

## A faunistic and ecological characterization of the water mites (Acari: Hydrachnidia) of the Branew River (central-eastern Poland)

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**Keywords** lotic zone, lentic zone, *Lebertia rivulorum*, synecological groups, species diversity, anthropogenic transformation

**Abstract** A characteristic feature of the Hydrachnidia communities of the Branew River, distinguishing its fauna from that of other Polish rivers, was the very high abundance of species of the genus *Lebertia*. Species of this genus accounted for as much as 53.1% of the collected material. The most numerous was *Lebertia rivulorum*, which was caught in numbers not found in other Polish rivers. *Lebertia inaequalis* and *L. oblonga* were also abundant. The largest synecological groups were rheophiles and rheobionts (94.9% combined). More individuals (1494) and species (27) were caught in the lentic zone of the river than in the lotic zone (1291 ind., 25 sp.). The species most associated with the lotic zone was *L. rivulorum*. This species was caught mainly on a substrate of gravel and stones with a small amount of sandy sediments, sparsely covered with *Elodea canadensis*. The species most associated with the lentic zone was *Forelia variegator*. The most abundant species in the Branew River, *Hygrobatas setosus*, was caught in much higher numbers in the littoral zone than in the central part of the river. The high similarity of fauna was observed between the lotic and lentic zones, and much lower similarity between sites. The results indicate intensive species migration in the transverse profile of the river and low migration in the longitudinal profile. Higher species diversity was recorded in the lentic zone than in the lotic zone of the river – both in the river as a whole and at the individual sites. In the anthropogenically transformed stretch of the river (straightened riverbed, concrete dam, and concrete bottom), species diversity was significantly lower ( $H' = 1.83$ ) than in the natural stretch ( $H' = 2.37$ ). The results confirm literature data describing the negative impact of such transformations on Hydrachnidia communities. Despite anthropogenic transformations in parts of the river, the structure of the fauna (a very large proportion of rheobionts and rheophiles), as well as the physicochemical parameters of the water, is indicative of the good ecological condition of the river.

## Faunistyczna i ekologiczna charakterystyka wodopójek (Acari: Hydrachnidia) rzeki Branew (środkowo-wschodnia Polska)

**Słowa kluczowe** strefa lotyczna, strefa lenityczna, *Lebertia rivulorum*, grupy synekologiczne, species diversity, przekształcenia antropogeniczne

**Streszczenie** Cechą specyficzną zgrupowań Hydrachnidia rzeki Branew, odróżniającą jej faunę od innych rzek Polski, była bardzo duża liczebność gatunków z rodzaju *Lebertia*. Gatunki z tego rodzaju stanowiły aż 53.1% zebranego materiału. Najliczniejsza była *Lebertia rivulorum*, którą łowiono w liczebnościach niespotykanych w innych rzekach Polski. Ponadto, w dużych liczebnościach łowiono *L. inaequalis* i *L. oblonga*. Najliczniejszymi grupami synekologicznymi były reofile i reobionty (łącznie 94.9%). Więcej osobników (1494) i gatunków (27) złowiono w strefie lenitycznej rzeki niż w strefie lotycznej (1291 osobn., 25 gat.). Gatunkiem najbardziej związanym ze strefą lotyczną była *L. rivulorum*. *Lebertia rivulorum* łowiono przede wszystkim na dnie żwirowo-kamienistym z niewielkim udziałem osadów piaszczystych, skąpo porośniętym *Elodea canadensis*. Gatunkiem najbardziej związanym ze strefą lenityczną była *Forelia variegator*. Najliczniejszy gatunek w rzece Branew – *Hygrobates setosus*, łowiono zdecydowanie liczniej w strefie przybrzeżnej, niż w centralnej części rzeki. Stwierdzono duże podobieństwa faun między strefą lotyczną i lenityczną i znacznie mniejsze podobieństwa faunistyczne między stanowiskami. Uzyskane wyniki świadczą o intensywnej migracji gatunków w profilu poprzecznym rzeki i słabej migracji w profilu podłużnym. Większą różnorodność gatunkową notowano w strefie lenitycznej, niż lotycznej rzeki – zarówno w skali całej rzeki, jak i na poszczególnych stanowiskach. Na przekształconym antropogenicznie odcinku rzeki (wyprostowane koryto, betonowa zaporą, wybetonowane dno) stwierdzono znacznie niższą różnorodność gatunkową ( $H' = 1.83$ ) niż na odcinku naturalnym ( $H' = 2.37$ ). Uzyskane wyniki potwierdzają dane literaturowe opisujące negatywny wpływ takich przekształceń na zgrupowania Hydrachnidia. Mimo lokalnych przekształceń antropogenicznych, struktura fauny (bardzo duży udział ilościowy reobiontów i reofili), a także wartości wskaźników fizyczno-chemicznych wody, świadczą o dobrym stanie ekologicznym rzeki.

## Introduction

A comparison of the number of publications on the Hydrachnidia of standing and flowing water bodies in Poland reveals that lotic ecosystems have been much less researched than lentic ecosystems. Data on the water mites of flowing water bodies in lowland areas of Poland can be found in studies by Pieczyński (1960), Bazan-Strzelecka (1964, 1986), Biesiadka (1970, 1972), Biesiadka and Kasprzak (1977), Kowalik (1981), Cichocka (1996a, 1996b, 2006), Stryjecki (2009, 2010), Stryjecki, Pawłęga, Ścibior (2012), Stryjecki, Bańkowska, Szenejko (2018), Zawal and Sadanowicz (2012), Stryjecki and Kowalczyk-Pecka (2013a), Zawal and Kowalik (2013), Bańkowska, Kłosowska, Stryjecki, Zawal (2015) and Zawal et al. (2017). Characterizations of the Hydrachnidia communities of rivers in upland areas of Poland can be found in works by Kowalik (1981), Kowalik and Biesiadka (1981), Stryjecki and Kowalczyk-Pecka (2013b), Kowalik, Zawal, Buczyńska (2014), and Biesiadka, Kowalik, Ścibior (2015). The least researched by far are the rivers of mountainous areas and foothills. The most important studies on these areas include works by Kupiszewska (1965), Biesiadka (1974, 1979), and Biesiadka and Cichocka (1993). Among the studies cited above, those which take into account longer stretches of rivers or their entire course are of particular value (Bazan-Strzelecka, 1964; Biesiadka, 1970, 1979; Kowalik, 1981; Cichocka, 1996a, 2006; Zawal et al., 2017; Stryjecki et al., 2018). Given that the water mite fauna of flowing water bodies of Poland is less well known than that of standing water bodies, there is a need for research on flowing water bodies to provide a more complete faunistic and ecological characterization of the Hydrachnidia communities of these ecosystems.

In addition to the recognition of the fauna of these ecosystems, the intensification of river research can contribute to a better understanding of the habitat requirements and ecological character of some species, especially taxa found in both flowing and standing waters (e.g. *Hygrobates longipalpis* (Hermann, 1804), *Forelia variegator* (Koch, 1837), and *Teutonia cometes* (Koch, 1837)). Another objective of such research is the provision of new data on the habitat preferences of taxa previously treated as one species, but currently recognized as two (or more) separate species. An example is *Hygrobates setosus* Besseling, 1942, a sister species of *H. nigromaculatus* Lebert, 1879. The two species, *H. setosus* associated with rivers and *H. nigromaculatus* with lakes, were not ultimately distinguished until relatively recently (Martin, Dabert, Dabert, 2010). Many papers on flowing water bodies (Kowalik, 1981; Kowalik, Biesiadka, 1981; Cichocka, 1996a, 2006; Martin, 1996, 1997; Martin, Speth, 1996; Gerecke, 2002) include *H. nigromaculatus* in the list of species, although it is highly likely that the data presented pertain to the river species *H. setosus*. The presentation of further data on the habitat preferences of *H. setosus* is important because it enables a more complete understanding of the habitat requirements of this species.

Research on rivers, especially in areas that have previously been overlooked, can provide new information on species distribution and population sizes. Data from areas that have previously been poorly researched are of particular importance for taxa considered to be rare. Such data contribute to a better understanding of the biology and ecology of these species.

Polish rivers have been subject to increasing anthropogenic transformation, most commonly water pollution, but also other forms of human impact, such as regulation of the river bed and modification of the structure of the banks and bottom of watercourses (Biesiadka, 1972; Biesiadka, Kasprzak, 1977; Kowalik, 1981; Kowalik, Biesiadka, 1981; Cichocka, 1996a; Zawal, Kowalik, 2013; Stryjecki et al., 2018). The effect of human impact on river ecosystems is increasing impoverishment of fauna. Therefore, there is an urgent need to document the state of the Hydrachnidia fauna of rivers, especially natural and unpolluted watercourses.

The aim of the study was a detailed faunistic and ecological analysis of the water mites of the small lowland Branew River (central-eastern Poland). The study analysed variation in environmental factors, the species composition of the fauna, dominance structure, species diversity, faunistic similarities, distribution of fauna in the transverse and longitudinal profiles of the river, and synecological structure, as well as the habitat preferences of selected species.

## Study area and sites

The Branew is a small lowland river about 22 kilometres long (Geoportal, 2019). It is a right-bank tributary of the Bukowa River. The river begins at the edge of Roztocze with a high-outflow source at an altitude of 245 m (50° 43' 57.95" N; 22° 33' 33.67" E), and finishes its course, emptying into the Bukowa, in the village of Momoty (50° 43' 57.95" N; 22° 33' 33.67" E). The area of the Branew basin is 73.4 km<sup>2</sup> (Michalczyk, Wilgat, 1998). The river catchment is narrow, running nearly north to south, with its upper part reaching Roztocze. Apart from the source and the short stretch of the river located in the edge zone of the Western Roztocze mesoregion and the Roztocze macroregion, the river flows through the Biłgoraj Plain mesoregion, which is part of the Sandomierz Basin macroregion (Kondracki, 2014). In the upper reaches, to about half its length, the river flows through open areas. The lower half of the river is in densely forested areas. The Branew River flows through the eastern part of the Janów Forests Landscape Park, crossing it from north to south. The park is located at an altitude of 150–220 m a.s.l., and its relief is not highly diverse. The forests are crossed by numerous parallel valleys of small rivers and streams

flowing from the edges of upland areas. An important element of the hydrographic network of the park is its numerous swamps and peatlands. Many wetlands and fragments of river valleys are occupied by large fish pond complexes situated among forests (Rąkowski et al., 2004).

Two sites were selected on the Branew River.

**Site 1** – in Flisy (50° 39' 33.65" N; 22° 29' 33.97" E)

A site located about 11 km from the source. This stretch of the river was located in an open area, surrounded by meadows. This part of the river has been transformed by human activity. The transformation involved straightening of the river bed, the partition of the river with a concrete dam, and concrete reinforcement of the bottom for a stretch of a dozen or so metres. The river was 1.5–2.0 m wide and 0.4–0.6 m deep upstream of the dam and 2.0–2.5 m wide and 0.2–0.4 deep downstream. The sediments were diverse, occurring in stretches with a stony, sandy and silty bottom. Below the dam, in the stretch with concrete reinforcement, the bottom consisted of gravel and stones with a small share of sandy sediment. In the shallow water of the lentic zone there were flooded grasses and sedges, as well as isolated specimens of *Juncus effusus* L. and *Equisetum fluviatile* L. In the deeper water of the lentic zone, there was abundant *Elodea canadensis* Michx. In the lotic zone, both upstream and downstream of the dam, *Elodea canadensis* Michx. occurred in places, but less abundantly than in the lentic zone.

**Site 2** – at Porytowe Wzgórze (50° 38' 05.27" N; 22° 27' 58.75" E)

A site located about 15 km from the source. This stretch of the river was surrounded by forest, with numerous meanders. It can be described as natural, without anthropogenic transformations. The river was 3.0–4.0 m wide and 0.1–1.0 m deep. Sandy sediments were dominant over most of the transverse profile of the river, giving way to sandy and silty sediments further from the central part of the river. Silty sediments were dominant by the shores and in pools. There was also a stretch with a stony bottom at this site. *Sparganium erectum* L. em. RCHB. s. s. grew in the marginal pools and to some extent midstream, forming large clumps. *Elodea canadensis* was present as well. The banks were covered with flooded grasses – *Poa palustris* L. and *Phalaris arundinacea* L.

## Methods and material

### Field research

The field research was conducted from April to November 1996 and from March to October 1997. Samples were taken once a month. At each, site samples were taken from two zones of the river: the lotic zone (in the middle of the river) and the lentic zone (at the riverbank). Sampling was done with a hand net. The net had a round frame of 0.25 m in diameter and 250 µm mesh size. A single sample was taken over a distance of about 10 m. A total of 64 samples were collected. The material comprised a total of 2,785 individuals. The material collected in the field was transported to the laboratory and segregated on white cuvettes. The works used to identify water mites were Viets (1936), Sokolov (1940), Davids et al. (2007), Di Sabatino, Gerecke, Gledhill, Smit (2010), and Gerecke, Gledhill, Pešić, Smit (2016). Species nomenclature and systematics were adopted according to Davids et al. (2007), Di Sabatino et al. (2010) and Gerecke et al. (2016). Allocation of species to synecological groups was based on literature data (Smit, van der Hammen, 2000; Davids et al., 2007; Di Sabatino et al., 2010; Gerecke et al., 2016), taking into

account the specific characteristics of Poland (Biesiadka, 2008) and the region under investigation (Kowalik, 1984).

During the collection of hydrobiological samples, the basic physical and chemical indicators of the water were measured: temperature ( $^{\circ}\text{C}$ ), pH, electrolytic conductivity ( $\mu\text{S}/\text{cm}$ ), dissolved oxygen ( $\text{mg O}_2/\text{l}$ ), and water saturation with oxygen (%). The measurements were made using a Slandi kit (TM204 thermometer, PH204 pH meter and CM204 conductivity meter) and an Elmetron CX401 multifunction meter. The water current was determined by the floating object method, by measuring the object's flow time over a distance of 10 m.

## Statistical analyses

Descriptive statistics (sums, means, range, and standard deviation) were calculated using PAST ver. 3.16/2019 software (Hammer, Harper, Ryan, 2001). The software was also used to calculate the Shannon-Wiener index ( $H'$ ) and to perform correspondence analysis (CA). Analyses of quantitative faunistic similarities based on the Bray-Curtis formula were carried out using BioDiveristy Pro ver. 2 software (McAleece, Gage, Lamshead, Paterson, 1997). Similarity dendrograms were generated using BioDiveristy Pro software. Group Average was used to create clusters.

The normality of the data distribution was checked by the Shapiro-Wilk test. The data were tested for homogeneity of variance using Levene's test. The t-test was used to compare two independent samples when data had a normal distribution and the variance was homogenous. The Mann-Whitney U test ( $Z$ ) was used to compare two independent samples when data did not have a normal distribution. The Spearman correlation coefficient ( $R_s$ ) was used to determine the relationship between parameters. All tests were carried out in Statistica 13.1 software. The statistical significance level was set at  $p = 0.05$ .

## Results

### Abiotic environmental parameters

The water temperature in the river during the study period ranged from 2.7 to 18.1 $^{\circ}\text{C}$ . Both extreme values were found at site 2 (Table 1). The average water temperature was higher at site 2 than at site 1, but the differences between sites were not statistically significant ( $t_{30} = -0.6397$ ,  $p = 0.5171$ ). Water pH ranged from 6.20 to 8.59 (Table 1). Both extreme values were recorded at site 1. The average value of this parameter was slightly higher at site 1 (7.75) than at site 2 (7.25). The differences were not statistically significant ( $t_{29} = 1.2038$ ,  $p = 0.2383$ ). Electrolytic conductivity during the study ranged from 239 to 970  $\mu\text{S}/\text{cm}$ . Both extreme values were found at site 1 (Table 1). Electrolytic conductivity was the only parameter for which the differences between sites were statistically significant ( $t_{31} = 2.3287$ ,  $p = 0.0265$ ). Markedly higher average electrolytic conductivity was recorded at site 1 (508  $\mu\text{S}/\text{cm}$  vs 384  $\mu\text{S}/\text{cm}$  at site 2). It should be emphasized that this parameter was highly variable during the study at both site 1 and site 2 ( $\pm\text{SD}$  181.31 and  $\pm\text{SD}$  114.23, respectively). Better oxygen conditions prevailed at site 1 (Table 1), with somewhat higher oxygen content in the water (on average 8.95  $\text{mg O}_2/\text{l}$  vs 8.69  $\text{mg O}_2/\text{l}$  at site 2) and higher oxygen saturation (86.1% vs 80.7% at site 2). The differences in dissolved oxygen content and oxygen saturation were not statistically significant ( $t_{23} = 0.3235$ ,  $p = 0.7491$ ;  $t_{23} = 0.8387$ ,  $p = 0.4102$ ). Water current values ranged from 0.26 to 0.55 m/s (Table 1). Statistically faster water flow was

recorded at site 2 (on average 0.33 m/s vs 0.38 m/s at site 1). The differences in water current between sites were not statistically significant ( $Z = 1.8112$ ,  $p = 0.0701$ ).

Table 1. Values of analyzed environmental parameters (range; mean;  $\pm$ SD)

Parameter	Site 1	Site 2
Temperature (°C)	2.8–16.4; 10.6; $\pm$ 4.32	2.7–18.1; 11.5; $\pm$ 4.23
pH	6.20–8.59; 7.75; $\pm$ 0.54	7.26–8.24; 7.55; $\pm$ 0.34
Electrolytic conductivity ( $\mu$ S/cm)	239–970; 508 <sup>a</sup> ; $\pm$ 181.31	251–695; 384 <sup>b</sup> ; $\pm$ 114.23
Dissolved oxygen (mg O <sub>2</sub> /l)	5.70–12.10; 8.95; $\pm$ 2.00	5.90–12.40; 8.69; $\pm$ 1.88
Water saturation with oxygen (%)	55.0–117.5; 86.1; $\pm$ 17.95	54.0–100.4; 80.7; $\pm$ 14.37
Water current (m/s)	0.28–0.55; 0.38; $\pm$ 0.08	0.26–0.55; 0.33; $\pm$ 0.07

<sup>a</sup>, <sup>b</sup> – the differences in the values between particular sites were statistically significant.

## Water mite fauna

### General characteristics, faunistic similarities and species diversity

A total of 2,785 individuals belonging to 32 species, 18 genera and 12 families were caught (Table 2). The dominant species in the material (dominance  $>5\%$ ) were *Hygrobates setosus* (18.8%), *Lebertia rivulorum* K. Viets, 1933 (16.1%), *Sperchon clupeifer* Piersig, 1896 (13.3%), *Lebertia inaequalis* Koch, 1837 (12.9%), *L. fimbriata* Thor, 1899 (11.5%) and *L. oblonga* Koenike, 1911 (10.3%). More individuals (1554) were caught at site 1 (Table 2), but the difference in the numbers of individuals caught at the two sites was not statistically significant ( $Z = 1.8322$ ,  $p = 0.0669$ ). Far more species (31) were caught at site 2 (Table 2). A statistically significant correlation was found between the number of individuals caught and the number of species recorded ( $R_s = 0.69$ ,  $p < 0.05$ ).

More individuals and species were recorded in the lentic zone of the river (1494 ind., 27 sp.), than in the lotic zone (1291 ind., 25 sp.), but the differences in the numbers of individuals caught in the two zones were not statistically significant ( $Z = 0.4541$ ,  $p = 0.6475$ ). The dominant species in the lentic zone were *Hygrobates setosus* (26.9%), *Sperchon clupeifer* (12.9%), *Lebertia inaequalis* (11.5%), *L. fimbriata* (11.2%), *L. rivulorum* (8.8%), *L. oblonga* (7.5%) and *Forelia variegator* (6.6%). The dominant species in the lotic zone were *Lebertia rivulorum* (24.6%), *L. inaequalis* (14.5%), *Sperchon clupeifer* (13.6%), *Lebertia oblonga* (13.4%), *L. fimbriata* (13.1%) and *Hygrobates setosus* (9.3%).

The fauna of the two sites was 36.3% similar, whereas the water mite communities of the lotic zone and the lentic zone of the river were 70.1% similar. Within each site, the similarity of Hydrachnidia communities of the lotic and lentic zones was nearly identical: 67.57% at site 1 and 67.60% at site 2 (Figure 1).

Table 2. Qualitative and quantitative composition of water mite fauna found in the Branew River. SG – synecological group; Rb – rheobionts, Rp – rheophiles, St – stagnobionts and stagnophiles, S/R – species occurring both in running and stagnant waters, Cf – crenophiles; le – lentic zone of the river, lo – lotic zone of the river, To – total at the site

No.	Species	SG	Site 1			Site 2			In the River		
			le	lo	To	le	lo	To	le	lo	To
1.	<i>Hydrachna globosa</i> (De Geer)	St				2		2		2	
2.	<i>Hydrodroma torrenticola</i> (Walt.)	Rp					1	1		1	
3.	<i>Hydryphantes placationis</i> Thon	St				1		1		1	
4.	<i>Hydryphantes planus</i> Thon	St				2		2		2	
5.	<i>Lebertia fimbriata</i> Thor	Rp	26	41	67	124	125	249	150	166	316
6.	<i>L. oblonga</i> Koen.	Rp	9	15	24	102	155	257	111	170	281
7.	<i>L. rivulorum</i> Viets	Rb	115	293	408	14	19	33	129	312	441
8.	<i>L. inaequalis</i> (Koch)	Rp	105	143	248	64	41	105	169	184	353
9.	<i>L. insignis</i> Neum.	Rp		5	5	1	2	3	1	7	8
10.	<i>L. pilosa</i> Maglio	Rp	8	2	10	115	18	56	46	20	66
11.	<i>L. porosa</i> Thor	Rp		1	1					1	1
–	<i>Lebertia</i> sp. (deutonymphs)	–	3	4	7	3	4	7	6	8	14
12.	<i>Sperchon clupeiifer</i> Piers.	Rb	177	147	324	14	25	39	191	172	363
13.	<i>S. setiger</i> Thor	Rb	1		1	2	1	3	3	1	4
–	<i>Sperchon</i> sp. (deutonymphs)	–	7	3	10				7	3	10
14.	<i>Sperchonopsis verrucosa</i> (Protz)	Rb	3	3	6	1	–	1	4	3	7
15.	<i>Teutonia cometes</i> (Koch)	S/R				5	–	5	5		5
16.	<i>Torrenticola amplexa</i> (Koen.)	Rb					1	1		1	1
17.	<i>Aturus scaber</i> Kram.	Rb					1	1		1	1
18.	<i>Parabrachypoda modesta</i> (Koen.)	Rp				3	2	5	3	2	5
19.	<i>P. montii</i> (Maglio)	Rp				18	3	21	18	3	21
20.	<i>Atractides distans</i> (Viets)	Rb	12	3	15	5	5	10	17	8	25
21.	<i>A. nodipalpis</i> Thor	Rb	10	26	36	5	10	15	15	36	51
22.	<i>A. ovalis</i> Koen.	S/R				–	1	1		1	1
–	<i>Atractides</i> sp. (deutonymphs)	–				1	2	3	1	2	3
23.	<i>Hygrobates calliger</i> Piers.	Rb				1	2	3	1	2	3
24.	<i>H. fluviatilis</i> (Ström)	Rb	20	12	32	5	6	11	25	18	43
25.	<i>H. longipalpis</i> (Herm.)	S/R				9	1	10	9	1	10
26.	<i>H. setosus</i> Bess.	Rp	261	85	346	135	33	168	396	118	514
–	<i>Hygrobates</i> sp. (deutonymphs)	–	3	1	4	4	7	11	7	8	15
27.	<i>Forelia variegator</i> (Koch)	S/R	9	1	10	88	15	103	97	16	113
28.	<i>Nautarachna crassa</i> (Koen.)	Rp				2	–	2	2		2
–	<i>Piona</i> sp. (deutonymphs)	–				1	–	1	1		1
29.	<i>Tiphys ornatus</i> Koch	St				2	–	2	2		2
30.	<i>Wettina podagrica</i> (Koch)	Cf				4	1	5	4	1	5
31.	<i>Mideopsis crassipes</i> Soar	Rp				55	21	76	55	21	76
32.	<i>M. roztoczensis</i> Bies. et Kow.	Rp				13	–	13	13		13
–	<i>Mideopsis</i> sp. (deutonymphs)	–				1	4	5	1	4	5
Total individuals			769	785	1,554	725	506	1,231	1,494	1,291	2,785
Total species			13	14	15	27	23	31	27	25	32

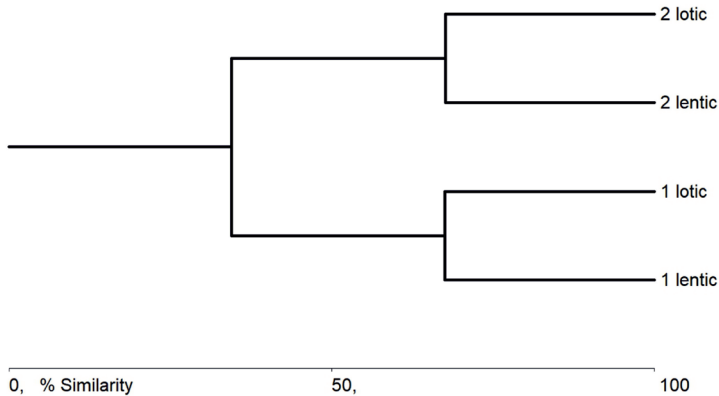


Figure 1. Faunistic similarities between zones at particular sites in the Branew River. 1–2 – sites, lentic – lentic zone, lotic – lotic zone

The total species diversity of the Hydrachnidia communities of the Branew River was  $H' = 2.33$ . Higher species diversity was found at site 2 ( $H' = 2.37$ ) than at site 1 ( $H' = 1.83$ ). Higher species diversity was recorded in the lentic zone than in the lotic zone of the river, both on the scale of the entire river and at each of the sites (Figure 2).

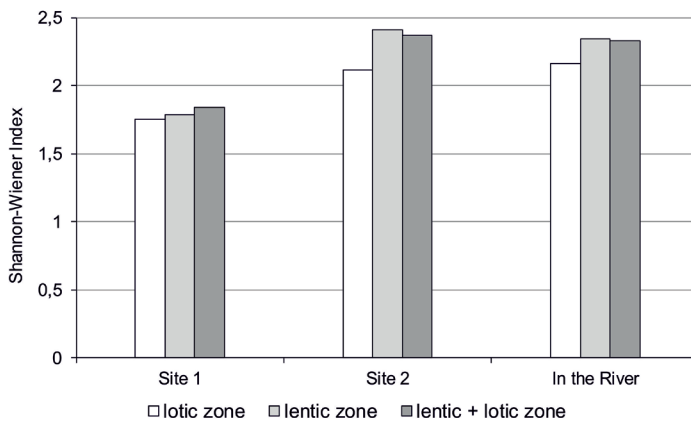


Figure 2. Shannon-Wiener index values at particular sites and lentic and lotic zones in the Branew River

### Synecological structure of the fauna

Rheophiles were the largest synecological group in the Branew River (76.4%, 13 sp.), followed by rheobionts (18.5%, 10 sp.). Four species classified as occurring in both running and stagnant waters accounted for only 4.7% of the collected fauna. The other two synecological elements, stagnobionts and stagnophiles (4 species) and crenophiles (1 species), made up a very



small proportion of the fauna (0.3% and 0.2%, respectively). Differences were noted in the synecological structure of the fauna between the lentic and lotic zones of the river. In the lentic zone, there was a noticeable (7.5%) share of taxa classified as species occurring both in running and stagnant waters, while the proportion of these species in the lotic zone was negligible (Figure 3). Water mites characteristic of running water bodies (rheobionts and rheophiles) together accounted for 91.7% of the fauna in the lentic zone, while in the lotic zone they made up as much as 98.5% of the collected fauna (Figure 3). Representatives of other synecological groups were caught in very small numbers or not at all in the central part of the river (Table 2).

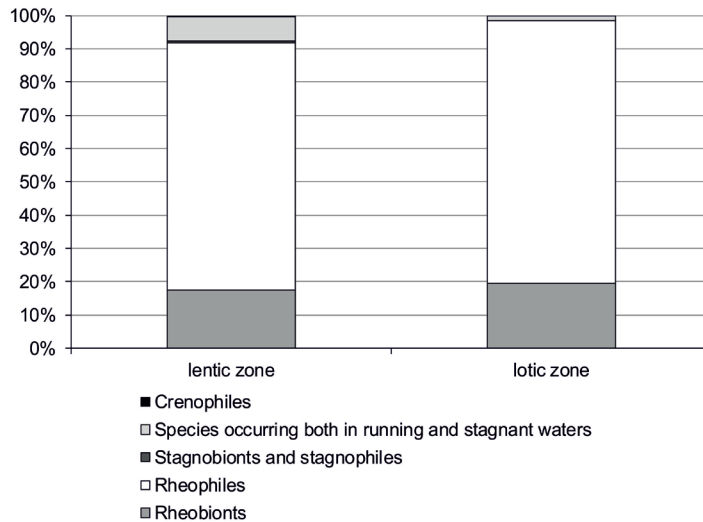


Figure 3. Quantitative synecological structure of water mite fauna in the lentic and lotic zone in the Branew River

### Occurrence and distribution of water mites in the transverse profile of the river

For the seven most abundant species (>100 specimens), an analysis was performed of the distribution in the transverse profile of the river. The species most associated with the lotic zone was *Lebertia rivulorum*, with as many as 70.7% of individuals caught in the central part of the river (Figure 4). Another species that preferred current environments was *L. oblonga* (60.5% of specimens caught in the lotic zone). Another two species present in high numbers in the lotic zone were *L. fimbriata* and *L. inaequalis*, but they were caught in only slightly higher numbers in the central part of the river than by the banks (52.5% and 52.1%, respectively). The species most associated with the lentic zone was *Forelia variegator* (85.8% of individuals were caught in this zone; Figure 4). Another species with clear preferences for the littoral zones of the river was *Hygrobates setosus*; 77.1% of individuals of this species were caught in the marginal pools. Another species that was somewhat more abundant outside the current zone was *Sperchon clupeiifer*, but this species cannot be considered to be associated with the lentic zone because its proportion was only slightly higher there (52.6%) than in the lotic zone.

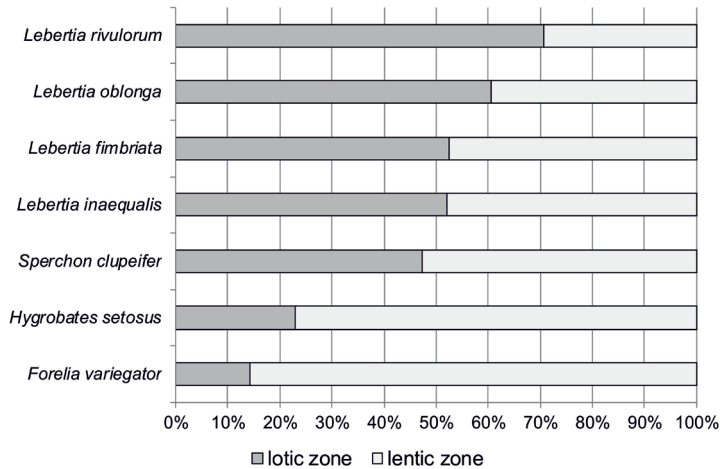


Figure 4. Percentage share of the most numerous species in lentic and lotic zone in the Branew River

### Occurrence and distribution of water mites in the investigated part of the river

Correspondence analysis was performed for the seven most abundant species (>100 specimens), taking into account the distribution in both the transverse and longitudinal profiles of the river. *Lebertia rivulorum* was caught in the upper course of the river (site 1), in the lotic zone, on a bottom of stones and gravel with an admixture of sandy sediment (Figure 5). Another characteristic species of this part of the river was *Sperchon clupeiifer*, with uniform distribution in the transverse profile of the river (Figures 4 and 5). Two species, *Hygrobatas setosus* and *Forelia variegator*, were clearly associated with the lentic zone of the river (Figure 5), but *Hygrobatas setosus* was caught mainly in the upper course of the river (site 1, silty bottom with *Elodea canadensis*), while as much as 91.5% of the population of *Forelia variegator* was caught in the lower course of the river (site 2, bottom of silt, silt and sand, and sand, with dominance of *Sparganium erectum* and some *Elodea canadensis*). *Lebertia fimbriata* and *L. oblonga* were also characteristic of the lower course of the river (Figure 5). *Lebertia oblonga* was associated with the lotic zone of the lower course of the river (site 2, sediments of sand or sand and silt with isolated *Sparganium erectum* plants and small patches of *Elodea canadensis*), while *L. fimbriata* showed a more even distribution in the transverse profile of the river, with only a slight preference for the current environment (Figures 4, 5). More specimens of *L. inaequalis* were caught in the upper course of the river and in the lotic zone, but this species was also found in high numbers at site 2 and in the lentic zone (Table 2, Figures 4, 5).

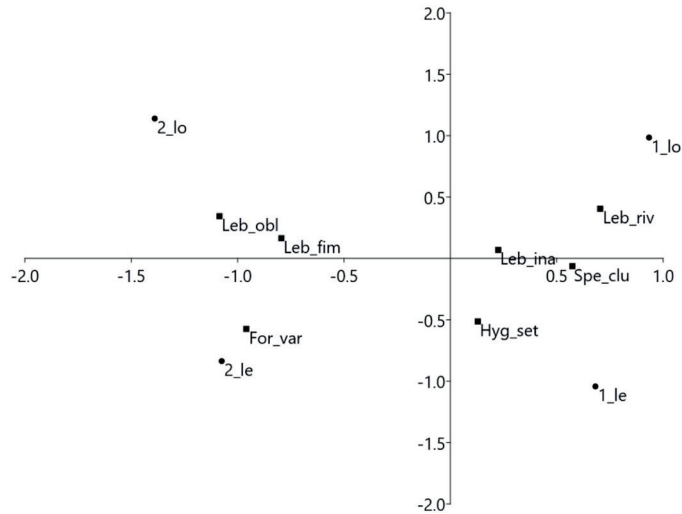


Figure 5. Correspondence analysis (CA) showing the occurrence of the most numerous species in the Branew River. 1–2 – sites, le – lentic zone, lo – lotic zone, For\_var – *Forelia variegator*, Hyg\_set – *Hygrobates setosus*, Leb\_fim – *Lebertia fimbriata*, Leb\_ina – *L. inaequalis*, Leb\_obl – *L. oblonga*, Leb\_riv – *L. rivulorum*, Spe\_clu – *Sperchon clupeiifer*

## Discussion

In the Hydrachnidia fauna of the Branew River, there are a few characteristic elements that distinguish the water mite assemblages of this river from other Polish rivers. The first was the very high abundance of *Lebertia rivulorum*. Apart from the Branew, this species has also been recorded in other rivers of the Janów Forests Landscape Park (Stryjecki, 2002; Stryjecki et al., 2018), as well as in other rivers of the Biłgoraj Plain (Zawal, Kowalik, 2013), but in much smaller numbers than in the Branew River. In rivers situated in neighbouring geographic regions, in some cases in close proximity to the Biłgoraj Plain, *L. rivulorum* has been caught in very small numbers (Kowalik, Biesiadka, 1981; Kowalik et al., 2014) or not at all (Kowalik, 1981; Stryjecki, 2009, 2010; Stryjecki et al., 2012; Stryjecki, Kowalczyk-Pecka, 2013b; Biesiadka et al., 2015). In rivers of other parts of Poland, this species has been recorded in small or very small numbers (Biesiadka, 1970, 1972; Zawal et al., 2017) or not at all (Biesiadka, 1979; Cichocka, 1996a, b, 2006; Zawal, Sadanowicz, 2012). The analysis indicates that the abundance of *L. rivulorum* in the rivers of the Sandomierz Basin macroregion and the Biłgoraj Plain mesoregion is a regional feature. *Lebertia rivulorum* has been recorded in small numbers in European rivers and streams (van der Hammen, Smit, 1996; Martin, Speth, 1996; Martin, 1997; Biesiadka, Cichocka, Moroz, 2004; Smit, Hop, Munts, 2008), or not recorded at all (Gledhill, 1973; Martin, 1996; Gerecke, 2002). The material collected during the study shows that the population of this species in the Branew River was not only the highest in Poland, but in all of Europe. *Lebertia rivulorum* is considered a rhithrobiont (Gerecke, 2009). It prefers an environment of mosses (Dittmar, 1955) and *Alnus* roots (Martin, Spetch, 1996). In the Branew, this species was caught primarily in the upper stretches of the river, on a bottom of gravel

and stones with a small amount of sandy sediment, sparsely covered with *Elodea canadensis*. The results contribute new data on the habitat preferences of this species.

Another characteristic element of the Hydrachnidia communities of the Branew River, which distinguishes the river from other Polish rivers, was the very high abundance of *Lebertia inaequalis*. This species has also been found in high numbers in other rivers of the Janów Forests Landscape Park (Stryjecki, 2002; Stryjecki et al., 2018) and in other rivers of the Biłgoraj Plain (Zawal, Kowalik, 2013). In the neighbouring macroregion of Roztocze, *L. inaequalis* has been much less abundant than in the rivers of the Sandomierz Basin (Kowalik, 1981; Stryjecki, Kowalczyk-Pecka, 2013b; Kowalik et al., 2014; Biesiadka et al., 2015). *Lebertia inaequalis* has been recorded in other lowland rivers in Poland (Biesiadka, 1972; Cichocka, 1996a, 2006; Zawal, Sadanowicz, 2012; Zawal et al., 2017), but in none of these has it reached such high abundance and dominance as in the Branew and other rivers of the Biłgoraj Plain.

Another distinctive feature was the high abundance of *Lebertia oblonga*. At just two sites in the small Branew, far more individuals were caught than at a greater number of sites in larger rivers of the Janów Forests Landscape Park (Stryjecki et al., 2018), the Biłgoraj Plain (Zawal, Kowalik, 2013), neighbouring Roztocze (Stryjecki, Kowalczyk-Pecka, 2013b; Kowalik et al., 2014; Biesiadka et al., 2015), and rivers located in other parts of Poland (Zawal, Sadanowicz, 2012; Zawal et al., 2017). In general, the high proportion of species of the genus *Lebertia* was a characteristic feature of the Hydrachnidia communities of the Branew River, distinguishing its fauna from that of other Polish rivers and other rivers of the region. Species of this genus accounted for as much as 53.1% of the collected material.

Among species of the genus *Lebertia* that were caught in high numbers in the Branew River, two – *L. oblonga* and *L. pilosa* Maglio, 1924 – are rare in Europe (Gerecke, 2009). As mentioned above, *L. oblonga* has been recorded in other Polish rivers, but never in such abundance as in the Branew. This species has been found in small numbers in the rivers and streams of other parts of Europe (Martin, 1997; Smit et al., 2015), or not at all (Martin, 1996; Martin, Speth, 1996; Gerecke, 2002; Biesiadka et al., 2004). The material collected during the study shows that the population of this species in the Branew River was the largest not only in Poland, but over its entire range of occurrence. *Lebertia oblonga* is found in high-order lowland streams, but also in clear lakes, often on sandy bottoms (Gerecke, 2009; Smit et al., 2015). In the Branew River, *L. oblonga* was caught primarily in the current zone, on a bottom of sand or sand and silt, with a small share of aquatic vegetation, in the lower course of the river. The data confirm the habitat preferences of this species known from the literature. *Lebertia pilosa* is a rare species, found only in small populations. Its distribution includes Europe, but only scattered records are known (Gerecke, 2009). In Poland, *L. pilosa* has been found in rivers in the central-eastern part of the country, sometimes in fairly high numbers (Kowalik, 1981; Kowalik, Biesiadka, 1981; Zawal, Kowalik, 2013; Biesiadka et al., 2015; Stryjecki et al., 2018). In other Polish rivers, the species has been found in low numbers (Cichocka, 1996a, 2006) or not at all (Zawal, Sadanowicz, 2012; Zawal et al., 2017). The fact that 66 *L. pilosa* individuals were found in the Branew, a small lowland river, is indicative of the faunistic value of this river. According to Kowalik (1981), *L. pilosa* prefers environments with a weaker current on bottoms covered with vegetation. In the Branew, it was found mainly in the littoral zone in the lower course of the river, in places with sediments of silt or sand and silt, overgrown with abundant aquatic vegetation, which confirms the previously reported habitat preferences of the species.

High similarity was noted between the fauna of the lotic and lentic zones of the river, and much lower similarity between sites. The results indicate intensive migration of species in the

transverse profile of the river and less migration in the longitudinal profile. The Branew River is a small watercourse; its width at the study sites ranged from 1.5 to 4.0 m, which was undoubtedly conducive to the exchange of species between the littoral zone and the central zone of the river. In the main river of the Janów Forests Landscape Park, i.e. the Bukowa River, Stryjecki et al. (2018) found high faunistic similarity between the lotic and lentic zones in the upper course of the river within the same site, but in the lower course of the river the fauna was grouped within the lotic or lentic zone of the various sites. In the Krąpiel River, Zawal et al. (2017) noted the highest faunistic similarity between similar habitats of different sites, especially in the lower course of the river. The Branew River is too small and short for such a pattern of faunistic similarities to be observed in its lower course.

Human impact and the transformation of lotic ecosystems causes changes in water mite fauna: rheophilic species, with narrow tolerance for environmental factors, vanish and are gradually replaced by species with a wider ecological valence, which are frequently found in standing water bodies as well (Biesiadka, 1972; Martin, 1996; van der Hammen, Smit, 1996). The largest synecological group in the Branew River was rheophiles and rheobionts. These two groups are usually dominant in rivers, especially natural rivers or those subject to little human impact (Biesiadka, 1970; Cichocka, 1996a; Zawal et al., 2017; Stryjecki et al., 2018). Dominance of rheobionts and rheophiles has also been noted in other lowland rivers in Poland (Biesiadka, 1970; Cichocka, 1996b, 2006; Zawal, Sadanowicz, 2012), as well as in upland and lowland rivers of central-eastern Poland (Kowalik, 1981; Stryjecki, Kowalczyk-Pecka, 2013b; Zawal, Kowalik, 2013; Kowalik et al., 2014; Biesiadka et al., 2015). The very high quantitative share of rheophiles and rheobionts in the fauna of the Branew River is indicative of its natural character. The values of the physicochemical parameters confirm the good water quality of the river.

The most abundant species in the Branew River, *Hygrobatas setosus*, was caught in much higher numbers in the littoral zone than in the central part of the river. Discussion on the habitat preferences of this species is impeded by the fact that many publications on flowing water bodies identify this species as *H. nigromaculatus*, a sister species occurring in lakes. The use of incorrect nomenclature in previous works is due to the fact that the river species (*H. setosus*) was not distinguished from the lake species (*H. nigromaculatus*) until relatively recently (Martin et al., 2010). Hence the species reported as *H. nigromaculatus* in many papers on lotic ecosystems was most likely *H. setosus*. This is suggested by the abundance of this species in the flowing water bodies discussed by the authors and its classification in these studies as a rheophile (Biesiadka, 1979; Cichocka, 1996a; Martin, 1996; Kowalik et al., 2014), whereas *H. nigromaculatus* is a typical lake species (Martin et al., 2010). In the Branew River, *H. setosus* displayed a very clear preference for the lentic zone of the river. In other Polish rivers, *H. setosus* has also been found mainly in marginal pools and habitats with slow current (Kowalik, 1981; Cichocka 1996a; Zawal, Sadanowicz, 2012; Zawal et al., 2017; Stryjecki et al., 2018). In the Pasłęka River, *H. setosus* clearly preferred pools with a sandy bottom without vegetation (Cichocka, 1996a). This species is much more frequently reported as characteristic of pool areas of rivers with organic (mud) sediments (Biesiadka, 1979; Martin, 1996), often with rich aquatic vegetation (Kowalik, 1981). A great deal about the preferences of this species can be learned from a comparison of the distribution of *H. setosus* in the Branew River and the larger Bukowa River, which the Branew flows into. At just two sites in the Branew, many more *H. setosus* individuals (514) were caught than at five sites in the much larger Bukowa River (107 individuals; Stryjecki et al., 2018). In the Bukowa River, sandy sediments were dominant and vegetation was generally sparse. In the Branew River, *H. setosus* was present in the highest numbers in the lentic zone of the river, where silty sediments

and abundant aquatic vegetation were dominant (mainly *Elodea canadensis*, but also *Sparganium erectum*). Comparison of the populations from the Bukowa and Branew Rivers indicates that sandy sediment and sparse aquatic vegetation are not suitable habitat conditions for the formation of such large populations of *H. setosus*. Suitable conditions are found in places with slow water flow and a silty bottom with abundant aquatic plants, which additionally slow down the water current. Documentation of the habitat preferences of *H. setosus* is important because it enables an increasingly precise understanding of these preferences.

At the anthropogenically transformed site 1, species diversity was much lower than at the natural site 2. According to Odum (1982), low biodiversity is characteristic of unstable biocoenoses subject to seasonal or periodic disturbances caused by humans or nature. The typical response of a biocoenosis to environmental stress is a decrease in the number of species that are represented in small numbers, with a simultaneous increase in the dominance of species with high tolerance to stress. In the case of site 1, the environmental stress was anthropogenic transformation of that stretch of the river. The low value of the Shannon-Wiener index at this site was influenced by both of its components: a small number of species (14) and an uneven distribution of dominance (very high abundance of *Lebertia rivulorum*, *Hygrobatas setosus*, *Sperchon clupeiifer* and *Lebertia inaequalis*). Straightening of the river bed, erection of a concrete dam and concrete reinforcement of the bottom in the investigated stretch of the river led to habitat impoverishment, which translated into species impoverishment. Few species were caught at site 1, with especially few species characteristic of standing water bodies, which were collected in the expansive marginal pools in the meanders at the natural site 2 (e.g. *Hydrachna globosa* (De Geer, 1778), *Hydryphantes placationis* Thon, 1899, and *Tiphys ornatus* Koch, 1836). The artificial, man-made bottom of stones and gravel, with a small admixture of sandy sediment, proved suitable for *Lebertia rivulorum*, which had a very large population here. These habitat conditions also proved favourable for *Sperchon clupeiifer*, which has not been found in any other river of the Janów Forests Landscape Park in such high numbers as in this anthropogenically transformed stretch of river. The concrete-reinforced bottom and substrate of stones and gravel with an admixture of sandy sediment was a substitute for the natural habitat conditions preferred by this species, i.e. a substrate of stones and sand (Di Sabatino, Gerecke, Martin, 2000). Human impact involving regulation of the river channel and changes in the bottom structure usually lead to habitat degradation and impoverishment of water mite fauna (Biesiadka, 1972; Martin, 1996; van der Hammen, Smit, 1996; Stryjecki et al., 2018). The results confirm literature data describing the negative effect of such transformations on the Hydrachnidia communities of rivers.

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