ECOLOGIA BALKANICA

2015, Vol. 7, Issue 1 June 2015 pp. 1-11

Alluvial Gravel Bars as an Example of Habitat of the Widest Ecological Spectrum in the Mountain Regions – A Case of Carpathians, Southern Poland

Aldona K. Uziębło*, Alicja Barć

University of Silesia, Department of Ecology,
28 Jagiellonska Str., 40-032 Katowice, POLAND
*Corresponding author: aldona.uzieblo@us.edu.pl

Abstract. Alluvial stream-bank gravel bars are one of the most interesting types of habitat in montane regions. The flora of two streams representative of Eastern and Western Carpathians were analysed. Both valleys are similar in respect to geomorphological shape, length and the influence of anthropopressure, but different in respect to vegetation adjacent to stream-bed and flora richness. Both streams were divided into three sections. Ecological differentiation of analysed gravel flora in both stream valleys was expressed by the share of elements of different syntaxa (and EUNIS types of habitat) and in the other hand by species characterised with selected ecological indices (pH, humidity, trophism and soil dispersal). This paper is focused on proving that heterogeneity of gravel bars as habitat which is caused by frequent submergences makes the close coexistence of plants with extremely different habitat requirements possible. The results showed that the flora of gravel bars of both streams in spite of their floristic differences and regardless of floristic richness represents almost entire ecological spectrum.

Key words: alluvial habitats, gravel bars, montane flora of streambanks, ecological differentiation.

Introduction

Alluvial habitats, especially those located near the stream current that are flooded each season, are one of the most untypical and biologically differentiated habitats (NILSSON, 1987; BANÁSOVÁ *et al.*, 1994; EDWARDS *et al.*, 1999; UZIĘBŁO & CIAPAŁA, 2006; ELLENBERG, 2009). Periodically changeable surface of area available for plants, the changeable structure of the dispersal of the soil substratum that is dependent on time and the intensity of submergences, unstable species composition, distribution and its distinct dependence on both the quality of adjacent vegetation and floods, are the main characteristics of gravel bars. Many of species occur on gravels as single individuals, sometimes for a number of seasons and sometimes ephemerally for only one season. They are able to change their localities as well. A species may occur in the upper part of stream valley in one season and it may spread into lower sections of valley in the next, disappearing from primal location (UZIĘBŁO, 2001; 2011).

Alluvial areas located far from the stream, which are rarely and less intensively flooded, are ecologically more stable and covered by vegetation typical for the distant zone from the stream-bed (NILSSON *et al.*, 1989; VERVUREN *et al.*, 2003). The vegetation on analysed area (the lower montane forest zone) is formed by riparian forests, mainly Carpathian alder tree (*Alnetum incanae*). Near the stream current, the most common

unforested community is tall-herbs with glabrous butterbur (*Petasitetum kablikiani*) (UZIĘBŁO, 2011).

In this altitudinal zone there is no stable community on gravel bars nearest the stream current. They may be flooded several times during a vegetation season after each torrential rain. Therefore, in V-shaped valleys, the surface of gravels is very changeable and not very large. In the lower parts of valleys, where streams become montane rivers with wide bottoms, the vegetation reveals specific zonation ranging from alluvial meadows through thickets with *Calamagrostis pseudophragmites* or *Myricaria germanica* (*Epilobietalia fleischerii*), willow thickets and further riparian forests with willows (*Salicetum albo-fragilis*), (MATUSZKIEWICZ, 2012). The objects of this study were only gravels – open habitats nearest to the stream current in the altitudinal zone of mixed and deciduous forests – which were in different stages of initial succession and which were regularly flooded. The aim of the study was to show the ecological spectrum of flora (syntaxa analysis and ecological indices analysis) and in the same way to indicate important role of these habitats in maintaining local biodiversity in the natural environment of mountains.

Material and Methods

Floristic investigations were carried out (with appropriate permissions) in two national parks, biosphere reserves, in two streams which flow through valleys with similar geomorphological profiles and have springs located high in the mountain (subalpine zone). Studies were carried out in southern Poland on the gravels of the Terebowiec stream valley in the Bieszczady National Park, Eastern Carpathians in 2008-2012 and along Rybny stream and its environs in the Babia Góra National Park, Western Carpathians in 2009-2013. The highest located parts of V-shaped valleys were omitted because of lack of habitats of our interest. Places, where in low water stage exposed gravels, were included into the study. Both streams are formed in Carpathian flysch and their valleys are similarly shaped. The stream-beds were arbitrarily divided into three sections according to combination between types of vegetation and synanthropisation sources – upper, middle and lower. The first and last sections are, or were some time ago, influenced by human activity that indicated the possibility of the occurrence of synanthropic flora (Table 1).

Both streams are mainly surrounded by forest vegetation (Carpathian alder forest *Alnetum incanae*, Carpathian beech forest *Dentario glandulosae-Fagetum* in the case of Terebowiec stream and mainly spruce monocultures in the case of Rybny stream) in the middle sections. The anthropopression occurs in the upper and terminal sections of the stream-beds. In these parts of the valleys, adjacent to the stream-bed, vegetation is formed by meadows and bushes (open habitats).

Each year lists of gravel flora were complemented at the turn of spring and summer seasons because this is the period between the two highest water stages, thus the composition of species is relatively stable and it makes it possible to obtain a full list of the species growing on gravels.

Ecological differentiation was expressed by variety of noted flora in aspect of ecological requirements (ecological indices; ZARZYCKI *et al.*, 2002) and connections with different types of phytocoenoses (syntaxa). Widely used Ellenberg's ecological indices (ELLENBERG *et al.*, 2001) do not take into account some Carpathian species (especially Eastern Carpathian's flora which occurs in the Terebowiec valley) therefore Zarzycki's scale (which is compatible with Ellenberg's) was used in this paper not to avoid any representatives of Polish flora. In the case of a wide tolerance to a given environmental factor and a given range of index values, the average of extreme values was taken into the analysis. Statistical relationships between particular sections in respect to the share of diagnostic species, number of syntaxa and the share of species with extreme habitat requirements (indices 1-2 and 4-6) were determined by principal components analysis (PCA) using statistical package Statistica Software version 10 (STATSOFT INC., 2011). The syntaxonomical

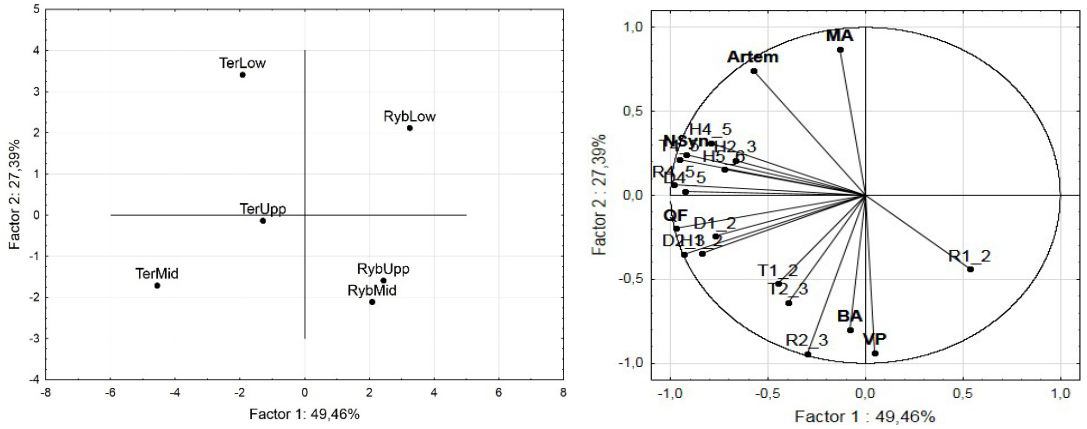
affinity of the vascular plants noted was adopted after DAVIES *et al.* (2004) and MATUSZKIEWICZ (2012), and nomenclature of species after MIREK *et al.* (2003). In the list of syntaxa represented in analysed type of habitat both EUNIS classification (DAVIES *et al.*, 2004) and classification commonly used in Poland (MATUSZKIEWICZ, 2012) were used in this paper. For comparison analysis of habitats published phytosociological data were used (KASPROWICZ, 1996; MICHALIK & SZARY, 1997; DENISIUK & KORZENIAK, 1999; ZEMANEK & WINNICKI, 1999; UZIĘBŁO, 2011). The length of the sections and the altitude above sea level was calculated using a GPS receiver.

Table 1. Characteristics of streams analysed.

Name of the stream	National Park	Locality of springs	Section	Altitude [m a.s.l.]	Section lenght [km]	Streambank vegetation	Sources of synanthropisation in vicinity of stream bed
Terebowiec The highest point of area studied 49°05'50.19"N 22°42'57.93"E	Bieszczady	N slope of the Tarniczka Mt. about 1200 m a.s.l.	Upper	840-805	1	Tall-herbs with glabrous butterbur (*Petasitetum kablikiani*), fertile beech forest (*Dentario glandulosae-Fagetum*)	Inactive timber storage area and quarry, strict reserve
			Middle	805-720	2.5	Tall-herbs with glabrous butterbur (*Petasitetum kablikiani*), fertile beech forest (*Dentario glandulosae-Fagetum*), riparian forest (*Alnetum incanae*)	Lack Strict reserve
			Lower	720-655	2	Tall-herbs with glabrous butterbur (*Petasitetum kablikiani*), meadow communities (*Arrhenatherion*)	Buildings
Rybny The highest point of area studied 49°35'52.99" N 19°32'34.59" E	Babia Gora	N slope of the Babia Gora Mt. 1445 m a.s.l	Upper	828-785	1	Tall-herbs with glabrous butterbur (*Petasitetum kablikiani*), meadow communities (*Arrhenatherion*)	Active timber storage area
			Middle	785-705	2.5	Tall-herbs with glabrous butterbur (*Petasitetum kablikiani*), riparian forest (*Alnetum incanae*), spruce monocultures	Lack
			Lower	705-670	1.5	Tall-herbs with glabrous butterbur (*Petasitetum kablikiani*), riparian forest (*Alnetum incanae*)	Buildings, road, streambank regulation

Results

Analysis of relationships between particular sections of both streams in respect to analysed parameters (PCA) revealed that they differ in respect to the share of species diagnostic for particular syntaxa, the degree of species variation expressed as a number of represented syntaxa, as well as the share of species with extremely different ecological requirements (Fig. 1a,b). The Rybny stream is distinguished with species of very acid habitats. Both streams weakly differ in respect to the contribution of tall-herbs species (*Betulo-Adenostyletea*) and species from *Vaccinio-Piceetea* class, but more significantly in respect to other classes. Lower sections of both streams are characterized mostly by greater share of meadow and synanthropic species (*Molinio-Arrhenatheretea* and *Artemisietea vulgaris*), and also by larger heterogeneity of flora (number of syntaxa) and the share of species of fertile, alkaline, heavy loams and claim habitats with entire spectrum of humidity as well. Upper and middle sections, particularly of Terebowiec stream, are dominated by the species of deciduous forests (*Querco-Fagetea*), and species of rocky and gravel habitats, rather poor and lightly acidic soils (Fig. 1a, b).



a) b)

Fig.1. a,b. Differentiation of particular sections of streams analysed in respect to vegetation parameters (PCA)

Abbreviations: RybUpp – Rybny stream upper section, RybMid – Rybny stream middle section, RybLow – Rybny stream lower section; TerUpp – Terebowiec stream upper section, TerMid – Terebowiec stream middle section, TerLow – Terebowiec stream lower section; Q-F – *Querco-Fagetea*, V-P – *Vaccinio-Piceetea*, B-A – *Betulo-Adenostyletea* (syn. *Mulgedio-Aconitetea)*, M-A – *Molinio-Arrhenatheretea*, Artem – *Artemisietea vulgaris,* NSyn – number of syntaxa; ranges of ecological indices: T – trophism, D – soil dispersion, H – soil humidity, R – pH

The flora of the entire part of Terebowiec stream that was analysed amounts 211 species, and amounts to only 154 on Rybny stream. The differences are less clear when division into particular sections is taken into account. 117 species were noted on gravels in the upper section of Terebowiec stream, 153 in middle section, and 142 in the lower section. In the case of Rybny stream, the number amounts to 110, 111 and 100 species, respectively (Appendix 1).

The gravel bars, thanks to a very heterogeneous structure, form microhabitats for species representing numerous extremely different ecological groups. In this study they were qualified as elements of miscellaneous syntaxa. Flora of both streams represents following types/classes: riparian woodland, mostly with dominant alder;

Fagus woodland; broadleaved swamp woodland (*Querco-Fagetea, Salicetea purpureae, Alnetea glutinosae* - EUNIS codes G1.1, G1.4, G1.6); conifer scrub close to the tree limit; coniferous woodland; mixed *Abies - Picea - Fagus* woodland; small coniferous anthropogenic woodlands (*Vaccinio-Piceetea* - F2.4, G3.1, G4.6, G5.4); swamps and marshes dominated by *Juncus effusus*; permanent mesotrophic pastures and aftermath-grazed meadows; low and medium altitude hay meadows; mountain hay meadows; moist or wet eutrophic and mesotrophic grasslands; moist or wet tall-herb meadows; (*Molinio-Arrhenatheretea, Agropyretea intermedio-repentis* - D5.3, E2.1, E2.2, E2.3, E3.4, E5.4), vegetated snow-patch; subalpine moist or wet tall-herb; subalpine deciduous scrub (*Betulo-Adenostyletea* syn. *Mulgedio-Aconitetea*) - E4.1, E5.5, F2.3); constructed, industrial and other artificial habitats (*Artemisietea vulgaris* - J); dry acid and neutral closed grassland (*Nardo-Callunetea* - E1.7); springs, spring brooks, *etc*. (*Montio-Cardaminetea* - C2.1), recently felled areas mostly clearings (*Epilobietea angustifolii* - G5.8); recently abandoned cultivated areas (*Stellarietea mediae* – I2.3); water-fringing reed beds and tall helophytes (*Phragmitetea* - C3.1); poor fens and soft-water spring mires (*Scheuchzerio-Caricetea nigrae* - D2.2); scree vegetation (*Asplenietea rupestria* - H2); periodically inundated shores with pioneer and ephemeral vegetation; (*Bidentetea tripartiti* - C3.5), perennial calcareous grassland (*Festuco-Brometea* - E1.2) and unvegetated or sparsely vegetated shores with non-mobile substrates or almost bare rock pavements, including limestone pavements (*Koelerio-Corynephoretea* - C3.7, H 3.5). In total 18 syntaxa and 28 EUNIS types of habitat are represented by flora of Terebowiec stream banks. In spite of floristic poverty of Rybny stream, elements of all vegetation classes mentioned above (with the exception of the last four) were noted on its gravels, and additionally *Quercetea robori-petraeae* (in total 15 syntaxa; 23 types). The middle section of Terebowiec stream had the highest number of represented syntaxa (15), while the number amounted to 11 occurred on the gravels of Rybny stream.

In total, the vegetation adjacent the stream-bed comprises more than half of the gravel flora of both streams (Fig. 2). Species of deciduous forests (*Querco-Fagetea)* are more numerous in the Terebowiec stream valley which in general more afforested than Rybny stream. The share of acidophilus species from coniferous forests (*Vaccinio-Piceetea*) is small and almost constant for both streams. Tall-herb species (*Betulo-Adenostyletea*) which gather mostly subalpine species, what is connected with locality of stream springs in the subalpine zone (Table 1), occurred in the upper and middle sections of Rybny stream (14%), and then their percentage decreases to 3%. These species occur in upper section of the Terebowiec stream valley (6%), but mostly in the middle part (8%), (springs of this stream are located 245 m lower than Rybny springs (Table 1). The contribution of meadow species (*Molinio-Arrhenatheretea)* in both streams increases in the lower sections from 22 through 19 to 31 in Rybny and from 18 through 17 to 25 in Terebowiec stream. The species from the *Artemisietea vulgaris* class (including synanthropic species) are almost double numerous in the Terebowiec stream valley than in the Rybny valley (Fig. 2) although Terebowiec valley has been taken under strict protection (since 1973), but in its case the history of anthropogenic influence is much longer and more diversified (timber storage, quarry, narrow railway and touristic route).

In analysed flora of gravel bars the most numerously represented syntaxa are simultaneously the communities adjacent to stream current or its springs (Fig. 2). It could be evidence that mentioned communities are external source of diaspores for gravel habitats by a seed rain and distant transportation. Quantitative differences in contribution of particular groups of species mentioned above reflect distribution and in certain sense also the area occupied by particular communities adjacent to stream current in both valleys.

The comparison of flora of gravel bars with flora of forest, meadow and tall-herb

habitats revealed dominance of species representing adequate classes and smaller differentiation of flora on comparative habitats (Fig. 2). Number of syntaxa on gravels of Terebowiec ranges respectively from 12 to 15, and on gravels of Rybny - from 10 to 11. The number of syntaxa on forest habitats of Terebowiec and Rybny amounts respectively five and seven, while in meadow habitats in both cases amounts eight. Flora of tall-herb habitats adjacent to Rybny springs contains species from seven syntaxa. The vegetation surrounding springs of Terebowiec is incomparable with subalpine tall-herbs from Western Carpathians because of completely different character of timberline and subalpine zone (beech forest and grasslands).

The analysis of the species composition of flora occurring on gravels of particular sections of both streams revealed that the flora represents almost entire ecological spectrum in respect to such habitat parameters as: acidity (Fig. 3a), humidity (Fig. 3b), trophism (Fig. 3c) and soil dispersal (Fig. 3d).

In reference to both streams analysed, each particular index value is represented with the exception of highest values of humidity in the Rybny stream (Fig. 3b). Therefore results of the analysis revealed that species from extremely acidic habitats and species from alkaline habitats, xerothermic and hydrophilous, extremely oligo- and eutrophic species, plants characteristic to rock slits near plants typical to heavy clay and loam coexist on one habitat and this is the main feature of ecological importance of gravel bars (Fig. 3a-d). It is obvious that the most numerous are species typical to a habitat that is moderately acidic, eutrophic, and with sandy-clay soils (the range of particular ecological indices for them amounts to 3-4).

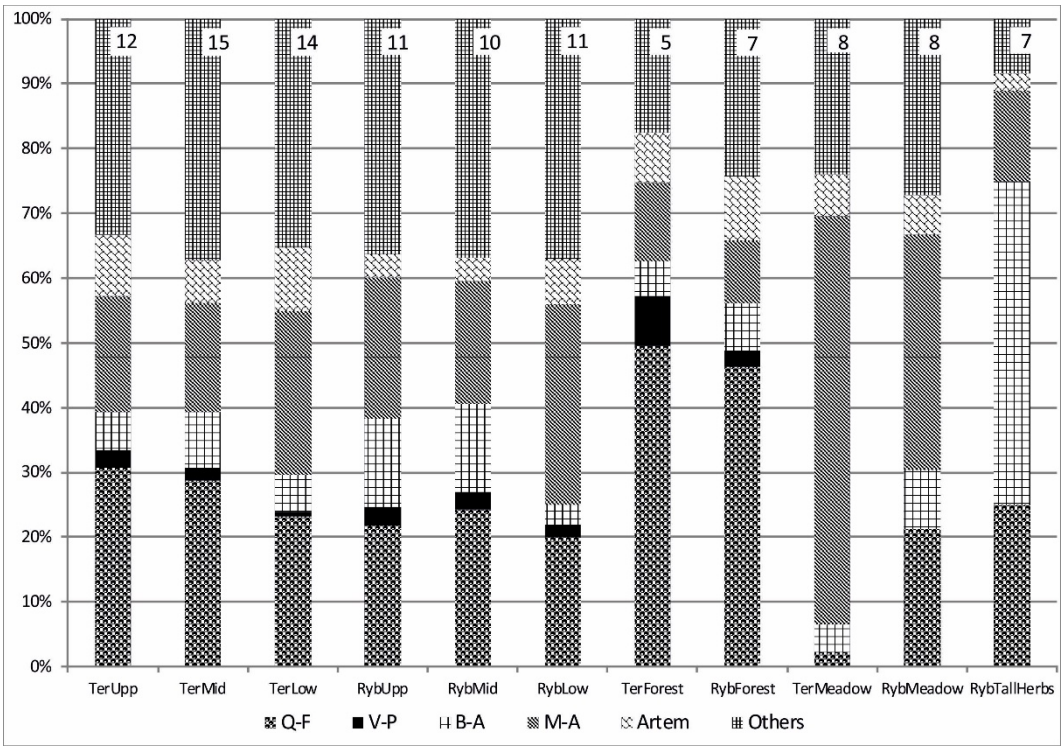


Fig.2. Comparison of differentiation of flora from gravel bars and adjacent habitats (only the most numerously represented syntaxa are distinguished; tall-herbs habitat from Terebowiec (TerTallHerbs) is excluded from the analysis – see comment in the text). Numbers in squares mean number of syntaxa.

Abbreviations: TerUpp – Terebowiec stream upper section, TerMid – Terebowiec stream middle section, TerLow – Terebowiec stream lower section; RybUpp – Rybny stream upper section, RybMid – Rybny stream middle section, RybLow – Rybny stream lower section; Q-F – *Querco-Fagetea*, V-P – *Vaccinio-Piceetea*, B-A – *Betulo-Adenostyletea* (syn. *Mulgedio-Aconitetea)*, M-A – *Molinio-Arrhenatheretea*, Artem – *Artemisietea vulgaris,* Others – syntaxa represented by a few species

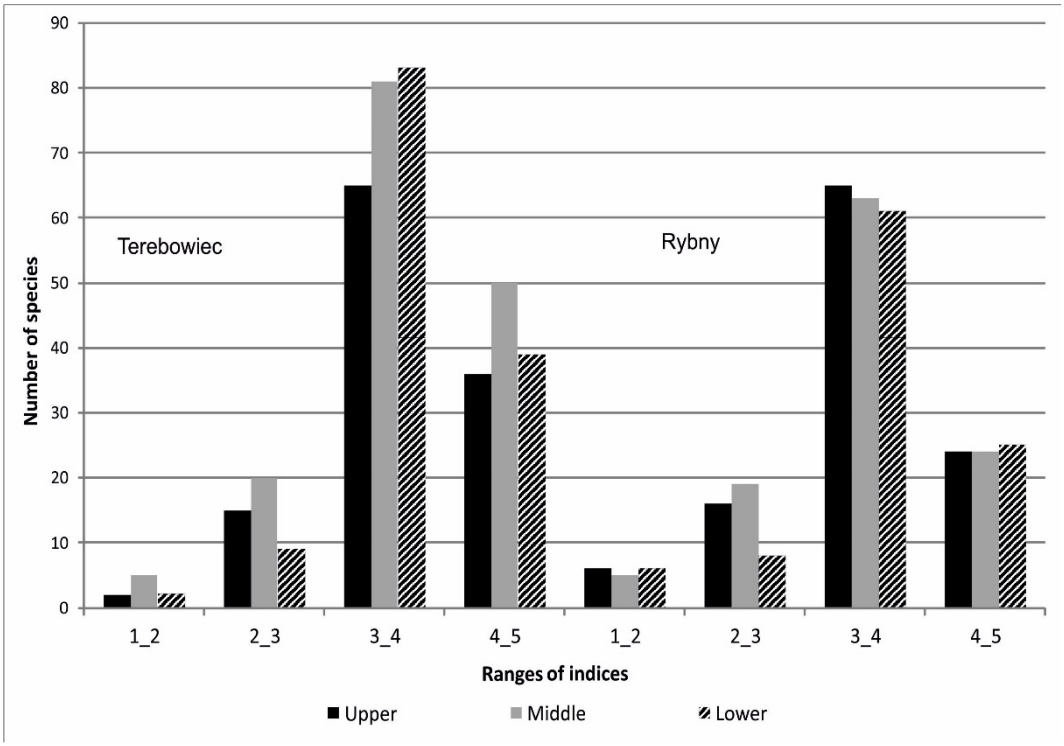


Fig.3a. Differentiation of species with various requirements to soil acidity (pH) in particular sections of streams analysed. Ranges of indices: 1_2 – strongly acid to acid, 2_3 – acid to middle acid, 3_4 – middle acid to neutral, 4_5 – neutral to alkaline

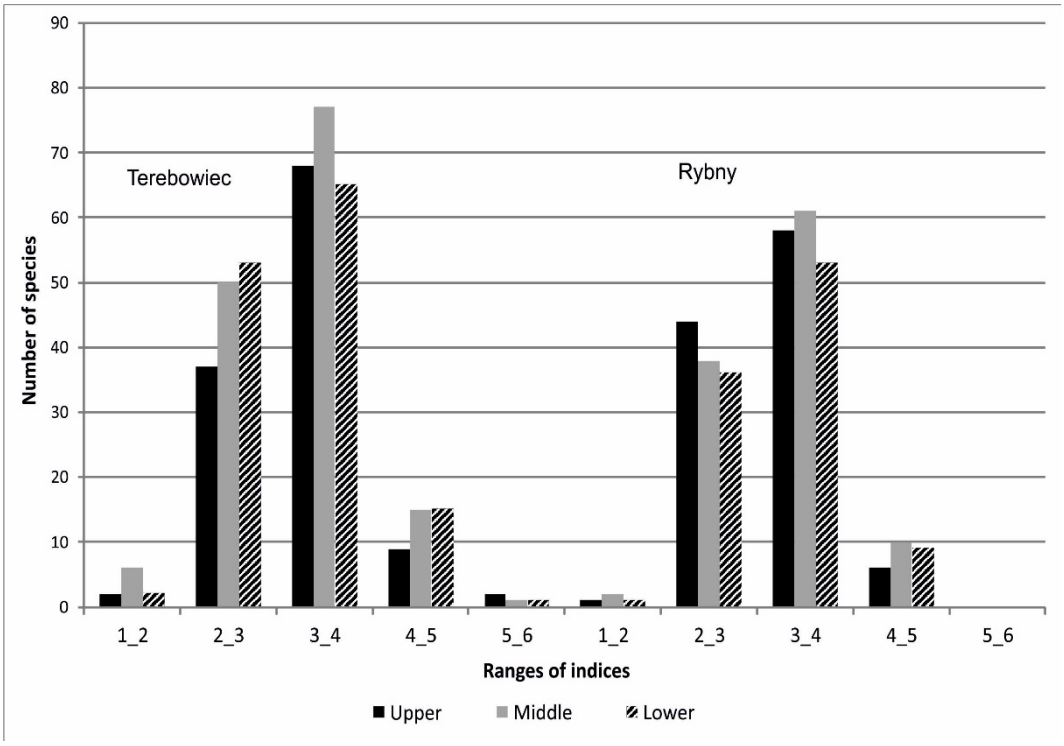


Fig.3b. Differentiation of species with various requirements to soil humidity in particular sections of streams analysed. Ranges of indices: 1_2 – dry to moderately dry, 2_3 – moderately dry to moderately moist, 3_4 – moderately moist to moist, 4_5 – moist to wet, 5_6 – wet to water

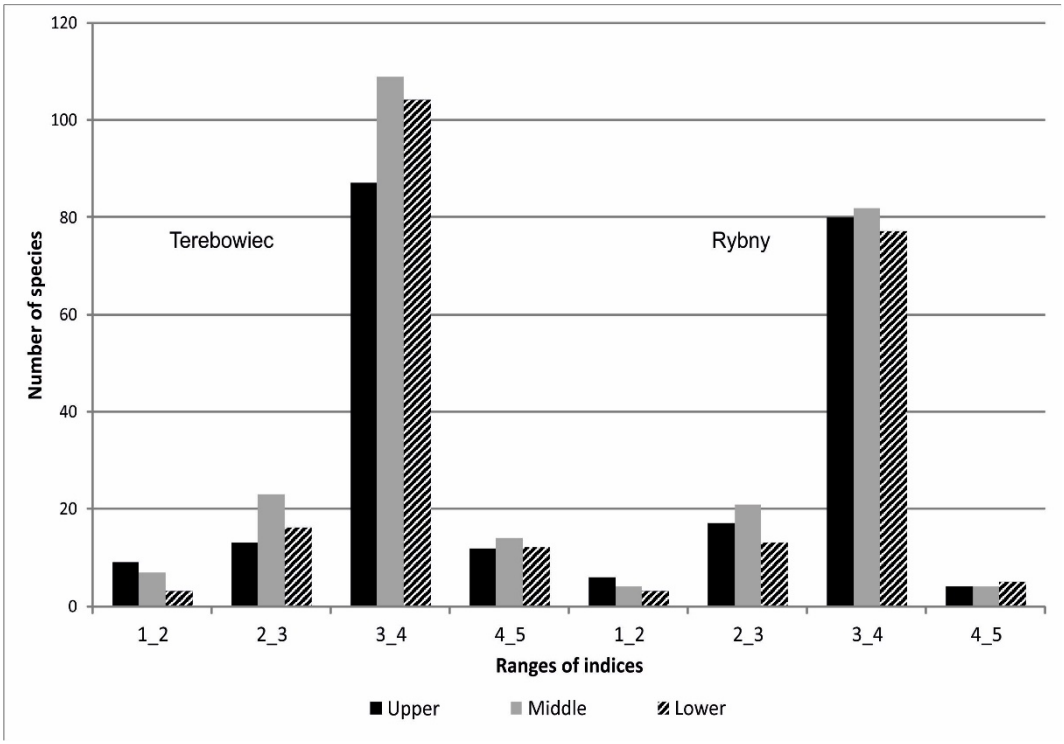


Fig.3c. Differentiation of species with various requirements to soil fertility in particular sections of streams analysed. Ranges of indices: 1_2 – extremely poor to poor , oligotrophic, 2_3 – poor to moderately poor; mesotrophic, 3_4 – moderately poor to fertile; eutrophic, 4_5 – fertile to extremely fertile

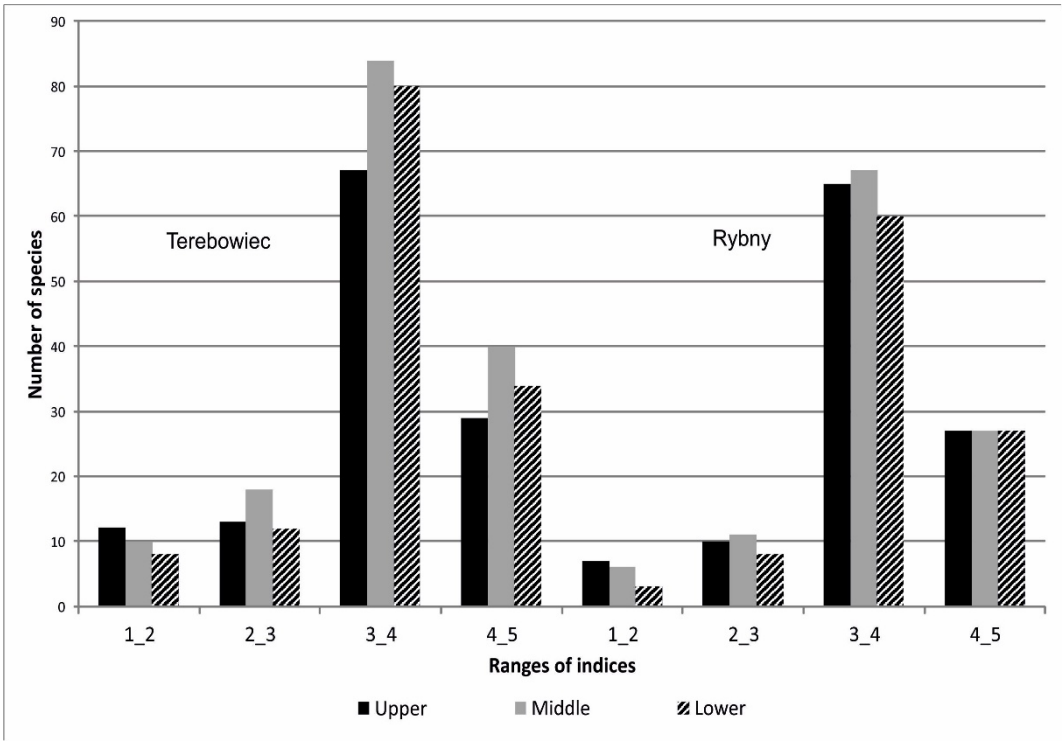


Fig.3d. Differentiation of species with various requirements to soil dispersion in particular sections of streams analysed. Ranges of indices: 1_2 – rocks, slits, debris, gravels, 2_3 – fine gravels to sand, 3_4 – sandy-loams, 4_5 – heavy loams to clays.

Summarising, it should be said that in spite of the quality and quantity differences between flora of both streams related to: (i) species richness, (ii) the adjacent communities, (iii) occurrence of species from higher altitudinal zones (tall-herbs), (Table 1, Fig. 2) the flora represents almost entire ecological spectrum that is connected with the specific character, structure and heterogeneity of the habitat.

Discussion

Alluvial gravels are one of the most interesting types of habitats in the natural environment of a montane area. Their structure resembles loose heaps formed by stones and gravels of various degrees of dispersal. In periods after floods they temporarily create a mosaic of microhabitats from small fens and silts suitable to be colonised by hydrophytes, through wet sandbanks to stony heaps with xerothermic conditions similar to those which are characteristic to rocks or dunes (BANÁSOVÁ *et al.*, 1994; EDWARDS *et al.*, 1999; DENISIUK, 2002; FRANCIS & GURNELL, 2006; UZIĘBŁO & CIAPAŁA, 2006; UZIĘBŁO, 2011).

These habitat extremes assembled over a relatively small area is conducive to forming short-lived plant configurations with unique compositions, where species of screes and xerothermic meadows are accompanied by species of deciduous forests, rushes or wet meadows (HOWARD-WILLIAMS & PICKMERE, 1994; HOLANDA *et al.*, 2005; UZIĘBŁO & CIAPAŁA, 2006). The specific conditions of a stream valley ecosystems cause that even if species appear only ephemerally for one vegetative season, they are able to undergo all life cycles and produce propagules which allow them to spread inside or outside of the valley thanks to temporal submergences or winds blowing within the interior of the valley (FRANCIS & GURNELL, 2006; UZIĘBŁO, 2011).

Flood, according to the vegetation period and the force of the flow, is an ecological factor of great importance (DENISIUK, 2002; VERVUREN *et al.*, 2003). On the one hand it washes away and deposits the sediments from silts, through sands, gravels to large stones, constantly modeling the structure of habitats of the bank zone (KRZEMIEŃ, 1976; EDWARDS *et al.*, 1999; DENISIUK, 2002; HOLANDA *et al.*, 2005); while on the other hand it transports diaspores, fragments of plants or all of the clumps of vegetation that were carried away from the upper parts of the stream valley (UZIĘBŁO, 2011). Moreover, the water that has subsided enriches poor, stony habitat with organic matter, and influences the temporal improvement of the humidity of soil from which water evaporates quickly into atmosphere (JAROLÍMEK *et al.*, 2000; FRANCIS & GURNELL, 2006). The relatively frequent influence of submergences limits interspecific competition as well, which particularly favors plants that are less resistant to this factor (BANÁSOVÁ *et al.*, 1994; EDWARDS *et al.*, 1999).

All of these factors create the possibilities for plants of extremely different habitat requirements to grow. This is very uncommon in a natural environment because most frequently species of similar requirements gather to form characteristic types of plant communities. This specific and mostly accidental species composition on gravels does not form any stable structure which could be classified as any plant association. Even *Petasitetum kablikiani* phytocoenoses, which occurred in this altitudinal zone as a dominant unforested association on alluvia, were distinguished by a very unstable species composition with over 90% sporadic species (UZIĘBŁO, 2011).

Relatively small number of species characteristic to poor and especially rocky, gravel habitats is rather surprising (Fig. 3d; indices 1-2), because we could expect that the type of habitat should have a larger group of specialized, stenotypic species. With such a range of abundance of particular ecological group of species which was noted we could state, that gravel bars can play a role of habitat for wide ecological spectrum of plants, but mainly as a vicarious or supportive habitat for forest and meadow plants in the event of any disturbances. There is an interaction between adjacent phytocoenoses and gravel bars because both of them can be a reservoir for diaspores for each other. Spreading of plants can occur in

two directions – along the valley or across it (seed bank, seed rain, distant transportation). These movements can also be a source of diaspores coming from communities other than the nearest to the stream.

Therefore the main characteristics of gravel vegetation could be defined as: significant ecological heterogeneity, unstable qualitative composition, distinct dependence on adjacent vegetation.

Both analysed streams are within the area of national parks which are biosphere reserves, thus the habitats and all natural processes are under protection. Particular attention in environmental management should be paid to naturally shaped gravel bars, especially in conditions of anthropogenic pressure outside the national parks and reserves. Legal base for protection of this kind can be found in EU Habitat Directive.

Conclusions

1. The gravel bars of montane streams create suitable conditions for plant of extremely different habitat requirements (or tolerance).

2. On alluvial gravels the highest share of flora representing adjacent vegetation is evidence that communities surrounding the streams are an important source of diaspores. Quantitative differences between the contributions of species coming from particular syntaxa reflect the local differentiation of ecosystems surrounding the streams.

3. The abundance of particular ecological groups of species indicates on a fact that in some circumstances gravel bars can play in environment a role of vicarious/supportive habitat for forest and meadow vegetation.

4. The gravel bars reveal the highest biodiversity on species level in comparison with habitats typical for mountain stream valleys (forest, meadow and tall-herb).

Acknowledgements

We thank Mrs. Michelle Simmons for proof reading of the English version of the text and an anonymous Reviewer for his valuable comments and notices concerning an earlier version of the manuscript.

References

BANÁSOVÁ H., H. OŤAHEĽOVÁ., I. JAROLÍMEK, M. ZALIBEROVÁ, Š. HUSÁK. 1994. Morava river floodplain vegetation in relation to limiting ecological factors. - *Ekológia, Bratislava*, 13: 24-262.

DAVIES C.E., D. MOSS, M.O. HILL. 2004. *EUNIS Classification revised 2004.* Report to: European Environment Agency, European Topic Centre on Nature Protection and Biodiversity. Available at: [www.eea.europa.eu]. Accessed: 23.07.2014.

DENISIUK Z. 2002. *Strategy of maintenance the bio- and landscape diversity in naturally valuable areas affected by flood disaster.* Cracow. Institute of Nature Protection Polish Academy of Sciences.

DENISIUK Z., J. KORZENIAK. 1999. Non-forest plant communities of valley areas of the Bieszczady National Park. – In: *Monografie Bieszczadzkie*, vol. 5, pp. 1-162. (In Polish, English summary).

EDWARDS P.J., J. KOLLMANN, A.M. GURNELL, G.E. PETTS, K. TOCKNER, J.V. WARD. 1999. A conceptual model of vegetation dynamics on gravel bars of a large Alpine river. - *Wetland Ecology Management,* 7(3): 141-153. DOI: 10.1023/A:1008411311774.

ELLENBERG H., H.E. WEBER, R. DÜLL, V. WIRTH, W. WERNER, D. PAULISSE. 2001. *Zeigerwerte von Pflanzen in Mitteleuropa,* Third ed. Scripta Geobotanica, vol. 18, pp. 1–248. (In German, English summary).

ELLENBERG H. 2009. *Vegetation Ecology of Central Europe*. Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, Delhi. Cambridge University Press.

FRANCIS R.A., A.M. GURNELL. 2006. Initial establishment of vegetative fragments within the active zone of a braided gravel-bed river (River Tagliamento, NE Italy). - *Wetlands*, 26(3): 641-648. DOI: 10.1672/0277-5212(2006)26[641:IEOVFW]2.0.CO;2

HOLANDA F.S.R., L. GALVÃO DA CUNHA SANTOS, C.M. DOS SANTOS, A.P. BARRETO CASADO, A. PEDROTTI, G.T. RIBEIRO. 2005. Riparian vegetation affected by bank erosion in the Lower São Francisco River, Northeastern Brazil. - *Revista Árvore*, 29(2): 327-336. DOI: 10.1590/S0100-67622005000200016.

HOWARD-WILLIAMS C., S. PICKMERE. 1994. Long-term vegetation and water quality changes associated with the restoration of a pasture stream. - In: Collier K.J. (Ed.). *Restoration of aquatic habitats*. Wellington. Department of Conservation, pp. 93-109.

JAROLÍMEK I., H. BANÁSOVÁ, H. OŤAHEĽOVA. 2000. Changes in alluvial grassland vegetation in relation to flood dynamics and soil moisture. - *Ekológia, Bratislava*, 19: 39-53.

KASPROWICZ M. 1996. Differentiation and transformations of vegetation of montane forest belts in the Babia Góra massif (Western Carpathians). – *Idee ekologiczne,* 9(3): 1-215. (In Polish, English summary).

KRZEMIEŃ K. 1976. Contemporary dynamics of the river bed of the Konina stream in the Gorce Mts. - *Folia Geographica Series Geographica-Physica*, 10: 87-122.

MATUSZKIEWICZ W. 2012. Guidebook to determination of plant communities in Poland. – In: Zienkiewicz I. (Ed.). *Vademecum Geobotanicum* 3. Warsaw. PWN.

MICHALIK S., A. SZARY. 1997. Forest communities of the Bieszczady National Park. - *Monografie Bieszczadzkie*, 1: 1-175. (In Polish, English summary).

MIREK Z., H. PIĘKOŚ-MIRKOWA, A. ZAJĄC, M. ZAJĄC. 2003. *Flowering plants and Pteridophytes of Poland. A checklist.* Cracow. Institute of Botany Polish Academy of Sciences.

NILSSON C. 1987. Distribution of stream-edge vegetation along a gradient of current velocity. - *Journal of Ecology,* 75(2): 513-522. DOI: 10.2307/2260430.

NILSSON C., G. GRELSSON, M. JOHANSSON, U. SPERENS. 1989. Patterns of plant species richness along riverbanks. - *Ecology,* 70: 77-84. DOI: 10.2307/1938414.

STATSOFT INC. 2011. *STATISTICA (Data analysis software system),* Vers. 10. [http://www.statsoft.com].

UZIĘBŁO A.K. 2001. The processes of overgrowing with plants the gravel heaps formed after flash flood of 1997 in the Babiogórski National Park. Preliminary studies. - *Ekológia, Bratislava*, 20, Suppl 4: 265-270.

UZIĘBŁO A.K. 2011. *Petasites kablikianus* Tausch ex Berchtold as a pioneer species and its abilities to colonise initial habitats. Katowice. *Scientific Papers of the University of Silesia,* 2886, 233 p.

UZIĘBŁO A.K., SZ. CIAPAŁA. 2006. Floristic and ecological diversity of the alluvial vegetation in the Babia Góra Mt. massive. - *Ochrona Beskidów Zachodnich,* 1: 93-104.

VERVUREN P.J.A., C.W.P., M. BLOM, H. DE KROON. 2003. Extreme flooding events on the Rhine and the survivaland distribution of riparian plant species. - *Journal of Ecology*, 91(1): 135-146. DOI: 10.1046/j.1365-2745.2003.00749.x.

ZARZYCKI K., H. TRZCIŃSKA-TACIK, W. RÓŻAŃSKI, Z. SZELĄG, J. WOŁEK, U. KORZENIAK. 2002. E*cological indicator values of vascular plants of Poland.* Cracow. Institute of Botany Polish Academy of Sciences.

ZEMANEK B., T. WINNICKI. 1999. Vascular plants of the Bieszczady National Park. - *Monografie Bieszczadzkie*, 3: 1-249. (In Polish, English summary).

Received: 29.01.2015
Accepted: 12.03.2015