The impact of high game density on enchytraeids in a mixed forest

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The potential impact of high densities of ungulate game on *Enchytraeidae* and other small annelids was studied in grazed and ungrazed plots in the municipal forest of the City of Brno (Czech Republic) from December 2003 to December 2004. In total 10 species of potworms were found. The community structure differed slightly between the game enclosure and the adjacent forest but strongly between plots of differing vegetation and thus humus layer. Plots with deciduous trees hosted many more species at higher densities than pure coniferous stands. At all sites *Fridericia* cf. *monochaeta* was found (43 % of all individuals). At the coniferous sites only on additional species, *Achaeta eiseni,* was found. The polychaetous annelid *Hrabeiella periglandulata* was found almost exclusively in plots with deciduous trees. Vertical distribution differed between all the sites, but generally most enchytraeids were found in the upper 9 cm. Enchytraeid abundances changed during the year. Maximal values were found in spring. Minimal differences in mean densities were found between sites with similar vegetation inside and outside the game preserve. The highest mean annual density (14 500 ind./m^2) was found in the game preserve deciduous stand. Abundances and vertical distribution of potworms did not show any significant differences between plots with similar vegetation inside and outside the game preserve.

Keywords: Enchytraeidae, *Hrabeiella periglandulata*, forest, game grazing.

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Introduction

The impact of herbivores on soil fauna has been usually addressed in respect to pastures, where sheep or cattle are kept. Such grazing of domestic animals has shaped many landscapes. Despite of its effects on soil (e.g. soil compaction; removal of biomass input by grazing - but massive input of dead organic matter and nutrients in dung patches; long-term changes in the character of the dead organic matter due to changes in vegetation) only a limited number of studies have looked on the impact of grazing on enchytraeids (King and Hutchinson, 1976, 1983; Hutchinson and King, 1980; Nakamura, 1980; Schlaghamerský and Kobetičová, 2006). We are not aware of any study concerning the effect of ungulates on the fauna of forest soils, in particular there is no information on enchytraeids in this context. The present study looks at the impact of high densities of hoofed game comparing plots inside and outside of a small game preserve located at the outskirts of the city of Brno in South Moravia, Czech Republic. Little is known on the fauna of enchytraeids and other small soil-dwelling annelids in Moravia (the Czech Republic's eastern part): except some faunistic data summarized by Chalupský (1988) there are only a few studies reporting details on the structure of enchytraeid assemblages either from coniferous forests in the Beskydy mountains (Chalupský, 1992, 1995) or from grasslands and an arable field in the White Carpathians (Schlaghamerský, 2005; Schlaghamerský and Kobetičová, 2005, 2006).

Material and methods

Study sites

The research was carried out in four circular plots (177 m^2 each), two of which were situated within a game preserve (the Holedná game preserve; 305 ha) and two in the adjacent forest, situated on the slopes west of Jundrov, a quarter of the city of Brno (South Moravia, Czech Republic). Each pair of plots included one plot dominated by deciduous trees and one almost pure coniferous stand (for the symbols of individual plots see Table 1). The coniferous stands were formed by spruce, pine and larch. The mixed stands were dominated by oak, beech and pine (for the tree composition in each plot see Table 2). The plots were situated at an altitude of 200 to 400 m a.s.l. and in 15 – 20 m distance from a forest road. The soil type in these plots was illimerized podsol, the soil texture class silt loam and the humus form moder (for further soil characteristics see Table 1). The mean annual rainfall for the area is 550 mm and the mean annual

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Table 1. Chemical characteristics of soil (composite samples based on 3 soil cores per plot); O – plot outside the game preserve, I – plot inside the game preserve, C – plot with coniferous trees only, D – plot with deciduous trees.

Plot	Soil layer [cm]	pH (H_2O)	pH (KCl)	P_{total} $mg.kg^{-1}$	C_{ox} [%]	N [%]	Na $mg.kg^{-1}$	K $mg.kg^{-1}$	Ca $mg.kg^{-1}$
OC	0 – 3	4.3	3.3	714	16.4	0.6	32	136	968
OC	3 – 12	3.9	3.1	266	3.4	0.2	70	20	82
OD	0 – 3	4.0	3.4	699	10.7	0.4	48	120	1024
OD	3 – 12	4.0	3.3	438	3.2	0.1	22	40	172
IC	0 – 3	4.0	3.3	983	23.3	1.0	24	180	1592
IC	3 – 12	3.9	3.2	563	5.6	0.4	80	52	258
ID	0 – 3	4.7	3.9	700	8.4	0.5	136	144	1504
ID	3 – 12	4.4	3.3	469	3.9	0.2	40	28	364

temperature 8°C (Čermák, 2003). The long-term (1961 – 1990) mean annual precipitation is 524 mm.

The distance between the plots outside the game preserve was about 200 m. The plot outside the game preserve dominated by coniferous trees (OC) was N-W-facing. The herb layer was very poor. The plot outside the game preserve with dominant deciduous trees (OD) was N-facing. Its herb layer was formed by dense patches of *Impatiens parviflora*.

The plots inside the game preserve were in about 30 m distance from each other. In both plots the herb layer was poorly developed. The plot dominated by coniferous trees (IC) had also a northern exposure (N-N-W), while the plot with deciduous trees (ID) was E-facing.

Moufflon (52), fallow deer (108), Dybowski's sika deer (11) and wild boar (11) were kept in the game preserve (official game stock numbers given in brackets; Kloz, in lit.), however, the wild boar were kept separate in a small enclosure within the preserve. The resulting game density potentially affecting the study plots was 0.56 individuals/ha of ungulate game or 0.3 red deer units per ha, which can be considered high for the forest stands present. Some of the moufflon and fallow deer in the preserve are very tame and were frequently observed to graze close to the roads and foot paths used by pedestrian visitors. No game was observed in the plots outside the game preserve and no official stock data were available. However, as this forest is of small size and surrounded by fenced gardens, residential houses and the fenced game preserve, at maximum a population of few individuals of roe deer is to be expected.

Table 2. Species composition of the tree layer (numbers of trees) in the individual plots inside and outside of the game preserve (for abbreviations of plots see Table 1).

Tree species / plot	**OC**	**OD**	**IC**	**ID**
Robinia pseudoacacia	-	-	-	1
Pinus sylvestris	5	9	7	7
Fagus sylvatica	-	-	-	2
Quercus robur	-	3	-	3
Larix decidua	-	-	3	-
Picea abies	15	-	10	-

Sampling and processing of samples

The plots were sampled monthly from December 2003 to December 2004. Per plot and date 6 randomly placed soil cores of 17 cm^2 surface area were taken down to 12 cm (exceptionally to 15 cm) depth using a cylindrical steel corer. Each soil sample was vertically subdivided into 4 layers according to the soil horizons (L – F, H – A_h, B_1 and B_2). Samples with badly differentiated horizons were subdivided into layers of 3 cm (0 – 3, 3 – 6, 6 – 9 and 9 – 12 cm). Annelids were extracted using a modified O´Connor method (wet funnel): after 12 h of cold extraction the soil surface temperature was gradually increased up to 43 ºC within 3 h. Specimens were stored in tap water at 8 ºC, counted and identified alive under a light microscope. In total 4 277 individuals were extracted and identified during the study period given above. Differences between enchytraeid densities in the plots with similar vegetation were tested by the Mann-Whitney-U-Test. To resolve the unclear identity of some of the species recorded, the plots ID and IC were resampled on Nov. 4, 2005, March 20 and May 3, 2006 (IC on the latter date only) and specimens investigated by the senior author. Species identities and presence in the plots as confirmed by this additional investigation are reported below.

Results

Mean annual densities (individuals per m^2 ± standard error of the mean) were: ID - 14 500 ± 4 900; OD – 14 200 ± 4 900; IC – 2 200 ± 1 500; OC – 2 600 ± 900 (values based on 13 monthly samplings, rounded up to the nearest hundred). The differences in mean enchytraeid numbers found between sites with similar vegetation inside and outside the game preserve were very small and not significant (Man-Whitney-U-Test; ID vs OD: p = 0. 69; IC vs OC: p = 0.39).

At most of the sampling dates the enchytraeid densities in the plots with deciduous trees exceeded those in the plots with coniferous trees substantially (Fig. 1). Maximal values were mostly found in spring. In most species, numbers decreased in late summer. The population dynamics of identical species differed between individual plots, for example, although the

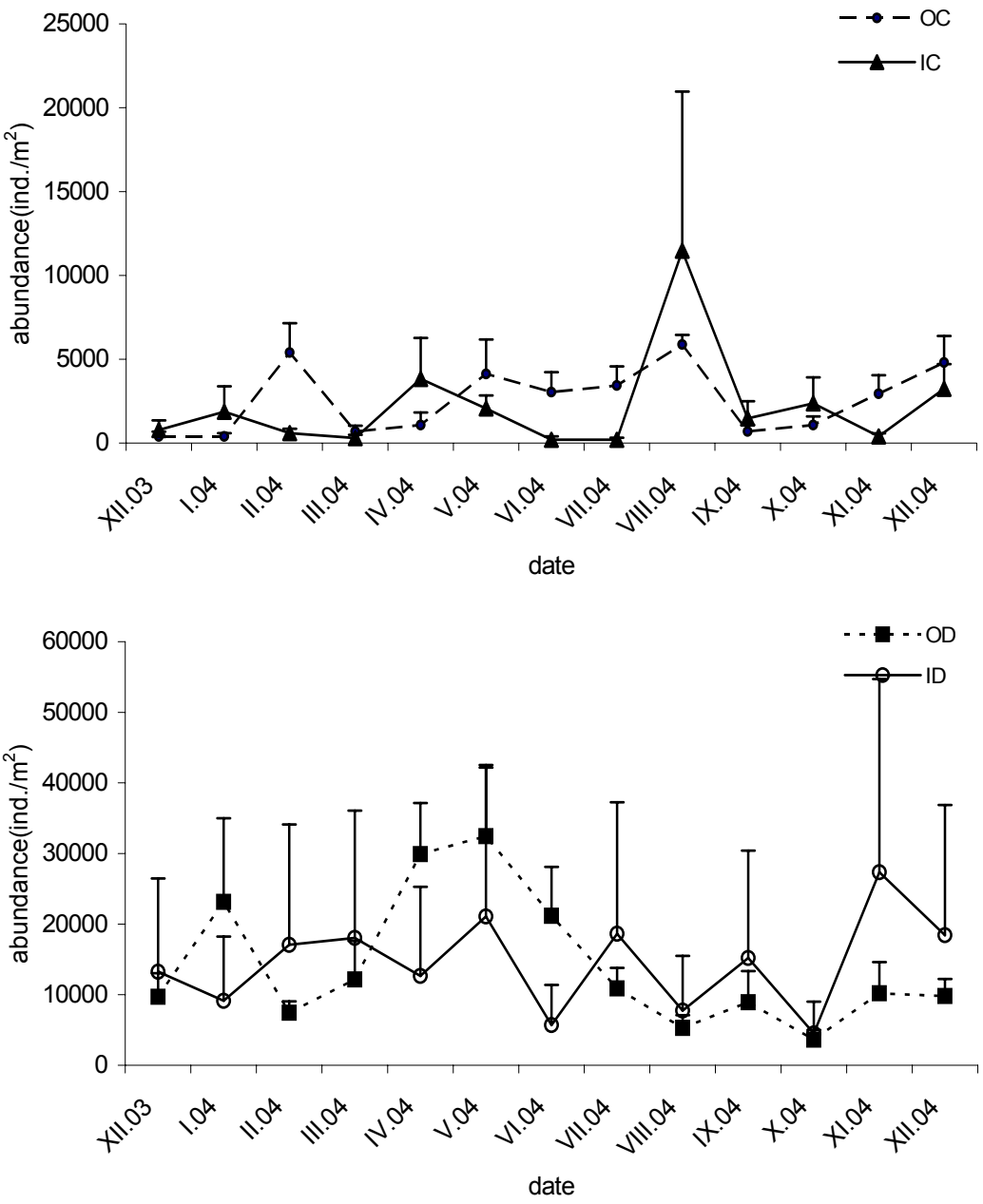

Fig. 1. Abundance dynamics of enchytraeids in each plot (monthly means with S.E. are given; only positive error bars are given for better visibility; for abbreviations of plots see Table 1).

same two species were involved in plots dominated by coniferous trees, their populations showed different oscillations during the year (the detailed presentation and interpretation of these data would exceed the scope of the present study).

Vertical distribution differed between the plots but on average few individuals were present below a depth of 9 cm (Fig. 2). In the plots outside the game preserve the enchytraeid distribution in the soil profile was more even than inside the preserve.

The community structure differed substantially between the coniferous and mixed stands; some differences were also found between the game enclosure and the adjacent forest (Table 3): While 8 and 9-10 species were recorded in the plots with deciduous trees (two species of *Fridericia* could only be discriminated based on additional samples in spring 2006, these samples included also *Stercutus niveus*, increasing the species number for ID to 11), only 2 species were found in the coniferous stands (*Fridericia* cf. *monochaeta* and *Achaeta eiseni*) during the study period (additional sampling of IC in May 2006 yielded one additional species, i.e. *Enchytronia parva*). The similarity of communities between the plots with deciduous trees was high (Sörensen´s quotient: 84 %; excluding data from the additional samplings in 2005

and 2006). *Fridericia* cf. *monochaeta* was found in all plots and made up for 43 % of all enchytraeids identified during the study (in ID 73 %). *Oconnerella cambrensis* reached a dominance of almost 60 % in OD while only few individuals were found in ID. *Fridericia ratzeli* was found only in ID. One of the abundant species in all plots and of particular importance in the coniferous stands was *Achaeta eiseni* (see Discussion). Additionally to enchytraeids one other small annelid species was found, that is *Hrabeiella periglandulata* ("Polychaeta"), a species reported for the first time from Moravia. *H. periglandulata* was found in all plots except OC but mainly in ID. Details on the occurrence of this species shall be presented elsewhere.

Discussion

Hoofed game can influence soil organisms by grazing, as phytomass is removed in most of the area (decreasing the amount of litter) and on the other hand organic matter is unevenly added in the form of excrements. A further effect is soil compaction and possibly damage of the herbaceous vegetation by trampling. The composition of litter might be changed, as selective grazing can influence the vegetation. The encountered enchytraeid community structure differed only slightly between the game enclosure and the adjacent forest. The found enchytraeid densities, particularly their changes in the course of the year, do not allow a simple interpretation. In the plots with similar vegetation densities were very similar. We did not find any significant impact of high game density on total enchytraeid density and our data do not support our initial hypothesis on the negative role of soil compaction by trampling and possibly of other types of habitat disturbance. This might be due to an insufficiently high game density in the studied preserve or its insufficiently high difference to the adjacent forest stand outside of the enclosure for which no game numbers were available. However, the latter assumption is very unlikely as the game stock of this small forest bordered by fenced gardens, residential houses and the fenced game enclosure must be very low, which is also shown by the much richer herb layer of the mixed and broadleaved stands present there. Also the official game stocking of the preserve is rather high for this type of forest (and official numbers tend to be underestimates). We had no exact data regarding actual intensity of grazing or passing through of the game in the actually studied plots. Although there are differences in tree composition between the plots, data on the soil characteristics show very similar values between plots inside and outside the preserve. This supports the impression that there is hardly a difference between the plots, which are influenced by game and plots without game. Soil reaction, density and maximum capillary

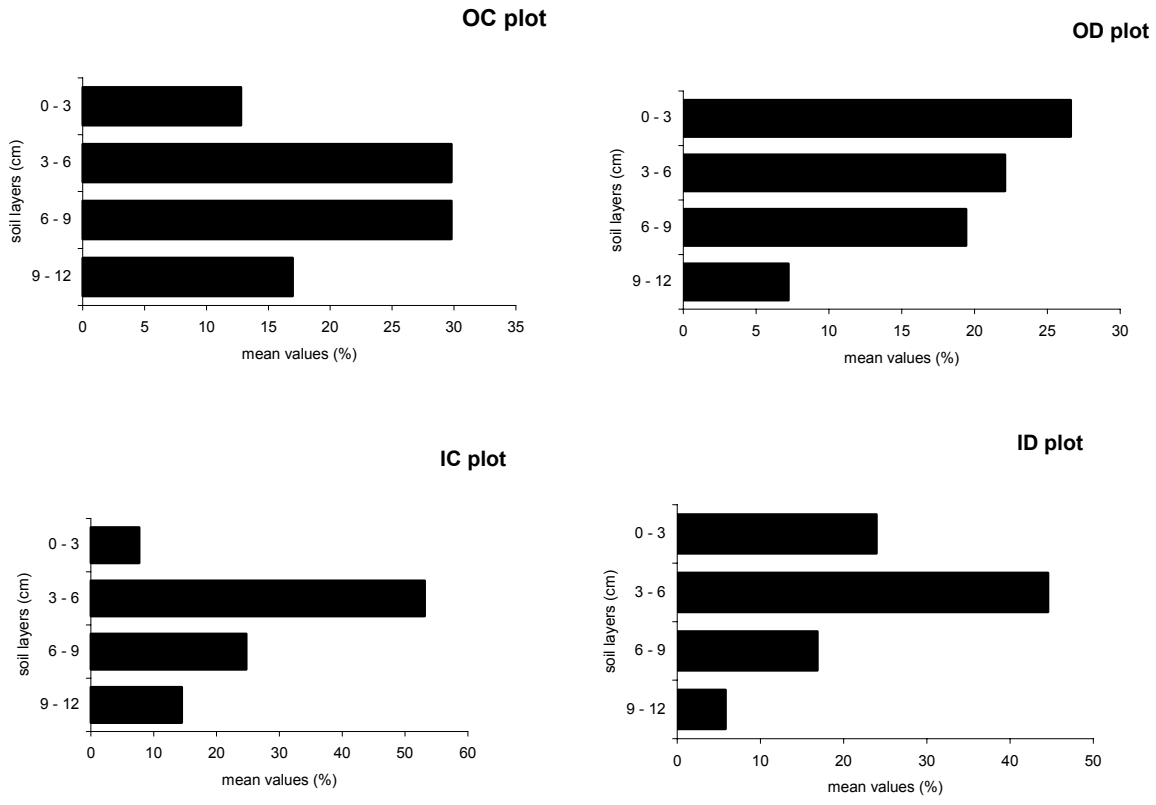

Fig. 2. Vertical distribution in each plot (for abbreviations of plots see Table 1).

Table 3. Species list for the studied plots with numbers of individuals and species (for abbreviations of plots see Table 1; + species recorded during additional samplings when only ID and IC were sampled; *Fridericia* spp. includes the recorded representatives except *F.* cf. *monochaeta*).

Species	OC	OD	IC	ID
Achaeta eiseni Vejdovsky, 1877	197	523	77	135
Buchholzia appendiculata (Buchholz, 1862)	-	18	-	35
Cognettia sphagnetorum (Vejdovsky, 1877)	-	60	-	12
Enchytraeus norvegicus Abrahamsen, 1969	-	28	-	21
Enchytronia parva Nielsen et Christensen, 1959	-	2	+	174
Fridericia cf. *monochaeta* Rota, 1995	98	151	215	1369
Fridericia ratzeli (Eisen, 1872)	-	-	-	42
Fridericia spp.	-	2	-	51
F. bisetosa (Levinsen, 1884)	-	-	-	+
F. paroniana Issel, 1904	-	-	-	+
Henlea sp.	-	2	-	-
Oconnerella cambrensis (O'Connor, 1963)	-	1021	-	50
Stercutus niveus Michaelsen, 1888	-	-	-	+
Number of species	**2**	**8(9?)**	**3**	**11**

water-holding capacity did not differ a lot between plots. Soil reaction was similar in all plots, only in ID soil pH was somewhat higher. Thus the marked difference in species composition between the coniferous and mixed stands can not be explained by a lower pH in the coniferous stands alone; the soil in the coniferous stands seemed much drier but soil moisture was not measured in the course of the study. Generally most enchytraeids were found in the upper 9 cm of soil and numbers decreased with the depth in most plots. One of the reasons why enchytraeid numbers in the upper-most layer seemed much lower than in the second organic layer, may be the fact, that this upper-most layer (L-F) was usually rather thin, that is less than 3 cm. Another reason might be that the upper layer was often dry at the time of sampling.

The community structure of both plots with deciduous trees differed somewhat: While *Fridericia* cf. *monochaeta* made up for over 70 % of individuals in the game preserve, its share outside the game preserve was much lower. Another species, i.e. *Oconnerella cambrensis*, was dominant in the mixed forest stand outside the game preserve. However, it is difficult to say if and to what degree this was an effect of the grazing or trampling of game. *Achaeta eiseni* was more abundant outside of the game preserve but generally one of the dominant species. In some adults from OC the spermathaecae were found to reach into segment X and these were initially identified as *A. bulbosa* Nielsen and Christensen, 1961. However, the only difference between the two species being the length of the spermathaecae, the validity of *A. bulbosa* has to be considered doubtful (U. Graefe, pers. comm.). As our specimens resembled in all other characters those with shorter spermathecae collected in the same plots, we assume the presence of only one species of this genus, *A. eiseni*, at our sites. *Cognettia sphagnetorum* is a species reaching rather high dominance in soils of the pH range found in the present plots. However, it was only found irregularly and in low densities in both mixed stands, perhaps as a consequence of the drier conditions assumed for the coniferous stands. In April 2004 the senior author microscoped one injured subadult specimen (all others were juvenile) finally assigned to this species whereas *Stercutus niveus* was considered an alternative possibility. Several specimens of *S. niveus* were then found in spring 2006 in ID, whereas not a single *C. sphagnetorum* was identified. This rises the question if *S. niveus* juveniles were not generally mistaken for *C. sphagnetorum*. However, this is most improbable as many of these specimens were identified during the summer months, that is at a time when *S. niveus* is inactive, undergoing aneonosis (Dózsa-Farkas, 1973).

The present study adds one first record for the Czech Republic's fauna: the species identified as *Fridericia* cf. *monochaeta* is either a new species for the Czech fauna or even a species new to science; differences to the original description of *Fridericia monochaeta*, the species closest to the investigated specimens, require further study. *Hrabeiella periglandulata* was found for the first time in Moravia; at present this is the south-eastern-most record of this species published.

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