BALTIC FORESTRY

http://www.balticforestry.mi.lt
ISSN 1392-1355
eISSN 2029-9230

Baltic Forestry 2020 26(1): 323
Category: research article
https://doi.org/10.46490/BF323

Litter-dwelling invertebrates in natural and plantation forests in the southern Carpathians, Romania

ALFRED-ŞTEFAN CICORT-LUCACIU[1], DIANA CUPŞA[1], FELICIA-NICOLETA SUCEA[2], SÁRA FERENŢI[1] AND SEVERUS-DANIEL COVACIU-MARCOV[1]*

[1] *University of Oradea, Faculty of Informatics and Sciences, Department of Biology, 1, Universităţii, Oradea 410087, Romania*
[2] *Jiu Gorge National Park, Str. Lt. Col. Dumitru Petrescu, Nr. 3, Târgu-Jiu, Romania*

* *Corresponding author: severcovaciu1@gmail.com*

Cicort-Lucaciu, A.Ş., Cupşa, D., Sucea, F.-N., Ferenţi, S. and Covaciu-Marcov, S.-D. 2020. Litter-dwelling invertebrates in natural and plantation forests in the southern Carpathians, Romania. *Baltic Forestry* 26(1): article id 323. https://doi.org/10.46490/BF323.

Received 18 October 2019 **Revised** 25 March 2020 **Accepted** 28 April 2020

Abstract

Forest plantations usually have a poorer fauna than native forests of the same region. Exceptions seem to appear in colder areas of Europe with few native forests. The Jiu Gorge National Park (JGNP) is situated in the Southern Romanian Carpathians, where numerous native, especially beech, forests are present. However, in the southern part of JGNP there are plantations with non-native species, like pine or black locust, where previous studies had reported a poor fauna. Based on this information, we supposed that this fauna poverty in plantations will be obvious also in the case of the litter macrofauna. This was verified by analyzing the litter macrofauna from 15 forests in the JGNP (10 natural forests and five forest plantations). We collected 12,950 individuals belonging to 28 invertebrate groups. The highest taxa number was registered in the sessile oak forest, while the highest individual number and taxa diversity was observed in two beech forests. In the beech and birch reforestation areas the fauna was poorer than in old, mature forests of the same tree species. In contrast to native forests, the fauna in plantations was much poorer, especially in pine plantations. Detritiphagous taxa were the most affected by plantations. In plantations, more mobile groups with various trophic regimes prevail. Plantations that are present in the southern areas of JGNP, replaced the original sessile oak forests, compared to which they have a much poorer fauna. Forest plantations from JGNP have low value for biodiversity, compared to the northern European areas where natural forests became very rare and the fauna is recent. JGNP is not in the same situation, having extended native forests, which are present in the area since the glacial periods. Therefore, these forests shelter the native fauna of the region. There are few plantations, present only in the disturbed part of JGNP, but even there they have only a very low importance for biodiversity. The data from JGNP confirms the fact that zones with high biodiversity and native forests should be conserved.

Keywords: Carpathians, beech, forest plantations, past, native, invertebrates, leaf litter, forestry

Introduction

Stopping the deforestation of primary forests and studying biodiversity of some groups could help to save the future of our planet, because nowadays nature is considered to be in a disastrous condition (see in: Schrödl 2019). This goal is even more important and actual, because at global scale, even in the last years, forested surfaces were reduced even in protected areas (Tracewski et al. 2016). In these circumstances, stopping the loss of more primary forests requires important changes in conservation politics (e.g. Mikoláš et al. 2019). In the Carpathian Mountains from Eastern Europe, primary forests are still well represented compared to the general situation on the continent (e.g. Sabatini et al. 2018). Nevertheless, primary forests are not in a good situation in some countries from this region (Mikoláš et al. 2019). Unlike other areas of Europe, Romanian Carpathians even nowadays shelter numerous primary old growth forests (e.g. Veen et al. 2010, Biriş et al. 2016, Sabatini et al. 2018).

In the Southern Romanian Carpathians, forested regions were present even in the glacial period, numerous species having refuge in this region (see in: Varga 2010, Mráz and Ronikier 2016). In historical times, approximately 80%–90% of the Romanian territory was covered by forests, which due to deforestations decreased to approximately 25%–27% in the present (see in: Paşcovschi and Sburlan 1966, Veen et al. 2010). The forest surface reduction in the country, even if fluctuating over time (e.g. Munteanu et al. 2016), was intensive in the last century, especially in the last years (e.g. Bohatereț 2012, Griffiths et al. 2012, Knorn et al. 2012a, b, Munteanu et al. 2016, Andronache et al. 2017, Mihai et al. 2017, Nita et al. 2018). In the last couple of years, the reduction of afforested areas was even higher in some protected areas than in their surroundings (Knorn et al. 2012a). Even if present-day forests in Romania were much affected by the past forest management (Munteanu et al. 2016), in the country, old-growth forests still exist, especially in the Southern Carpathians (e.g. Veen et al. 2010). In the same time, the connectivity of the forests around the Carpathian Mountains is considered high (Stăncioiu et al. 2018).

A well-forested region in Southern Carpathians is the Jiu Gorge National Park (JGNP). This area is almost completely covered by beech forests and shelters numerous protected species, or species with zoogeographic importance (e.g. Petrescu et al. 2004, Bussler et al. 2005, Covaciu-Marcov et al. 2009, Tomescu et al. 2011, Telcean et al. 2017, Sucea 2019). Nevertheless, the Jiu River, which crosses and gives the name of the protected area, is threatened by hydro energetic works, which would reduce dramatically the river flow, affecting the biodiversity (e.g. Telcean et al. 2017, Carpa et al. 2017). Wooded areas are an important part of the protected area, which is situated in a region with dense beech forests (e.g. Blada et al. 2002, Knorn et al. 2012b). In the central part of the JGNP, these forests shelter the most diverse and representative fauna, which is much poorer in the southern part of the area (Covaciu-Marcov et al. 2009, Tomescu et al. 2011). This fact is a consequence of the increased anthropogenic impact upon the southern JGNP, and the fact that it has fewer native forests, most of them being replaced by pine or black locust plantations, with less herpetofauna and terrestrial isopod species (Covaciu-Marcov et al. 2009, Tomescu et al. 2011). This fauna poverty in forest plantations is not surprising, as it was repeatedly underlined in other zones (e.g. Magura et al. 2003, Stephens and Wagner 2007, Wiezik et al. 2007, Brockerhoff et al. 2008, Gardner et al. 2008, Paritsis and Aizen 2008, Bremer and Farley 2010, Gallé et al. 2018). However, in some cases plantations with non-native species were considered conservatively valuable, especially in areas where the native forests had become very rare (e.g. Humphrey et al. 2002, Quine and Humphrey 2010, Procter et al. 2015). This is not the case of JGNP, which is situated in a region where numerous natural old-growth forests are present (e.g. Veen et al. 2010, Knorn et al. 2012b).

Considering the previous studies which indicated fauna poverty in JGNP forest plantations in the case of herpetofauna and terrestrial isopods (Covaciu-Marcov et al. 2009, Tomescu et al. 2011), we hypothesized that in JGNP forest plantations with non-native species shelter a poorer fauna than native forests also in the case of other groups. Also, because the area is naturally occupied by forests, we supposed that the native beech or oak forests will contain the richest fauna. These were verified by analyzing the litter fauna from all forest types from the JGNP, where we proposed the following objectives 1. to establish the composition of the litter invertebrate fauna from different forest types from the JGNP; 2. to find the most favorable forest type for the litter macro-fauna; 3. to recommend some forest management measures from JGNP, based on our results.

Materials and methods

The field activity took place during April 15–17, 2015. We sampled 15 forests from the JGNP (Table 1), of which 10 were native, and five forest plantations with non-native species (four pine and one black locust plantation). The plantations are situated in the southern part of the JGNP. Among native forests we sampled one sessile oak, six beech, one alder and two birch forests. One beech and one birch forest were reforestations, the others being old-growth native forests, which, even if were probably subject to forestry managing activities in the past, had not been exploited for a long time. The sessile oak occupies very small areas in the southern JGNP where forest plantations dominate, because of the high human impact from the past. Old photographs show that approximately 100 years ago, during the railroad construction, the slopes from southern JGNP were completely deforested in the area (Berinde 2013). JGNP is situated in southwestern Romania, in the southern part of the Southern Romanian Carpathians, on the higher reaches of the Jiu River, which forms a gorge of approximately 18 km length (Ujvári

Table 1. Characteristics and coordinates of the sampling points

Forest dominant tree species	Location	Altitude	Geographic coordinates	Forest type
Sessile oak	**Bumbesti**	426	45º11'27.83"N 22º23'02.59"E	Natural
Beech	**Meri**	380	45º12'54.84"N 23º22'33.72"E	Natural
Beech	**Comanda**	503	45º15'07.22"N 23º23'35.50"E	Natural
Beech	**Bumbesti Plai**	696	45º12'27.20"N 23º23'53.67"E	Natural
Beech regeneration	**Meri**	341	45º12'46.88"N 23º22'48.36"E	Natural
Beech, linden	**Meri**	362	45º13'07.56"N 23º22'37.14"E	Natural
Beech, spruce	**Bratcu**	820	45º14'39.00"N 23º20'28.84"E	Natural
Alder	**Meri**	348	45º12'57.40"N 23º22'35.43"E	Natural
Birch	**Comanda**	796	45º15'01.34"N 23º24'49.29"E	Natural
Birch regeneration	**Bumbesti**	455	45º11'38.52"N 23º23'54.41"E	Natural
Black-locust	**Bumbesti**	512	45º11'47.43"N 23º23'52.78"E	Plantation
Pine	**Bumbesti tunnel**	355	45º11'26.78"N 23º23'14.79"E	Plantation
Pine	**Bumbesti low**	352	45º11'25.87"N 23º23'36.18"E	Plantation
Pine	**Bumbesti medium**	428	45º11'34.65"N 23º23'45.24"E	Plantation
Pine	**Bumbesti up**	588	45º11'55,21"N 23º23'59.58"E	Plantation

1972). There are no human settlements in this area, only some scattered houses, monasteries and railway stations.

Previous studies, which highlighted the fauna poverty from the southern JGNP with non-native forest plantations, were realized with qualitative methods and were focused only on some animal groups, like herpetofauna or terrestrial isopods (Covaciu-Marcov et al. 2009, Tomescu et al. 2011). We realized a quantitative sampling, using the litter sieve. We chose not to use pitfall traps as they affect much more animal groups including animals, which are not characteristic for the litter fauna, and would be just unnecessary victims. The litter sieve permits the analysis of the small and less mobile fauna, characteristic for the litter, which is the typical fauna of the region. The litter sieve had 5 mm meshes. In each habitat the sampling was made by the same two persons, which had collected the same amount of litter in the same time period. In each of the 15 studied forests we collected only one sample with the litter sieve. The samples were standardized by the amount of litter introduced in the litter sieve. At each sample the same person introduced in the litter sieve three times the amount of litter that could be taken so that the space between the hands was full of litter. The samples were conserved in plastic bags with alcohol. Field sampling lasted only 5–10 minutes in each forest. Unlike this, the laboratory work consumed much longer time, lasting in the case of very rich samples even many consecutive days of work. The taxa were determined subsequently in the laboratory with a stereomicroscope, with the help of the keys from Romania (e.g. Radu and Radu 1967, 1972, Ionescu and Lacătușu 1971). Invertebrates were determined to the lowest possible taxonomic level, taking into account the huge individual number belonging to a high number of groups. The determination level is comparable to the one used in other studies (e.g. Turner and Foster 2009, Zahn et al. 2009, Cupșa et al. 2010). To the identified taxa we added a category represented by pre-adult stages, containing larvae of different arthropod groups which could not be determined exactly because of their reduced dimension and incomplete developmental stage. The samples are kept in the scientific collection of the Department of Biology from University of Oradea.

After the taxa determination we calculated the percentage abundance of each taxa, both totally and in the case of each forest. Also, we calculated the frequency of occurrence of each taxon in the 15 studied forests. The diversity was calculated with the Shannon index. Also, we calculated the taxa evenness. The significance of the abundance differences between the leaf-litter fauna from different types of forests was calculated with the Mann Whitney Index. The similarity was estimated both between the identified taxa and between the 15 studied forests using the Jaccard Index. The affinity of different taxa for different forest types was modeled with the Correspondence Analysis. The statistical analyses were realized with Past 3x (Hammer et al. 2001).

Results

In the 15 studied forests in JGNP we have determined 12950 individuals belonging to 28 invertebrate taxa. Five taxa were present in all the 15 forests, and two in only one forest (Table 2). The highest number of taxa / habitat was 25, being registered in the sessile oak forest. The smallest number of groups was only 10, registered in one of the pine plantations. The number of taxa was higher in natural forests compared with plantations (Table 2). The taxa number in forest recoveries was lower than in natural forests of the same type (Table 2). The highest number of individuals was collected from beech and birch mature forests, and the lowest from the birch recovery and from plantations. Just like in the case of the taxa number, the individuals` number was smaller in plantations than in native mature forests (Table 2). The total diversity of the leaf litter invertebrate assemblages from JGNP forests was $H = 2.11$.

The percentage abundance of different taxa varied between the 15 investigated forests (Table 2); each group reaching high percentage abundance in different forest types, without any obvious rule. Nevertheless, flying, or invertebrates with high mobility (Nematocera, Hymenoptera), reached higher percentage abundance in plantations; meanwhile non-flying taxa had higher percentage abundance in natural forests. In the same time, detritiphagous invertebrates (Isopoda, Diplopoda, Diplura, Protura, Collembola) were missing or very rare in plantations, unlike natural forests (Table 2).

Differences between the leaf litter invertebrate assemblages from the 15 studied forests in JGNP, taken two by two, were usually significant according to the Mann Whitney test. First, significant differences were registered between the assemblages from native forests and plantations, but also between some natural forests (Table 3). Among the 15 studied forests, the most different leaf litter fauna was present in pine plantations. When comparing assemblages from groups of forests, there were significant differences of the taxa composition both between natural forests and plantations ($p = 0.0004$), and between beech forests and pine plantations ($p = 0.0003$).

According to the Jaccard index, native forests were similar between them and different from plantations (Figure 1). Correspondence analysis reveals that almost all animal groups have affinity towards native forests (Figure 2). Thysanoptera was the only group with affinity towards pine plantations, and Formicidae towards black locust and pine plantations (Figure 2). Oligochaeta and Heteroptera have affinity for birch and alder (Figure 2).

Discussion and conclusions

The leaf litter fauna from the investigated forests in JGNP have confirmed our hypothesis. Therefore, natural forests contain the richest leaf litter fauna, and forest plantations have a much poorer fauna both as taxa and individual numbers. Beech forests shelter approximately

Table 2. The percentage abundance (P%), frequency of occurrence (f%), diversity, evenness, individual number and richness of the taxa identified in the 15 forests in JGNP

	Sessile oak Bumbesti	Beech Meri	Beech Comanda	Beech Bumbesti Plai	Beech reg. Meri	Beech, linden Meri	Beech, spruce Bratcu	Alder Meri	Birch Comanda	Birch reg. Bumbesti	Black-locust Bumbesti	Pine Bumbesti tunnel	Pine Bumbesti low	Pine Bumbesti medium	Pine Bumbesti up
Nematoda	13.42	4.56	5.17	2.41	37.73	15.60	9.29	12.21	9.11	-	-	-	11.11	-	1.52
Oligochaeta	0.16	-	-	0.65	-	-	-	0.36	-	1.21	-	-	-	-	-
Gastropoda	0.58	2.98	1.78	0.65	2.07	3.12	1.22	0.51	1.55	1.21	11.18	0.20	-	0.50	0.57
Pseudoscorpionida	1.82	1.24	2.23	3.73	0.93	1.36	1.73	0.77	0.57	1.21	0.62	0.41	-	5.52	2.09
Opilionida	0.16	0.33	-	0.43	0.31	0.25	0.51	0.05	0.16	-	1.24	-	-	0.50	-
Araneae	0.99	1.49	3.12	0.87	1.76	0.64	1.94	1.19	1.31	14.63	3.72	1.03	4.44	2.51	2.47
Acarina	18.14	10.45	19.26	2.19	8.00	14.62	17.67	27.07	28.32	10.97	17.39	67.63	5.55	18.09	21.67
Isopoda	0.16	1.49	0.53	0.21	0.51	0.38	0.71	0.36	0.32	-	-	-	-	-	-
Pauropoda	-	-	0.17	-	-	-	0.40	0.10	0.16	-	-	-	-	-	-
Symphyla	0.16	0.16	1.24	-	-	-	0.20	-	0.32	-	-	-	-	-	-
Penicillata	23.11	8.04	20.07	9.45	0.51	4.91	6.33	-	11.24	7.31	23.60	3.94	30	15.57	25.85
Chilognatha	0.58	1.32	2.31	1.09	3.43	0.29	0.81	0.05	0.41	-	-	-	-	1.00	0.19
Chilopoda	1.49	4.48	4.63	0.21	3.53	0.85	1.32	0.72	3.61	1.21	0.62	-	1.11	2.01	0.57
Protura	0.91	0.66	2.23	-	0.10	0.04	0.61	0.20	1.47	-	-	-	-	-	0.19
Diplura	0.08	-	0.62	-	0.41	0.08	1.94	-	0.90	-	-	-	-	-	-
Collembola	20,29	48.05	22.03	62.19	23.18	40.82	31.35	26.45	16.09	26.82	16.14	4.97	14.44	18.09	20.53
Blattodea	0.08	-	-	-	-	-	-	-	-	-	-	0.20	-	-	-
Dermaptera	-	-	-	0.43	-	-	-	-	-	-	-	-	-	-	-
Heteroptera	0.16	-	-	-	0.10	0.04	0.10	0.10	0.90	1.21	-	-	-	-	-
Auchenorrhyncha	0.08	0.08	-	0.21	-	-	-	-	0.08	1.21	-	-	-	-	-
Sternorrhyncha	0.91	3.40	1.24	-	-	0.12	1.02	0.77	0.57	-	-	-	-	-	0.19
Thysanoptera	-	-	-	-	-	.	-	-	0.08	-	-	0.62	-	-	0.57
Psocoptera	0.16	-	1.60	-	1.45	0.72	0.10	0.51	0.08	-	0.62	-	2.22	1.00	0.19
Coleoptera	2.56	1.32	2.40	0.87	1.97	1.88	1.83	1.45	0.73	2.43	3.72	1.03	-	2.01	1.33
Nematocera	0.08	0.16	0.08	0.65	0.10	0.21	1.02	0.05	0.32	3.65	0.62	-	4.44	0.50	0.19
Brachycera	-	-	-	-	-	0.04	-	-	-	-	-	-	-	-	-
Hymenoptera*	0.16	0.16	-	-	0.10	-	-	0.15	-	-	1.24	0.41	-	-	0.38
Formicidae	1.73	1.41	1.60	0.21	0.83	1.66	0.91	0.15	1.31	18.29	8.07	3.94	3.33	11.05	2.85
preadult stage	11.93	8.13	7.58	13.40	12.89	12.27	18.89	26.66	20.27	8.53	11.18	15.56	23.33	21.60	18.63
No. of taxa	25	20	20	18	20	21	22	21	24	14	14	12	10	14	18
No. of individuals	1207	1205	1121	455	962	2339	979	1924	1218	82	161	482	90	199	526
P%	9.32	9.30	8.65	3.51	7.42	18.06	7.55	14.85	9.40	0.63	1.24	3.72	0.69	1.53	4.06
f%	86.20	68.96	68.96	62.06	68.96	72.41	75.86	72.41	82.75	48.27	48.27	41.37	34.48	48.27	62.06
Diversity	2.08	1.94	2.31	1.41	1.90	1.85	2.10	1.69	2.09	2.12	2.11	1.15	1.90	2.06	1.88
Evenness	0.64	0.64	0.77	0.49	0.63	0.60	0.68	0.55	0.66	0.80	0.80	0.46	0.82	0.78	0.65

* except Formicida.

Table 3. The significance of differences between the leaf litter assemblages from different forests from the JGNP

1 – Sessile oak Bumbesti, 2 – Beech Meri, 3 – Beech Comanda, 4 – Beech Bumbesti Plai, 5 – Beech regeneration Meri, 6 – Beech, linden Meri, 7 – Beech, spruce Bratcu, 8 – Alder Meri, 9 – Birch Comanda, 10 – Birch regeneration Bumbesti, 11 – Black-locust Bumbesti, 12 – Pine Bumbesti tunnel, 13 – Pine Bumbesti low, 14 – Pine Bumbesti medium, 15 – Pine Bumbesti up.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1															
2	0.856														
3	0.796	0.734													
4	**0.042**	0.095	**0.042**												
5	0.433	0.613	0.367	0.211											
6	0.993	0.862	0.956	0.067	0.487										
7	0.968	0.993	0.550	**0.031**	0.534	0.925									
8	0.616	0.581	0.417	0.167	0.899	0.609	0.588								
9	0.857	0.783	0.771	**0.017**	0.397	0.912	0.919	0.433							
10	**0.0005**	**0.004**	**0.002**	0.190	**0.018**	**0.004**	**0.001**	**0.009**	**0.0005**						
11	**0.003**	**0.019**	**0.009**	0.391	0.059	**0.013**	**0.011**	**0.041**	**0.004**	0.692					
12	**0.002**	**0.018**	**0.007**	0.247	**0.032**	**0.008**	**0.006**	**0.021**	**0.002**	0.972	0.739				
13	**0.0003**	**0.001**	**0.0007**	0.084	**0.005**	**0.001**	**0.0006**	**0.003**	**0.0002**	0.524	0.321	0.580			
14	**0.007**	**0.026**	**0.016**	0.442	0.079	**0.017**	**0.013**	0.058	**0.005**	0.638	0.899	0.663	0.284		
15	**0.050**	0.152	0.083	0.891	0.304	0.114	0.075	0.219	**0.032**	0.156	0.311	0.191	0.061	0.356	

the same number of taxa, with small differences between them. Among beech forests, the poorest fauna was in the forest from Bumbești and in the recovery from Meri. At Bumbești the beech forest is situated on a plateau surrounded by an open area used as pastures. The recovery from Meri is young, with uniform trees, resulted after a complete deforestation, the secondary forests having also in other cases a much poorer fauna compared with primary forests (e.g. Gardner et al. 2008, Ferenți et al. 2012). Although poorer, compared with the mature beech and sessile oak forests, the recovery still shelters a richer leaf litter fauna compared to plantations. According to these results, the natural recovery of forests should be practiced, while native species should be favored instead of the exotic ones (Hartley 2002). Being surrounded with natural forests, the recovery will be colonized gradually by the native fauna.

JGNP is covered mostly with beech forests, a fact reflected by the relative uniformity and high diversity of the leaf litter fauna in beech forests. Despite the fluctuations in individual numbers, all beech forests shelter approximately the same taxa number. Nevertheless, the highest number of taxa was not registered in a beech forest, but in the sessile oak forest from JGNP`s southern limit. Although situated in an affected area of JGNP, this is a natural forest, as the sessile oak is characteristic for hilly and lower mountain areas (e.g. Pașcovschi and Sburlan 1966). Nevertheless, not a single taxon was present exclusively in the sessile oak forest. The lower areas from the southern part of JGNP were probably initially occupied by sessile oak forests. This fact seems to be confirmed by the high number of taxa from the sessile oak forest litter, the fact that they are the same with the ones from the beech forests, and by the differences from the plantations. In this

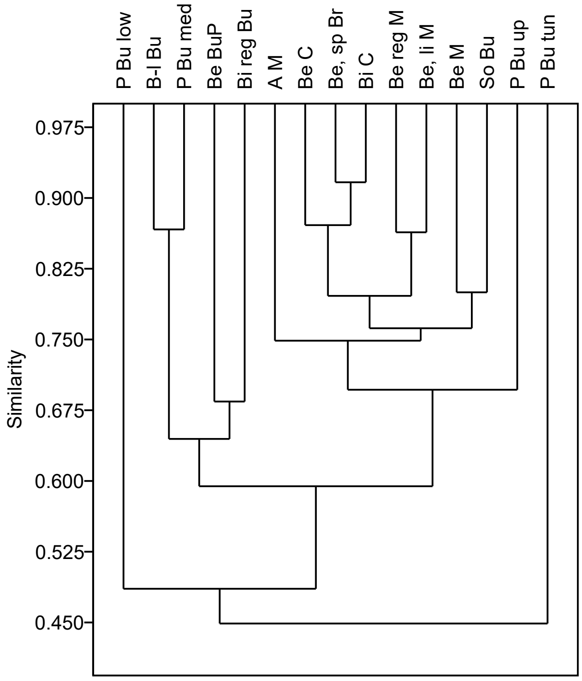

Figure 1. The Jaccard similarity between the leaf litter assemblages from different forests from the JGNP

P Bu low – Pine Bumbesti low, B-l Bu – Black-locust Bumbesti, P Bu med – Pine Bumbesti medium, Be BuP – Beech Bumbesti Plai, Bi reg Bu – Birch regeneration Bumbesti, A M – Alder Meri, Be C – Beech Comanda, Be sp Br – Beech spruce Bratcu, Bi C – Birch Comanda, Be reg M – Beech regeneration Meri, Be li M – Beech linden Meri, Be M – Beech Meri, So Bu – Sessile oak Bumbesti, P Bu up – Pine Bumbesti up, P Bu tun – Pine Bumbesti tunnel.

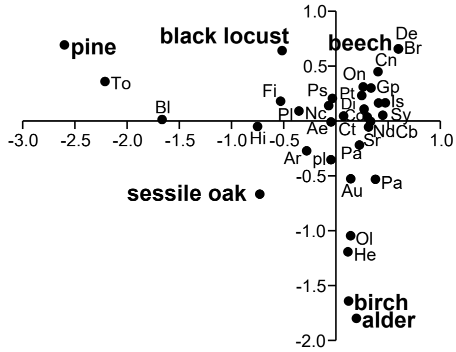

Figure 2. Correspondence analysis between the forest types and leaf litter taxa in the JGNP

Nd – Nematoda, Ol – Oligochaeta, Gp – Gastropoda, Ps – Pseudoscorpionida, On – Opiliones, Ae – Araneae, Ar – Acari, Is – Isopoda, Pa – Pauropoda, Sy – Symphyla, Pl – Penicillata, Cn – Chilognatha, Co – Chilopoda, Pr – Protura, Di – Diplura, Cb – Collembola, Bl – Blattodea, De – Dermaptera, He – Heteroptera, Au – Auchenorrhyncha, Sr – Sternorrhyncha, To – Thysanoptera, Pt – Psocoptera, Ct – Coleoptera, Nc – Nematocera, Br – Brachycera, Hi – Hymenoptera winged, Fi – Formicidae, pl – preadult stage.

way, the leaf litter invertebrates can indicate the initial aspect of the region`s forests.

Unlike native forests from JGNP, pine plantations` leaf litter fauna is the most distinct one, sheltering a small number of groups and individuals. Coniferous plantations were frequently proved to have a poorer fauna than native forests (e.g. Sinclair and New 2004, Finch 2005, Wiezik et al. 2007, Paritsis and Aizen 2008, Robson et al. 2009, Gallé et al. 2018). The reduced biodiversity from coniferous plantations, which replaced native beech forests, is determined by the changes in the soil properties determined by the coniferous (Kostić et al. 2012). The coniferous litter is poorer, and the soil pH is different (e.g. Finch 2005, Robson et al. 2009, Kostić et al. 2012), facts which affect detritophages. Also, in JGNP detritophages are missing or are very rare in pine plantations. Unlike them, more mobile, flying taxa, with more diverse trophic regime are present in plantations, although in smaller number than in native forests. Terrestrial isopods, important animals in litter decomposition (e.g. Hornung 2011), even if well represented in JGNP (Tomescu et al. 2011, Cicort-Lucaciu and Sucea 2015) and numerous in the region's natural forests, are missing in plantations. The isopod assemblages can be used as indicators of forests with high conservative importance (Ferenți et al. 2012). Also, in other cases forest plantations shelter only one isopod species (Ianc and Ferenți 2014). The situation from JGNP confirms this fact; terrestrial isopods from beech forests do not tolerate the leaf litter from coniferous plantations present outside their distribution range. In the same way, diplopods are missing or very rare in plantations.

Plantations with non-native species both to the country and the JGNP region, shelter a poorer fauna compared to native forests. This fact was underlined many times; the fauna from plantations was repeatedly proved to be poorer than the fauna of native forests (e.g. Magura et al. 2003, Finch 2005, Stephens and Wagner 2007, Brockerhoff et al. 2008, Gardner et al. 2008, Turner and Foster 2009, Bremer and Farley 2010, Gallé et al. 2018). Plantations are considered to shelter only a subset from the region`s native forest fauna (e.g. Sinclair and New 2004, Cunningham et al. 2005, Gardner et al. 2008). Nevertheless, in some cases plantations proved to have a positive value, sheltering native elements with conservative importance (e.g. Humphrey et al. 2002, Pawson et al. 2008, Quine and Humphrey 2010, Procter et al. 2015). Usually these situations were registered in regions where native forests were massively deforested for a long time and nowadays most forests are plantations (e.g. Brockerhoff et al. 2008, Quine and Humphrey 2010, Procter et al. 2015). In those cases, the fauna had no other solution except plantations. Some of these studies have targeted mobile animals, like ants (Procter et al. 2015). Ants were in other cases well represented also in plantations (Ratsirarson et al. 2002), a fact also true in JGNP. In the first-place plantations affect the less mobile animals and detritophages, characteristic for leaf litter. Plantations seem to be favorable for biodiversity in northern Europe (e.g. Humphrey et al. 2002, Quine and Humphrey 2010, Procter et al. 2015), a region covered in the past by ice sheet, and where the entire fauna has migrated recently. Probably because the fauna is anyway new in those regions, it accommodates easier to new habitat types, like plantations. Unlike this, in the Romanian Carpathians there are numerous endemic and relict species, which evolved in the region (see in: Varga 2010, Mráz and Ronikier 2016). They survived in arboreal refuges, thus evolved alongside a certain vegetation in a certain region, as the Romanian Carpathians were certified as an important Extra-Mediterranean refuge (see in: Varga 2010, Mráz and Ronikier 2016). Thus, the situation from the Carpathians is not similar with the one from northern Europe, the beech forest fauna diversity being higher in the Carpathians than in regions situated northwards (Walentowski et al. 2014). Recent studies indicated that beech survived the glacial periods also in refuges situated in the Romanian Carpathians (e.g. Willner et al. 2009, Magyari et al. 2017). In the areas with a richer and more diverse fauna the effect of plantations which replace native forests is more negative. Plantations probably help the native fauna in regions where the remaining native forests are extremely rare (e.g. Quine and Humphrey 2010, Procter et al. 2015), but in JGNP, and generally in the Carpathians, native forests are still a majority.

Forest plantations from JGNP are not quite green deserts as sometimes plantations were considered (see in: Brockerhoff et al. 2008), but they shelter only a small part of the region's native forest fauna, like in other cases (Gardner et al. 2008). Instead, they are way stations where more mobile taxa reach accidentally just to have from where to leave. In the same time, they are neither the slightest evil of the evil (Brockerhoff et al. 2008), because in the JGNP there are a lot of forests, which are not only good, but simply natural. Having plenty of natural habitat at its disposal, the native fauna has no reason to struggle in surrogates like plantations. Although it is important to know which habitats are replaced by plantations, because they are preferable instead of degraded lands terrains (e.g. Stephens and Wagner 2007, Brockerhoff et al. 2008), as well in JGNP the existing natural forests are preferable to plantations. In fact, plantations from JGNP are only unfortunate solutions, memories of periods when coniferous plantations were favored, a fact that modified in a certain degree the ratio between different tree species in the country, reducing the beech surface (e.g. Munteanu et al. 2016). Such fact should not be repeated, native forests should be protected as they are. The highest diversity of leaf litter fauna was registered in native old growth forests. This confirms the qualitative observations about the fauna poverty in forest plantations from JGNP (Covaciu-Marcov et al. 2009, Tomescu et al. 2011). Forest management in JGNP should take this into account, the extension of coniferous being a danger for relict species related to deciduous forests (Buse 2012).

Acknowledgements

This study was realized at the request and with the support of the administration of Jiu Gorge National Park.

References

Andronache, I., Fensholt, R., Ahammer, H., Ciobotaru, A.-M., Pintilli, R.-D., Peptenatu, D., Drăghici, C.-C., Diaconu, D.C., Radulović, M., Pulighe, G., Azihou, A.F., Toyi, M.S. and Sinsin, B. 2017. Assessment of textural differentiation in forest resources in Romania using fractal analysis. *Forests* 8(3): 54. https://doi.org/10.3390.f8030054.

Berinde, A. 2013. Realizarea liniei Bumbeşti-Livezeni, „confiscată" de comunişti [The realization of „Bumbeşti-Livezeni" railway line confiscated by the communists]. *Historia* 141: 50–53 (in Romanian).

Biriş, I.-A., Teodosiu, M., Turcu, D.-O., Merce, O., Lorenţ, A., Apostol, J. and Marcu, C. 2016. 24.000 ha de păduri primare de fag, propunerea României pentru Patrimoniul Mondial UNESCO. [24000 ha beech primary forests, Romania`s proposal for UNESCO World Heritage Site]. *Bucovina Forestieră* 16(1): 107–116 (in Romanian).

Blada, I., Alexandrov, A.H., Postolache, G., Turok, J. and Doniţă, N. 2002. Inventories for *in situ* Conservation of Broadleaved Forest Genetic Resources in South-eastern Europe. In: Engels, J.M.M., Ramanatha Rao, V., Brown, A.H.D. and Jackson, M.T. (Eds.) Managing Plant Genetic Diversity, CABI Publishing, UK, p. 217–227.

Bohatereţ, V.M. 2012. Readjusting Romania's Forestry Policy with a view to the Year 2050. *Journal of Settlements and Spatial Planning* 3(Special 1): 27–42.

Bremer, L.L. and Farley, K.A. 2010. Does plantation forestry restore biodiversity or create green deserts? A synthesis of the effects of land-use transitions on plant species richness. *Biodiversity and Conservation* 19: 3893–3915.

Brockerhoff, E.G., Jactel, H., Parrotta, J.A., Quine, C.P. and Sayer, J. 2008. Plantation forest and biodiversity: oxymoron or opportunity? *Biodiversity and Conservation* 17: 925–951.

Buse, J. 2012. "Ghosts of the past": flightless saproxylic weevils (Coleoptera: Curculionidae) are relict species in ancient woodlands. *Journal of Insect Conservation* 16: 93–102.

Bussler, H., Müller, J. and Dorka, V. 2005. European Natural Heritage: The Saproxylic Beetles in the proposed Parcul National Defileul Jiului. *Anale ICAS* 48: 3–19.

Carpa, R., Maior, M.C. and Dejeu, C. 2017. Romania ecosystems need EU protection. *Science* 358(6365): 880–881.

Cicort-Lucaciu, A.-Ş. and Sucea, F.-N. 2015. *Haplophthalmus danicus* (Isopoda, Oniscidea) in Jiu Gorge National Park, Romania. *South Western Journal of Horticulture, Biology and Environment* 6(2): 137–139.

Covaciu-Marcov, S.-D., Cicort-Lucaciu, A.S., Dobre, F., Ferenţi, S., Birceanu, M., Mihuţ, R. and Strugariu, A. 2009. The herpetofauna of the Jiului Gorge National Park, Romania. *North-Western Journal of Zoology* 5(suppl. 1): S1–S78.

Cunningham, S.A., Floyd, R.B. and Weir, T.A. 2005. Do *Eucalyptus* plantations host an insect community similar to remnant *Eucalyptus* forests? *Austral Ecology* 30: 103–117.

Cupşa, D., Kovács, É-H., Ferenţi, S., Hodişan, O. and Purtan, S. 2010. Terrestrial invertebrate communities from Resighea region (Satu-Mare County, Romania). *Biharean Biologist* 4(1): 45–55.

Ferenţi, S., Kovács, É-H., Cupşa, D. and Ianc, R.M. 2012. Some data on the terrestrial isopod assemblages from Livada Forest, north-western Romania. *Entomologica Romanica* 17: 13–19.

Finch, O.-D. 2005. Evaluation of mature conifer plantations as secondary habitat for epigeic forest arthropods (Coleoptera: Carabidae; Araneae). *Forest Ecology and Management* 204: 21–34.

Gallé, R., Szabó, A., Császár, P. and Torma, A. 2018. Spider assemblage structure and functional diversity patterns of natural forest steppes and exotic forest plantations. *Forest Ecology and Management* 411: 234–239.

Gardner, T.A., Hernández, M.I.M., Barlow, J. and Peres, C.A. 2008. Understanding the biodiversity consequences of habitat change: the value of secondary and plantation forests for neotropical dung beetles. *Journal of Applied Ecology* 45: 883–893.

Griffiths, P., Kuemmerle, T., Kennedy, R.E., Abrudan, I.V., Knorn, J. and Hostert, P. 2012. Using annual time-series of Landsat images to assess the effects of forest restitution in post-socialist Romania. *Remote Sensing of Environment* 118: 199–214.

Hammer, Ø., Harper, D.A.T. and Ryan, P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1): 9.

Hartley, M.J. 2002. Rationale and methods for conserving biodiversity in plantation forests. *Forest Ecology and Management* 155: 81–95.

Hornung, E. 2011. Evolutionary adaptation of oniscidean isopods to terrestrial life: Structure, physiology and behavior. *Terrestrial Arthropod Reviews* 4: 95–130.

Humphrey, J.W., Ferris, R., Jukes, M.R. and Peace, A.J. 2002. The Potential Contribution of Conifer Plantations to the UK Biodiversity Action Plan. *Botanical Journal of Scotland* 54(1): 49–62.

Ianc, R.M. and Ferenţi, S. 2014. Data upon the terrestrial isopod assemblages from Pădurea Craiului Mountains karst area, western Romania. *North-Western Journal of Zoology* 10(Supplement 1): S87–S93.

Ionescu, M.A. and Lăcătuşu, M. 1971. Entomologie [Entomology]. Editura Didactică și Pedagogică, București, 416 pp. (in Romanian).

Knorn, J., Kuemmerle, T., Radeloff, V.C., Szabo, A., Mindrescu, M., Keeton, W.S., Abrudan, I., Griffiths, P., Gancz, V. and Hostert, P. 2012a. Forest restitution and protected area effectivness in post-socialist Romania. *Biological Conservation* 146: 204–212.

Knorn, J., Kuemmerle, T., Radeloff, V.C., Keeton, W.S., Gancz, V., Biriş, I.-A., Svoboda, M., Griffiths, P., Hagatis, A. and Hostert, P. 2012b. Continued loss of temperate old-growth forests in the Romanian Carpathians despite an increasing protected area network. *Environmental Conservation* 40(2): 182–193.

Kostić, O., Mitrović, M., Jarić, S., Djurdjević, L., Gajić, G., Pavlović, M. and Pavlović, P. 2012. The effects of forty years of spruce cultivation in a zone of beech forests on Mt. Maljen (Serbia). *Archives of Biological Sciences Belgrade* 64(3): 1181–1195.

Magyari, E., Vincze, I., Orbán, I., Bíró, T. and Pál, I. 2017. Timing of major forest compositional changes and tree expansions in the Retezat Mts during the last 16,000 years. *Quaternary International* 477: 40–58.

Magura, T., Tóthmérész, B. and Elek, Z. 2003. Diversity and composition of carabids during a forest cycle. *Biodiversity and Conservation* 12: 73–85.

Mihai, B., Săvulescu, I., Rujoiu-Mare, M. and Nistor, C. 2017. Recent forest cover changes (2002–2015) in the Southern Carpathians: A case study of the Iezer Mountains, Romania. *Science of the Total Environment* 599/600: 2166–2174.

Mikoláš, M., Ujházy, K., Jasík, M., Wiezik, M., Gallay, I., Polák, P., Vysoký, J., Čiliak, M., Meigs, G.W., Svoboda, M., Trotsiuk, V. and Keeton, W.S. 2019. Primary forest distribution and representation in a Central European landscape: Results of a large-scale field-based census. *Forest Ecology and Management* 449: 117466.

Mráz, P. and Ronikier, M. 2016. Biogeography of the Carpathians: evolutionary and spatial facets of biodiversity. *Biological Journal of the Linnean Society* 119: 528–559.

Munteanu, C., Nita, M.D., Abrudan, I.V. and Radeloff, V.C. 2016. Historical forest management in Romania is imposing strong legacies on contemporary forests and their management. *Forest Ecology and Management* 361: 179–193.

Nita, M.D., Munteanu, C., Gutman, G., Abrudan, I.V. and Radeloff, V.C. 2018. Widespread forest cutting in the aftermath of World War II captured by broad-scale historical Corona spy satellite photography. *Remote Sensing of Environment* 204: 322–332.

Paritsis, J. and Aizen, M.A. 2008. Effects of exotic conifer plantations on biodiversity of understory plants, epigeal beetles and birds in *Nothofagus dombey* forests. *Forest Ecology and Management* 255: 1575–1583.

Paşcovschi, S. and Sburlan, D. 1966. Pădurile României. Editura Agrosilvică, Bucharest, 261 pp. (in Romanian).

Pawson, S.M., Brockerhoff, E.G., Meenken, E.D. and Didham, R.K. 2008. Non-native plantation forests as alternative habitat for native beetles in a heavily modified landscape. *Biodiversity and Conservation* 17: 1127–1148.

Petrescu, A., Petrescu, I., Răduleţ, N., Iftime, A. and Ban, C. 2004. Date faunistice preliminare din zona viitorului Parc Naţional "Defileul Jiului" [Preliminary faunistic data from the future "Jiu Gorge" National Park]. *Oltenia Studii şi Comunicări Ştiinţele Naturii* 20: 229–240 (in Romanian).

Procter, D.S., Cottrell, J., Watts, K. and Robinson, E.J.H. 2015. Do non-native conifer plantations provide benefits for a native forest specialist, the wood ant *Formica lugubris*? *Forest Ecology and Management* 357: 22–32.

Quine, C.P. and Humphrey, J.W. 2010. Plantations of exotic tree species in Britan: irrelevant for biodiversity or novel habitat for native species? *Biodiversity and Conservation* 19: 1503–1512.

Radu, V.G. and Radu, V.V. 1967. Zoologia Nevertebratelor, volumul II, Editura Didactică și Pedagogică, București [Invertebrate Zoology, volume II. Didactic and Pegagogic Publishing House, Bucharest], 708 pp. (in Romanian).

Radu, V.G. and Radu, V.V. 1972. Zoologia nevertebratelor, volumul I, ediția a 2-a revizuită. Editura Didactică și Pedagogică, București [Invertebrate Zoology, volume I, 2nd revised edition. Didactic and Pegagogic Publishing House, Bucharest], 608 pp. (in Romanian).

Ratsirarson, H., Robertson, H.G., Picker, M.D. and van Noort, S. 2002. Indigenous forest versus exotic eucalypt and pine plantations: a comparison of leaf-litter invertebrate communities. *African Entomology* 10(1): 93–99.

Robson, T.C., Baker, A.C. and Murray, B.R. 2009. Differences in leaf-litter invertebrate assemblages between radiate pine plantations and neighbouring native eucalypt woodland. *Austral Ecology* 34: 368–376.

Sabatini, F.M., Burrascano, S., Keeton, W.S., Levers, C., Lindner, M., Pötzschner, F., Verkerk, P.J., Bauhus, J., Buchwald, E., Chaskovsky, O., Debaive, N., Horváth, F., Garbarino, M., Grigoriadis, N., Lombardi, F., Duarte, I.M., Meyer, P., Midteng, R., Mikac, S., Mikoláš, M., Motta, R., Mozgeris, G., Nunes, L., Panayotov, M., Ódor, P., Ruete, A., Simovski, B., Stillhard, J., Svoboda, M., Szwagrzyk, J., Tikkanen, O.-P., Volosyanchuk, R., Vrska, T., Zlatanov, T. and Kuemmerle, T. 2018. Where are Europe's last primary forests? *Diversity and Distributions* 24: 1426–1439.

Schrödl, M. 2019. A scientist's warning: Stop neglecting biodiversity in climate change! *Spixiana* 42(1): 1–5.

Sinclair, J.E. and New, T.R. 2004. Pine plantations in south eastern Australia support highly impoverished ant assemblages (Hymenoptera: Formicidae). *Journal of Insect Conservation* 8: 277–286.

Stăncioiu, P., Niță, M.D. and Lazăr, G.E. 2018. Forestland connectivity in Romania – Implications for policy and management. *Land Use Policy* 76: 487–499.

Stephens, S.S. and Wagner, M.R. 2007. Forest Plantations and Biodiversity: A Fresh Perspective. *Journal of Forestry* 105(6): 307–313.

Sucea, F.-N. 2019. The Second Record of a Rare Lizard Species, *Darevskia praticola* (Eversmann, 1834), in the Jiu Gorge National Park, Romania. *Ecologia Balkanica* 11(1): 239–241.

Telcean, I.C., Mihuţ, R.E. and Cupşa, D. 2017. The fishes' last stand: the fish fauna of Jiu River Gorge between decades of coal mining and present day hydroenergetic works. *eco.mont* 9(1): 15–21.

Tomescu, N., Ferenţi, S., Teodor, L.A., Covaciu-Marcov, S.D., Cicort-Lucaciu, A.S. and Sucea, F.N. 2011. Terrestrial Isopods (Isopoda: Oniscoidaea) from Jiului Gorge National Park, Romania. *North-Western Journal of Zoology* 7(2): 277–285.

Tracewski, Ł., Butchart, S.H.M., Donald, P.F., Evans, M., Fishpool, L.D.C. and Buchanan, G.M. 2016. Patterns of twenty-first century forest loss across a global network of important sites for biodiversity. *Remote Sensing in Ecology and Conservation* 2(1): 37–44.

Turner, E.G. and Foster, W.A. 2009. The impact of forest conversion to oil palm on arthropod abundance and biomass in Sabah, Malaysia. *Journal of Tropical Ecology* 25: 23–30.

Ujvári, I. 1972. Geografia apelor României [Geography of waters from Romania]. Editura Științifică, București, 592 pp. (in Romanian).

Varga, Z. 2010. Extra-Mediterranean refugia, post-glacial vegetation history and area dynamics in eastern Central Europe. In: Habel, J.C. and Assman, T. (Eds) Relict species: Phylogeography and conservation biology, Springer-Verlag, Berlin, Heidelberg, p. 57–87.

Veen, P., Fanta, J., Raev, I., Biriş, I.-A., de Smidt, J. and Maes, B. 2010. Virgin forests in Romania and Bulgaria: results of two national inventory projects and their implications for protection. *Biodiversity and Conservation* 19: 1805–1819.

Walentowski, H., Müller-Kroehling, S., Bergmeier, E., Bernhardt-Römermann, M., Gossner, M.M., Reif, A., Schulze, E.-D., Bußler, H., Strätz, C. and Adelmann, W. 2014. Faunal diversity of *Fagus sylvatica* forests: A regional and European perspective based on three indicator groups. *Annals of Forest Research* 57(2): 215–231.

Wiezik, M., Svitok, M. and Dovčiak, M. 2007. Conifer introduction decrease richness and composition of litter-dwelling beetles (Coleoptera) in Carpathian oak forests. *Forest Ecology and Management* 247: 61–71.

Willner, W., Di Pietro, R. and Bergmeier, E. 2009. Phytogeographical evidence for post-glacial dispersal limitation of European beech forest species. *Ecography* 32: 1011–1018.

Zahn, A., Rainho, A., Rodrigues, L. and Palmeirim, J.M. 2009. Low macro-arthropod abundance in exotic *Eucalyptus* plantations in the Mediterranean. *Applied Ecology and Environmental Research* 7(4): 297–301.