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## Earthworm (*Oligochaeta: Lumbricidae*) populations in four types of beech wood *Fagetum carpaticum* in the Bieszczady National Park (south-eastern Poland). Part I. Species composition, diversity, dominance, frequency and associations

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Abstract. In four types of beech wood *Fagetum carpaticum* in the Bieszczady National Park: dry and poor *F. c. festucetosum drymejae*, fresh *F. c. typicum*, moist *F. c. lunarietosum*, and *F. c.* variant with *Alium ursinum*, 13 species of earthworms were found. These are – *Dendrobaena alpina*, *D. octaedra*, *Allolobophora cernosvitoviana*, *A. rosea*, *A. caliginosa*, *A. carpathica*, *Fitzingeria platyura montana*, *Lumbricus terrestris*, *L. rubellus*, *Octolasion lacteum*, *Octodrilus transpadanus*, *Dendrodrilus rubidus tenuis*, and *Eisenia lucens*. In order to determine the species diversity, the S'/S test was used. Some biocenosis indicators: dominance, frequency and association were considered as well. Of 13 species only *D. alpina*, *A. cernosvitoviana* and *A. carpathica*, present at all sites, occurred in large numbers.

Key words: earthworms, species diversity, dominance, frequency, associations, beech wood, Poland.

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### I. INTRODUCTION

Researches on earthworms (*Lumbricidae*) in European beech wood forests have been carried out by numerous authors: BALTZER (1956), PLISKO (1971, 1973), NORDSTRÖM, RUNDGREN (1973, 1974), ZAJONC (1967, 1986), PHILLIPSON et al. (1976), POP (1987), RÖMBKE (1987) and others.

So far there has been lack of information concerning the ecology of beech wood earthworm fauna in Polish literature; only some faunistic data are available.

We are grateful to Miss Ewa BIAŁCZYK for her drawings, typing and occasional help with many details in the preparing of this text.

## II. STUDY AREA AND BIOTOPES

This research was carried out in beech woods *Fagetum carpaticum* (ZARZYCKI 1963) in the Bieszczady National Park (BNP) (S-E corner of Poland). Four sites were chosen for study (Fig. 1):

**Site I:** situated in the Bieszczady National Park (BNP), about 750 m above sea level in dry and poor *Fagetum carpaticum festucetosum drymejae* (variant with *Festuca drymeja* and *Carex pilosa*);

**Site II:** BNP area, about 750 m above sea level, in fresh *Fagetum carpaticum typicum* (variant with *Dentaria bulbifera* and *Asperula odorata*);

**Site III:** Pszczeliny area, 650 m above sea level, moist variant (*Fagetum carpaticum lunarietosum*, variant with *Lunaria rediviva* and *Petasites officinalis*); and

**Site IV:** BNP area, on the way to Rozsypaniec, 950 m above sea level in *Fagetum carpaticum*, variant with *Alium ursinum*.

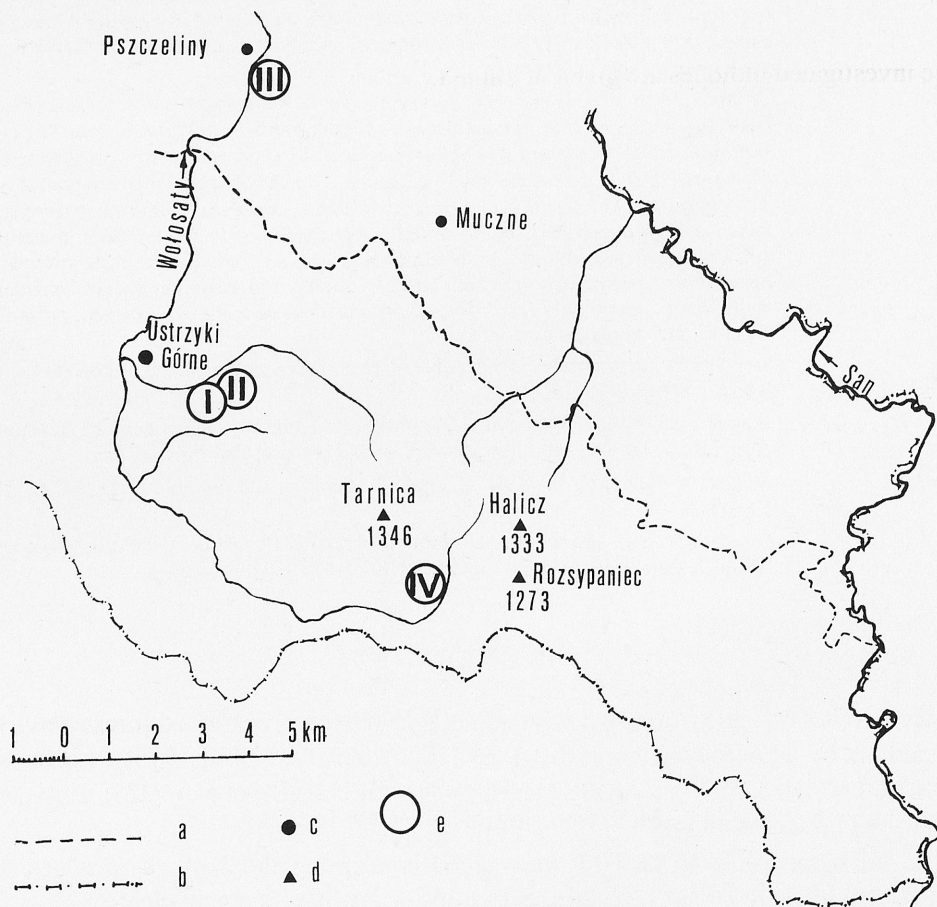


Fig. 1. Sketch map of study area. a – NE boundary of eastern part of the BNP, b – state frontier, c – settlements, d – mountain peaks, e – research sites (I-IV).

### III. METHODS

#### 1. Earthworm sampling

A combination of methods was used (ZAJONC 1970), namely hand picking and expelling with weak formalin solution (about 0.4%). Six samples were dug out (each 25 by 25 cm and 20 cm deep) from each site, each month from July to November 1986 and from May to November 1987.

The earthworms from the 0-10 cm and 10-20 cm layers were picked out by hand. From the deeper soil layers they were expelled by a weak formalin solution. The specimens were placed in 4 % formalin solution on the spot and weighed after being identified a few days later.

#### 2. Soil characteristics

Every month, soil temperature was taken at depths of 10 and 20 cm at all the sites. To measure the soil moisture, soil samples were taken at depths of 0-10 cm and 10-20 cm. Then they were weighed and dried at 105°C. The pH (in water and KCl) and the contents of the main food components were also determined once for the soil samples (10 samples (5+5) from each site). The data obtained were elaborated statistically. The attributes of the investigated biotopes are given in Table I.

### IV. RESULTS

#### 1. Species composition

In the investigated *Fagetum carpaticum* territory, 13 species of earthworms were found (nomenclature after EASTON 1983):

*Dendrobaena alpina alpina* (ROSA, 1884), *Dendrobaena octaedra* (SAVIGNY, 1826), *Allolobophora cernosvitoviana* (ZICSI, 1967), *Aporrectodea rosea* (SAVIGNY, 1826), *Aporrectodea caliginosa* (SAVIGNY, 1826), *Allolobophora carpathica* (COGNETTI, 1927), *Fitzingeria platyura montana* (ČERNOSVITOV, 1932), *Lumbricus terrestris* LINNAEUS, 1758, *Lumbricus rubellus* (HOFFMEISTER, 1843), *Octolasion lacteum* (ÖRLEY, 1881), *Octodrilus transpadanus* (ROSA, 1884), *Dendrodrilus rubidus tenuis* (EISEN, 1874), and *Eisenia lucens* (WAGA, 1857). The list of species found by individual sites is given in Table II.

#### 2. Earthworm species diversity

In order to check the ecological "fullness" of the earthworm communities at the study sites, the S'/S test given by LLOYD-GERALDI (SOUTHWOOD 1966) was used:

$$M(S) = c \left\{ \log_{10} N - \frac{1}{N} \sum_{r=\lambda}^S n_r \log_{10} n_r \right\}$$

where: N = number of all specimens, S = number of species,  $n_r$  = number of specimens in particular species; S' is found in tables giving the M/S value, and the relation S'/S is defined as the percentage of the obtained species potentially inhabiting a given area.



Table I

Important food components in soil of four beech wood sites in the Bieszczady National Park

Site	Soil description	pH	Ca <sub>org</sub>		N <sub>org</sub>	C/N	[mg/100 g soil]			Mean soil temp	Humidity at 10 cm at 20 cm (±SD), (5 samples for each depth)
			%	%			P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	Mg		
I. <i>Fagetum carpaticum festucetosum</i>	podsol light loamy 30 cm deep	3.3	4.36	0.33	13.0	2.25	3.10	4.05	86.40	2.50	36.9(7.8)31.3(4.4)
II. <i>Fagetum carpaticum typicum</i>	brown medium loam, dusty>30 cm deep	4.1	3.16	0.24	13.1	1.55	2.00	8.00	1160.70	21.45	35.1(3.9)27.4(3.3)
III. <i>Fagetum carpaticum lunarietum</i>	brown soil, in part heavy gley, 20-30 cm deep	5.0	4.74	0.35	13.54	2.10	19.60	12.88	754.63	8.38	34.3(5.3)32.2(8.8)
IV. <i>Fagetum carpaticum allietosum</i>	black fen soil, heavy skeletal, 15-30 cm deep	4.9	4.79	0.38	21.61	3.65	16.00	13.98	832.7	12.40	39.8(6.7)33.6(16.5)

Table II

A list of earthworm species found in four beech wood sites in the Bieszczady National Park

Species	Sites			
	I	II	III	IV
<i>Allolobophora carpathica</i> COGNATI, 1927	+	+	+	+
<i>Aporrectodea caliginosa</i> (SAVIGNY, 1826)	–	–	+	+
<i>Aporrectodea rosea</i> (SAVIGNY, 1826)	–	+	+	+
<i>Allolobophora cernosvitoviana</i> (ZISCI, 1967)	+	+	+	+
<i>Dendrobaena alpina alpina</i> (ROSA, 1884)	+	+	+	+
<i>Dendrobaena octaedra</i> (SAVIGNY, 1826)	+	+	+	+
<i>Dendrodrilus rubidus tenuis</i> (EISEN, 1874)	+	–	+	+
<i>Eisenia lucens</i> (WAGA, 1857)	–	+	–	+
<i>Fitzingeria platyura montana</i> (CERNOSVITOV, 1932)	–	–	–	+
<i>Lumbricus rubellus</i> (HOFFMEISTER, 1843)	–	+	–	–
<i>Lumbricus terrestris</i> LINNEAUS (1758)	–	–	+	–
<i>Octolasion lacteum</i> (ÖRLEY, 1881)	+	+	+	+
<i>Octodrilus transpadanus</i> (ROSA, 1884)	–	–	–	+
Number of species in particularly sites:	6	8	9	11

Table III shows the S'/S index applicable to the study area and to beech woods described by NORDSTRÖM and RUNDGREN (1973) and PHILLIPSON et al. (1976).

The S'/S index suggests that for example, the ten species found at sites in the U.K. constitute only 70-80 % of the total number of earthworm species that could be accommodated in that habitat. Similarly, the species counts at sites near Ustrzyki Górne constitute 50-80 % "fullness". In contrast, the two Swedish woodlands, with 6 and 8 species, might be considered ecologically full with respect to earthworms.

Table III

S'/S index in *Fagetum carpaticum* and other European beech woods

	Bieszczady NP					Sweden		U.K.	
	Site				F. carp. total	a	b	c	d
	I	II	III	IV					
LLOYD-GHELARDI index S'/S	0.5	0.5	0.8	0.8	1.0	1.0	1.0	0.8	0.7
number of species on the site	6	8	9	11	13	6	8	10	10

- a. Beech wood 4 (Sweden) – NORDSTRÖM, RUNDGREN (1973).  
 b. Beech wood 17 (Sweden) – NORDSTRÖM, RUNDGREN (1973).  
 c. Brodgen's Belt (U. K./ 1971-72) – PHILLIPSON et al. (1976).  
 d. Brodgen's Belt (U. K.) 1972-73 – PHILLIPSON et al. (1976).

### 3. Dominance

Of the 13 species found at the sites investigated 9 showed a high dominance indicator: *D. alpina*, *A. cernovitoviana*, *A. rosea*, *A. caliginosa*, *O. lacteum*, *L. terrestris*, *A. carpathica*, *F. platyura montana* and *O. transpadanus* (Table IV).

Only three of the species present at all sites occurred there in large numbers: *D. alpina*, *A. cernovitoviana* and *A. carpathica*. *A. rosea* was present at three sites and was rather numerous. *A. caliginosa* was characteristic of sites III and IV and was numerous. Other species were found at single sites only, but in larger numbers: *L. terrestris*, *F. platyura montana* and *O. transpadanus*.

Unlike the others, *O. lacteum* was present at all sites but was clearly dominant only at site III. *D. octaedra*, *D. rubidus*, *E. lucens* and *L. rubellus* were rare.

### 4. Frequency

The highest frequency in the beech woods in the Bieszczady Mts. was noted for *D. alpina*, *A. cernovitoviana*, *A. caliginosa*, *A. carpathica*, *O. lacteum* and *L. terrestris* (Table V).

### 5. Species associations

The SORESENSEN QS index (SOUTHWOOD 1966) and the MARCZEWSKI & STEINHAUS S index (GÓRNY, GRÜM 1981) were used to investigate relations among species:

$$QS = 2j/a+b$$

$$S = j/a+b-j$$

$j$  = number of species A and B occurring together

$a$  = number of species A occurring without species B

$b$  = number of species B occurring without species A

The results of both indices showed interdependence between species:

Site I. *D. octaedra* – *D. rubidus*, *A. carpathica* – *D. alpina*.

Site II. *A. cernovitoviana* – *A. rosea*, *A. cernovitoviana*, *A. rosea* – *D. alpina*, *A. cernovitoviana*, *A. rosea*, *D. alpina* – *A. carpathica*.

Site III. *O. lacteum* – *A. caliginosa*, *O. lacteum*, *A. caliginosa* – *L. terrestris* and *D. alpina* – *A. cernovitoviana*.

In site IV there were stronger relations between *A. cernovitoviana* – *O. transpadanus* and *F. platyura* – *A. caliginosa*.

The results are presented graphically in dendrograms (Fig. 2a-d).

Table IV

Species composition (%) of earthworms in four types of beech wood in the Bieszczady National Park

<i>Fagetum carpaticum</i>					
Species	<i>festucetosum</i>	<i>typicum</i>	<i>lunarietosum</i>	<i>alietosum</i>	Total
<i>D. alpina</i>	72.0	21.2	16.4	6.2	18.3
<i>D. octaedra</i>	3.5	2.3	0.7	1.6	1.6
<i>A. cernosvitoviana</i>	2.3	30.3	5.9	13.5	16.6
<i>A. rosea</i>	–	29.6	4.4	12.0	15.3
<i>A. caliginosa</i>	–	–	21.0	29.0	14.4
<i>A. carpathica</i>	19.8	10.3	2.0	4.9	6.6
<i>F. platyura montana</i>	–	–	–	15.5	3.9
<i>L. terrestris</i>	–	–	26.9	–	9.1
<i>L. rubellus</i>	–	2.6	–	–	0.9
<i>O. lacteum</i>	0.1	2.5	22.5	2.0	9.1
<i>O. transpadanus</i>	–	–	–	10.0	2.5
<i>D. rubidus tenuis</i>	1.2	–	0.2	0.9	0.3
<i>E. lucens</i>	–	1.1	–	4.4	1.5

Table V

Frequency (%) of earthworms in four types of beech woods in the Bieszczady National Park

<i>Fagetum carpaticum</i>					
Species	<i>festucetosum</i>	<i>typicum</i>	<i>lunarietosum</i>	<i>alietosum</i>	Total
<i>D. alpina</i>	41.3	61.1	37.5	20.8	40.6
<i>D. octaedra</i>	4.2	11.2	5.5	1.4	5.6
<i>A. cernosvitoviana</i>	1.4	75.0	33.3	47.2	39.2
<i>A. rosea</i>	–	65.3	19.4	34.7	29.9
<i>A. caliginosa</i>	–	–	50.1	55.5	26.4
<i>A. carpathica</i>	20.8	49.8	9.7	16.7	24.3
<i>F. platyura montana</i>	–	–	–	33.3	8.3
<i>L. terrestris</i>	–	–	65.3	–	15.6
<i>L. rubellus</i>	–	19.1	–	–	4.9
<i>O. lacteum</i>	1.4	12.5	47.2	9.7	17.7
<i>O. transpadanus</i>	–	–	–	33.3	8.3
<i>D. rubidus tenuis</i>	1.4	–	1.4	4.2	1.7
<i>E. lucens</i>	–	8.3	–	11.1	4.9



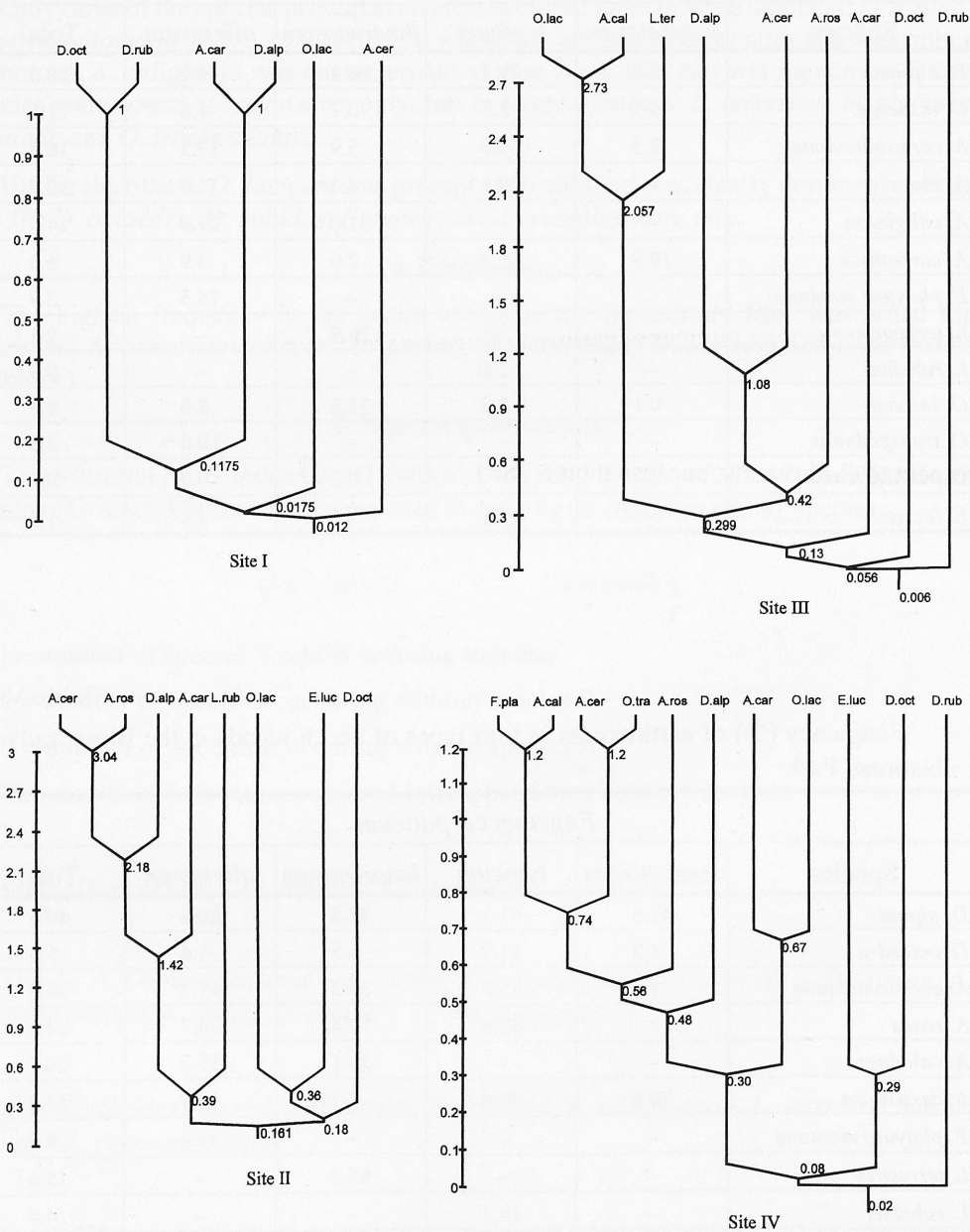


Fig. 2. Dendrograms of earthworm species associations at four beech wood *Fagetum carpaticum* sites (according to the MARCZEWSKI and STEINHAUS index).

## V. DISCUSSION

Earthworms are generally present in all types of soil except long-term dry type. Each ecosystem has a characteristic earthworm species composition.

In European beech woods, 2-16 species of earthworms can be found together, forming their species compositions (Table VI).

The beech woods of the Bieszczady National Park have fairly rich species compositions: at site I, 6 species of earthworms were recorded; at site II, 8 species; at site III, 9; and at site IV, 11 species of earthworms (altogether 13 species).

This fairly varied species composition was observed in spite of mountain conditions (very low pH and severe climate).

The S'/S test (LLOYD-GHERALDI, after SOUTHWOOD 1966) suggests that the 6, 8, 9 and 11 species found at sites I, II, III and IV constitute, respectively, only 50%, 60%, 80% and 80% of the total number of earthworm species that could be accommodated by those habitats. Similar percentages (70% and 80%) of ecological fullness were obtained for beech wood sites investigated in England by PHILLIPSON et al. (1973, 1978). In contrast, two Swedish beech woods with 6 and 8 species might be considered ecologically full with respect to earthworms, because their  $S'/S=1$ .

The S'/S test gives the number of species in relation to "ideal" ecological conditions for them. In this connection, the existence of an "empty" ecological niche is a result of restrictive ecological factors; for example, site I had a very low pH (3.32) and this indicates that low pH inhibits earthworm activity (LAVERACK 1961, after LEE 1985). It may be concluded, too, that the beech wood sites investigated in the Bieszczady Mts by KOSTECKA (unpubl. data), like the sites investigated in the U.K. by PHILLIPSON et al. (1976), have a greater habitat heterogeneity than either of the two Swedish ones.

As shown in Table VI, 32 species of earthworms have been recorded from European beech woods. Of the 13 species found at the sites investigated in the Bieszczady Mts, 7 were megaporeutic, occurring in a wide variety of habitats. The other 6 were oligoporeutic, characteristic of the Carpathians.

One of the oligoporeutic species, *A. cernosvitoviana* ZICSI, 1967, was new to Polish earthworm fauna (KOSTECKA, ROŻEN 1988; KOSTECKA in press). The occurrence of *A. cernosvitoviana* in neighboring countries, and the absence of this species in the Bieszczady Mts area ten years ago, indicate rapid expansion northward and westward along the range of the Carpathians.

In terms of dominance and frequency the species can be divided into following groups: a) below 25%; b) between 25% and 50%, c) between 50% and 75%, and d) above 75%.

For dominance, group a includes *D. alpina* – (3), *D. octaedra* – (4), *A. rosea* – (2), *A. cernosvitoviana* – (3), *A. carpathica* – (4), *A. caliginosa* – (1), *O. lacteum* – (4), *F. platyura montana* – (1), *L. rubellus* – (1), *D. rubidus* – (3), *O. transpadanus* – (1) and *E. lucens* – (2) (number of occurrences at the four sites studied).

Group b was represented by *A. rosea* – (1), *A. cernosvitoviana* – (1), *A. caliginosa* – (1) and *L. terrestris* – (1).

Table VI

Earthworm species found in some European beech woods (taxa accepted after ZICSI, 1982)

Species	Species from beech woods in the BNP (present study)	PLISKO (1971) Poland	ZAJONC (1967, 1986) Czechoslovakia	Pop 1987 Rumania	RÖMBKE (1987) Rumania	BALZER* (1956) Germany	NORDSTRÖM (1975) Sweden	PHILLIPSON et al. (1976) U.K.
<i>D. alpina</i> (ROSA, 1884)	x	x	x	x	-	-	-	-
<i>D. octaedra</i> (SAVIGNY, 1826)	x	x	-	-	-	x	x	-
<i>D. byblica</i> (ROSA, 1883)	-	-	-	x	-	-	-	x
<i>D. mammalis</i> (SAVIGNY, 1826)	-	-	-	-	-	-	-	-
<i>D. platyura montana</i> (CERNOSVITOV, 1932)	-	-	x	-	-	-	-	-
<i>D. platyura depressa</i> (ROSA, 1883)	-	-	x	-	-	-	-	-
<i>D. clujensis</i> POP, 1938	-	-	-	x	-	-	-	-
<i>D. rubida</i> (SAVIGNY, 1826)	x	x	-	-	x	-	x	-
<i>A. carpathica</i> (COGNETTI, 1927)	x	x	-	-	-	-	-	-
<i>A. caliginosa</i> (SAVIGNY, 1826)	x	-	x	-	-	x	x	-
<i>A. cernosvitoviana</i> (ZICSI, 1967)	x	-	-	-	-	-	-	-
<i>A. chlorotica</i> (SAVIGNY, 1826)	-	-	-	-	-	-	-	x
<i>A. longa</i> (UDE, 1885)	-	-	-	-	-	-	-	x
<i>A. rosea</i> (SAVIGNY, 1826)	x	x	-	x	-	x	x	-
<i>A. limicola</i> (MICHAELSEN, 1890)	-	-	-	-	-	-	-	-
<i>E. muldali</i> (GATES, 1968)	-	-	-	-	-	-	-	-
<i>E. lucens</i> (WAGA, 1857)	-	x	-	-	-	-	-	-
<i>E. submontana</i> VEIDOVSKY, 1875	-	-	x	-	-	-	-	-
<i>E. parva</i> EISEN, 1874	-	-	-	-	-	-	-	-
<i>E. tetraedra</i> (SAVIGNY, 1826)	-	x	x	-	-	-	-	-
<i>L. terrestris</i> (LINNAEUS, 1758)	x	x	-	-	-	-	-	-
<i>L. rubellus</i> (HOFMEISTER, 1843)	x	-	x	-	x	x	x	-
<i>L. castaneus</i> (SAVIGNY, 1826)	-	-	-	-	-	-	-	-
<i>L. polyphemus</i> (FITZINGER, 1833)	-	x	x	-	-	-	-	-
<i>O. lacteum</i> (ÖRLEY, 1885)	x	x	x	-	-	-	-	-
<i>O. montanum</i> (WESSELY, 1905)	-	-	x	-	-	-	-	-
<i>O. cyaneum</i> (SAVIGNY, 1826)	-	-	-	-	-	x	-	x
<i>O. bihariensis</i> (POP, 1987)**	-	-	-	-	-	-	-	-
<i>O. complanatus</i> (DUGES, 1828)	-	x	-	x	-	-	-	-
<i>O. frivaldskyi</i> (ÖRLEY, 1885)	-	-	-	-	-	-	-	-
<i>O. transpadanus</i> (ROSA, 1886)	x	-	x	-	-	-	-	-
number of species	13	13	8	6	2	10	8	10

\* after NORDSTRÖM, RUNDGREN (1973).

\*\* after POP (1987).

\*\*\* summarized from different part of Czechoslovakia.

In group c with a high dominance index, there was only one species, *D. alpina*, at site I.

There were no species in group d, with a very high dominance index.

The likelihood of finding species representatives (frequency index) in the investigated *Fagetum carpaticum* sites varied.

Group a (accidental species) included most of the earthworm species found. Only four, *D. alpina*, *A. cernosvitoviana*, *A. rosea* and *A. caliginosa*, fell into group b (accessory species) (Table IV). There were no species in groups c or d (constant species).

The investigated sites did not have uniform soil or phytosociological characteristics, so they differed in their earthworm populations as well:

Site I: its soil can be classified as podsol, light loamy, and skeletal. The pH was very low (3.3) and Mg, Ca and Na content was low too. This site had the least number of earthworm species (6). *D. alpina* and *A. carpathica* were dominant there, being tolerant to very low pH.

Site II: brown soil, medium loam, dusty, the deepest soil of all the investigated sites; pH was 4.12. Fluctuations in soil moisture were the lowest there; this was the site with a particularly high Calcium (Ca) content. 8 species of earthworms occurred there. *A. cernosvitoviana*, *A. rosea*, *D. alpina*, and *A. carpathica* were dominant. *L. rubellus* was not dominant but occurred only at that site.

Site III: brown soil, in part heavy clay, pH – 5.01. This site was situated on a typical mountain slope. The moisture was the highest at that site. 9 species occurred there. It was the only site where *O. lacteum* was clearly dominant, and the only site where *L. terrestris* was present and dominant.

Site IV: fen black soil, flooded every spring by thawing snow from higher mountain pasture. In the course of that flooding, much organic matter is deposited there (black humus). Soil aeration and moisture conditions are good all year. The species composition was the richest: 11 species were found, but earthworms were not numerous there. The three largest-sized species occurred at that site: *F. platyura montana*, *A. carpathica* and *O. transpadanus*. *A. caliginosa* was clearly dominant there (29%).

According to many authors, *O. lacteum* is connected with clayey soil (ZAJONC 1970; NORDSTRÖM and RUNDGREN 1973; ROŽEN 1982). In the present study this species occurred at all sites, in mineral soil with clay and in organic soil, but it was clearly dominant (22.5%) and showing the highest frequency (47.2%) only at site III, which had the highest clay content.

GUILD (1948, after NORDSTRÖM and RUNDGREN 1973) showed that the number of *L. terrestris* was lower in soil with heavier clay. In the present study and in NORDSTRÖM and RUNDGREN (1973), a high clay content had no negative effect on the abundance of this species. Moreover, site III (in part heavy clay) was the only one where *L. terrestris* occurred. We think that the sites investigated were not all typical for *E. lucens*. OMODEO (1962, after KASPRZAK 1983) writes that in Italy this species is found only in mountain stream-bottom litter. In Czechoslovakia (ZAJONC 1983) 46% of the *E. lucens* individuals were found at watery sites, 52% at moist sites and only 2% at dry ones. In *Fagetum carpaticum*, at the driest site III and site I, not an individual of that species was found.



Comparing the numbers of the smallest-sized species (*D. octaedra* and *D. rubidus*) found at the investigated sites with the results of ZAJONC (1981) and ROŻEN (1982), it can be said that in *F. carpaticum*, litter-dwellers were very rare. This may be connected with the difficult mountain conditions (great temperature fluctuations during the day and the absence of thick turf, which can produce low ground temperatures even at the height of the vegetative season).

In the present investigations the earthworm species occurred in a few associations; this does not mean that their requirements are necessarily similar, only that they regularly occur together.

QS and S Index – demonstrated associations:

*D. octaedra* – *D. rubidus* (recorded by NORDSTRÖM, RUNDGREN 1973; and ROŻEN 1982) *O. lacteum* – *A. caliginosa*, *O. lacteum*, *A. caliginosa* – *L. terrestris* (*A. caliginosa* – *O. lacteum* recorded by ROŻEN 1982), *A. caliginosa* – *L. terrestris* (recorded by PHILLIPSON et al. 1976; and NORDSTRÖM, RUNDGREN 1972)

Residual associations:

*D. alpina* – *A. carpatica*, *A. cernosvitoviana* – *A. rosea*, *A. cernosvitoviana*, *A. rosea* – *D. alpina*, *A. cernosvitoviana*, *A. rosea*, *D. alpina* – *A. carpatica*, *A. cernosvitoviana* – *O. transpadanus* and *F. platyura* – *A. caliginosa*: affected species typical mainly of Carpathian' earthworm fauna.

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