecosystem services bundles to instruct river management. *International Journal of Biodiversity Science, Ecosystem Services & Management* 13(1): 330–341. DOI 10.1080/21513732.2017.1365773.

Wagner V., Chytrý M., Jiménez-Alfaro B., Pergl J., Hennekens S., Biurrun I., Knollová I., Berg C., Vassilev K., Rodwell J. S., Škvorc Ž., Jandt U., Ewald J., Jansen F., Tsiripidis I., Botta-Dukát Z., Casella L., Attorre F., Rašomavičius V., Ćušterevska R., Schaminée J. H. J., Brunet J., Lenoir J., Svenning J.-C., Kącki Z., Petrášová-Šibíková M., Šilc U., García-Mijangos I., Campos J. A., Fernández-González F., Wohlgemuth T., Onyshchenko V., Pyšek P. 2017. Alien plant invasions in European woodlands. *Diversity and Distributions* 23(9): 969–981. DOI 10.1111/ddi.12592.

Wang X., Wang C., Li Q. 2015. Wind Regimes above and below a Temperate Deciduous Forest Canopy in Complex Terrain: Interactions between Slope and Valley Winds. *Atmosphere* 6(1): 60. DOI 10.3390/atmos6010060.

Wierzcholska S., Dyderski M.K., Pielech R., Gazda A., Smoczyk M., Malicki M., Horodecki P., Kamczyc J., Skorupski M., Hachułka M., Kałucka I., Jagodziński A. M. 2018. Natural forest remnants as refugia for bryophyte diversity in a transformed mountain river valley landscape. *Science of the Total Environment* 640-641: 954–964. DOI 10.1016/j.scitotenv.2018.05.340

Wilczkiewicz M. 1982. Rys historyczny gospodarki w lasach sudeckich. *Sylwan* 126(6): 49–54.

Witek M. 2013. Morfologia doliny Czerwonej Wody w Górach Stołowych. *Przyroda Sudetów* 16: 147–179.

Wójcik G. 2017. Powtórne odnalezienie gnidosza rozesłanego *Pedicularis sylvatica* L. (Orobanchaceae) w Górach Stołowych. *Przyroda Sudetów* 20: 49–60.

Authors' contribution

A.M.J., A.G., R.P., M.K.D. – concept of the study and developing the methods; R.P., M.M., M.Sm., M.K.D., A.G. – data set; A.M.J., A.G., R.P., M.M., M.Sm., M.K.D., P.H., S.W., M.Sk., J.K., I.K., M.H. – writing the text.

Translated by: Barbara Przybylska