DOI: 10.1515/frp-2016-0021
Available online: www.lesne-prace-badawcze.pl

Leśne Prace Badawcze / *Forest Research Papers*
Wrzesień / September 2016, Vol. 77 (3): 186–203

ORIGINAL RESEARCH ARTICLE

e-ISSN 2082-8926

Saproxylic springtails (Collembola) of the Wigry National Park

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Abstract. Faunistic and ecological studies on saproxylic *Collembola* species were carried out in the Wigry National Park (NE Poland). Nine sites representing *Tilio-Carpinetum*, *Serratulo-Pinetum* and *Peucedano-Pinetum* habitats each including three different levels of disturbance were visited twice in 2015. Samples from fallen logs in different stages of decay, neighboring litter and soil as well as arboreal epiphytes were taken on each visit. The *Collembola* specimens were then extracted using Tullgren funnels resulting in a total of 73 838 specimens from 270 samples. Specimen identification revealed the occurrence of 63 species, including 5 saproxylobiontic, 7 saproxylophilous, 4 xerophilous species living in epiphytic mosses and lichens as well as 47 hemiedaphic or euedaphic species. This composition of saproxylic fauna seems to be typical for the region with the most diverse assemblages being found in *Tilio-Carpinetum* habitats, while *Serratulo-Pinetum* and *Peucedano-Pinetum* are clearly less diverse. Additionally, a slight decrease in the number of *Collembola* species with increasing forest disturbance was observed. Furthermore, an increase in the number of *Collembola* species with the degree of dead wood decomposition was also found. This indicates that saproxylic springtail assemblages are sensitive to anthropogenic changes.

Keywords: dead wood, saproxylobiontic, saproxylophilous species, forest types, NE Poland

1. Introduction

Richness and diversity of saproxylic organism communities depend on a number of factors. It seems that the most imperative is the presence of no less than the smallest quantities of deadwood with suitable assortment and locality. Sustainability of forest natural ecological processes as well as pertinent distribution of deadwood throughout forest areas are equally important aspects (Gutowski et al. 2004; Stockland et al. 2012; Gossner et al. 2013; Czerepko et al. 2014; Holeksa et al. 2014; Szwagrzyk 2014). Nonetheless, one more factor should not be forgotten, that is, global biogeographic conditions that fundamentally affect the local biodiversity.

In Poland, there hardly ever occur natural forests, distinctive of deadwood abundance. In view of the postulates by M*üller and Bütler (2010*), safeguarding biological diversity requires the following threshold amounts of deadwood: 20–30 m^3/ha in boreal coniferous forests, 30–50m^3/ha in lowland deciduous forests and 30–40 m^3/ha in mixed mountain forests. In that case we can take as read that in Poland, there fall inside the above ranges only forests in national parks, with average deadwood quantity being 37.4 m^3/ha (data from BULiGL, 2015).

In contrast, Poland's managed forests reach sub-threshold values, with deadwood amounts ranging from 4.3 to 8 m^3/ha.

Hence, the question arises if one would say that sustainability of forest ecosystems can be maintained at the aforesaid undersized abundance of deadwood in managed forests. No ultimate answer can be expected, taking into consideration local characteristics of anthropogenic impacts and differentiated sensitivity of specific groups of saproxylic organisms.

The Wigry National Park (WNP) protects Wigry lake ecosystems along with those of adjoining lakes, as well as forests, which were intensively managed only 25 years ago; thus the average deadwood volume here is no more than 13.5 m^3/ha (Wigierski Park Narodowy 2014). From the time of park designation as the protected area, forest stands have been under reconstruction, and little by little there has been increasing deadwood abundance; consequently, the conditions for continued existence of saproxylic organisms have been improved. Even so, the question still remains, whether there were radi-

Submitted: 18.06.2016, reviewed: 6.04.2016, accepted after revision: 27.04.2016.

cally disturbed natural ecological processes in the past and that would have critical effects on the present representation of sproxylic fauna. Interdisciplinary inventory studies should provide the answer to this question.

Springtails (*Collembola*) belong to the group of arthropods (Arthropoda) frequently found in deadwood (Sterzyńska et al. 2007; Skubała, Maślak 2009; Piwnik et al. 2014; Skarżyński, Piwnik 2016). Knowledge of saproxylic springtails has yet been limited; however, approximate data indicate that about 40% of Poland's springtail fauna species is associated with deadwood and about 5% are saproxylobiontic (Piwnik et al. 2014). Springtails are sensitive to forest management because of their specific ecological preferences and low dispersion capability. On the other hand, this group of organisms can be used in biomonitoring and bioindication (Skibińska, Chudzicka 2000; Sławska 2005; Skarżyński, Piwnik 2016). Faunistic studies on *Collembola* have been carried out in the WNP since 2013, but gathered data (a list of 80 items) has not been published yet. Only a popular scientific paper by Krzysztofiak et al. (2014) appeared in print, which comprised information on a few rare springtail species.

The present faunistic and ecological study was conducted in the WNP, with the aim of evaluating the richness and diversity of *Collembola* communities in deadwood with reference to wood decomposition levels as well as forest habitat types and their transformation degrees.

2. Materials and methods

The study was carried out on nine plots representing three main forest types in WNP, that is, deciduous forest (*Tilio-Carpinetum*, TC), sub-boreal mixed coniferous forest (*Serratulo-Pinetum,* SP) and continental fresh pine forest (*Peucedano-Pinetum*, PP). Each assemblage was represented in three variants (plot 1 situated in nearly natural forest, in the conservation zone of planned activities on strict, active or stabilising protection; plot 2 situated in a transformed stand, but with the features of a typical forest habitat, in the zone of planned activities on forest restoration; plot 3 situated in a severely transformed stand, in the zone of planned activities on forest reconstruction). The study plots were located in the following forest management units: TC1: 117; TC2: 106, 117; TC3: 105; SP1: 170, 171, 174; SP2: 163; SP3: 113, 126, 133; PP1: 170, 174; PP2: 351; PP3: 351. In July and September 2015, from each of the nine study plots, three app. 0.25 l samples of deadwood (laying, with epixylic lichen and bryophyte layer) were collected. The samples represented deadwood in three decomposition stages (I: detached bark, soft wood decayed no more than on the surface; II: almost total absence of the bark, decayed wood fragments easy to separate with fingers; III: no bark, wood almost totally decomposed, but tree trunk shape remains). Also, within each plot, three samples of epiphytic mosses and lichens from alive trees as well as three litter and soil samples were collected. Altogether 270 samples were taken (90 from each forest type studied – TC, SP and PP), comprising 162 deadwood samples (TC, SP and PP × 54), 54 soil and litter samples and 54 samples of epiphytic mosses and lichens (TC, SP and PP ×18).

The samples collected under field conditions were transported to the laboratory, where springtails were extracted with the use of a Tullgren funnel. Springtail specimens from the collecting vessel were preserved in 75% alcohol and identified at the species level, using stereomicroscope. When necessary, microscope slides were mounted (with the use of Nesbitt's fluid and Swan's fluid) and springtails were identified to the species level using phase-contrast microscope.

In the present study, conventional diversity indices such as frequency, domination as well as the Margalef diversity index were used.

Frequency was computed in accordance with the following equation:

$$F_i = \frac{s}{S} 100\%$$

where
F_i – frequency of *i*th species,
s – the number of sites of *i*th species,
S – the number of all sites.

Domination (percentage share) was computed in accordance with the following equation:

$$D_i = \frac{n_i}{N} 100\%$$

where:
D_i – domination of *i*th species,
n_i – population number of *i*th species,
N – the total number of all species specimens.

The Margalef index (d) was computed in accordance with the following equation:

$$d = \frac{S - 1}{\ln N}$$

where:
S – the number of species in community,
N – the total number of specimens.

3. Results

Under the conditions of the present study, overall, 73, 838 springtail specimens of 63 species (deadwood samples: 42, 574, litter-soil samples: 11, 165, epiphytic moss and lichen samples: 20,099) were collected (Table 1). The majority of identified springtail species (59) was observed in deadwood, the next most numerous species group was found in the soil and litter (48), and in epiphyte samples, only 16 species were identified. A greater part of springtail species observed in the soil, litter and epiphytes was recorded in the deadwood samples as well (Table 1).

Table 1. A list of Collembola collected in the Wigry National Park. Abbreviations: D – dead wood, SG – litter and soil, E – epiphytic mosses and lichens.

Species	Number of specimens / localities			Frequency [%]			Dominance [%]		
	D	SG	E	D	SG	E	D	SG	E
Saproxylobiontic species:									
Proisotoma minima (Absolon 1901)	1931/42	159/2	-	25.93	3.70	-	4.54	1.42	-
Desoria nivea (Schäffer 1896)	185/11	-	-	6.79	-	-	0.43	-	-
Hymenaphorura polonica (Pomorski 1990)	92/6	-	-	3.70	-	-	0.22	-	-
Vertagopus cinereus (Nicolet 1841)	115/5	-	-	3.09	-	-	0.27	-	-
Xenylla corticalis (Börner 1901)	41/4	-	-	2.47	-	-	0.10	-	-
Saproxylophilous species:									
Micraphorura absoloni (Börner 1901)	4573/114	858/28	2/1	70.37	51.85	1.85	10.74	7.68	0.01
Entomobrya corticalis (Nicolet 1841)	1052/68	42/5	504/14	41.98	9.26	25.93	2.47	0.38	2.51
Neanura muscorum (Templeton 1835)	600/64	16/8	-	39.51	14.81	-	1.41	0.14	-
Friesea claviseta (Axelson 1900)	751/34	-	-	20.99	-	-	1.76	-	-
Pseudachorutes parvulus (Börner 1901)	781/13	13/2	-	8.02	3.70	-	1.83	0.12	-
Pseudachorutella asigillata (Börner 1901)	57/6	-	-	3.70	-	-	0.13	-	-
Neanura minuta (Gisin 1963)	6/2	-	-	1.23	-	-	0.01	-	-
Bryophilous xerophiles:									
Xenylla boerneri (Axelson 1905)	7119/55	525/4	15392/37	33.95	7.41	68.52	16.72	4.70	76.58
Anurophorus laricis (Nicolet 1842)	1692/45	-	2901/30	27.78	-	55.56	3.97	-	14.43
Entomobrya marginata (Tullberg 1871)	164/23	59/9	353/22	14.20	16.67	40.74	0.39	0.53	1.76
Entomobrya nivalis (Linnaeus 1758)	21/10	1/1	2/2	6.17	1.85	3.70	0.05	0.01	0.01
Litter and soil species:									
Lepidocyrtus lignorum (Fabricius 1793)	2714/95	1783/53	14/2	58.64	98.15	3.70	6.37	15.97	0.07
Parisotoma notabilis (Schäffer 1896)	4285/85	1749/42	5/1	52.47	77.78	1.85	10.06	15.67	0.02
Mesaphorura macrochaeta (Rusek 1976)	3894/82	1785/46	2/2	50.62	85.19	3.70	9.15	15.99	0.01
Desoria hiemalis (Schött 1893)	2448/81	106/17	-	50.00	31.48	-	5.75	0.95	-
Pogonognathellus flavescens (Tullberg 1871)	847/70	166/26	-	43.21	48.15	-	1.99	1.49	-
Micranurida pygmaea (Börner 1901)	1930/67	351/17	2/1	41.36	31.48	1.85	4.53	3.14	0.01
Isotomiella minor (Schäffer 1896)	3255/65	1528/33	-	40.12	61.11	-	7.65	13.69	-
Orchesella flavescens (Bourlet 1839)	232/48	88/23	1/1	29.63	42.59	1.85	0.54	0.79	-
Mesaphorura critica (Ellis 1976)	821/43	493/24	-	26.54	44.44	-	1.93	4.42	-
Lipothrix lubbocki (Tullberg 1872)	275/38	6/2	2/1	23.46	3.70	1.85	0.65	0.05	0.01
Orchesella bifasciata (Nicolet 1841)	168/36	96/20	4/2	22.22	37.04	3.70	0.39	0.86	0.02
Megalothorax minimus (Willem 1900)	241/34	39/6	-	20.99	11.11	-	0.57	0.35	-
Xenylla maritima (Tullberg 1869)	119/23	5/4	83/16	14.20	7.41	29.63	0.28	0.04	0.41

Species	Number of specimens / localities			Frequency [%]			Dominance [%]		
	D	SG	E	D	SG	E	D	SG	E
Mesaphorura tenuisensillata (Rusek 1974)	283/23	133/9	-	14.20	16.67	-	0.66	1.19	-
Protaphorura armata (Tullberg 1869)	263/22	278/18	-	13.58	33.33	-	0.62	2.49	-
Tomocerus vulgaris (Tullberg 1871)	106/21	36/9	-	12.96	16.67	-	0.25	0.32	-
Lepidocyrtus lanuginosus (Gmelin 1788)	92/16	70/10	-	9.88	18.52	-	0.22	0.63	-
Caprainea marginata (Schött 1893)	56/16	17/6	-	9.88	11.11	-	0.13	0.15	-
Willemia denisi (Mills 1932)	336/15	44/8	-	9.26	14.81	-	0.79	0.39	-
Arrhopalites spinosus (Rusek 1967)	51/13	13/5	-	8.02	9.26	-	0.12	0.12	-
Willemia anophthalma (Börner 1901)	300/12	75/4	-	7.41	7.41	-	0.70	0.67	-
Micranurida granulata (Agrell 1943)	28/12	1/1	-	7.41	1.85	-	0.07	0.01	-
Friesea truncata (Cassagnau 1958)	82/11	75/3	-	6.79	5.56	-	0.19	0.67	-
Sminthurinus alpinus (Gisin 1953)	193/11	61/13	-	6.79	24.07	-	0.45	0.55	-
Sphaeridia pumilis (Krausbauer 1898)	49/9	25/3	-	5.56	5.56	-	0.12	0.22	-
Paratullbergia callipygos (Börner 1903)	67/6	4/2	-	3.70	3.70	-	0.16	0.04	-
Arrhopalites secundarius (Gisin 1958)	16/6	-	-	3.70	-	-	0.04	-	-
Arrhopalites sericus (Gisin 1947)	8/6	-	-	3.70	-	-	0.02	-	-
Folsomia manolachei (Bagnall 1939)	77/4	120/4	-	2.47	7.41	-	0.18	1.07	-
Pseudosinella zygophora (Schille 1908)	8/4	32/4	-	2.47	7.41	-	0.02	0.29	-
Pseudachorutes subcrassus (Tullberg 1871)	17/3	20/5	-	1.85	9.26	-	0.04	0.18	-
Folsomia candida (Willem 1902)	18/3	-	-	1.85	-	-	0.04	-	-
Neelides minutus (Folsom 1901)	4/3	-	-	1.85	-	-	0.01	-	-
Dicyrtoma fusca (Lubbock 1873)	23/3	1/1	-	1.85	1.85	-	0.05	0.01	-
Allacma fusca (Linnaeus 1758)	7/3	-	-	1.85	-	-	0.02	-	-
Ceratophysella denticulata (Bagnall 1941)	2/2	1/1	-	1.23	1.85	-	-	0.01	-
Anurophorus septentrionalis (Palissa 1966)	13/2	152/11	-	1.23	20.37	-	0.03	1.36	-
Desoria propinqua (Axelson 1902)	12/2	7/1	-	1.23	1.85	-	0.03	0.06	-
Folsomia quadrioculata (Tullberg 1871)	19/2	21/3	-	1.23	5.56	-	0.04	0.19	-
Pratanurida boerneri (Schött 1902)	1/1	-	12/5	0.62	-	9.26	-	-	0.06
Folsomia penicula (Bagnall 1939)	31/1	4/1	-	0.62	1.85	-	0.07	0.04	-
Entomobrya nicoleti (Lubbock 1867)	1/1	-	-	0.62	-	-	-	-	-
Tomocerina minuta (Tullberg 1976)	2/1	19/6	-	0.62	11.11	-	-	0.17	-
Xenylla brevicauda (Tullberg 1869)	-	83/2	820/1	-	3.70	1.85	-	0.74	4.08
Pseudachorutes dubius (Krausbauer 1898)	-	3/3	-	-	5.56	-	-	0.03	-
Superodontella lamellifera (Axelson 1903)	-	1/1	-	-	1.85	-	-	0.01	-
Stenaphorura quadrispina (Börner 1901)	-	1/1	-	-	1.85	-	-	0.01	-
Number of specimens	42574	11165	20099						
		73838							

Twelve springtail species identified can be considered as saproxylic. Five of these, that is, *Xenylla corticalis* (Börner, 1901), *Hymenaphorura polonica* (Pomorski, 1990), *Desoria nivea* (Schäffer, 1896), *Proisotoma minima* (Axelson, 1901) and *Vertagopus cinereus* (Nicolet, 1841), are saproxylobiontic. The remaining seven species – *Friesea claviseta* (Axelson, 1900), *Pseudachorutes parvulus* (Börner, 1901), *Pseudachorutella asigillata* (Börner, 1901), *Neanura muscorum* (Templeton, 1835), *Neanura minuta* (Gisin, 1963), *Micraphorura absoloni* (Börner, 1901) and *Entomobrya corticalis* (Nicolet, 1841) – are saproxylophilous, that is, species that prefer deadwood but they also live in other habitats.

Amongst the above, there can be distinguished residents of the space under tree bark (*X. corticalis*, *F. claviseta*, *D. nivea*, *V. cinereus*, *E. corticalis*) and of decaying wood (*H. polonica*), as well as springtail species that occur in both microhabitats (*P. parvulus*, *P. assigillata*, *N. muscorum, N. minuta*, *M. absoloni, P. minima*).

Four xerophilous springtail species living in epiphytic mosses, lichens and bark hollows, who are also associated with deadwood were observed: *Xenylla boerneri* (Axelson, 1905)*, Anurophorus laricis* (Nicolet, 1842)*, Entomobrya marginata* (Tullberg, 1871) and *Entomobrya nivalis* (Linnaeus, 1758). These hardly can be considered as purely saproxylic species, because they inhabit both dead and alive trees. The remaining identified 43 species are typical residents of the litter and soil, who find good life conditions in deadwood. The proportions of the above springtail ecological groups in the total pool of species found in the WNP deadwood are presented in Figure 1.

Springtail species with high frequency in deadwood samples are saproxylophilous, such as *M. absoloni* (70.37%), *E. corticalis* (41.98%) and *N. muscorum* (39.51%); saproxylobiontic, such as *P. minima* (25.93%); numerous litter and soil species, for example, *Lepidocyrtus lignorum* (Fabricius, 1793) (58.64%) and *Parisotoma notabilis* (Schäffer, 1896) (52.47%); as well as several xerophilous springtail species living in epiphytic mosses and lichens, such as *X. boerneri* (33.95%) and *A. laricis* (27.78%). Frequency of the remaining four saproxylobionts showed low values ranging from 2.47% to 6.79% (Table 1).

In springtail communities that reside in deadwood, xerophilous species living in epiphytic mosses and lichens such as *X. boerneri* (16.72%), saproxylophilous such as *M. absoloni* (10.74%) and litter-soil species such as *P. notabilis* (10.06%) dominate. At the same time, saproxylobiontic springtail dominance is comparatively lower and ranges from 4.54% for *P. minima* to 0.1% for *X. corticalis* (Table 1).

Evaluation of species richness of springtail communities with regard to preference of deadwood at different decomposition stages showed notable primacy of the stage III over stages II and I (Fig. 2). The results of the assessment of *Collembola* population numbers presented analogous patterns: wood decomposition stage III, 15,262 specimens; stage II, 13, 933; and stage I, 13, 379.

The richest and most diverse communities of saproxylic springtails were observed in *Tilio-Carpinetum* assemblage. Springtail populations observed in coniferous assemblages, and especially those in *Peucedano-Pinetum*, were comparatively less abundant and diverse (Figs. 3 and 4; Tables 2–4). This pattern was reflected by the total numbers of springtail species observed in the assemblages studied and the numbers of saproxylic species (Fig. 3), including those saproxylobiontic and saproxylophilous (fig. 4), as well as the Margalef index values (Fig. 5). The differences between the three assemblages with regard to the richness and diversity of springtail communities are explicitly noticeable, other than those between the areas with different naturalness levels inside individual assemblages (Fig. 3). However, a decreasing trend in the gradient can be detected: habitat nearly natural → habitat transformed to a small extent → habitat transformed to a great extent. This arrangement was proved by the obtained results on the total numbers of springtail species and the numbers of saproxylic springtails

Figure 1. The share of ecological groups in the total pool of species found in dead wood

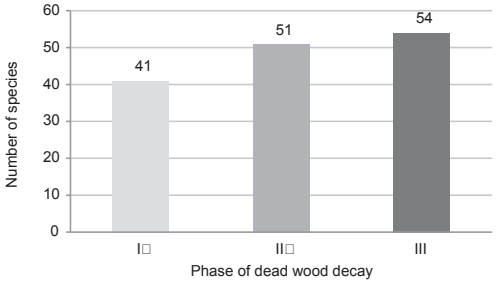

Figure 2. Number of Collembola species collected in dead wood in I-III phases of decay

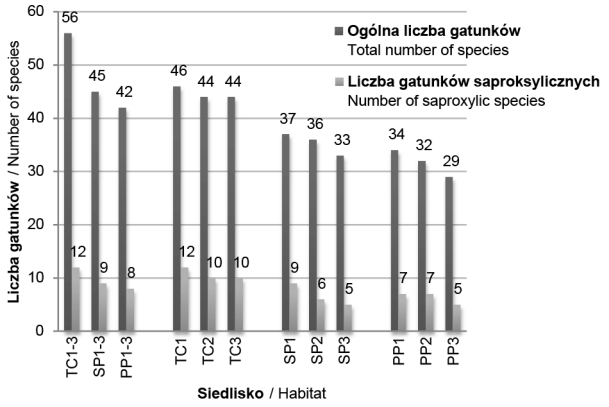

Figure 3. Number of Collembola species collected in dead wood. Abbreviations: TC – *Tilio-Carpinetum*, SP – *Serratulo-Pinetum*, PP – *Peucedano-Pinetum*, TC1, SP1, PP1 – dead wood in semi-natural forest, TC2, SP2, PP2 – dead wood in deformed forest, but with typical habitat features, TC3, SP3, PP3 – dead wood in highly deformed forest.

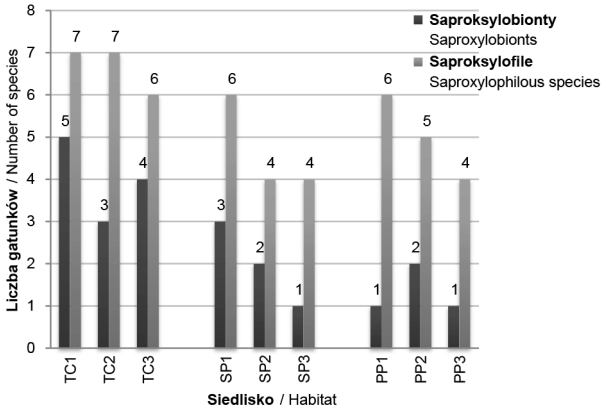

Figure 4. Number of saproxylobiontic and saproksylofilous Collembola collected in dead wood. Abbreviations: TC – *Tilio-Carpinetum*, SP – *Serratulo-Pinetum*, PP – *Peucedano-Pinetum*, TC1, SP1, PP1 – dead wood in semi-natural forest, TC2, SP2, PP2 – dead wood in deformed forest, but with typical habitat features, TC3, SP3, PP3 – dead wood in highly deformed forest.

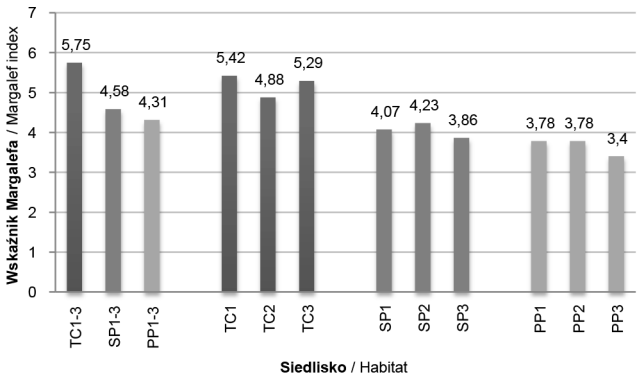

Figure 5. Species richness of dead wood Collembola. Abbreviations: TC – *Tilio-Carpinetum*, SP – *Serratulo-Pinetum*, PP – *Peucedano-Pinetum*, TC1, SP1, PP1 – dead wood in semi-natural forest, TC2, SP2, PP2 – dead wood in deformed forest, but with typical habitat features, TC3, SP3, PP3 – dead wood in highly deformed forest.

(Fig. 3), including those saproxylobiontic and saproxylophilous (Fig. 4). However, the trend was not confirmed by the obtained Margalef index values (Fig. 5).

4. Discussion

Springtail communities that reside in deadwood in the WNP comprise primarily soil and litter species. Saproxylic species (mainly saproxylophilous) constitute about one-fifth of the total number of specimens (Fig. 1; Table 1). The list of saproxylic *Collembola* recorded in the Park (12 species) is as far as 22 items behind the national register (34 species), which was prepare based on the studies by Fjellberg (1998, 2007), Smolis (2002, 2006), Potapova (2001), Piwnik et al. (2014), Piwnik and Skarżyński (2015) as well as Skarżyński and Piwnik (2016). The register includes the following species: *X. corticalis*, *Mesogastrura ojcoviensis* (Stach 1919), *F. claviseta*, *P. parvulus*, *Pseudachorutes corticicolus* (Schäffer 1897), *P. asigillata*, *Pseudachorutella bescidica* (Smolis, Skarżyński 2007), *Micranurida bescidica*

Table 2. A list of Collembola collected in *Tilio-Carpinetum* (TC). Abbreviations: TC1 – dead wood in semi-natural forest, TC2 – dead wood in deformed forest but with typical habitat features, TC3 – dead wood in highly deformed forest, I–III – phases of dead wood decay, SG – litter and soil, E – epiphytic mosses and lichens.

Species	Number of specimens / localities											
	TC1			TC2			TC3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Saproxylobiontic species:												
Xenylla corticalis (Börner 1901)	-	41/4	-	-	-	-	-	-	-	-	-	41/4
Hymenaphorura polonica (Pomorski 1990)	-	2/1	81/2	-	-	2/1	-	-	7/2	-	-	92/6
Desoria nivea (Schäffer 1896)	-	-	5/1	1/1	17/1	-	34/3	1/1	-	-	-	58/7
Vertagopus cinereus (Nicolet 1841)	12/1	-	-	-	-	-	8/2	-	-	-	-	20/3
Proisotoma minima (Absolon 1901)	30/1	-	35/4	42/2	37/3	45/3	7/1	300/2	29/2	-	-	525/18
Saproxylophilous species:												
Friesea claviseta (Axelson 1900)	401/6	46/2	1/1	30/3	22/4	-	40/2	-	-	-	-	540/18
Pseudachorutes parvulus (Börner 1901)	119/2	2/1	1/1	18/1	-	-	20/2	1/1	-	-	-	161/8
Pseudachorutella asigillata (Börner 1901)	-	-	1/1	32/1	-	-	-	20/1	-	-	-	53/3
Neanura minuta (Gisin 1963)	1/1	-	-	-	-	5/1	-	-	-	-	-	6/2
Neanura muscorum (Templeton 1835)	30/4	61/4	19/4	120/5	43/5	90/4	7/1	29/3	13/2	7/4	-	419/36
Micraphorura absoloni (Börner 1901)	163/5	70/6	156/4	295/4	221/6	211/6	67/2	367/4	51/3	63/5	-	1664/45
Entomobrya corticalis (Nicolet 1841)	93/4	8/2	1/1	57/5	-	-	30/4	17/2	3/1	3/1	1/1	213/21
Bryophilous xerophiles:												
Xenylla boerneri (Axelson 1905)	168/3	60/3	-	2252/4	-	10/1	289/6	107/3	84/3	3/1	6468/17	9441/41
Anurophorus laricis (Nicolet 1842)	-	-	-	-	-	-	36/4	13/2	42/3	-	68/4	159/13
Entomobrya marginata (Tullberg 1871)	4/2	-	-	5/2	-	-	-	-	-	4/3	18/3	31/10
Entomobrya nivalis (Linnaeus 1758)	-	-	-	2/1	-	-	-	3/1	3/2	1/1	-	9/5

Species	Number of specimens / localities											
	TC1			TC2			TC3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Litter and soil species:												
Ceratophysella denticulata (Bagnall, 1941)	-	-	2/2	-	-	-	-	-	-	1/1	-	3/3
Xenylla maritima (Tullberg 1869)	-	-	-	1/1	-	-	1/1	1/1	1/1	1/1	2/2	7/7
Willemia anophthalma (Börner 1901)	-	-	12/1	-	-	-	-	85/1	10/1	4/1	-	111/4
Willemia denisi (Mills 1932)	-	-	10/1	-	-	-	-	5/1	3/1	15/3	-	33/6
Friesea truncata (Cassagnau 1958)	-	9/2	5/2	-	-	7/1	-	-	-	-	-	21/5
Micranurida granulata (Agrell 1943)	-	-	1/1	3/1	1/1	7/2	-	-	4/1	1/1	-	17/7
Micranurida pygmaea (Börner 1901)	24/1	29/3	10/2	35/2	33/2	87/3	1/1	17/2	19/2	46/2	-	301/20
Pratanurida boerneri (Schött 1902)	-	-	-	-	-	-	-	1/1	-	-	11/4	12/5
Pseudachorutes dubius (Krausbauer 1898)	-	-	-	-	-	-	-	-	-	1/1	-	1/1
Pseudachorutes subcrassus (Tullberg 1871)	3/1	2/1	-	-	-	-	12/1	-	-	6/2	-	23/5
Superodontella lamellifera (Axelson 1903)	-	-	-	-	-	-	-	-	-	1/1	-	1/1
Protaphorura armata (Tullberg 1869)	13/1	15/2	63/4	-	16/3	71/6	-	3/1	79/4	270/16	-	530/37
Mesaphorura critica (Ellis 1976)	-	31/2	44/2	-	-	79/4	-	-	65/5	145/8	-	364/21
Mesaphorura macrochaeta (Rusek 1976)	-	77/3	222/6	-	25/3	206/6	-	8/1	235/5	519/17	-	1292/41
Mesaphorura tenuisensillata (Rusek 1974)	5/1	-	16/2	-	-	49/4	-	-	45/2	59/4	-	174/13
Paratullbergia callipygos (Börner 1903)	-	-	5/1	-	-	53/2	-	-	-	4/2	-	62/5
Anurophorus septentrionalis (Palissa 1966)	-	-	-	-	-	-	-	-	-	9/2	-	9/2
Desoria hiemalis (Schött 1893)	343/6	130/5	2/1	199/5	224/4	38/3	1/1	311/3	21/3	24/3	-	1293/34
Desoria propinqua (Axelson 1902)	-	-	-	9/1	-	3/1	-	-	-	7/1	-	19/3
Folsomia candida (Willem 1902)	-	-	-	-	11/2	7/1	-	-	-	-	-	18/3

Species	Number of specimens / localities											
	TC1			TC2			TC3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Folsomia manolachei (Bagnall 1939)	-	-	1/1	-	5/1	-	-	-	71/2	120/4	-	197/8
Folsomia quadrioculata (Tullberg 1871)	-	-	2/1	-	-	-	-	-	17/1	21/3	-	40/5
Folsomia penicula (Bagnall 1939)	-	-	-	-	-	-	-	-	31/1	-	-	31/1
Isotomiella minor (Schäffer 1896)	132/2	64/2	227/5	374/2	82/3	435/6	-	-	80/3	734/14	-	2128/37
Parisotoma notabilis (Schäffer 1896)	225/4	126/4	92/4	76/2	134/4	418/6	-	-	206/5	618/16	-	1895/45
Orchesella bifasciata (Nicolet 1841)	48/4	3/1	2/1	6/3	-	1/1	-	12/1	7/3	20/5	-	99/19
Orchesella flavescens (Bourlet 1839)	5/1	2/1	-	3/2	-	5/2	1/1	-	6/3	12/6	-	34/16
Lepidocyrtus lanuginosus (Gmelin 1788)	-	10/2	9/2	5/1	-	2/1	-	-	7/2	24/2	-	57/10
Lepidocyrtus lignorum (Fabricius 1793)	64/3	73/4	140/3	34/2	56/3	72/4	23/1	43/3	130/6	608/17	-	1243/46
Pseudosinella zygophora (Schille 1908)	-	1/1	1/1	-	-	-	-	-	2/1	7/3	-	11/6
Pogonognathellus flavescens (Tullberg 1871)	11/1	5/1	3/3	29/3	97/3	13/4	7/1	76/3	40/3	34/9	-	315/31
Tomocerina minuta (Tullberg 1976)	-	-	-	-	-	-	-	-	-	11/3	-	11/3
Tomocerus vulgaris (Tullberg 1871)	-	3/2	5/2	7/4	1/1	25/3	11/1	20/1	4/1	28/5	-	104/20
Megalothorax minimus (Willem 1900)	15/1	5/1	9/3	38/1	14/3	27/4	-	3/1	-	12/1	-	123/15
Neelides minutus (Folsom 1901)	-	-	-	-	1/1	1/1	-	-	2/1	-	-	4/3
Arrhopalites secundarius (Gisin 1958)	-	-	-	-	-	4/1	-	-	-	-	-	4/1
Arrhopalites sericus (Gisin 1947)	-	1/1	-	-	-	1/1	-	-	-	-	-	2/2
Arrhopalites spinosus (Rusek 1967)	2/1	-	-	6/1	2/1	5/1	-	-	2/1	-	-	17/5
Sminthurinus alpinus (Gisin 1953)	3/1	-	-	26/2	-	-	9/1	-	4/1	19/5	-	61/10
Lipothrix lubbocki (Tullberg 1872)	19/2	7/2	3/1	12/3	8/4	8/2	2/1	8/2	6/2	6/2	-	79/21

Species	Number of specimens / localities											
	TC1			TC2			TC3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Dicyrtoma fusca (Lubbock 1873)	-	1/1	-	-	-	-	-	-	-	-	-	1/1
Sphaeridia pumilis (Krausbauer 1898)	5/1	2/1	-	-	-	2/1	-	-	-	10/1	-	19/4
Caprainea marginata (Schött 1893)	-	1/1	3/1	3/1	-	-	-	-	6/2	8/3	-	21/8
Allacma fusca (Linnaeus 1758)	-	-	-	1/1	-	-	-	-	1/1	-	-	2/2
Number of specimens	1938	887	1189	3721	1050	1989	606	1451	1336	3486	6568	
	4014			6760			3393			10054		
	14167											
	24221											
Number of species	26	30	34	30	21	32	20	24	36	40	6	
	46			44			44			42		
	56											
	60											
Margalef index	5,42			4,88			5,29					
	5,75											

Table 3. A list of Collembola collected in *Serratulo-Pinetum* (SP). Abbreviations: SP1 – dead wood in semi-natural forest, SP2 – dead wood in deformed forest but with typical habitat features, SP3 – dead wood in highly deformed forest, I–-III – phases of dead wood decay, SG – litter and soil, E – epiphytic mosses and lichens.

Species	Number of specimens / localities											
	SP1			SP2			SP3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Saproxylobiontic species:												
Desoria nivea (Schäffer 1896)	1/1	6/2	-	-	120/1	-	-	-	-	-	-	127/4
Vertagopus cinereus (Nicolet 1841)	15/1	-	-	-	-	-	-	-	-	-	-	15/1
Proisotoma minima (Absolon 1901)	7/1	241/4	72/2	12/1	41/3	-	-	-	48/2	159/2	-	580/15
Saproxylophilous species:												
Friesea claviseta (Axelson 1900)	32/2	105/3	-	3/1	16/1	-	10/1	10/1	5/1	-	-	181/10

Species	Number of specimens / localities											
	SP1			SP2			SP3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Pseudachorutes parvulus (Börner 1901)	-	601/2	-	-	-	-	-	-	-	3/1	-	604/3
Pseudachorutella asigillata (Börner 1901)	-	1/1	-	-	-	-	-	-	-	-	-	1/1
Neanura muscorum (Templeton 1835)	5/1	22/4	10/2	-	9/2	-	-	25/3	17/2	1/1	-	89/15
Micraphorura absoloni (Börner 1901)	23/3	250/5	178/5	55/2	146/5	89/4	90/2	226/6	196/4	424/8	-	1677/44
Entomobrya corticalis (Nicolet 1841)	148/6	28/3	7/1	129/4	12/1	-	48/5	-	-	14/2	4/3	390/25
Bryophilous xerophiles:												
Xenylla boerneri (Axelson 1905)	2220/5	515/5	10/1	10/1	21/1	5/1	343/5	32/1	-	15/1	6967/13	10138/34
Anurophorus laricis (Nicolet 1842)	180/1	-	-	107/2	-	-	114/2	48/4	20/2	-	1690/11	2159/22
Entomobrya marginata (Tullberg 1871)	10/1	2/1	-	34/3	1/1	-	7/2	7/2	11/1	42/2	56/6	170/19
Entomobrya nivalis (Linnaeus 1758)	5/1	-	-	-	-	-	4/2	2/1	-	-	1/1	12/5
Litter and soil species:												
Xenylla maritima (Tullberg 1869)	11/2	1/1	-	17/4	5/2	1/1	56/1	2/1	3/2	3/2	76/11	175/27
Willemia anophthalma (Börner 1901)	-	-	6/2	-	15/1	67/2	-	-	-	-	-	88/5
Willemia denisi (Mills 1932)	-	-	-	-	26/2	40/2	-	-	3/1	6/2	-	75/7
Friesea truncata (Cassagnau 1958)	-	10/1	-	-	-	-	-	7/2	19/2	75/3	-	111/8
Micranurida granulata (Agrell 1943)	-	-	-	-	-	-	-	2/1	-	-	-	2/1
Micranurida pygmaea (Börner 1901)	-	43/2	152/4	-	41/2	28/2	10/1	218/4	148/4	40/3	-	680/22
Pratanurida boerneri (Schött 1902)	-	-	-	-	-	-	-	-	-	-	1/1	1/1
Pseudachorutes dubius (Krausbauer 1898)	-	-	-	-	-	-	-	-	-	2/2	-	2/2
Pseudachorutes subcrassus (Tullberg 1871)	-	-	-	-	-	-	-	-	-	4/2	-	4/2

Species	Number of specimens / localities											
	SP1			SP2			SP3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Protaphorura armata (Tullberg 1869)	-	-	-	-	3/1	-	-	-	-	3/1	-	6/2
Mesaphorura critica (Ellis 1976)	-	19/3	53/2	-	-	194/4	1/1	23/2	42/3	275/9	-	607/24
Mesaphorura macrochaeta (Rusek 1976)	-	72/4	195/5	-	60/3	906/6	20/1	121/4	286/6	830/16	1/1	2491/46
Mesaphorura tenuisensillata (Rusek 1974)	-	-	20/2	-	11/1	67/2	-	8/1	4/1	68/4	-	178/11
Paratullbergia callipygos (Börner 1903)	-	-	-	-	-	8/2	-	1/1	-	-	-	9/3
Stenaphorura quadrispina (Börner 1901)	-	-	-	-	-	-	-	-	-	1/1	-	1/1
Anurophorus septentrionalis (Palissa 1966)	-	-	3/1	-	-	-	-	-	-	49/4	-	52/5
Desoria hiemalis (Schött 1893)	30/2	109/6	74/4	-	215/5	12/3	50/1	58/2	20/2	45/6	-	613/31
Isotomiella minor (Schäffer 1896)	-	53/1	253/6	28/1	243/3	136/3	-	130/4	254/5	242/6	-	1339/29
Parisotoma notabilis (Schäffer 1896)	-	164/3	334/5	33/1	70/3	323/5	25/1	272/4	341/5	516/13	-	2078/40
Orchesella bifasciata Nicolet 1841	4/1	17/3	10/2	3/1	1/1	7/2	-	-	3/1	55/7	-	100/18
Orchesella flavescens (Bourlet 1839)	-	18/3	14/3	18/3	10/3	47/5	25/4	24/3	7/2	30/7	1/1	194/34
Lepidocyrtus lanuginosus (Gmelin 1788)	-	14/1	-	-	6/1	15/2	-	-	-	31/4	-	66/8
Lepidocyrtus lignorum (Fabricius 1793)	3/1	183/5	205/6	16/1	59/4	240/6	43/4	102/4	117/3	857/18	-	1825/52
Pseudosinella zygophora (Schille 1908)	-	-	-	-	-	-	-	-	4/1	25/1	-	29/2
Pogonognathellus flavescens (Tullberg 1871)	2/1	38/4	76/4	3/2	28/4	66/5	25/2	141/4	24/2	85/8	-	488/36
Tomocerina minuta (Tullberg 1976)	-	-	-	-	-	2/1	-	-	-	4/1	-	6/2
Tomocerus vulgaris (Tullberg 1871)	-	5/1	-	-	-	17/3	-	-	-	4/2	-	26/6
Megalothorax minimus (Willem 1900)	-	12/2	10/1	-	3/1	-	1/1	16/4	7/1	-	-	49/10

Species	Number of specimens / localities											
	SP1			SP2			SP3			SG	E	**Razem** Total
	I	II	III	I	II	III	I	II	III			
Arrhopalites secundarius (Gisin 1958)	-	-	-	2/1	2/1	-	-	-	4/1	-	-	8/3
Arrhopalites sericus (Gisin 1947)	-	-	3/1	-	-	1/1	1/1	-	-	-	-	5/3
Arrhopalites spinosus (Rusek 1967)	-	2/1	-	-	-	14/2	-	3/1	-	-	-	19/4
Sminthurinus alpinus (Gisin 1953)	-	3/1	-	-	-	-	-	-	-	11/3	-	14/4
Lipothrix lubbocki (Tullberg 1872)	1/1	4/2	-	-	-	2/1	-	33/3	2/1	-	-	42/8
Dicyrtoma fusca (Lubbock 1873)	-	-	-	-	-	21/1	-	-	-	-	-	21/1
Sphaeridia pumilis (Krausbauer 1898)	-	5/1	-	-	3/1	-	-	10/1	18/1	-	-	36/4
Caprainea marginata (Schött 1893)	-	-	3/1	-	-	1/1	-	-	27/2	-	-	31/4
Number of specimens	2697	2543	1688	470	1167	2309	873	1521	1630	3919	8797	
	6928			3946			4024			12716		
	14898											
	27614											
Number of species	17	29	21	15	26	25	18	25	26	31	9	
	37			36			33			34		
	45											
	49											
Margalef index	4,07			4,23			3,86					
	4,58											

(Smolis, Skarżyński 2004), *Deutonura albella* (Stach 1921), *Deutonura conjuncta* (Stach 1951), *Deutonura plena* (Stach 1951), *Deutonura stachi* (Gisin 1952), *Deutonura weinerae* (Deharveng 1982), *Endonura carpatica* (Smolis 2006), *Endonura dudichi* (Loksa 1967), *Endonura incolorata* (Stach 1951), *Endonura tatricola* (Stach 1951), *Galanura agnieskae* (Smolis 2000), *N. minuta* (Gisin 1963), *N. muscorum*, *Neanura parva* (Stach 1951), *Thaumanura carolii* (Stach 1920), *Morulina verrucosa* (Börner 1903), *H. polonica*, *Heteraphorura carpatica* (Stach 1954), *M. absoloni*, *Orthonychiurus rectopapillatus* (Stach 1933), *Folsomia inoculata* (Stach 1946), *D. nivea*, *V. cinereus*, *Proisotoma clavipila* (Axelson 1903), *P. minima*, *E. corticalis* and *Rusekianna bescidica* (Smolis, Skarżyński 2006).

By comparison, in the Karkonosze National Park, 19 species of saproxylic springtails were recorded (Piwnik, Skarżyński 2015; Skarżyński, Piwnik 2016), whereas the results of the study carried out in the Bałowieża National Park (using different methodology) showed only 10 such species (Smolis 2002; Sławska 2005). Territorially close to each other, the WNP and the Bałowieża National Park (deadwood abundance of 123 m^3/ha, Bobiec 2002) differ in terms of naturalness but have comparable fauna, which is also saproxylic. In the WNP, *P. corticicolus* does not occur, whereas in the Bałowieża National Park, *X. corticalis* and *D. nivea* do not occur. The above data indicate that deadwood abundance is not related to the number of springtail species associated with this habitat, in the same way as in the case of saproxylic insects studied by Plewa et al. (2014). Amon-

Table 4. A list of Collembola collected in *Peucedano-Pinetum* (PP). Abbreviations: PP1 – dead wood in semi-natural forest, PP2 – dead wood in deformed forest but with typical habitat features, PP3 – dead wood in highly deformed forest, I–III – phases of dead wood decay, SG – litter and soil, E – epiphytic mosses and lichens.

Species	Number of specimens / localities											
	PP1			PP2			PP3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Saproxylobiontic species:												
Vertagopus cinereus (Nicolet 1841)	-	-	-	80/1	-	-	-	-	-	-	-	80/1
Proisotoma minima (Absolon 1901)	16/1	934/6	2/1	-	31/1	-	-	1/1	1/1	-	-	985/11
Saproxylophilous species:												
Friesea claviseta (Axelson 1900)	8/3	17/2	-	-	-	-	5/1	-	-	-	-	30/6
Pseudachorutes parvulus (Börner 1901)	-	1/1	3/1	15/1	-	-	-	-	-	10/1	-	29/4
Pseudachorutella asigillata (Börner 1901)	1/1	-	-	-	2/1	-	-	-	-	-	-	3/2
Neanura muscorum (Templeton 1835)	1/1	66/5	3/1	1/1	3/2	13/4	3/1	5/2	5/1	8/3	-	108/21
Micraphorura absoloni (Börner 1901)	102/5	272/5	119/5	28/1	86/4	322/5	200/1	336/6	254/6	371/15	2/1	2092/54
Entomobrya corticalis (Nicolet 1841)	88/5	5/1	-	118/6	72/4	13/3	109/5	60/3	6/2	25/2	499/10	995/41
Bryophilous xerophiles:												
Xenylla boerneri (Axelson 1905)	800/5	122/4	71/3	-	-	-	-	-	-	507/2	1957/7	3457/21
Anurophorus laricis (Nicolet 1842)	411/2	46/2	-	210/5	143/5	3/1	240/6	55/3	24/1	-	1143/15	2275/40
Entomobrya marginata (Tullberg 1871)	28/3	-	-	-	7/1	-	26/3	22/1	-	13/4	279/13	375/25
Entomobrya nivalis (Linnaeus 1758)	-	-	-	1/1	1/1	-	-	-	-	-	1/1	3/3
Litter and soil species:												
Xenylla brevicauda (Tullberg 1869)	-	-	-	-	-	-	-	-	-	83/2	820/1	903/3
Xenylla maritima (Tullberg 1869)	13/3	-	2/1	4/1	-	-	-	-	-	1/1	5/3	25/9
Willemia anophthalma (Börner 1901)	-	5/1	20/1	-	-	70/1	-	-	10/1	71/3	-	176/7
Willemia denisi (Mills 1932)	-	-	10/1	-	20/1	148/3	-	53/1	18/1	23/3	-	272/10

Species	Number of specimens / localities											
	PP1			PP2			PP3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Friesea truncata (Cassagnau 1958)	-	-	25/1	-	-	-	-	-	-	-	-	25/1
Micranurida granulata (Agrell 1943)	-	-	3/1	-	-	-	2/1	2/1	3/2	-	-	10/5
Micranurida pygmaea (Börner 1901)	50/1	172/5	93/3	18/3	96/4	279/6	-	192/3	135/5	265/12	2/1	1302/43
Pseudachorutes subcrassus (Tullberg 1871)	-	-	-	-	-	-	-	-	-	10/1	-	10/1
Protaphorura armata (Tullberg 1869)	-	-	-	-	-	-	-	-	-	5/1	-	5/1
Mesaphorura critica (Ellis 1976)	13/2	33/2	29/2	-	17/2	103/3	-	19/2	56/2	73/7	-	343/22
Mesaphorura macrochaeta (Rusek 1976)	69/2	150/5	335/5	-	139/3	320/6	-	208/3	240/5	436/13	1/1	1898/43
Mesaphorura tenuisensillata (Rusek 1974)	5/1	-	14/2	-	-	19/2	-	20/2	-	6/1	-	64/8
Anurophorus septentrionalis (Palissa 1966)	-	-	-	-	-	10/1	-	-	-	94/5	-	104/6
Desoria hiemalis (Schött 1893)	36/2	334/6	31/4	44/2	74/2	19/5	-	61/2	12/2	37/8	-	648/33
Folsomia penicula (Bagnall 1939)	-	-	-	-	-	-	-	-	-	4/1	-	4/1
Isotomiella minor (Schäffer 1896)	34/1	25/1	182/3	10/1	11/1	129/4	20/1	170/3	183/4	552/13	-	1316/32
Parisotoma notabilis (Schäffer 1896)	10/1	150/3	523/6	22/1	87/3	247/6	22/1	161/2	224/6	615/13	5/1	2066/43
Orchesella bifasciata (Nicolet 1841)	-	6/2	13/3	-	2/1	7/2	9/1	7/2	-	21/8	4/2	69/21
Orchesella flavescens (Bourlet 1839)	5/2	8/2	13/4	-	3/2	-	-	18/2	-	46/10	-	93/22
Entomobrya nicoleti (Lubbock 1867)	-	1/1	-	-	-	-	-	-	-	-	-	1/1
Lepidocyrtus lanuginosus (Gmelin 1788)	-	-	16/2	-	-	4/1	-	-	4/1	15/4	-	39/8
Lepidocyrtus lignorum (Fabricius 1793)	21/3	150/3	214/4	4/1	144/4	222/6	5/2	226/3	125/6	318/18	14/2	1443/52
Pogonognathellus flavescens (Tullberg 1871)	5/1	34/3	63/4	-	12/4	2/1	3/1	34/3	10/3	47/9	-	210/29
Tomocerina minuta (Tullberg 1976)	-	-	-	-	-	-	-	-	-	4/2	-	4/2

Species	Number of specimens / localities											
	PP1			PP2			PP3			SG	E	Total
	I	II	III	I	II	III	I	II	III			
Tomocerus vulgaris (Tullberg 1871)	-	8/2	-	-	-	-	-	-	-	4/2	-	12/4
Megalothorax minimus (Willem 1900)	-	29/3	10/2	-	3/1	12/2	-	5/1	22/1	27/5	-	108/15
Arrhopalites secundarius (Gisin 1958)	-	-	-	-	-	4/2	-	-	-	-	-	4/2
Arrhopalites sericus (Gisin 1947)	-	-	-	-	-	1/1	-	-	-	-	-	1/1
Arrhopalites spinosus (Rusek 1967)	-	3/1	-	-	-	-	-	7/2	5/1	13/5	-	28/9
Sminthurinus alpinus (Gisin 1953)	40/1	-	-	60/2	19/1	-	29/1	-	-	31/5	-	179/10
Lipothrix lubbocki (Tullberg 1872)	-	6/2	-	2/1	46/2	34/2	28/2	44/2	-	-	2/1	162/12
Dicyrtoma fusca (Lubbock 1873)	-	-	1/1	-	-	-	-	-	-	1/1	-	2/2
Sphaeridia pumilis (Krausbauer 1898)	-	-	-	-	-	-	-	3/1	1/1	15/2	-	19/4
Caprainea marginata (Schött 1893)	-	-	-	-	-	3/1	-	5/3	4/3	9/3	-	21/10
Allacma fusca (Linnaeus 1758)	-	-	-	-	-	-	-	5/1	-	-	-	5/1
Number of specimens	1756	2577	1795	617	1018	1984	701	1719	1342	3760	4734	
	6128			3619			3762			8494		
	13509											
	22003											
Number of species	21	24	24	15	22	23	14	25	21	34	14	
	34			32			29			37		
	42											
	47											
Margalef index	3,78			3,78			3,40					
	4,31											

gst others, this is due to biogeographic conditions. The range of species from the sub-family Neanurinae that comprises nearly half of the species composition of Poland's saproxylic fauna indicates the connection with Pleistocene glaciations. Neanurinae fauna is the richest in south-eastern Poland, where recolonisation from south European refugees lasted for the longest period of time. In western and northern parts of the country, saproxylic fauna is, by and large, less species-rich (Smolis 2000).

Overall, the WNP mainly lacks springtail species, whose range in Poland is limited to the Carpathian and Sudety Mts.

Consequently, the species composition of saproxylic springtails evaluated in the Park can be assented as characteristic for the region. Therefore, it can be concluded that irrespective of low deadwood abundance in the Park, sustainability of ecological processes has been maintained, and this allowed for continued existence of saproxylic springtail species. In this context, the estimations by Czerepko et al. (2008) appear to be justified that 3–10 m^3 of deadwood per hectare can provide satisfactory living conditions for several saproxylic organisms and 10–30 m^3/ha can support majority of them.

Low frequency and dominance values obtained for saproxylobiontic *Collembola* species are perplexing (Table 1). Taking into account to date knowledge, it is difficult to decide whether such patterns are due to natural scarcity of these species or a result of anthropogenic pressure on the habitats of the WNP.

The numbers of *Collembola* species and specimens increase with deadwood decomposition rates, as severely decayed deadwood attracts not only saproxylic species but also those residing in the soil and litter as well. Skarżyński and Piwnik (2016) presented similar results from the Karkonosze National Park. The lowest values of species richness of *Collembola* communities in deadwood at the first stage of decomposition (I) were attributed by the authors to difficult life conditions in this very habitat. On the other hand, Skubała and Maślak (2009), who investigated microarthropod communities in laying spruce (*Picea abies* L.) logs in the Babia Góra National Park, reported the highest densities of springtails and mites (*Acari*) in deadwood at the second stage (II) of decomposition (evaluated using five-point scale). When compared to decomposition stage II, densities of *Collembola* were considerably decreased in wood at the stages I and III–V, whereas densities of mite were relatively lower only at the stage I of deadwood decomposition.

In the WNP, likewise in the Karkonosze National Park (Skarżyński, Piwnik 2016), the richest and most diverse springtail communities were recorded in deadwood situated in deciduous forests (WNP, *Tilio-Carpinetum*; KNP, oak -hornbeam and beech forests). As *Collembola* communities, observed in deadwood situated in *Serratulo-Pinetum* and *Peucedano-Pinetum* in WNP as well as in lower montane zone spruce forests in KNP, were less species-rich, it can be concluded that coniferous forests offer less favourable conditions for endurance of saproxylic springtails when compared with deciduous habitats. The reasons behind this status include abiotic factors, such as temperature and humidity, as well as biotic factors. As stated by Skarżyński and Piwnik (2016), deadwood of birch (*Betula pendula* Roth.) and beech (*Fagus sylvatica* L.) is more attractive to saproxylobiontic *Collembola* when compared to deadwood of spruce.

There was observed all-embracing a minor decrease in the number of *Collembola* species in deadwood in conjunction with habitat deformation degrees, which indicates sensitivity of saproxylic springtail communities to anthropogenic pressures. Skarżyński and Piwnik (2016) noted similar relations when evaluating *Collembola* communities in deadwood situated in semi-natural deciduous forests and artificially introduced spruce monocultures.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements and funding sources

The study was financed by the Forest Fund of the State Forests, within a framework of the project realized in 2015: ‘Studies on saproxylic fauna of springtails (Collembola) in selected forest habitats of the Wigry National Park in view of realized and recommended restoration activities’. The authors thank the Park authorities and staff for their cooperation and the reviewers of the manuscript for their valuable comments.

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Authors' contribution

D.S., A.P. – study conception, collection and identification of study material, production of results, manuscript text; A.K. – study conception, collection of study material, manuscript edition.

Translated by: Bożena Kornatowska