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INFLUENCE OF PLANT DIVERSITY AND EARTHWORM CASTS ON THE ABUNDANCE AND SPECIES COMPOSITION OF THE ENCHYTRAEIDS (OLIGOCHAETA: ENCHYTRAEIDAE) IN A LYSIMETRIC EXPERIMENT

ABSTRACT: An experiment was conducted in plastic pots filled with loamy sand and inserted into the soil. Half of the pots were sown with one species, orchard grass, and half with a mixture of six grass species. Every year at the end of May, half of the pots in each variant was enriched with 300 g d.w. of earthworm casts per pot. The experiment was continued for three years. Changes in numbers of enchytraeids were observed, and at the end of the experiment also their species composition. Total numbers steadily increased from about 5 10^3 ind. m^{-2} to over 60 10^3 ind. m^{-2}. In all years, enchytraeids were significantly more abundant in monoculture of orchard grass. No statistically significant effect of earthworm casts on enchytraeid abundance was found. A total of 10 enchytraeid species were recorded. No unequivocal differences in the species composition and dominance structure of enchytraeid community were found between different variants of the experiment.

KEY WORDS: Enchytraeidae, plant diversity, earthworm casts

1. INTRODUCTION

Agricultural treatments account for structural simplification of many ecosystems, including grasslands. In Poland, orchard monoculture are increasingly common in areas earlier supporting multicoloured herb layer. These processes are accompanied by deep changes in the structure and functioning of the whole biocoenosis (Wasilewska and Kajak 1995). So far, in experiments on biodiversity typically more or less complex systems were constructed, and the course of basic ecosystemic processes was observed (Naeem *et al.* 1994, Tilman and Downing 1994). In the field studies, mainly of agrocoenoses, most often the effects of crops on soil fauna were investigated (Swift and Anderson 1993). No such studies exist on Enchytraeidae. In natural ecosystems only Abrahamsen (1972) found a relationship between floral richness of the herb layer in coniferous forests and the abundance and number of enchytraeid species.

The problem of relationships between enchytraeids and earthworms is also little understood, and views of different authors are inconsistent (Brown 1995, Makulec 1996). Some suggest competitive or antagonistic interactions between these families (Healy 1980, Schaefer and Schauermann 1990), whereas others found positive interactions, especially with respect to their food (Zachariae 1967).

To get a deeper insight into processes occurring in simplified vegetation systems, a lysimetric experiment was designed (Kajak *et al.* 1995). An attempt was made to find out whether the diversity of meadow vegetation, combined with soil enrichment with earthworm casts, has an effect on the abundance and species composition of enchytraeid community. Earthworms play an important part in transformation of soil habitat, and they are considered to be ecosystem engineer's organisms (Jones *et al.* 1994, Lawton 1994). In the experiment only their casts were used, taking into account their positive effect on microflora and soil food resources.

2. MATERIAL AND METHODS

The experiment was conducted in the field, using plastic pots 0.16 m^2 in surface area and 50 cm deep (Fig. 1). They were filled with mixed and uniform alluvial loamy-sand underlain by coarse sandy soil, and inserted into the soil. A total of 80 pots was installed. In 1986, half of the pots were sown with one species of grass, orchard grass (*Dactylis glomerata* L.) – the variant called monoculture (Mo), and the other half was sown with a mixture of six grasses (*Dactylis glomerata* L., *Festuca pratensis* Huds., *Festuca rubra* L., *Phleum pratense* L., *Poa pratensis* L., *Lolium perenne* L.) – the variant called mixture (Mi) (Kajak *et al.* 1995, Wasilewska 1995). These plants were harvested twice a season, at the end of May and in August. The second factor, partly replacing the activity of earthworms, was their casts. Each year, portions of 300 g d.w. casts per pot were added at the end of May. They were picked up from urban lawns not frequently visited by people.

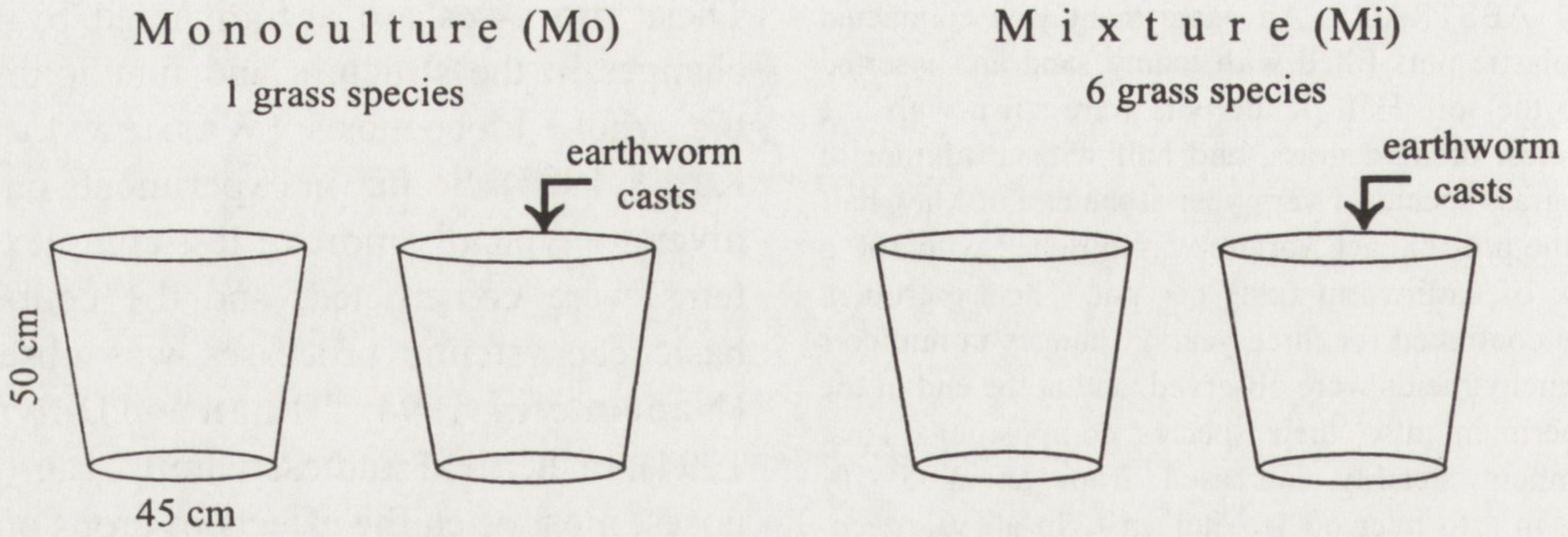

Fig. 1. Experimental design

Table 1. Basic physico-chemical properties of soil in lysimeters

Soil[1]:	Alluvial loamy sand	
Mean content at 0–20 cm:	Initial (1986)	Final (1989)
Total C (%)	0.68	0.67
Humic acids (mg/100g soil)	1.32	1.58
Fulvic acids (mg/100g soil)	139	130
pH_{KCl}	6.5	
Sum of rainfall for the period April–September (mm)[2]		
1987	279	
1987	295	
1989	320	

[1] after Kusińska (1989),
[2] after Pawłat (1989).

Experimental design and some biotic and physico-chemical properties of the experimental systems are given in Figure 1 and Table 1.

To estimate the abundance of Enchytraeidae, soil samples 10 cm^2 in surface area and 10 cm deep were taken three times per season: in June, August, and October of 1987–1989. The three sampling periods correspond to the spring and autumn maxima and the summer minimum in population dynamics of enchytraeids under natural conditions. In 1987 and 1988, 6 samples and in 1989, 8 samples were taken on each occasion from each variant. Each year a different set of pots was used. Enchytraeids were extracted by using the classical O'Connor (1955) method. ANOVA was used for statistical analyses.

To determine the species composition of enchytraeids, samples were taken early in May and late in October of 1989. In these periods, the proportion of mature individuals, whitch are the basis for species identification, was expected to be highest. A total of 1190 individuals were used for this purpose.

3. RESULTS

3.1. ENCHYTRAEID DENSITY

The total density of enchytraeids increased over the study period, especially in the third year of the experiment (Fig. 2). In the monoculture, enchytraeid densities in the last study exceeded over 9 times, and in the mixture 13 times their original densities. A similar tendency was also observed on successive sampling periods, mostly in the second and third years (Fig. 3). At that time in autumn, the enchytraeid community reached a highest density of about 140 10^3 ind. m^{-2} in the variant with orchard grass and 75 10^3 ind. m^{-2} in the variant with grass mixture. Mean numbers of enchytraeids in the three seasons and also most of the results for successive sampling periods were significantly higher in the variant with orchard grass (Figs 2 and 3). This was particularly well pronounced in the second and third years.

No statistically significant effect of earthworm casts on enchytraeid density was found (Figs 4 and 5). Differences were not significant (except for one case) for the first samples taken one month after the introduction of casts (June) nor were they significant on successive sampling periods (Fig. 5). However, in the third year of the experiment in both August and October of 1989, enchytraeids were much more abundant in the variants enriched with earthworm casts (Fig. 5). It can thus be suggested that this may be an important factor but at suitable soil moisture and high microflora activity (Tables 1 and 2).

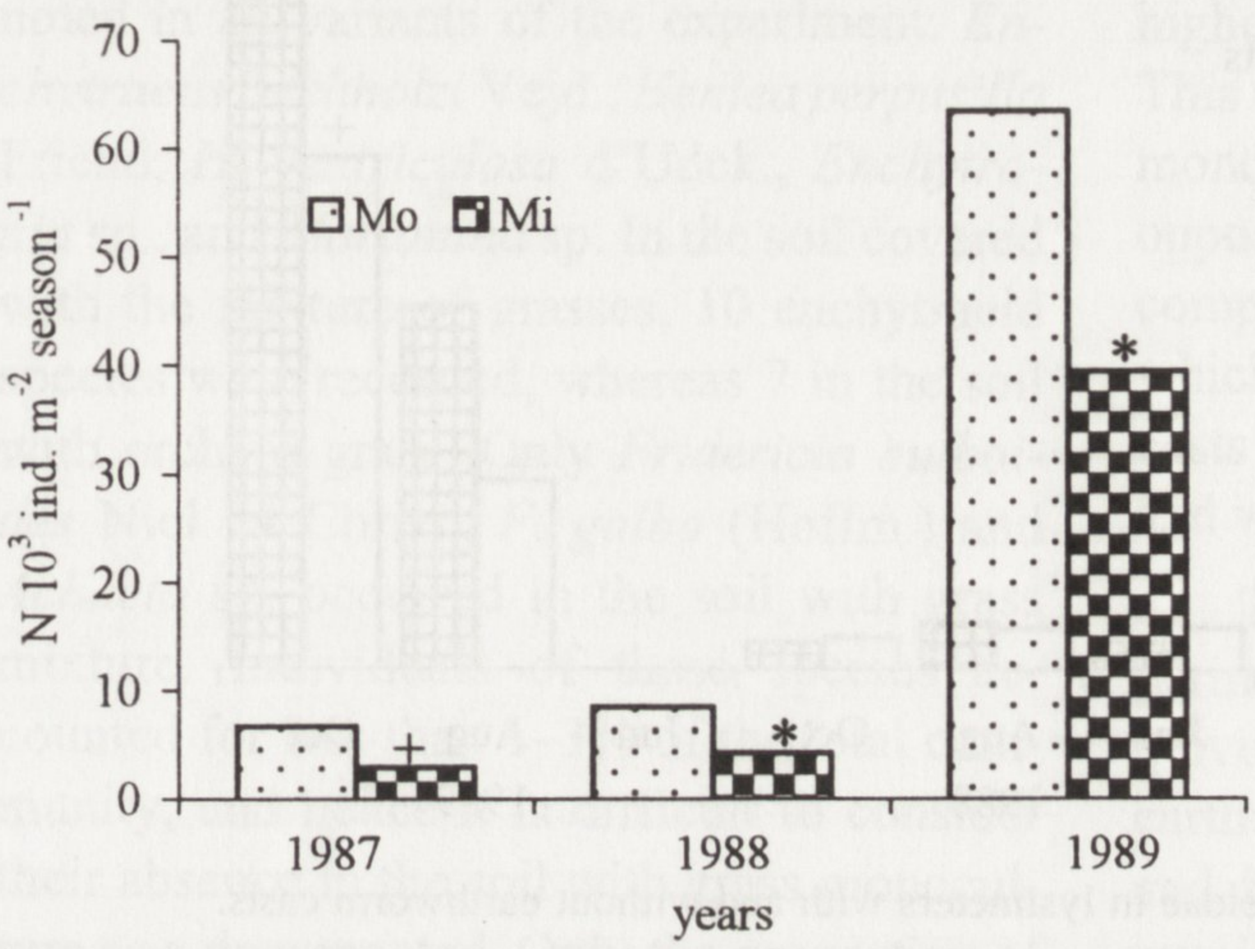

Fig. 2. Mean densities of Enchytraeidae in lysimeters with the monoculture (Mo) and with mixture (Mi) in three years
* $0.01 \leq P \leq 0.05$, ** $0.001 \leq P \leq 0.01$,
$^{+}$ $0.05 \leq P \leq 0.1$

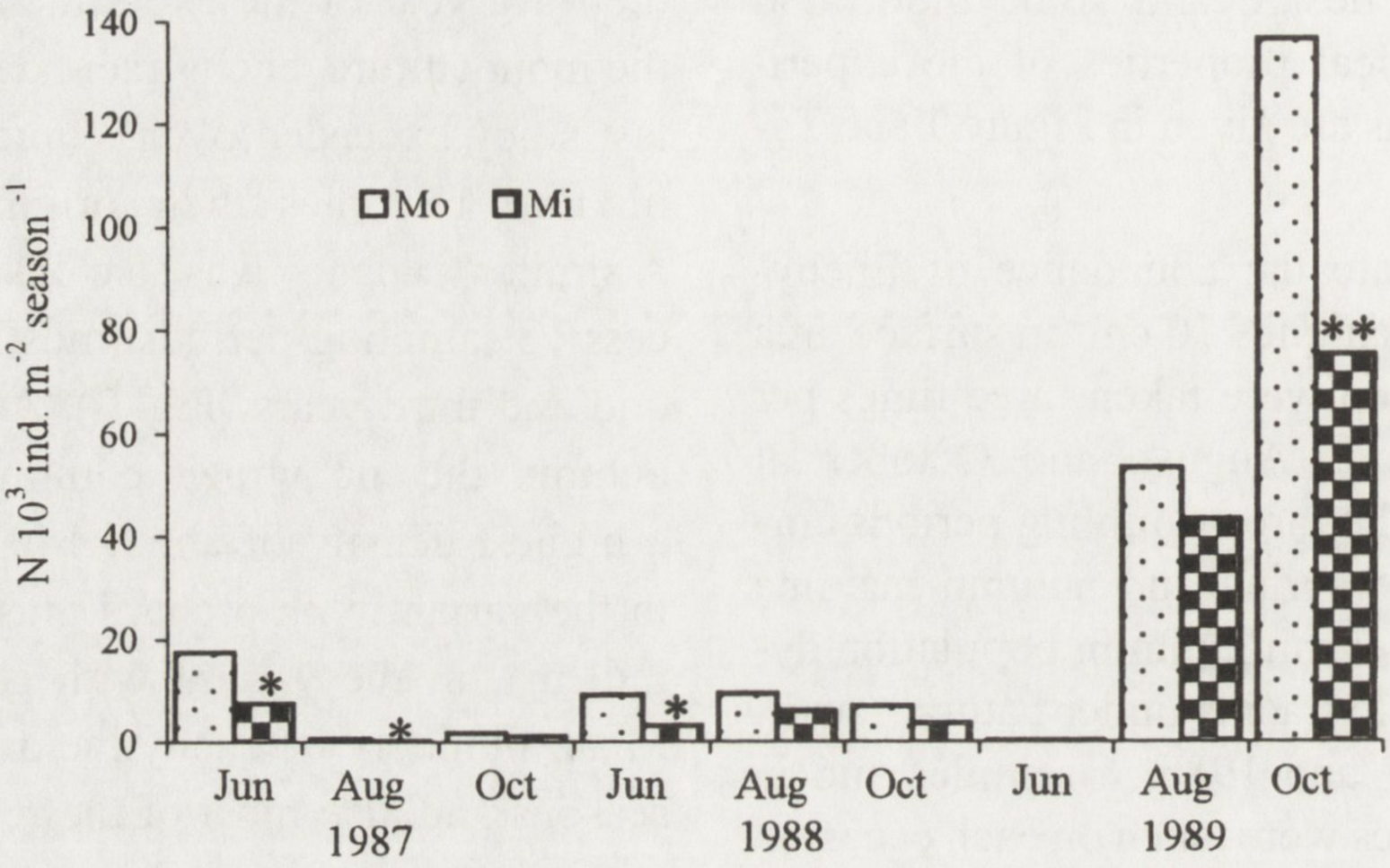

Fig. 3. Seasonal changes in density of Enchytraeidae in lysimeters with monoculture (Mo) and mixture (Mi). (For explanations see Fig. 2)

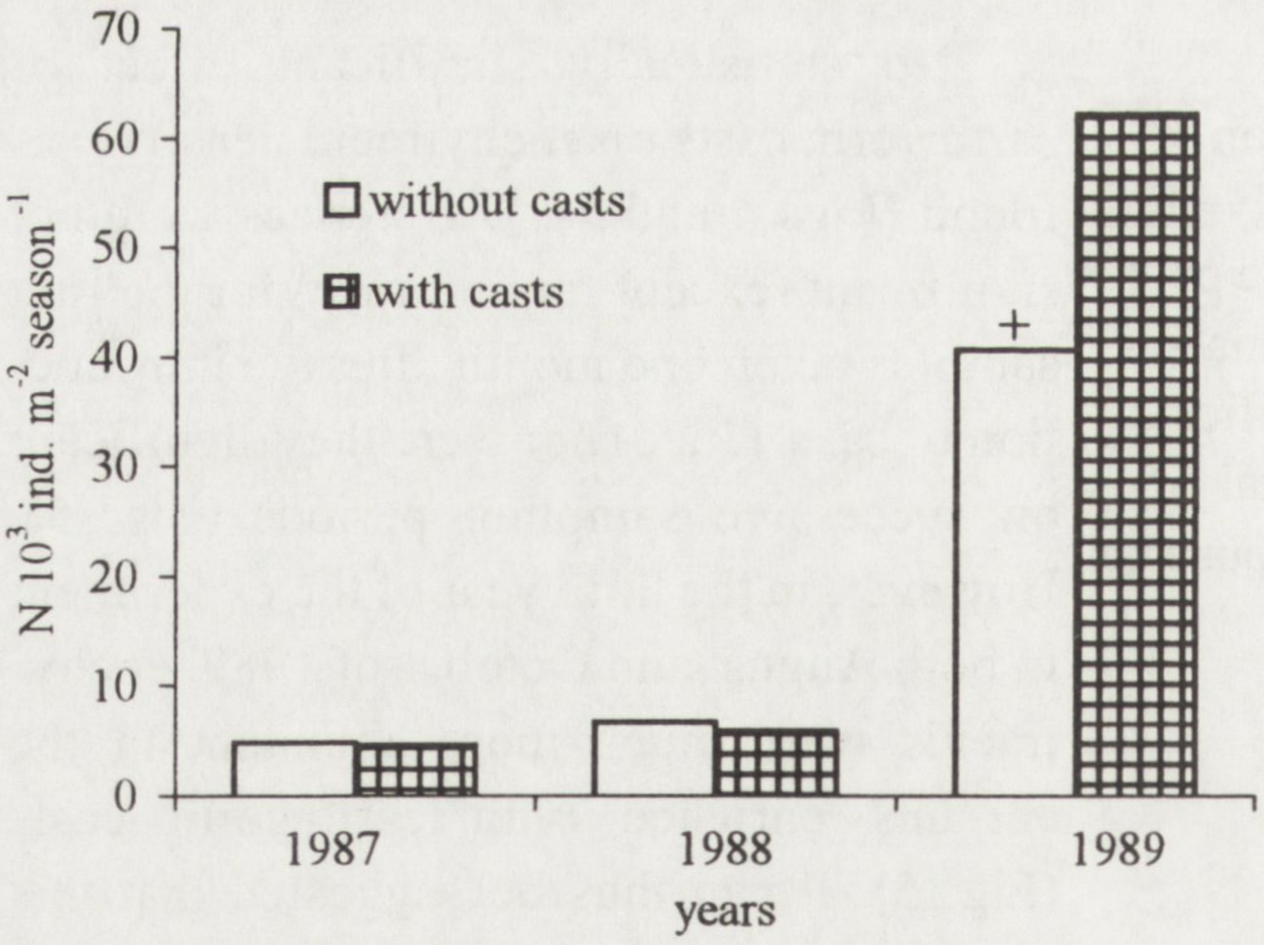

Fig. 4. Mean densities of Enchytraeidae in control and enriched with earthworm casts lysimeters in three years. (For explanations see Fig. 2)

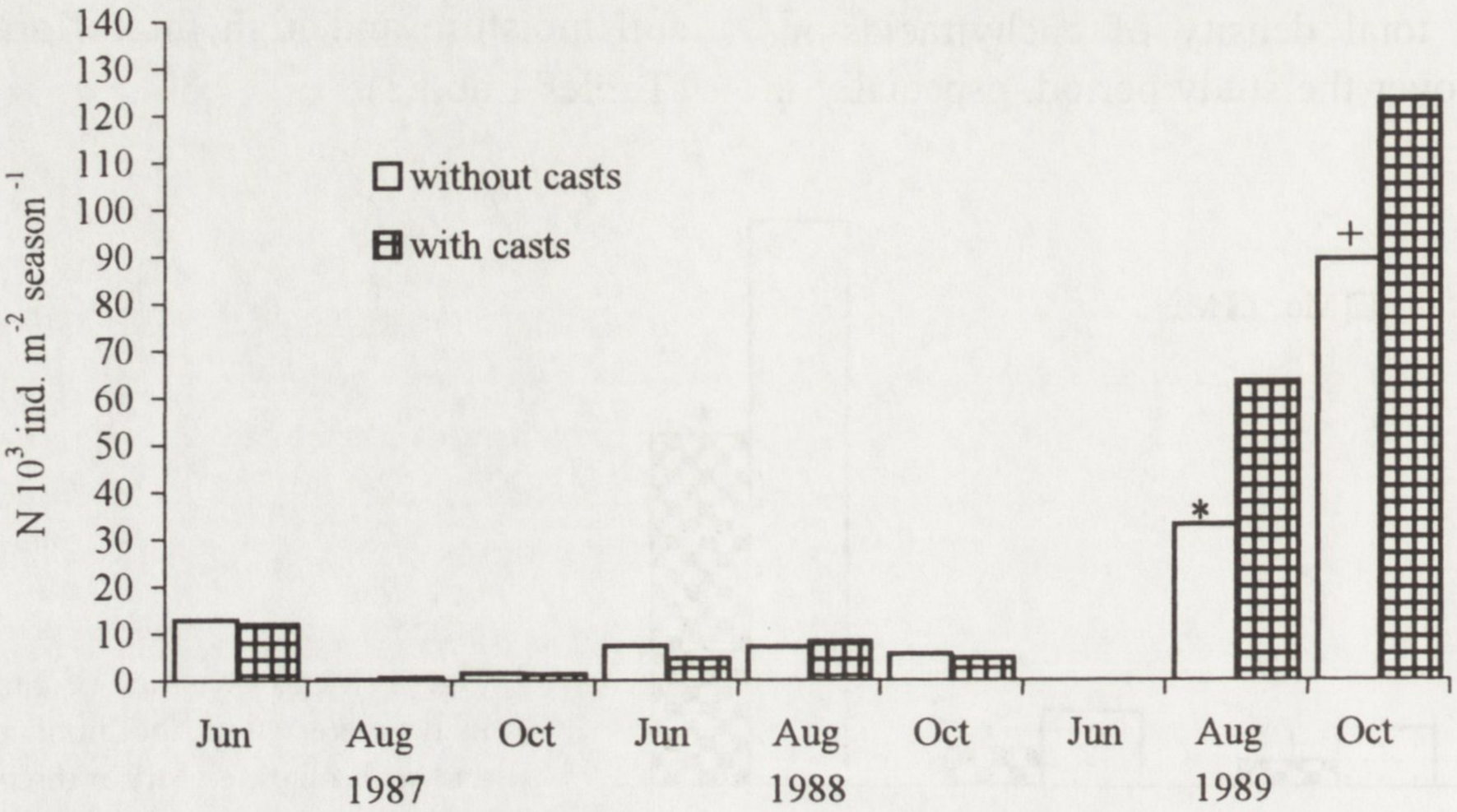

Fig. 5. Seasonal changes in density of Enchytraeidae in lysimeters with and without earthworm casts. (For explanations see Fig. 2)

Table 2. Vegetation and microflora in different variants of the experiment

	Monoculture (Mo)		Mixture (Mi)		Signif. differ. at $P \leq 0.05$
	Without casts (O)	With casts (C)	Without casts (O)	With casts (C)	
Vegetation[1]:					
Number of species in 1986	1		6		
Number of species in 1989	14	16	20	20	
Mean yield in 1987–89 (g d.wt.m^{-2})	175.9	185.9	239.4	252.3	Mo/Mi O/C
Microflora (N·10^5·g^{-1}d.wt.)[2]:					
Bacteria	160.2	115.4	132.4	147.3	MoC/MiC MoO/MoC MoO/MiO
Actinomycetes	9.89	7.54	8.41	7.36	MoO/MoC Mo/Mi O/C
Fungi	0.47	0.64	0.46	0.67	
Cellulase (µg glucose $g^{-1}24\ h^{-1}$)	49.45	38.70	40.03	44.21	Mo/Mi O/C
Protease (mg glicine $g^{-1}24\ h^{-1}$)	1.082	1.092	0.960	1.343	Mo/Mi MiO/MiC

[1] after Pawłat (1989),
[2] after Stefaniak and Ślizak (1989)

3.2. SPECIES COMPOSITION OF ENCHYTRAEIDS

A total of 10 enchytraeid species were recorded from the soil of the lysimeters. Immature individuals of three species were identified only to genus (Table 3). These were species living in different habitats, highly tolerant of moisture, acidity, and fertility of the soil. The following species were noted in all variants of the experiment: *Enchytraeus buchholzi* Vejd., *Henlea perpusilla* Friend, *H. ventriculosa* d'Udek., *Enchytronia* sp., and *Marionina* sp. In the soil covered with the mixture of grasses, 10 enchytraeid species were recorded, whereas 7 in the soil with orchard grass. Only *Fridericia bulboides* Niel. et Christ., *F. galba* (Hoffm.) and *Achaeta* sp. occurred in the soil with grass mixture. Individuals of these species accounted for less than 1–3% of the total community, and hence it is difficult to consider their absence in the soil with grass monoculture as a documented. Only the proportion of the dominant species, *H. perpusilla*, was higher in the soil with the mixture of grasses.

No differences were found in the number of enchytraeid species between the variants with and without earthworm casts added. Individual species showed variable responses to the presence or absence of earthworm casts in the soil.

An exception was the dominant species, *H. perpusilla*, the proportion of which was higher in the soil without earthworm casts. This tendency occurred in both variants, with monoculture and with mixture of grasses. An opposite relationship can be observed when comparing proportions of *H. ventriculosa*, which were higher in the soil with earthworm casts for both variants with the orchard grass and with the mixture of grasses (Table 3).

To sum up, it can be stated that under experimental conditions there was no unequivocal effect of vegetation diversity and earthworm casts on the species composition and dominance structure of enchytraeid communities.

Table 3. Species composition and proportions (% in abundance) of different species in enchytraeid community

Species	Monoculture (Mo)		Mixture (Mi)	
	Without casts (O)	With casts (C)	Without casts (O)	With casts (C)
Henlea perpusilla Friend.	34	19	38	25
Henlea ventriculosa d'Udek.	<1	9	<1	10
Henlea sp.	2	20	15	7
Enchytraeus buchholzi Vejd.	2	1	2	<1
Enchytraeus sp.	2	18	8	1
Fridericia bulboides Niel. et Christ.				3
Fridericia galba (Hoffm.)				<1
Fridericia leydigi (Vejd.)	1		1	1
Fridericia ratzeli Eis.		1	<1	
Fridericia sp.	21	12	14	18
Enchytronia sp.	29	11	6	18
Marionina sp.	9	9	16	14
Achaeta sp.			<1	

4. DISCUSSION

A relatively uniform, mixed soil was used in the experiment, so it can be assumed that numbers and species composition of enchytraeids were similar in all pots at the beginning of experiment. It is known that agricultural treatments such as ploughing or harrowing reduce numbers of enchytraeids shortly afterwards (Kasprzak and Ryl 1978). Manipulations during the preparation of the experiment could have a similar effect. During the succession over the study years, not only enchytraeids but also the whole biocoenotic system evolved. The number of plant species increased, although the initial monoculture orchard grass accounted for about 75% of the yield biomass in the last year (Table 2) (Kajak and Wasilewska 1995). Clear differences occurred in plant production and in microflora abundance and activity (Table 2). Against this background also total numbers of enchytraeids were increasing. The observed levels of their abundance were similar to those reported by other authors. Kasprzak (1986) found at different sites from about 1 to 25 10^3 ind. m^{-2} in soils of urban lawns and about 1.5 10^3 ind. m^{-2} in the Arrhenatheretum meadow. Numbers obtained in the present experiment did not differ from their results at the beginning but were any times higher in the third year. According to the review by Didden (1993), mean enchytraeid densities in grassland ecosystems rarely exceed 100 10^3 ind. m^{-2}. Maximum enchytraeid density observed in the lysimetric pots was about 140 10^3 ind. m^{-2}. This means that experimental conditions had no limiting effect on enchytraeid numbers.

A rapid increase of enchytraeids in the third year of the study was not only due to the

development of the whole community but also an effect of higher rainfall as compared with that in earlier years (Table 1). One of reasons for a more abundant occurrence of enchytraeids in monoculture may be a higher abundance and enzymatic activity of soil microflora than in the grass mixture (Table 2). This situation creates suitable food conditions for enchytraeids. The effect of earthworm casts on enchytraeid community in the third year of the study (Figs 4 and 5) may have been an intermediate effect of an increased food supply in the soil and forming microflora abundance and composition. The higher number of fungi and other microfloral groups in earthworm casts than in surrounding soil was reported from many sites (Czerwiński *et al.* 1974, Daniel and Anderson 1992, Makulec and Chmielewski 1994). Remarkably higher abundances of fungi in the variant with earthworm casts in both the monoculture and the mixture (Table 2) can explain the increase in the number of enchytraeids for which fungi belong to important components of their diet (Persson *et al.* 1980, Didden *et al.* 1997).

Differential conditions of the experimental setup had no noticeable effect on the species composition and dominance structure of enchytraeid communities. Among other things, this was due to a high plasticity of the species that occurred there. All of them were recorded from the soil of urban lawns in Warsaw (Kasprzak 1986). Higher number of species in the variant with grass mixture than with only orchard grass can be indicative of the community enrichment. Restoration of the structure of enchytraeid community after disturbance, which certainly took place when the pots were being filled with soil, is completed after 2–4 years (Abrahamsen and Thompson 1979). Abrahamsen (1972) signalized a relationship between the species richness of enchytraeids and the number of plant species, but only in floristically rich habitats. Many authors emphasized a complexity of the relationship between enchytraeids and earthworms (Didden 1993, Brown 1995, Makulec 1996). Positive and negative relationships between individual species, and mutual effects on the abundance of whole groups are known from the literature. The enchytraeid numbers decreased significantly in mesocosmos study with *L. terrestris* after three months of exposure (Lagerlöf and Lofs-Holmin 1987). Undoubtedly, the response of enchytareids to earthworms differs from their response to earthworm casts. According to Zachariae (1967), enchytraeids consume earthworm casts. Górny (1984), who studied enchytraeids in polders of the Netherlands, found that their numbers were largely reduced, including *H. ventriculosa*, after the introduction of earthworms. In laboratory experiments, this author also found that the mortality of enchytraeids, including the genus *Henlea*, was higher in soil extracts earlier occupied by earthworms as compared with that in soil extracts never occupied by earthworms (Górny 1975). The conclusion was that faeces and secretions of earthworms had a negative effect on enchytraeids. A higher proportion of *H. ventriculosa* in the variant with earthworm casts may have been a result of the positive response to the presence of casts, or this species could have a high resistance to the presence of casts, or this may have been a response to the decline of a closely related species, *H. perpusilla*. The decline in *H. ventriculosa* noted by Górny (1984) may have been due to its response to the presence of live earthworms.

Only comparative studies on the effect of both live earthworms and their casts on enchytraeids could resolve this problem.

5. CONCLUSIONS

1. The total density of Enchytraeidae increased several times over their successional development of the biocenotic system. Improvement of moisture conditions in the third year was of great importance.

2. The abundance of enchytraeids was significantly higher in the orchard grass monoculture. One of the reasons may be higher numbers and activity of microflora in this variant.

3. Enchytraeids tended to be more abundant in lysimeters enriched with earthworm casts, especially at high population densities. This may be related to an increase in the available food supply in the experimental system.

4. A total of 10 enchytraeid species were recorded. This community was predominated by species of the genus *Henlea*. No unequivocal effect of vegetation and earthworm casts on the species composition and dominance structure was found.

6. SUMMARY

An experiment was conducted in the field, using plastic pots 0.16 m^2 in surface area and 50 cm deep (Fig. 1). They were filled with mixed and uniform alluvial loamy-sand underlain by coarse sandy soil, and inserted into the soil (Table 1). A total of 80 pots was installed. In 1986, half of the pots were sown with one species of grass, orchard grass (*Dactylis glomerata* L.) – the variant called monoculture (Mo), and the other half was sown with a mixture of six grasses (*Dactylis glomerata* L., *Festuca pratensis* Huds., *Festuca rubra* L., *Phleum pratense* L., *Poa pratensis* L., *Lolium perenne* L.) – the variant called mixture (Mi). These plants were harvested twice a season, at the end of May and in August. The second factor, partly replacing the activity of earthworms, was their casts. Each year, portions of 300 g d.w. casts per pot were added at the end of May. The experiment was continued for three years.

The total density of enchytraeids increased over the study period from about 5 10^3 ind. m^{-2} to over 60 10^3 ind. m^{-2} (Fig. 2). Mean numbers of enchytraeids in the three seasons and also most of the results for successive sampling periods were significantly higher in monoculture of orchard grass (Figs 2 and 3). This was particularly well pronounced in the second and third years.

No statistically significant effect of earthworm casts on enchytraeid density was found (Figs 4 and 5). However, in the third year of the experiment in both August and October of 1989, enchytraeids were much more abundant in the variants enriched with earthworm casts (Fig. 5). It can thus be suggested that this may be an important factor but at suitable soil moisture and high microflora activity (Tables 1 and 2).

A total of 10 enchytraeid species were recorded (Table 3). No unequivocal differences in the species composition and dominance structure of enchytraeid community were found between different variants of the experiment.

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