

# Arthropod biodiversity in virgin and managed forests in Central Europe

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## Abstract

The species composition of arthropods was used for a pair-wise comparison of the biodiversity in virgin forests of the Ukrainian Carpathians and managed Swiss forests with similar tree species composition. In both countries, pure beech forests and fir-spruce-beech forests were assessed at comparable altitudes and exposures.

Both types of extensively managed forests in Switzerland yielded slightly more species and considerably more individuals in most arthropod taxa than their virgin counterparts in Transcarpatia. On the other hand, the Shannon index of diversity and evenness were almost consistently higher in the Ukrainian virgin forests.

Separating the collected arthropods into trophic groups highlights the Saprophaga and Xylophaga as indicators for natural or virgin forests.

The size spectrum of the predatory carabid beetles was much broader in virgin forests than in managed forests; both large and very small species were lacking in the managed forests in Switzerland, indicating a limited potential for ecosystem functions.

Keywords: pristine forest, primary forest, arthropod diversity, fauna, comparison, Central Europe

## 1 Introduction

Based on the intuitively plausible but scientifically controversial concept of the “balance of nature” (PIMM 1991), biological diversity can be seen as a general indicator for ecosystem stability and ecological resilience. In a similar way, natural or even virgin forests serve as a model for sustainably managed forests in Europe. While in the boreal zones of Europe the concept of nature-oriented silviculture has its main emphasis on maintaining biodiversity, the main goal in Central Europe so far has been on manipulating forest stand development towards the probable original forest cover (PARVIAINEN and DIACI 1999). It is therefore no surprise that there are very few direct comparisons between the biodiversity found in virgin and managed forests in Central Europe. One component of forest biodiversity that is functionally and taxonomically important consists of the arthropods.

In Europe, the only large remnants of virgin forests are located in the Nordic countries (Finland, boreal Poland and Russia), as well as in the eastern parts of Central Europe along the Carpathian belt. While there are some comparative studies regarding arthropod biodiversity in virgin and managed boreal forests (e.g. HAILA *et al.* 1994; HUHTA 2002), we were unable to locate reports on a direct comparison between managed forests and large remnants of virgin forest in Central Europe. On the other hand, there are some published studies comparing virgin forests in Central Europe with managed forests in Western Europe (SCHNITZLER and BORLEA 1998; VALLAURI *et al.* 2003). The study presented here is of this type, namely a comparison between two types of virgin forests in the Ukrainian Carpathians with sustainably managed versions of the same two types of forests in Switzerland.

The main questions were:

- What are the basic differences in species composition and diversity between virgin and managed forests with similar tree species composition?
- What taxonomic groups of arthropods may serve as indicators of natural forest ecosystems?

## 2 Material and methods

### 2.2 Study sites and collecting method

The study sites were located in the Carpathian Biosphere Reserve and the Carpathian National Natural Park, Ukraine, and in prealpine regions (Sihlwald, close to Zürich, and Emmental) in Switzerland. In 1999 we compared managed and virgin beech forests, while in 2001 virgin and managed fir-beech forests were sampled. Table 1 summarizes the characteristics of the sampled sites.

All comparable sites corresponded in their elevation above sea level and their exposition. However, the sites differed in vegetation structure and management practice. The virgin beech forests of Uholska and Shyrokiy Looch (Carpathian-beech-1 and 2) consist of an almost pure Fagetum with poorly developed herbage, constituting a Fagetum nudum. The Swiss Fagetum sites, on the other hand, were surrounded by beech stands with up to 20 % other tree species. In addition, the herbaceous layer was richer in species in the Swiss managed beech forest sites than in the Ukrainian virgin beech forests.

The study areas in the Ukraine contained more standing volume of wood stock than their Swiss counterparts (770 m<sup>3</sup> vs. 524 m<sup>3</sup>). Considerably more dead wood was available in the Carpathian areas (111 m<sup>3</sup>/ha vs. 8 m<sup>3</sup>/ha, COMMARMOT *et al.* this issue). The mixed beech-fir forests, managed as selection forests (“Plenterwald”) in Switzerland, were transformed from a natural stage, although the tree species composition was similar to that in the virgin forests. With surface areas of 8000 and 10000 ha, the latter were also much larger than the Swiss forests, which covered only a few hundred hectares.

To collect surface-dwelling arthropods, we used pitfall-traps with a funnel diameter of 15 cm. For the collection of flying insects we employed a combination of window interception traps and yellow water-pan traps (DUELLI *et al.* 1999). At each site four pitfall-traps and two combination-traps were maintained for one full vegetation period.

Table 1. Abbreviation for and properties of the eight sampled sites:

Abbreviation used in text	N sites	Year sampled	Forest type	Altitude (m)	Locality	Country
Swiss-beech-1 + 2	2	1999	Even aged managed forest	600–700	Sihlwald	Switzerland
Swiss-fir-beech-3 + 4	2	2001	Uneven aged managed forest	900–1000	Emmental	Switzerland
Carpathian-beech-1	1	1999	Virgin beech forest	600	Uholska	Ukraine
Carpathian-beech-2	1	1999	Virgin beech forest	700	Shyrokiy Looch	Ukraine
Carpathian-fir-beech-3	1	2001	Virgin fir-beech forest	950	Chornohory	Ukraine
Carpathian-fir-beech-4	1	2001	Virgin fir-beech forest	1050	Horhan	Ukraine

## 2.2 Data evaluation

The main epigaic arthropod groups in the samples (Coleoptera, Araneae and Myriapoda) were identified to the species level by specialists in the Ukraine. A preliminary evaluation showed that these groups contribute about 75 % of all species in the collected samples. A total of 29 129 individuals were identified, the majority of which were beetles (21 295).

## 3 Results

### 3.1 Relative quantity

The total number of trapped individuals of arthropods in managed forests was almost double that of natural forests: c. 19 000 vs. 10 000 (Table 2). Furthermore, beech forests are characterized by much higher arthropod abundance than fir-beech forests.

In contrast to this, Myriapoda were one and a half times more abundant in the Ukrainian natural forests (1543 to 926). This difference was most pronounced in the fir-beech forests.

Table 2. Comparison of the numbers of individuals, species, and diversity indices.

Test area	Number of individuals	Number of species	Shannon's index	Evenness	Number of prevailing species
Carpathian-beech-1	2803	176	3.84	0.74	2
Carpathian-beech-2	3297	196	3.41	0.65	2
Swiss-beech-1	5468	216	3.34	0.62	3
Swiss-beech-2	5743	207	2.86	0.54	2
Carpathian-fir-beech-3	2101	178	4.08	0.79	5
Carpathian-fir-beech-4	1920	176	4.23	0.82	1
Swiss-fir-beech-3	3616	229	3.97	0.73	3
Swiss-fir-beech-4	4173	265	4.13	0.74	5

### 3.2 Number of species

All in all, we found slightly more species in the managed forests in Switzerland than in the Ukrainian forests (Table 2). This was largely due to the high species numbers of the Araneae, which consistently yielded more species in the Swiss managed forests. For all other taxa the results were inconsistent: there were more species in beech forests in one country, and more species in mixed forests in the other. For the Myriapoda and “All Coleoptera” the virgin forests showed slightly higher species counts (Table 3), while the staphylinid beetles tended to be richer in species in managed forests.

Table 3. Species richness of identified taxonomic groups.

Test area	In total	Araneae	Myriapoda	All Coleoptera	Carabidae	Staphylinidae
Swiss-beech-1	216	49	24	118	16	29
Swiss-beech-2	207	48	22	115	19	34
Swiss-fir-beech-3	229	59	15	147	20	44
Swiss-fir-beech-4	265	60	16	182	31	45
Swiss-beech-1 + 2	292	61	26	168	23	50
Swiss-fir-beech-3 + 4	329	82	18	218	31	61
<b>Swiss in total</b>	<b>492</b>	<b>107</b>	<b>33</b>	<b>304</b>	<b>35</b>	<b>89</b>
Carpathian-beech-1	176	26	20	117	15	31
Carpathian-beech-2	196	29	19	130	20	30
Carpathian-fir-beech-3	178	22	28	117	18	28
Carpathian-fir-beech-4	176	33	19	107	16	23
Carpathian-beech-1 + 2	270	37	24	182	26	50
Carpathian-fir-beech-3 + 4	293	42	42	189	29	47
<b>Ukraine in total</b>	<b>470</b>	<b>65</b>	<b>43</b>	<b>311</b>	<b>36</b>	<b>80</b>

### 3.3 Comparison of diversity indices (Shannon index)

In contrast to species abundances (Table 2) and species richness (Table 3), diversity indices turned out to be higher in the virgin forest ecosystems in total (Table 2) and for the majority of the taxonomic groups, in particular the predatory Carabidae and Staphylinidae (not shown here). Evenness was consistently higher in the Ukrainian virgin forests, as was the Shannon index, albeit with exceptions in the fir-beech forests.

The dendrogram of faunistic similarities between trap sites in Figure 1 illustrates that geographical distance plays more of a role than the type of forest, beech or fir-beech. However, the influence of geographical distance cannot be separated from the influence of forest management, since all Swiss forests are managed, and all Ukrainian forests tested in this study are unmanaged. Among the same type of forest and management, the Swiss forest sites seem to be more similar, faunistically, than the Ukrainian sites.

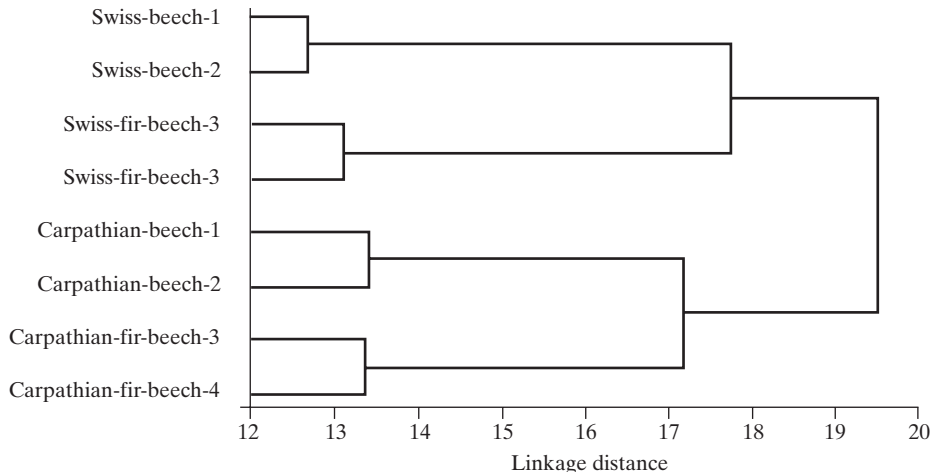


Fig. 1. Dendrogram of faunistic similarity, based on complete linkage clustering.

### 3.4 Body size distribution of Carabidae

Assuming that mature, ecologically balanced and resilient ecosystems such as virgin forests contain a broader and more densely packed spectrum of ecological niches, we tested the hypothesis that carabid beetles (as an example) varied more in size in virgin than in managed forests. A comparison of the size distributions shown in Figures 2 and 3 shows that this is indeed the case. According to the method of ŠUSTEK (1987) the predominance of species is given for different body sizes. In the virgin forests of the Ukraine (Fig. 2), the genera with medium (11–16 mm) and large (23–30 mm) sizes prevail. The spectrum ranges from tiny species of the genera *Dischirius* and *Trechus* up to the largest (*Carabus coriaceus*), with few rather small size gaps.

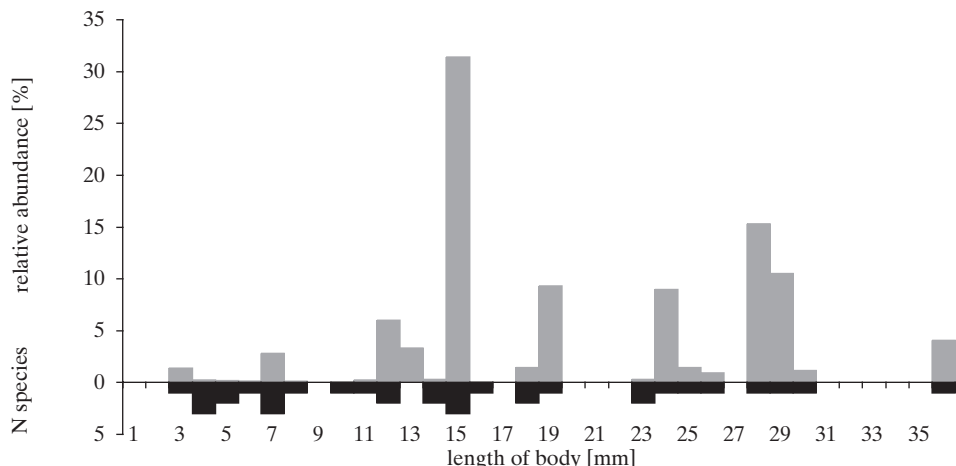


Fig. 2. Body size spectrum, relative abundance (grey), and species numbers (black) of the carabid community in the two virgin beech forest sites of the Ukraine.

In the Swiss managed forests, with about the same number of species, the size spectrum is clearly constrained (no Carabidae under 4 mm) and contains a prominent gap in the range of 25–35 mm (Fig. 3).

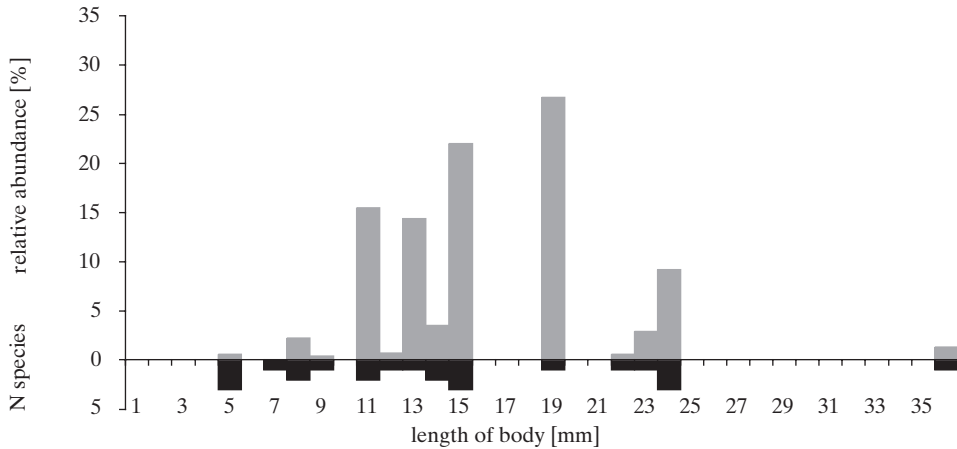


Fig. 3. Body size spectrum, relative abundance (grey), and species numbers (black) of the carabid community in the two managed beech forest sites of Switzerland.

### 3.5 Ecological guilds in comparison

Analyzing functional groups of arthropods separately, only the saprophagous guild had a higher number of individuals in virgin forests, whereas the predatory, phytophagous and xylobiont species were twice or three times more abundant in managed forests (Table 4).

Table 4. Number of individuals per functional group.

Test area	Total	predators	herbivores	saprophages	xylobionts
Swiss-beech-1	5468	3038	2040	390	1736
Swiss-beech-2	5743	4726	738	289	534
Swiss-fir-beech-3	3616	2243	1039	411	1057
Swiss-fir-beech-4	4173	2857	1075	306	775
Carpathian-beech-1	2803	1338	563	707	286
Carpathian-beech-2	3297	1499	488	1337	323
Carpathian-fir-beech-3	2101	1512	232	395	353
Carpathian-fir-beech-4	1920	1239	281	520	394

The species numbers of predators and herbivores were clearly higher in the managed forests (Table 5). Moreover, the diversity is higher in fir-beech forests than in beech forests. This is easily explained by the fact that these forests are characterized by higher floral abundance and diversity and, accordingly, the niche availability for herbivores, and finally for predators, increases.

As to saprophages and xylobionts, species richness and abundance were generally higher in Ukraine (110 to 100 species for xylobionts, 88 to 64 for saprophages).

Table 5. Number of species per functional group.

Test area	predators	herbivores	saprophages	xylobionts
Swiss-beech-1	127	68	30	41
Swiss-beech-2	129	56	27	27
Swiss-fir-beech-3	154	60	27	40
Swiss-fir-beech-4	168	78	38	58
Carpathian-beech-1	98	45	32	34
Carpathian-beech-2	109	50	39	47
Carpathian-fir-beech-3	104	36	43	45
Carpathian-fir-beech-4	111	40	31	39

The Shannon diversity of the functional groups (Fig. 4) was rather consistent for the four forest areas tested. It was highest for the Carpathian fir-beech forest, lowest for the Swiss beech forest, and somewhat inconsistent only for the saprophagous guild.

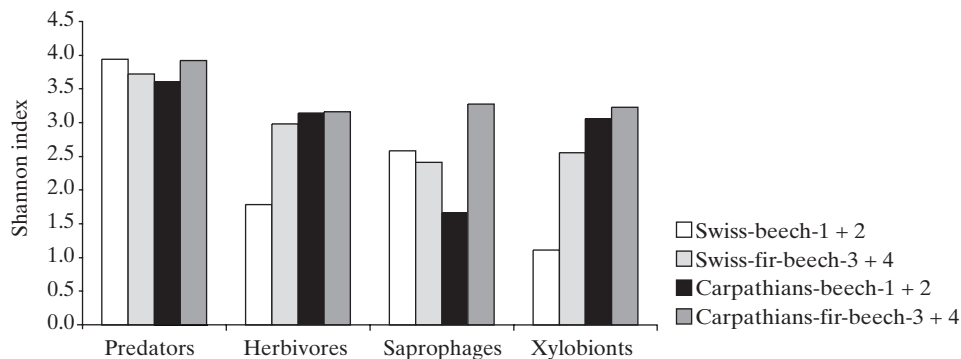


Fig. 4. Shannon diversity of ecological groups.

## 4 Discussion

All in all, the numbers of species in our study tended to be slightly higher in managed forests than in virgin forests, whereas the diversity indices were higher for virgin forests. Notable exceptions were the saprophagous and the xylobiont guilds, where potential indicator groups for qualitative assessments in virgin and natural forests were identified.

The number of trapped arthropod specimens was much higher in managed forests. That is to say, in spite of less phytomass, arthropod biomass seems to prevail in managed forests. The amount of dead wood available as habitat source is at least ten times higher in virgin forests than in managed forests (VALLAURI *et al.* 2003), so it had to be expected that xylobiont beetles and saprobiont millipeds were more abundant and diverse in virgin forests. Obviously, these guilds are good candidates as indicator groups for evaluating biodiversity in natural forests.

Our sampling design is severely hampered by a high amount of autocorrelation: All managed forests were in Switzerland, all unmanaged forests in Ukraine. The similarity diagram in Figures 1 thus basically reflects the geographical distances between the trap stations. Nevertheless, within the forest areas the similarities between the catches of the trap stations were higher in the managed Swiss forests. So, while alpha-diversity turned out to be higher in the managed forest stands, beta-diversity appears to be higher in the unmanaged stands.

Higher species richness in managed forests compared to natural forests was also found for beetles in Finland (VÄISÄNEN *et al.* 1993) and for Carabidae in Belgium (DESENDER *et al.* 1999). In both cases, however, the fauna of the rare and stenotopic species was impoverished in managed forests. In British deciduous woodlands, on the other hand, TERRELL-NIELD (1990) was able to show, again with carabids, that species richness was significantly higher in old stands of forests than in new ones. The main reason for a higher diversity of stenotopic forest species in natural forests could be the amount of dead wood in unmanaged forests (VALLAURI *et al.* 2003). In a recent publication, BUSSLER *et al.* (2005) report that in Rumanian virgin forests it was easy to find within a few hectares half the set of the 12 xylobiont beetle species designated by the EU as “FFH species” (Flora-Fauna-Habitat Directive 92/43/EEC; Treaty of Accession 2003), while in Germany it is rare to find more than two of those species even in the most natural forests. MÜLLER *et al.* (2005) reason that the crucial factor for a full set of FFH-species is the habitat history of the permanent natural forest. Obviously, our standardized trap devices in the Ukrainian virgin forests were not able to detect such rarities among the xylobiont beetles.

Apart from species richness or rare and threatened species, another important aspect of biodiversity is ecosystem functioning. In our study, the carabid beetles exemplify a smaller body size spectrum in managed forests than in virgin forests, which suggests there are unfilled niches and hence reduced ecosystem functions in managed forests. The broad size spectrum we found in the Ukrainian forests is typical for Carabidae in the virgin beech forests of the Carpathians (RIZUN 2003).

In Finland, HUHTA (2002) found few differences in arthropod species richness and biomass between planted birch stands and natural forests. The study presented here gives strong evidence that the overall abundance and species diversity of arthropods are not markedly different in virgin or managed forests. The most important qualitative faunistic differences are based on the higher amount of dead wood in virgin forests. To confirm the results of our case study, pairwise comparisons between virgin and managed forest stands without autocorrelation will be necessary. Inevitably, this excludes forest plots in countries without virgin forests.

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