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DIVERSITY OF HYDROMORPHOLOGICAL CONDITIONS OF RIVERS IN THE LOWLAND AND MOUNTAIN CATCHMENT SCALE

ZRÓŻNICOWANIE WARUNKÓW HYDROMORFOLOGICZNYCH RZEK W SKALI ZLEWNI NIZINNEJ I GÓRSKIEJ

Summary. The nature of a river bed, in addition to water chemical parameters, is one of the main factors influencing the occurrence and development of aquatic flora and fauna. Heterogeneous in terms of the occurrence of natural morphological forms and elements, a habitat shows a high potential as a place where different organisms can settle in. This paper focuses on the presentation of the diversity of river habitats, depending on the altitude type of basins. The material for the analysis came from studies conducted in the catchment of the Wel River (lowland river) in 2009 and the Skawica River (mountain river) in 2011. The studies demonstrated differences in the characteristics of lowland and mountain river catchments including types of flows and river bed substrate. Factor analyses indicated trees and accompanying elements as the main factor differentiating habitat conditions in the studied river catchments. Flows and river bed material differentiate the environment of the mountain watercourses to a lesser extent than that of the lowland watercourses. The hydromorphological condition was indicated only as the third factor which differentiates a habitat for organisms.

Key words: river catchment, hydromorphology, river assessment, River Habitat Survey

Introduction

Adopted in 2000, the Water Framework Directive (WFD) significantly changed the approach to the assessment of surface waters. The need to assess the entire ecosystem, not just a small group of factors (physico-chemical parameters) was recognized. On this basis, surface waters are assessed in terms of organisms living in them and their habitats (hydromorphological and physico-chemical status). When assessing the ecological status according to the WFD, we should consider, among others, the altitude types (lowland, upland and mountain) of water bodies and the degree of their modification (natural, heavily transformed, artificial) (DIRECTIVE 2000/60/EC... 2000).

The reduction of natural conditions of watercourses was associated with the development of infrastructure in river valleys. Efforts taken to make greater economic use of river valleys were among the major factors leading to the loss of naturalness. Hydrotechnical works such as profiling and straightening of river channels, construction of bank revetments, embankments and flow control structures resulted in the hydromorphological degradation of fluvial ecosystems (ŻELAZO 2006).

Hydromorphological conditions of watercourses result from the interaction of water flow and sediment movement. Diverse hydrological regime and the processes of erosion, transport and accumulation change the morphology of watercourses. Both the hydrological regime of a river and the amount and type of sediment transported depend on the geographical characteristics of the catchment area and its use. Rivers with dominating slow flows have more stable beds, and thus morphological changes occur in them very slowly. Fast-flowing rivers have unstable beds which constantly evolve. On this basis, we can identify, among others, alpine river sections, with stones and rock fragments in the bottom substrate, and lowland river sections with sand and gravel bottom material (ŻELAZO and POPEK 2002).

River morphology is also modified by the type and intensity of river engineering works. In recent decades, we have been observing gravel exploitation, and replacement of multi-thread channels with straight single-thread channels with reinforced banks in mountain rivers (RADECKI-PAWLIK 2011). In lower reaches, as a result of river engineering, channels underwent a significant shortening (WYŻGA et AL. 2008). Watercourse regulation leading to an increase in agricultural land productivity and flood protection included mostly meander and oxbow lake cutoffs, straightening, deepening and building embankments, as well as the construction of drainage facilities affecting water level and the speed of flowing water (POFF et AL. 2003). This type of transformations takes place mainly in lowland rivers. Areas in the immediate vicinity of a watercourse are also often subjected to such transformations. Trees are removed, shrubs cut out and vegetation structure becomes uniform, which is a disadvantage as bank shrubs and trees serve as a buffer, especially in areas at risk of biogenic substance inflow (RYSZKOWSKI et AL. 1999). Under the influence of anthropogenic factors, river bed development processes get modified.

The aim of this paper is a comprehensive comparison of lowland and mountain rivers including hydrological and morphological aspects of both the river bed and the bank zone. The studies aimed at showing differences in the hydromorphological conditions of watercourses throughout the catchment areas which determine the quality of habitat for different groups of aquatic organisms.

Material and methods

The hydromorphological surveys were carried out using the Polish version of the River Habitat Survey method (RHS) (SZOSZKIEWICZ et AL. 2008). The RHS system is now very widely used in various studies to determine the hydromorphological conditions of local fluvial systems and to assess habitat for aquatic organisms (GEBLER and JUSIK 2012, STANISZEWSKI et AL. 2012). A single field study is carried out on a 500 m section of a river, determining the characteristics of the channel (e.g. bank material, bottom substrate, type of flow), and areas in the immediate vicinity of the watercourse. Field data also allow the calculation of a number of different synthetic hydromorphological indicators making it possible to compare different river sections.

The material used in this paper comes from the studies conducted in the Wel River and its main tributaries (a total of 19 sections), and the Skawica River and its tributaries (21 sections) (Fig. 1).

The Wel River is a left-bank and the largest tributary of the Drwęca River. The river is 107.5 km long, and the average grade is 1.17‰. The river catchment area of over 800 km^2 is located entirely within the Chełmińsko-Dobrzyński Lake District. The catchment is mainly used for intensive (60%) and extensive (12%) agricultural farming. There are also quite a lot of natural and semi-natural areas (27%). Sampling sections located in the Wel River basin are of six abiotic types (type 17 – sandy lowland stream, type 18 – gravel lowland stream, type 19 – sandy-clay lowland river, type 20 – gravel lowland river, type 24 – peat valley river, type 25 – watercourse connecting lakes; BŁACHUTA and PASZTELANIEC 2011).

Skawica is a left-bank tributary of the Skawa River. It is 24 km long, and the average grade of the river is more than 5‰. The Skawica catchment is 147 km^2 and is located within the Maków Beskids (Beskid Makowski). The basin is dominated mainly by forests (about 60%). All watercourses within the basin are flysch streams (type 12) (BIELAK 2012).

Results and discussion

The range of field measurements has resulted in a wealth of information on hydromorphological conditions of watercourses in the lowland and mountain basins. The collected material has enabled detailed examination of the river habitat diversity parameters in the selected catchments.

The primary analyses show significant differences in the hydromorphological conditions of both river catchments. The histograms present average percentage share of each type of flows (Figs. 2, 3) and the bottom substrate in individual catchments (Figs. 4, 5).

The analysis of flow distribution in individual catchments indicates significant differences in this element. Six different types of flows occurred in the lowland rivers, but two of them clearly dominated. The share of the smooth and swift flow was more than 80% of the summed lengths of the river sections studied. The presence of rapid flow was also clearly observed here. A small share of other flows indicates their occasional occurrence. Eight types of flows were reported in the Skawica basin. Rapid and rippled

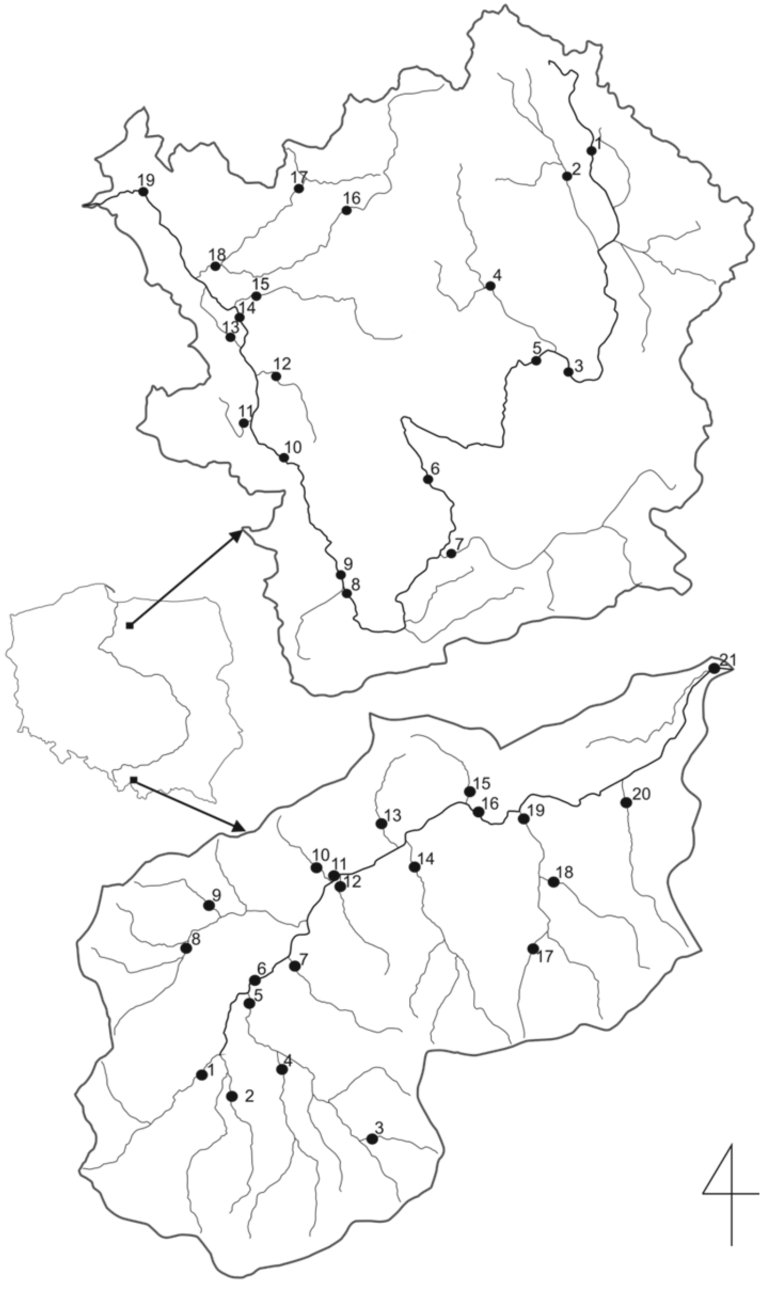

Fig. 1. Catchments of the Skawica River (down) and the Wel River (up) along with survey sites

Rys. 1. Zlewnia rzeki Skawicy (u dołu) oraz rzeki Wel (u góry) wraz z zaznaczonymi stanowiskami badawczymi

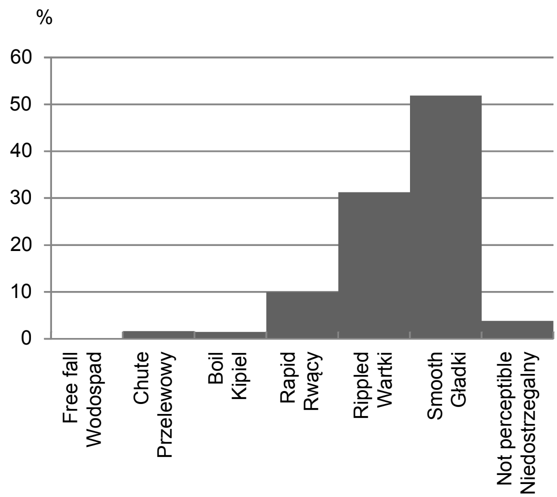

Fig. 2. Share of different flow types – the Wel River
Rys. 2. Udział różnych typów przepływów – rzeka Wel

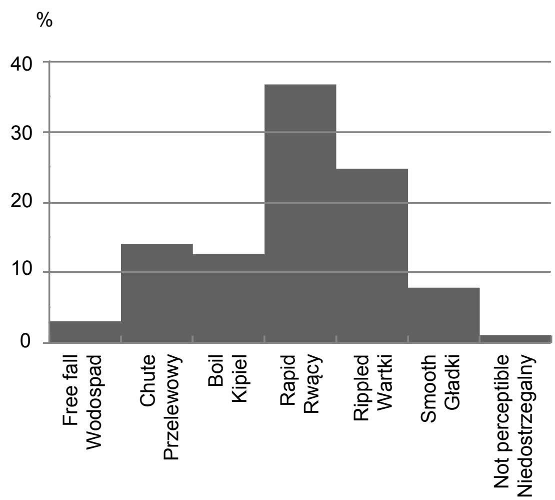

Fig. 3. Share of different flow types – the Skawica River
Rys. 3. Udział różnych typów przepływów – rzeka Skawica

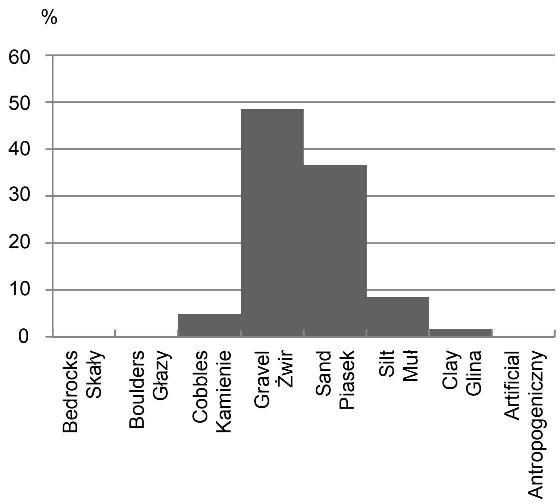

Fig. 4. Share of different fractions in the river bed material – the Wel River
Rys. 4. Udział różnych frakcji w materiale dennym – rzeka Wel

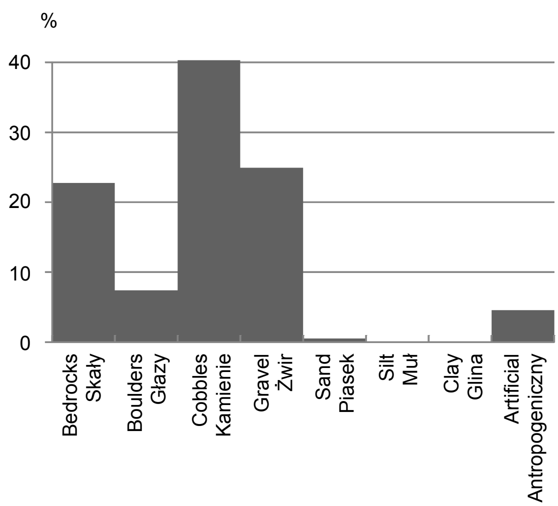

Fig. 5. Share of different fractions in the river bed material – the Skawica River
Rys. 5. Udział różnych frakcji w materiale dennym – rzeka Skawica

flows prevailed here, but their dominance was not as clear as in the case of the smooth and swift flows in the Wel River. In the studied mountain catchment, other dynamic flows were also present: billows and overflow, which may indicate the presence of waterfalls or other natural river bed structures (rapids, boulders, tree trunks) (SZOSZKIEWICZ et AL. 2008).

The analyses also showed significant differences in the bottom substrate in the studied catchments. The river bed material in the Wel River was dominated by two factions: gravel and sand which, in total, occurred in more than 80% of the length of the studied rivers. There was also a small share of silt, stones and clay, however, the share of any of these substrates did not exceed 10%. The Skawica River catchment was more heterogeneous in terms of the river bed material. The dominant substrate was stones (40%), followed by more than a 20% share of gravel and rock outcrops. There were also less than 10% of stones, as well as an even smaller proportion (less than 5%) of artificial material and a small amount of sand fraction.

The occurrence of the differences in the two above hydromorphological features of the rivers is directly related to topographic conditions of the studied catchments. Differences in the grade of the river beds affect the flow type which, in turn, in conjunction with geomorphological characteristics of the catchment, affects the river bed material. Both features have also a strong influence on the formation of different river bed structures. They determine habitat conditions for all major groups of organisms living in flowing waters (CORTES et AL. 2002).

The variability sets in the rivers of individual basins were distinguished using the Principal Components Analysis (PCA). This method is used for finding structures in a data set. In this paper, the PCA involved 27 variables describing the habitat of lowland rivers (Table 1) and 28 variables describing mountain rivers (Table 2). Differences in the selection of variables are related to the above-described flow types and substrates. In each PCA, variables that did not occur in a particular type of catchment (e.g. no silt in the mountain river substrate and no waterfalls in the lowlands) were rejected. Lack of these elements and the related lack of variability disqualify the data from the analysis.

In the set of habitat variables of the Wel and Skawica River basins, three main factors of variability were isolated, which explained respectively 60% and 54% of the variance. The results show that in both basins, the most important factor influencing the spatial variability of habitats are trees and accompanying elements (including shade and woody debris). Flows (in particular, swift and smooth) and natural elements of river bed morphology (outwashes, rapids, pools) are the second factor of variability in lowland rivers, explaining almost the same percentage of variance as the first factor. Subsequently, the fluvial environment diversity is affected by the hydromorphological condition. In the rivers of the Skawica basin, the second PCA factor is also associated mainly with flow types, although to a lesser extent than in the lowland catchment, and with pools, one of the morphological elements. In the Skawica River and its tributaries, the hydromorphological condition of the studied sections is only the third factor responsible for the diversity of habitats.

The PCA results indicate a very important role (main role) of trees located on bank slopes in shaping the structure of the river ecosystems. Associated morphological natural elements such as: underwater roots, woody debris, and fallen trees create a peculiar

Table 1. Results of factor analysis for the Wel River
Tabela 1. Wyniki analizy czynnikowej dla rzeki Wel

Variables Zmienne		1st factor Czynnik 1.	2nd factor Czynnik 2.	3rd factor Czynnik 3.
Hydromorphological indices Wskaźniki hydromorfologiczne	Habitat Quality Assessment (HQA) Wskaźnik naturalności siedliska	0.50	0.34	0.56
	Habitat Modification Score (HMS) Wskaźnik przekształcenia siedliska	–0.10	–0.09	**–0.84**
	River Habitat Quality (RHQ) Klasa stanu hydromorfologicznego	–0.26	–0.10	**–0.86**
Flow types Typy przepływu	Chute – Przelewowy	0.41	0.35	–0.34
	Boil – Kipiel	**0.74**	0.11	–0.14
	Rapid – Rwący	0.65	0.65	–0.08
	Rippled – Wartki	0.19	**0.77**	–0.28
	Smooth – Gładki	–0.50	**–0.75**	0.21
	Not perceptible – Niedostrzegalny	–0.32	–0.64	0.42
River bed material Substrat dna	Cobbles – Kamienie	**0.74**	0.04	–0.04
	Gravel – Żwir	0.18	**0.77**	0.03
	Sand – Piasek	–0.26	–0.51	–0.20
	Silt – Muł	–0.20	–0.42	0.31
	Clay – Glina	–0.03	0.03	–0.29
Trees and accompanying elements Zadrzewienia i elementy towarzyszące	Shading – Zacienienie	**0.74**	0.05	0.36
	Overhanging boughs Zwisające konary	0.61	0.24	0.47
	Exposed bank roots Korzenie na brzegu	**0.71**	0.01	0.13
	Underwater roots Korzenie podwodne	**0.73**	0.22	–0.02
	Fallen trees – Powalone drzewa	0.68	0.00	0.36
	Woody derbis – Rumosz drzewny	**0.81**	–0.01	0.23
Natural morphological features Naturalne elementy morfologiczne	Eroding cliffs Erodujące podcięcia brzegu	–0.05	0.44	0.33
	Stable cliffs Stabilne podcięcia brzegu	–0.19	0.64	0.34
	Side bars – Odsypy brzegowe	–0.03	0.66	–0.13
	Point bars – Odsypy meandrowe	–0.21	**0.70**	0.54
	Riffles – Bystrza	0.10	**0.83**	0.23
	Pools – Plosa	0.09	**0.72**	0.27
	Large bedrocks – Głazy	**0.78**	0.16	–0.14
Percentage of explained variance Procent wyjaśnionej wariancji		23%	23%	14%

Table 2. Results of factor analysis for the Skawica River
Tabela 2. Wyniki analizy czynnikowej dla rzeki Skawicy

Variables Zmienne		1st factor Czynnik 1.	2nd factor Czynnik 2.	3rd factor Czynnik 3.
Hydromorphological indices Wskaźniki hydromorfologiczne	Habitat Quality Assessment (HQA) Wskaźnik naturalności siedliska	0.62	–0.02	**0.73**
	Habitat Modification Score (HMS) Wskaźnik przekształcenia siedliska	–0.21	–0.31	**–0.71**
	River Habitat Quality (RHQ) Klasa stanu hydromorfologicznego	–0.14	–0.10	**–0.91**
Flow types Typy przepływu	Free fall – Wodospad	0.19	–0.11	0.09
	Chute – Przelewowy	0.34	0.57	0.05
	Boil – Kipiel	0.36	0.53	0.26
	Rapid – Rwący	0.05	0.68	–0.07
	Rippled – Wartki	–0.50	–0.66	0.08
	Smooth – Gładki	0.24	–0.67	–0.25
	Not perceptible – Niedostrzegalny	0.26	–0.53	–0.51
River bed material Substrat dna	Bedrocks – Skały	0.05	0.51	–0.14
	Boulders – Głazy	0.12	0.54	0.06
	Cobbles – Kamienie	–0.26	–0.04	0.10
	Gravel – Żwir	0.24	–0.50	0.41
	Artificial – Antropogeniczny	–0.11	–0.14	–0.59
Trees and accompanying elements Zadrzewienia i elementy towarzyszące	Shading – Zacienienie	**0.84**	0.22	0.24
	Overhanging boughs – Zwisające konary	**0.84**	0.25	0.05
	Exposed bank roots Korzenie na brzegu	**0.92**	0.14	0.13
	Underwater roots – Korzenie podwodne	0.65	0.14	–0.01
	Fallen trees – Powalone drzewa	**0.77**	0.03	0.42
	Woody derbis – Rumosz drzewny	**0.85**	–0.02	0.06
Natural morphological features Naturalne elementy morfologiczne	Eroding cliffs Erodujące podcięcia brzegu	0.29	–0.30	0.57
	Stable cliffs – Stabilne podcięcia brzegu	0.07	–0.27	0.52
	Side bars – Odsypy brzegowe	0.56	0.55	0.15
	Point bars – Odsypy meandrowe	0.50	0.00	0.13
	Riffles – Bystrza	0.52	0.12	0.50
	Pools – Plosa	–0.16	0.11	0.60
	Large bedrocks – Głazy	0.21	**0.74**	0.33
Percentage of explained variance Procent wyjaśnionej wariancji		22%	16%	16%

habitat for almost all the major groups of aquatic organisms being a substrate for vegetation (moss, algae), and creating the right conditions for the reproduction and development of aquatic animals (macroinvertebrates, fish) (CORTES et AL. 2002, SCHNEIDER and WINEMILLER 2008).

Less effect of flow on the diversity of habitat conditions within the mountain catchment area is likely due to small differences in this respect in the studied sections of the Skawica River and its tributaries. Despite seven different types of flows and the dominance of fast flows within the basin, there were no significant differences between the very survey sections. Most types of flows (five of seven) were recorded in all sections. Other authors point to a fairly important role of flows as a factor conditioning the variability of the aquatic environment, which confirms the above assumptions (FLEITUCH and AMIROWICZ 2005).

The analyses have shown that the hydromorphological condition of watercourses was distinguished only as the third factor of the PCA, so both types of the rivers tested exhibit less diversity in this respect than in the case of flows and a complex of attributes associated with wooded areas. Therefore, the morphological class is not the key factor determining the diversity of studied river habitats, which determines the biodiversity of rivers.

Conclusions

1. Significant differences between lowland and mountain rivers in the quantitative share of different types of river bed material and types of flows have been demonstrated. Similarities in the spatial variability of habitats have been demonstrated, which in both types of catchments to the greatest extent is determined by the diversity of elements related to wooded areas. These elements are particularly important for the diversity of some groups of organisms, including benthic macroinvertebrates in particular. Shading caused by trees on river banks significantly affects the growth of aquatic vegetation.

2. Flow diversity as a factor differentiating habitat conditions is more evident in the lowland catchment scale than the mountain one.

3. In both examined catchments the hydromorphological condition of watercourses is only the third factor differentiating the habitat.

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ZRÓŻNICOWANIE WARUNKÓW HYDROMORFOLOGICZNYCH RZEK W SKALI ZLEWNI NIZINNEJ I GÓRSKIEJ

Streszczenie. Charakter koryta rzecznego, obok parametrów chemicznych wody, jest jednym z głównych czynników kształtujących występowanie i rozwój flory i fauny wodnej. Heterogenne pod względem występowania naturalnych form i elementów morfologicznych siedlisko wykazuje duży potencjał osiedlania się różnych organizmów. Niniejsza praca skupia się na przedstawieniu zróżnicowania siedlisk rzecznych w zależności od typu wysokościowego zlewni. Materiał do analiz pochodził z badań prowadzonych w zlewni rzeki Wel (rzeka nizinna) w roku 2009 oraz w zlewni Skawicy (rzeka górska) w roku 2011. Wykazano różnice w charakterystyce cieków zlewni nizinnej i górskiej, m.in. typy przepływów oraz substrat dna. Analizy czynnikowe wskazały zdrzewnienia i elementy im towarzyszące jako główny czynnik różnicujący warunki siedliskowe w ciekach badanych zlewni. Przepływy i materiał korytowy w mniejszym stopniu różnicują środowisko cieków górskich niż nizinnych. Stan hydromorfologiczny został wskazany dopiero jako trzeci czynnik różnicujący siedlisko dla organizmów.

Słowa kluczowe: zlewnia rzeczna, hydromorfologia, ocena rzek, metoda River Habitat Survey

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