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ENCHYTRAEIDS (OLIGOCHAETA) IN THE AGRICULTURAL LANDSCAPE

ABSTRACT: Enchytraeids are the most important detritophages in farmland. Their density, species composition, and body length were assessed in four crop fields and adjacent shelterbelts in Turew area (Wielkopolska, West Poland). The density in crop fields varied between 3000 and 13000 ind. m^{-2}, whereas in woodlots from 7000 to 15000 ind. m^{-2}. In the absence of earthworms in cultivated fields, enchytraeids contributed to 2–5% of the total biomass of soil invertebrates. Enchytraeid species living in crop fields were not specific of this habitat.

The community occurring in the ecotone (between the woodlot and field) was similar to that in the crop fields with respect to the species composition, and to the youngest woodlots with respect to the abundance and body size.

Over the last 25-year period, numbers and diversity (H') of enchytraeids in investigated fields did not change but the size of an average individual decreased.

KEY WORDS: enchytraeids, numbers, species composition, crop fields, shelterbelts

1. INTRODUCTION

Investigation of enchytraeids are not common, especially as compared to earthworms. Moreover there have been relatively few studies done in cultivated fields. Didden (1993) in review paper documented that only 9 crop fields were studied in the total number of 70 habitats concerned enchytraeids.

The Wielkopolska region (West Poland) where this study was conducted is quite exceptional with respect to the knowledge of enchytraeids. The first Polish faunistic studies of this group where done there (Moszyński 1928, 1932). Four of nine studies considered in crop field by Didden (1993) were obtained in this region (Ryl 1977, 1980, Kasprzak 1982). The studies done 25 years ago in these crop fields have dealt with species composition, vertical distribution, density, biomass and respiration of enchytraeids. The present study was conducted in the same sites to estimate what kind of changes occurred in enchytraeid communities during this 25 years period of intensive cultivation and mineral fertilizing.

Area of Turew in Wielkopolska was deforested and cultivated earlier than other regions of Poland. However, almost 200 years ago the shelterbelts were established in farmland and it enhanced the biodiversity of landscape (Ryszkowski 1996). The aim of the paper is to evaluate the importance of shelterbelts to enchytraeids in adjacent fields.

2. STUDY AREA AND METHODS

The soils of the Turew area (West Poland) are fairly uniform. They are situated in the area of alfisols, and slightly loamy sand over light loam prevail in the studied site (Marcinek 1996, Ryszkowski *et al.* 2003). Detailed information on local differences in soils of this area is given by Kostro-Chomać (2003).

The investigations have been done in the period May–October of 1999 and 2000. The weather was similar in both these seasons: 358 mm and 355 mm of rainfall and mean daily temperatures of 14.8°C and 15.0°C, respectively.

In the first study year, the samples were taken four times from a 6-years old shelterbelt (S7) and from adjacent maize field situated on its east side (leeward). In the next year the field was sown with wheat. In the field the samples were taken from three plots: field margin (ecotone – EF) and at distances of 10 m and 50 m from the shelterbelt (F_{10} and F_{50}).The first distance (10 m) was at the area of the influence of trees on microclimate (Ryszkowski 1996), and the farther distance was considered to be representative for the open space. Often both these field plots (F_{10}, F_{50}) were analysed jointly and marked as F7.

In the second year samples where taken three times from the same sites and from the six additional sites – three shelterbelts of different age: 2 years (S2), 5 years (S5), and more than 100 years old (S150). The fields adjoining S2 (F2) and S150 (F150) were also sampled. They were sown with oats and barley respectively. One oat field located in a large complex of crop fields with no woods in the vicinity (F0) was also sampled. Two fields, barley (F150) and oats (F0), were under study also 25 years ago.

Design of new shelterbelts (2–7 years old) was aimed at obtaining possibly high diversity of forests. Thus, basic species in most new plantings was oak (appropriate for oak-hornbeam forest habitats, which dominate in the area), accompanying by maple, birch, beech, elm, linden, mountain ash, white beam, larch, pine and spruce. The herb layer of this shelterbelts was formed in the patches (approximately 0.25 m^2 area) covered by different herb species. In the old shelterbelt locust tree (*Robinia pseudoacacia*) dominated.

To estimate numbers of enchytraeids, sample series of 15 soil cores were taken 15 cm deep and 10 cm^2 in surface area. Each sample was divided into three 5-cm layers, and the animals were extracted by using the O'Connor method of wet funnels. Enchytraeids were measured under microscope to the nearest 0.5 mm to calculate their biomass from the formulas (Makulec 1983):

$$y = 6.22x^{1.55} \quad (1)$$

$$Y = 20.14 \ln y - 62.38 \quad (2)$$

where x is the length in mm, y is biomass – the wet weight μg, and Y is the dry weight in μg.

An important problem of this study is a comparison of the current results with those from before 25 years (Ryl 1977, 1980, Ryszkowski 1996). Sampling sites in both these periods were the same, and only minor changes were introduced to the sampling procedure. The surface area of the current samples is a little larger (10 cm^2 versus variable surface area, most often 5 cm^2 in the earlier study), shallower (15 cm versus 30 cm), and taken less frequently. Because of the smaller depth of the present samples, up to about 26% of the number of enchytraeids may be missing in the driest months (recalculated from Ryl, 1980). These are probably the smallest species of the genus Acheta (Didden and de Fluiter, 1988).

The reliability of the results was estimated by t-Student test, test "u" of difference between structure indices, and analysis of variance. Cluster analysis was used for the analysis of similarity, in which Euclidean distances and complete linkages clustering were considered.

3. RESULTS

3.1. Comparison of enchytraeids of fields and shelterbelts

Mean enchytraeid densities in the study sites were low, and they did not show large differences as they ranged from 3.4×10^3 ind. m^{-2} in one of the fields (F7) to 15.3×10^3 ind. m^{-2} in the shelterbelt 7 years old (S7). Also differences in numbers between the group of four fields and woodlots were low (Table 1). Generally, enchytraeids were more abundant in shelterbelts (11000 ind. m^{-2}) than in the fields (6000 ind. m^{-2}). However no statistically significant differences were found in their numbers between the two groups of sites ($P = 0.11$). Enchytraeid densities in barley field adjacent to the oldest shelterbelt (F150) were three times higher than in the other fields, and equal to their densities in shelterbelts. The lowest density in fields was found in the oat plot located in the large complex of crop fields (F0). Among wood strips, the youngest one (S2) was significantly less densely inhabited by enchytraeids.

Table 1. Mean values of density, biomass and body size of enchytraeids in study sites in 2000. Shelterbelts: S2 – two years old, S5 – 5 years old, S7 – 7 years old, S150 – >100 years old and their adjacent fields F2, F7, F150. F0 – field in area without wood.

Site	Number ind * 10^3 m^{-2}	± SE	Body size mm	± SE	Biomass (mg w wt) m^{-2}
F150	13.2	4.33	2.76	0.13	394
F0	4.1	1.22	2.95	0.13	137
F2	4.9	1.02	2.70	0.11	142
F7	3.4	0.55	3.18	0.12	127
S2	6.9	1.52	2.87	0.09	220
S5	12.7	1.64	4.92	0.19	956
S7	15.3	2.70	4.10	0.16	848
S150	11.9	2.57	3.26	0.14	466

The mean length of enchytraeid individuals was estimated for each site (Table 1). No significant differences were found among sites in the mean individual size ($P = 0.11$), but extreme values in fields and shelterbelts differed significantly ($P < 0.05$).

Based on length measurements, mean body weight of individuals was calculated and their total biomass in each site. The mean body weight ranged from 29 μg in the field F2 to 73 μg in the shelterbelt S5. Enchytraeid biomass varied from 220 to 956 mg w.wt.m^{-2} in shelterbelts and from 127 to 394 mg w.wt.m^{-2} in the fields (Table 1).

The species composition of enchytraeids was almost identical in the shelterbelts and crop fields. Of 20 species found, 18 occurred in the shelterbelts and 16 in the fields (Table 2). The shelterbelts were inhabited by 8–12 species and crop fields by 4–11 species. *Enchytraeus* sp. strongly predominated in most of the sites under study. At 5 of 9 investigated plots (F0, F2, F150, S2, S7), the species composition of communities was very similar to each other (Fig. 1) and different from that in field F7 and its ecotone EF, also from that in two shelterbelts, S5 and S150. Acid soils of the *Robinia* shelterbelt (S150) were inhabited by the community of *Acheta* sp. and *Cognettia sphagnetorum* characteristic of pine forests (Pilipiuk 1993). In the study area such species composition occurs only at this site. In shelterbelt S5, species of the genus *Fridericia* constituted the bulk of the enchytraeid community.

Little diversified species composition and high dominance (even up to 78%) of the genus Enchytraeus resulted in low Shannon Wiener diversity indices. The values of H' varied from 1.03 in field F2 to 2.62 in shelterbelt S5 (Table 2). The values of H' in the fields varied from 1.03 (F2) to 1.91 (F0). No significant differences were found in the diversity between the fields and the shelterbelts ($P = 0.52$).

The estimated parameters: density, mean body size, and diversity index, were used to assess similarity in the structure of enchytraeid communities among the sites (Fig. 2). Also two components of the species composition were considered: proportion of the genus *Fridericia* in the total numbers of individuals, (the species is more abundant in fertile habitats like in deciduous forests, Pilipiuk 1997, Kasprzak 1986) and of the genus *Acheta* inhabiting deeper, less fertile soil horizons (Didden and de Fluiter 1988). The selected parameters clearly categorize the enchytraeids of the study habitats into two groups: the group associated with fields, with low densities and small body size of individuals and the group associated with forests with greater densities and larger individuals. The "forest group" occured in the three shelterbelts and in the field adjoining the oldest of them. To the "field group" communities besides the three fields, the ecotone between S7 and ad-

Table 2. Species composition and dominance (% of total numbers) in enchytraeid community at various sites in 2000. (Site symbols see Table 1 and Fig. 1).

Sites	F150	F0	F2	F7	EF	S2	S5	S7	S150
Acheta bohemica (Vejd.)	+	+		1	1				2
„ *camerani* Cog	8	9	26	49	36	4	4	2	54
Enchytraeus sp. *	68	64	71	34	46	78	8	72	
„ *norvegicus* Abrah	1	4			+			2	
Henlea venticulosa d'Udek	2			1		1	3	5	2
„ *perpusilla* Friend	9	2		1	9	3	1	1	
„ *heleotropha* Steph								+	
Enchytronia parva Niel etCh		1		1		1	18	3	
Buchholzia fallax Mich.									1
„ *appendiculata* (Buch)	1								
Hemifridericia parva NietCh			1	2					
Fridericia bisetosa (Lev.)	11	9		7	1	5	26	9	5
„ *bulboides* Niel.etChri	1	5		4	6	1	31	5	
„ *gracilis* Bülow				1		+		+	
„ *leydygi* (Vejd.)		+					2		5
„ *perieri* (Vejd.)							2		
„ *ratzeli* Eis.					+		+		
„ *galba* (Hoffm.)		2					2	+	
Cognetia sphagnetorum (Vejd.)									31
Marionina sp.		3			1	7	1		+
number of species	9	11	4	10	9	9	12	11	8
H' diversity index	1.61	1.91	1.03	1.87	1.77	1.35	2.60	1.62	1.76

*Enchytraeus sp** = *E.buchholzi* + *E.christenseni*

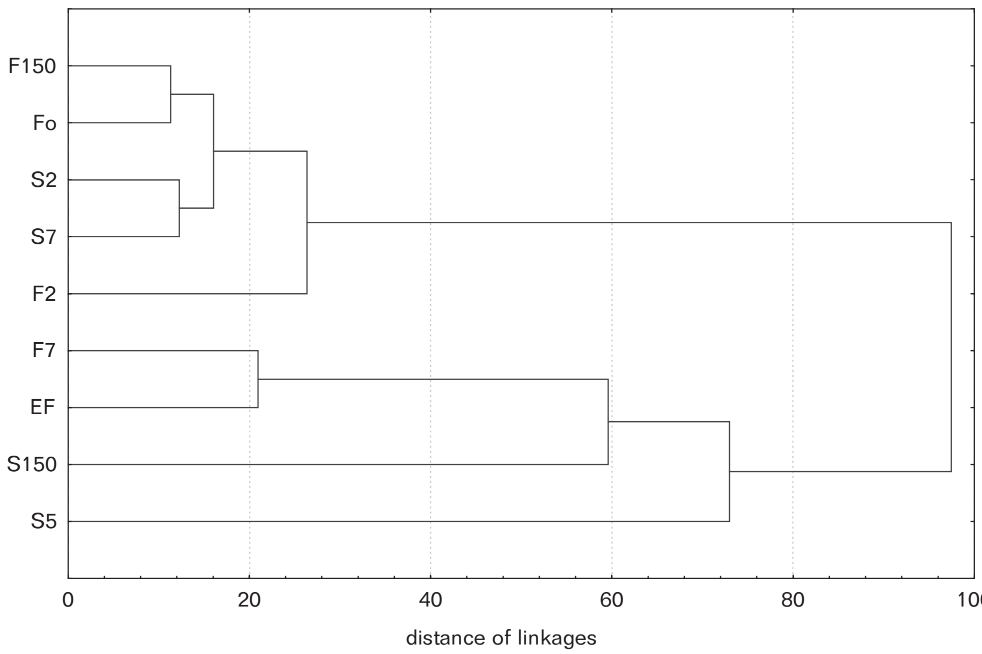

Fig. 1. Similarity in the species composition of enchytraeids among various study sites (Euclidean distance, complete linkage clustering). Sites shelterbelts: 2 years old – S2, 5 years old – S5, 7 years old – S7, >100 years old – S150, and their adjacent fields: F2, F7, F150, field in the area without wood F0, ecotone between S7 and F7 – EF.

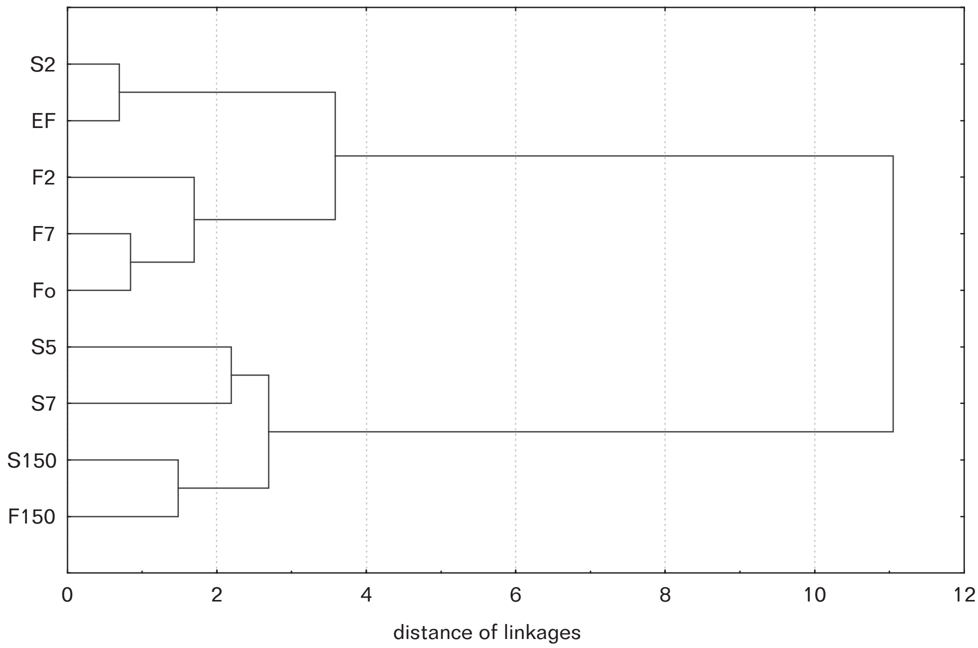

Fig. 2. Similarity in the structure (based on numbers, biomass, diversity and proportion of two species) of enchytraeid communities among various sites (Sites see Fig. 1).

jacent field and the youngest shelterbelt (S2) were included. Although these two last habitats were located far from each other the similarity between them was higher than to the remaining fields.

3.2. Relationship between enchytraeid communities of shelterbelt and adjoining field

Generally, shelterbelts are considered to be sources of the fauna colonizing adjacent crop fields (Ryszkowski 1995). Changes in numbers and species composition of enchytraeids were analysed in two successive years within the shelterbelt (S7), at the edge of this belt (EF), and at distances of 10 m and 50 m from the tree line (F_{10} and F_{50}, respectively). In both these years, mean annual densities decreased with the increasing distance from the shelterbelt: $S7 > EF > F_{10} > F_{50}$, although in some months, the highest numbers were recorded in the ecotone (twice) and the lowest in the field F_{10} (four times) (Table 3). The same pattern of changes in numbers was observed in the crop field and in the adjacent shelterbelt (Fig. 3) but the amplitude of these fluctuations was higher in the crop field (from 100 to 3% of maximal density, whereas in the shelterbelt – from 100 to 11%).

Table 3. Spatial variation of numbers (CV%) of enchytraeid community in the sequence of sites: shelterbelt (S7) and adjacent field (F7) in the distance 0 m (ecotone EF), 10 m (F_{10}) and 50 m (F_{50}) from belt.

Date	S7	EF	F_{10}	F_{50}	F7
1999					
May 85	79	108	55	78	
Jun	107	82		184	
Sept.	209	77	56	103	80
October	105	107	74	69	68
For period 1999	135	107	154	170	161
2000					
April	91	112	101	89	93
July	101	112	139	120	126
Sept.	108	104	143	136	138
For period 2000	113	109	125	119	122

In the shelterbelt the trees as well as the herb layer vegetation form a mosaic of patches. In spring, numbers of enchytraeids varied significantly from patch to patch ($P = 0.018$), on later sampling dates differences are not significant ($P = 0.09$). Although most frequently it was higher in the crop field compared with the shelterbelt on separate sampling dates, the maximum values were noted in the belt. This was the case, though the homogeneity of

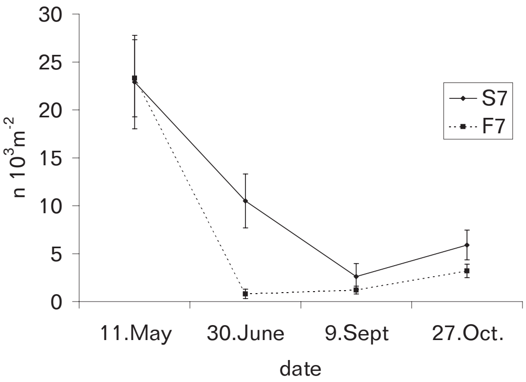

Fig. 3. Changes in numbers of enchytraeids in midle aged shelterbelt S7 and in adjacent crop field F7 in 1999.

crops contrasted with patchy distribution of vegetation in this shelterbelt. In spring, numbers of enchytraeids varied from patch to patch (P =0.018), but not significantly so on later sampling dates (P =0.09). Mean enchytraeid density in patches declined in the following order: *Rumex sp.>Taraxacum sp.>Agropyron sp.>Carduus sp.* The patchy distribution of vegetation inside this shelterbelts contrasted with the homogeneity of crops. Nevertheless spatial variation in numbers (CV%) did not show clear differences among plots (Table 3). Although the maximum values were noted in the belt, frequently the values were higher in the crop field (predominantly in wheat field in 2000). Over all variation – spatial and temporal, was higher in the field.

In successive two years, a significant decrease in numbers (P <0.05) was found in the crop fields community (6.5×10^3 ind. to 3.4×10^3 ind. m^{-2}) whereas in the shelterbelt the enchytraeid number in the same time increased not significantly (from 9.3×10^3 to 15.3×10^3 ind m^{-2}, P =0.09). This differences in the field might have been a result of changes in agricultural treatments associated with the shifting from maize in 1999 to wheat in 2000 (Table 4).

In the plot sequence from wood strip to the crop field (S7 – F_{50}), the mean body size of enchytraeids was significantly lower in the crop field compared with the shelterbelt (Table 4). The decrease in the mean body size in this sequence can be a result of two processes: the increasing proportion of young individuals in the population and the higher proportion of small size species. In the crop field, the proportion of the smallest species such as *Acheta sp.* increased and at the same time the proportion of mature individuals (with clitellum) decreased. This was true for estimates concerning all enchytraeids, and the most abundant genus *Enchytraeus sp.* as well (Table 5).

Table 5. Proportion (%) of sexually mature enchytraeids and individuals of genus Enchytraeus in 1999 and 2000 in sites sequence: shelterbelt seven years old (S7), ecotone (EF) and adjoining field (F7).

Site	Year	S7	EF	F7	Significance of difference (P <0.05)		
Enchytraeus	1999	24	25	4		*	*
sp.	2000	30	8	30	*	*	
Both years		28	18	10	*	*	*
Enchytraeidae	1999	20	23	11		*	*
(all)	2000	28	14	19	*		*
Both years		24	18	14	*		*

4. DISCUSSION

Karg and Ryszkowski (1996) estimated the biomass of all animals (saprophages, phytophages and predators) in agroecosystems of Turew area (West Poland) at 1541 g dry wt. m^{-2}. Enchytraeids,

Table 4. Characteristics of enchytraeid communities in the sequence of sites: shelterbelt S7 and adjacent field in the distance 0 m (EF – ecotone), 10 m (F_{10}), 50 m (F_{50}) from belt.

	Year	S7	EF	F10	F50	Significance of difference P <0.05			
						S7/EF	EF/F_{10}	F_{10}/F_{50}	S7/F_{50}
Numbers [2] ind 10^3m^{-2}	1999	9.3	8.0	6.1	6.2				
	2000	15.3	4.9	2.8	3.9				*
Diversity H'	1999	2.09	1.88	1.43	1.62	*	*		*
	2000	1.62	1.74	2.17	1.18		*	*	*
Acheta sp. %	1999	14	38	54	32	*	*	*	*
	2000	2	37	38	59	*		*	*
Body size mm	1999	3.75	3.28		2.68	*	*		*
	2000	4.10	3.28		3.18	*			*

which all are detritophages, accounted for 2 to 5% of this biomass. Makulec (2004, this issue) found that earthworms are almost absent in these fields. In the absence of earthworms in crop fields enchytraeids are the most abundant group of detritophages, important to soil processes.

The crop fields under study were not manured and the soil received small amount of detritus like post-harvest residues. The input of detritus was much higher in the shelterbelts, where it was close to the value of primary production. In response to this big difference in the available food supply, numbers and biomass of enchytraeids in the shelterbelt were only twice as high as in the crop field. In the same situation earthworms change their numbers from 0.9 in the field to 144 ind. m^{-2} in the woodstrip (Makulec 2004, this issue) and biomass of the larvae of insects increased 80 times (Olechowicz 2004, this issue). Crop fields are unfavourable habitats to many of soil animals due to frequent agricultural treatments. Enchytraeids show a high resistance to physical environmental conditions. Compared with earthworms and larvae of insects, enchytraeids – weak competitors – become the most important detritophages in farmland.

The competitive elimination of enchytraeids from habitats suitable for other detritophages was also documented in other situations. Enchytraeid numbers in shelterbelts accounted for merely one-tenth of the maximum number of enchytraeids noted in peatlands and in pine forests (Didden 1993). These habitats with numerous enchytraeids are unsuitable for many other saprophages (e.g., earthworms are scarce) because of difficult (too dry or too wet) physical soil conditions. The situation is analogous as in the case of crop fields. In Denmark, where earthworms do not occur in conventionally cultivated crop fields, enchytraeids account for 3.3% of animal biomass, whereas in integrated agriculture with soil not disturbed by ploughing, with a higher input of organic matter and in the presence of earthworms where are not disturbed by ploughing, enchytraeids decline as one of the few groups (Zwart *et al.* 1994).

After 25 years from the previous studies in Turew, the content of organic matter in the soils of crop fields did not change (Kostro-Chomać 2003), nor the composition nor the abundance of enchytraeids. Their densities found by Ryl (1980), ranged from 4.8×10^3 to 12.5×10^3 ind. m^{-2} (excluding a potato crop treated with manure), were in the same range as presently found abundance; the species composition was similar as well.

It seems that a signal of future changes in crop fields is the decreasing mean body size of individuals. The mean individual weight accounts for one-third of that observed years ago. It is, among others, the effect of changes in the proportion of species composition. In 1976, small species of *Acheta* contributed to merely 1–8% of enchytraeid abundance (Ryl 1980), whereas in 2000, its contribution varied from 8 to 50%. This diminution of average size of the enchytraeids means their higher respiration and shorter life cycle. This implies a shorter retention time of mineral nutrients in animal biomass and a higher respiration, that is, higher organic matter mineralization in the soil.

The species composition remained the same after 25 years from the previous study, but the specific proportion between species in the community seems to differ. Dominance structure is sharper. *Enchytraeus sp.* accounted for 24 and 32% of the total numbers of individuals in the studies of Ryl (1980) and recently they account for 50–71%. As a consequence, the index of species diversity H' is recently a bit lower in crop fields than it was earlier, but the differences between crop fields and permanent ecosystems were in both periods not significant. The conclusion of Ryszkowski (1995) that there is no clear decline in the diversity of enchytraeids inhabiting cropfields is still valid.

It is known that agricultural treatments (the ploughing, application of chemicals) cause that crop fields are unfavorable habitats to animals. Large seasonal fluctuations in enchytraeid numbers and great differentiation of their spatial distribution are the results of this effect. Variation in spatial distribution of this group on field sites is comparable to that in patchy areas inside the shelterbelt. The fact that in terms of the abundance and species composition of enchytraeids these habitats are very similar to two-years old shelterbelt implies that young shelterbelts can conserve the fauna characteristic for crop fields.

5. CONCLUSIONS

Densities of enchytraeids in crop fields are only slightly lower than in shelterbelts. This group is likely to use ecological niches not occupied by other saprophages.

The species composition of enchytraeids was found not to be specific of crop fields. So, shelterbelts are good sources of enchytraeids for this ecosystem exposed to site disturbances.

Crop fields are inhabited by smaller individuals of enchytraeids than shelterbelts, large species and adult individuals being less abundant in the former. This accounts for a higher contribution of enchytraeids to organic matter mineralization in crop fields.

After 25 years of intensive agricultural management, decrease of individual size of enchytraeids due to larger proportion of small size species and smaller size individuals was the only noticeable change.

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