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DRAINED FENS: COMPARISON OF NITROGEN MINERALIZATION RATE AND BIOTIC STRUCTURES IN TWO PERIODS OF SECONDARY SUCCESSION

ABSTRACT: The grasslands on drained fens, differentiated by water holding capacity and soil origin, derived from sedge-moss (SMP), tall-sedge (TSP), and alder peat (AP) were compared in terms of soil properties, N mineralization rate and composition of dominant microbial and faunal communities. Comparison was done for two periods of secondary succession: 15 (earlier or first period) and 30 years after drainage (later or second period). In both compared periods soil properties remained significantly different between study sites, however differences in respect to biota were lower in the later period.

In all compared sites in the second period a decrease was noted in soil moisture, pH, and total C and N contents accompanied by an increase in bulk density and cation-exchange capacity. The periodically over-dried AP grassland differed significantly from moist grasslands, located on sedge originated soils.

The rate of nitrogen mineralization was the highest in AP soil in both periods compared, but decomposition of new, dead plant material was retarded. Amount of N accumulated in plant detritus accounted for 30, 42 and 91% of live plant biomass in compared SMP, TSP and AP sites, respectively. The low efficiency of soil organisms in the decomposition of detritus in AP soil may be illustrated by relations between invertebrate biomass and the amount of accumulated detritus. Nitrogen in soil invertebrates contributed to 81% of total N in litter in both sedge originated grasslands and to 19% only, in alder grassland.

The decrease in the number of microbivorous and plant parasitic nematodes, stimulating mineralization processes was noted in AP soil in the second period. The density of humus forming invertebrates (Enchytraeidae, Lumbricidae) was significantly lower there in both periods.

The paper focuses on historical processes to explain the discrepancy between low abundance of humus forming invertebrates and high humus content in alder soil.

KEY WORDS: drained fens, N mineralization rate, biotic structures, secondary succession

1. INTRODUCTION

The decline of peat deposits is the major problem in drained wetlands. After drainage of fens, soil oxygen content increases and organic matter stored in peat over centuries is gradually mineralized (Marcinek 1976, Okruszko 1976, 1993, Tallis 1983, Franzes and Vasander 1995). The mineralization rate depends on many factors among which water holding capacity is the most important. Water content, in the area of the same precipitation, depends on the size and distribution of soil pores – properties strictly connected with the structure of plant communities from which peat originated. In a consequence properties of peat-forming plant communities affect decomposition rate of organic matter in drained fens (Kajak and Okruszko 1990, Okruszko 1993). Secondary succession on drained fens proceeds rapidly, the soil properties, composition of vegetation, invertebrate and microbial communities are variable, and change over time (Kajak *et al.* 1985, Pętal 1991). We compared in our investigations changes with time in the intensity of mineralization processes and in community structures in three grassland sites located on peat soils differentiated by peat origin and by water holding capacity. The objective of our investigation was to compare in these three grasslands:

– biological activity, nitrogen mineralization rate and immobilization in plant and heterotrophic communities,

– changes in mineralization rate and in biotic structures in these grasslands after 30 years of secondary succession after drainage.

2. STUDY AREA AND METHODS

Investigations were carried out at the Wizna fens (53° 10' N, 22° 30' E, northeastern Poland) drained between the 1960 and 1965. Before drainage this area was covered mostly by Caricetalia and carr forests (Pałczyński 1966). Grasslands were mown and hay of low quality gathered. After drainage forests were clear cut. The soil was ploughed and rolled and a mixture of several grass species sown. We compared three grassland sites, situated on soils derived from different peats:

– sedge-moss peat (SMP), originated from plant communities of small sedges and brown mosses (*Caricion lasiocarpae*) in the emersion zone of the river valley. This peat is 4 m deep. At present the prevailing vegetation components belong to the class Molinio-Arrhenatheretea, dominant plant species are *Alopecurus pratensis* and *Poa pratensis*.

– tall-sedge peat (TSP), developed in the flooded, immersive zone from communities of Magnocaricion. Now *Poa pratensis* and *Taraxacum officinale* predominate in the biomass of yield (Kotowska 1998 *et al.*). The thickness of peat layer is 4 m.

– alder peat (AP), developed in the border zone of the valley by the carr forest (Carici elongatae-Alnetum*). Poa pratensis* and *Festuca rubra* predominate in the yield. The thickness of peat is 2.65 m.

The following study periods were compared:

Period (a): 1994–1995, after approximately 30 years of secondary succession since drainage.

Period (b): 1978–1980, after approximately 15 years of secondary succession.

An analysis of period (b), has been done on the basis of previously published data.

Climatic conditions over the growing season (April–September) did not differ significantly between both periods and were characterized by mean air temperatures of 12.5–14.2 °C and of 13.9–14.1 °C in the periods (b) and (a), respectively. The sum of precipitation amounted to 260–470 mm in the period (a) and to 293–466 mm in the period (b).

All analyzed grasslands were mown 2–3 times annually and fertilized with NPK (Kaczmarek 1991). In the second period sedge originated grasslands were fertilized with 180 kg N per ha annually, the grassland located on alder peat soil was not N fertilized. Detailed informations of soil properties and management practice at the Wizna fen have been given by Okruszko 1977, Szuniewicz and Szymanowski 1977, Kaczmarek 1991, Pętal and Churski 1991, and about composition of plant communities by Pałczyński 1966, Kowalczyk and Łękawska 1977, Kotowska *et al.*1998.

Several parameters were measured in both compared periods (soil properties, nitrogen mineralization rate, number and biomass of invertebrates, microbial numbers and enzymatic activity) others (plant biomass, N content, cation release) were analysed in the later period (a) only.

Nitrogen mineralization rate was measured in soil cores (10 cm^2 in area, 7.5cm deep) during 1995 growing season (April–October) at monthly intervals. Five samples constituted the reference material and another 5 were incubated at 15 °C and ca 70% moisture for 14 days. Before the incubation, green parts of vegetation were removed. Soil cores were covered with deionized water and shaken for one hour, then the filtered solution was analysed for ionic content ($N\text{-}NH_4^+$, $N\text{-}NO_3^-$, Na^+, K^+, Mg^{2+}, Ca^{2+}) by ion chromatography (Gotkiewicz 1977, 1991, Zimka, Stachurski 1996).

The total nitrogen content of the soil was estimated by Kjeldahl method using a Kjeltec Tecator. Organic carbon was determined using potassium bichromate as an oxidiser. Humus compounds were separated with a mixture of sodium pyrophosphorane and sodium hydroxide (Kononova 1968). Five samples were taken from each site on each sampling date (May, July and September).

Aboveground plant biomass was estimated in samples of 0.1 m^2 (10 per habitat on each sampling date) taken 3 times during the growing season. Belowground plant biomass was assessed by washing soil cores (100 cm^2, 15 cm deep) using nettings of 1 mm and 0.49 mm mesh size (Pasternak-Kuśmierska *et al.* 1997).

The samples for assessment of the number of heterotrophic organisms were taken each year 3–5 times during the growing season, in spring, summer and autumn.

For microbial and faunal numbers, 10 samples were taken per habitat on each sampling date. Soil cores 2 cm^2 × 25 cm deep were used for Nematoda, 10 cm^2 × 7 cm deep for mesofauna (Acarina, Collembola, Enchytraeidae) and microbes. Tullgren funnels or O'Connor wet funnels were applied to extract mesofauna. Nematodes were extracted by Baermann funnels. Earthworms were dislodged by the formalin method from 0.09 m^2 frames. Samples for Nematoda and microbes were bulked.

Plate count method was used in analysis of microbial numbers and colorimetric methods in analysis of soil enzymes (Chmielewski 1991).

Significance of differences between the grasslands were tested by Mann-Whitney U test (microbial and nematode numbers, activity of enzymes) and by t-test (soil properties) or by one way ANOVA. Differences between the two periods were tested by t-test.

3. RESULTS AND DISCUSSION

3.1. SOIL PROPERTIES – DIFFERENCES BETWEEN GRASSLANDS, CHANGES WITH TIME

The water content decreases in the sequence of soils originated from sedge-moss peat (SMP) > tall-sedge peat (TSP) and > alder peat (AP). This is accompanied by a decrease in total carbon content and by an increase in bulk density and base exchange capacity (Table 1).

Table 1. Physical and chemical properties of three peat soils (layer 0–15 cm) after 30 years (a) and 15 years (b) of management. SMP – soil originated from sedge-moss peat, TSP – from tall-sedge peat, AP – from alder peat. (Data after Pętal and Churski 1991, Zimka and Stachurski 1996, Kusińska unpubl.)

Properties	Period	SMP	TSP	AP	F	*P*
Water content (% by weight, seasonal mean)	a	74.2c	71.7d	61.4k	47.6	0.0000
	b	79.6	76.2	66.0		
Bulk density (g cm^{-3})	a	0.217e	0.220e	0.252k	20.8	0.0000
	b	0.209	0.208	0.236		
Thickness of peat deposit (cm)	a	400	400	265		
Total C content (%)	a	35.6c	35.1d	34.6e	3.805	0.0320
	b	47.45	46.1	45.5		
Total N content (%)	a	2.92i	2.86j	2.72k	21.501	0.0000
	b	3.11	3.60	3.80		
Ca^{2+}+Mg^{2+}+Na^++K^+ (c cmol kg^{-1} dry soil)	a	134.20i	136.40j	149.20k	14.841	0.0000
pH (in KCl)	a	5.0i	5.4j	5.2k	25.523	0.0000
	b	5.8	5.9	5.8		
C-humic acids (% dry soil)	a	7.33i	6.21j	9.68k	249.8	0.000
C-fulvic acids (% dry soil)	a	6.0c	6.11cd	7.0d	62.81	0.000

Notes: Differences between sites were tested by t-test. Values within each line followed by a different letter are significantly different: c, d, e – $P < 0.05$; f, g, h – $P < 0.01$; i, j, k – $P < 0.001$.

During 15 years between the compared periods (a) and (b), a decrease in the total C and total N contents accompanied by an increase in cation exchange capacity, soil bulk density and acidity had been found in all compared soils (Table 1). The rate of change in the content of nitrogen was the highest at AP site. N content in this soil was in the first period (b) the highest, but in the second period (a), was significantly lower, than in two other soils. Soil derived from alder peat was significantly different from the two others in respect to all analysed parameters. It had in both periods the lowest moisture and total carbon content. Moorsh was more humified there, the content of humic and fulvic acids was the highest in this soil (Table 1). The highest mineralization rate of organic matter, measured by CO_2 diffusion have been also found in soil originated from alder peat (Kowalczyk 1977, Szanser 1991).

3.2. NITROGEN MINERALIZATION RATE AND UTILIZATION

The mineralization rate of nitrogen was negatively related to water content in the soil (Gotkiewicz 1991, Zimka and Stachurski 1996), and it was in both periods more than two times higher in AP soil than in the two other soils compared (Table 2). Higher N content was found there also in above ground plant biomass (Stachurski and Zimka 1998). Intensive nitrification resulted in the selective release of cations (Ca^{2+}, Mg^{2+}) to the soil solution, higher at the AP site than at SMP and TSP sites (Stachurski and Zimka 1998). Potassium was released in the similar, constant rate from all compared soils (Table 2). In consequence the proportion among released nutrients differed significantly between sites. The N/K ratio was ca 2 times higher in dry (AP) than in wet (SMP) soils. This resulted in a difference in the utilization of released elements by plants. The N/K ratios in the biomass of the two dominant plant species in the sward – *Alopecurus pratensis* and *Poa pratensis*, were 2–3 times higher at the AP than in SMP site (Stachurski and Zimka 1998). The higher N/K ratio was found also in the detritus in AP, than at the two other sites (Table 3). The similar N/K ratio in plant biomass, to this found at the AP site was assessed in the herb layer of a natural Carici elongatae Alnetum community, from which AP soil originated (Czerwiński and Pracz 1995, Pasternak-Kuśmierska 1995). The low efficiency of K uptake by plants growing under conditions of a high nitrogen mineralization rate may be explained according to Zimka and Stachurski (1996) by the antagonism between K^+ and NH_4^+ ions.

Table 2. Nitrogen mineralization rate and release of nutrients (g m^{-2} $season^{-1}$) (May–October) in peat soils after 30 years (a), and 15 years (b) of management. (Data after Gotkiewicz 1991, Stachurski and Zimka 1998). Explanations in Table 1.

	Period	SMP	TSP	AP
N-mineralization	a	13.4f	17.3g	35.8k
	b	6.5	16.5	34.6
Cation release				
Ca^{2+}	a	15.8c	28.7d	41.6cd
Mg^{2+}	a	1.5if	2.3jd	3.8ge
Na^+	a	2.3if	2.8jd	3.2ge
K^+	a	3.1ic	2.8jg	3.3ch

Notes: Values within each line followed by a different letter are significantly different: c, d, e – $P < 0.05$; f, g, h – $P < 0.01$; i, j, k – $P < 0.001$ according to t-test.

Plant biomass and plant production decreased along a decreasing soil moisture gradient (SMP > TSP > AP), however the amount of above- as well as below-ground detritus increased along this gradient (Table 3). At the SMP site detritus accounted for 32% of live plant biomass at the TSP site for 54% and at the AP site for as high as 111% , respectively. These data suggest, that the plant production and the decomposition rate of new plant matter were inhibited in dry soils compared to soils with a higher moisture content.

The biomass of soil fauna per g of detritus was in AP site 4 times lower than in the two other grasslands compared (Table 4). Wachendorf *et al.* (1997) found similar relations comparing contribution of fauna in decomposition in wet and dry, alder peat forests. C loss induced by soil fauna exceeded 50% of total loss in wet conditions and only 13% in dry forest.

The analysed study sites differed significantly in nitrogen economy (Table 5). The amount of nitrogen retained in the live plant biomass and in detritus was in SMP and TSP sites several times higher than the N mineralized during season (Table 5). The missing amount was supplied by N fertilizers. At the AP site, characterised by higher N minerali-

Table 3. Seasonal mean of plant biomass (g dry wt m^{-2}), N and K retention in it (g m^{-2}) and the N/K ratio of plant mass in grasslands of various peat origin after 30 years of management. (Data after Pasternak-Kuśmierska *et al.* 1997, Pętal 1999). Symbols explained in Table 1.

	SMP				TSP				AP			
	Biomass	N	K	N/K	Biomass	N	K	N/K	Biomass	N	K	N/K
Live above and below ground plant biomass	1505.5	35.2	13.37	2.63	1231.8	31.5	6.58	4.79	919.9	34.3	5.70	4.42
Above and belowground detritus	476.0	10.5	0.58	18.10	663.2	13.3	0.63	21.11	1022.5	22.8	0.56	40.71

Table 4. Nitrogen retention in total soil invertebrate biomass (g dwt m^{-2}) after 30 (a) and 15 (b) years of management in three grasslands. Values are seasonal means. Symbols explained in Table 1.

Period	SMP		TSP		AP	
	Biomass	N	Biomass	N	Biomass	N
a	10.5	1.2	12.2	1.4	4.5	0.5
b	17.7	1.95	6.5	0.71	2.0	0.22

Table 5. Indices of nitrogen storage and decomposition rate in three grasslands (Explanations in Table 1). Data after Zimka and Stachurski 1996, Pasternak-Kuśmierska *et al.* 1997, Pętal 1999, Wasilewska unpubl. data, Makulec unpubl. data.

Index	Period	SMP	TSP	AP
N live plant B/N mineralized (%)	a	260	182	70
N detritus prod/N mineralized (%)	a	41.8	46.3	45.8
N litter/N aboveground plant B (%)	a	14.1	13.9	22.1
N soil detritus/N belowground plant B (%)	a	38.6	39.9	45.6
N faunal B/N litter (%)	a	80.6	81.3	19.4
Earthworm B/Nematode B ratio	a	34.9	24.0	6.02
	b	33.2	7.7	0.74

Notes: N live plant B – N in mean above and belowground plant biomass, N mineralized – amount mineralized between May–October, detritus prod – increase of the amount of detritus during growing season, litter and soil detritus – seasonal mean.

zation rate and lower plant production such fertilising was not needed.

Summing up the decomposition of new plant material was retarded under drought conditions in the soil originated from alder peat (AP). This finding is contradictory to the highest N- mineralization rate found there.

3.3. THE BIOMASS OF MICROBIAL AND FAUNAL COMMUNITIES

Microbial and faunal communities differed significantly among the study sites in both periods compared i.e. 30 and 15 years after fen management. In the later period (a) numbers of bacteria were significantly lower at AP site, than at the two other sites, while numbers of Actinomycetes and Fungi were similar in all sites compared. In the earlier period (b) the differences in numbers of bacteria were not significant (Table 6). In the contrary Actinomycetes and some microfaunal groups (plant parasitic, bacterial- and fungivorous nematodes) were significantly more abundant in AP, than in the two other grasslands (Tables 6 and 7). The activity of soil enzymes, dehydrogenase and urease, was in both periods of research, several times lower

Table 6. Comparison of seasonal means of microbial abundance (cells g^{-1} dry soil) and soil enzymatic activity in three grasslands of various peat origin after 30 (a) and 15 years (b) of management. (Explanations in Table 1). Data after Chmielewski 1991, Chmielewski unpubl.

	Period	SMP	TSP	AP	F	*P*
Bacteria 10^7	a	21.6c	24.6c	15.6c	8.3	0.0004
	b	25.7c	19.9c	19.3c	2.6	n.s.
		n.s.	n.s.	n.s.		
Actinomycetes 10^6	a	15.7c	16.7c	13.3c	0.62	n.s.
	b	5.0f	2.9g	15.7k	9.13	0.0015
		n.s.	**	n.s.		
Fungi 10^5	a	23.7c	29.8c	23.2c	0.75	n.s.
	b	14.9c	18.4c	17.9c	0.26	n.s.
		n.s.	*	*		
Dehydrogenase (μl H_2g^{-1} 24 h^{-1})	a	51.12c	50.12c	19.63d	5.95	0.005
	b	63.2c	50.8cg	13.5kh	13.5	0.0001
		n.s.	n.s.	n.s.		
Urease (pp m NH_4-N $18h^{-1}$)	a	47.62c	43.80cd	24.78ce	2.41	n.s.
	b	61.0c	47.7cd	28.7he	2.06	n.s.
		n.s.	n.s.	n.s.		

Notes: Level of significance between periods according to t-test: $*P < 0.05$, $**P < 0.01$, $***P < 0.001$, n.s. – not significant. Level of significance between sites tested by Mann-Whitney U test. Values within each line followed by a different letter are significantly different: c, d, e – $P < 0.05$; f, g, h – $P < 0.01$; i, j, k – $P < 0.001$.

Table 7. Mean density of microfauna (ind. 10^6 m^{-2}) after 30 (a) and 15 years (b) of management in three grasslands of various soil origin. Site symbols explained in Table 1. (Data after Wasilewska 1991 and Wasilewska unpubl).

Taxa	Period	SMP	TSP	AP	F	*P*
Nematoda (total)	a	5.0c	5.3c	6.2c	0.14	n.s.
	b	3.8c	5.5c	16.6	7.14	0.0009
		n.s.	n.s.	**		
Nematoda (plant parasities)	a	3.12c	2.63c	3.1c	0.03	n.s.
	b	0.45c	0.97cg	8.1kh	7.42	0.0007
		***	n.s.	*		
Nematoda (bacteri+fungivores)	a	1.82c	1.78c	2.31c	0.19	n.s.
	b	2.8c	3.1c	7.1d	3.0	n.s.
		n.s.	n.s.	***		
Nematoda (omnivores+predators)	a	0.22c	0.24ce	0.53cd	14.56	0.0000
	b	0.3c	0.25c	0.12c	2.07	n.s.
		n.s.	n.s.	***		

Notes: Level of significance between periods according to t-test: $*P < 0.05$, $**P < 0.01$, $***P < 0.001$, n.s. – not significant. Level of significance between sites tested by Mann-Whitney U test. Values within each line followed by a different letter are significantly different: c, d, e – $P < 0.05$; f, g, h – $P < 0.01$; i, j, k – $P < 0.001$.

at the dry AP site than at the two other sites (Table 6).

The microbiphagic and plant parasitic nematodes can be categorized as stimulators of the mineralization and nutrient releasing processes (Trofymov and Coleman 1982, Ingham *et al.* 1985, Beare *et al.* 1992, Griffiths 1994). Actinomycetes are treated by several authors as decomposers of humic compounds, or as organisms participating in humus forming processes (Myśków 1968, Hunter-Cevera and Eveleigh 1990, Paul and Clarck 1996). As far as in the AP grassland where abundance of Actinomycetes was the highest, mineralization rate of peat organic matter proceeded more rapidly than in the other grasslands, we can suggest that in this case, Actinomycetes function as decomposers of humic compounds.

Thirty years after management the differences between grasslands in numbers of the microbial and microfaunal groups which enhance the mineralization rate were not significant. Among nematodes only the density of omnivores and predators was significantly higher in the AP site, than in sedge originated grasslands and only in this feeding group an increase with time was noted (Table 6). Our findings, that the organic matter content decreased in the highest rate in the site, where number of Actinomycetes was significantly higher, suggest that this microbial group is involved in peat decomposition.

In both periods the total invertebrate biomass and nitrogen retention in it was lower in dry than in wet soils. Thirty years after management a significant increase in the faunal biomass and in the amount of nitrogen accumulated in it was found at the AP and the TSP sites, while at the wet SMP site a decrease of these values was observed (Table 6).

Mites (Oribatida and Astigmata) were the only mesofaunal component of significantly higher density in dry, AP soil than in soils with higher moisture (Table 8).

Significantly higher densities of earthworms and enchytraeids (saprophages treated in literature as humus forming and ecosystem engineers Kozlovskaya 1976, Jenny 1980, Jones *et al.* 1994, Makulec and Kusińska 1997) were found in SMP and TSP grasslands than in AP grassland (Table 8). Earthworms facilitate nutrient release but also retain nutrients in stable soil structures and in their bodies. The density of earthworms was highly variable along the time gradient, but a tendency of increase in the later period was noted in all sites. An increase was especially high (2–3 times) in grasslands where the number was low in the earlier period. As a consequence of these changes in density the differences among sites were less distinct after 30 years of management than before (Table 8).

The ratio between the biomass of macro- to microfauna (earthworms/nematodes) was in the earlier period several times lower at AP site than in the two other grasslands (Table 5). During 15 years this ratio increased in all sites, but the increase was the highest (8 times) at the driest site (AP). Such shift towards larger animals implies that the process of organic matter mineralization proceeded in the later period at a slower rate, especially at the AP site. A decrease in the density of microbivorous nematodes that, accelerate decomposition processes and an increase in the biomass of earthworms that stimulate forma-

Table 8. Mean density (ind. m^{-2}) of meso- and macrofauna in three grasslands of various soil origin after 15 (b) and 30 (a) years of management. Site symbols explained in Table 1. (Data after Kajak *et al.* 1985, Nowak and Pilipiuk 1997, Kaczmarek 1991, 1998, Makulec 1991, Malulec unpubl. and Petrov unpubl.).

Faunal group		SMP	TSP	AP	F	P
Enchytraeidae 10^3	a	15.0c	25.9dj	9.3ek	9.17	0.0001
	b	25.6c	24.8c	9.2k	28.3	0.0000
		***	n.s.	n.s.		
Oribatida 10^3	a	2.1c	35.5cd	63.8ce	2.82	n.s.
Collembola 10^3	a	4.75c	6.38c	5.53c	0.351	n.s.
	b	15.32c	8.04c	10.75c		n.s.
Lumbricidae	a	242.0c	333.6cd	15.6ce	4.17	0.016
	b	144.0f	87.7g	25.2i	26.94	0.000
		n.s.	**	n.s.		
Araneae	a	112.1c	138.1c	67.7f	4.29	0.017
	b	45.6c	72.5cf	34.2ch	6.72	0.0013

Notes: Level of significance between periods and sites tested by t-test $*P < 0.05$, $**P < 0.01$, $***P < 0.001$, n.s. – not significant. Significant level between sites: values within each line followed by a different letter are significantly different: c, d, e – $P < 0.05$; f, g, h – $P < 0.01$; i, j, k – $P < 0.001$.

tion of stable soil structures retaining nutrients suggests that there is a tendency in heterotrophic communities to reduce the mineralization rate at the AP site.

The highest content of humus acids and the highest humification degree were found in AP soil (Table 1), while the density of humus forming invertebrates was the lowest there (Table 8). This contradiction can be explained by historical processes. In intact carr forest, Carici elongatae-Alnetum in fertile sedge tussocks, seasonally flooded and then emerged for several months, peat rich in humus compounds is formed (Kulczyński 1940). Such tussocks are inhabited by abundant communities of invertebrates stimulating humification (Olechowicz 1984). After drainage the accumulated humus compounds are gradually decomposed. It is likely that Actinomycetes, which were in the first period after drainage several times more numerous in drained alder, than in sedge soils (Table 5), are involved in processes of humus decomposition. Our suggestions can be confirmed by findings, that in soils derived from alder peat, humus content was higher in deeper i.e. older peat horizons than in moorsh in the top layer (Okruszko and Kozakiewicz 1973, Okruszko 1993). Opposite trends were found in soils derived from sedges.

The results concerning the invertebrate system are in an agreement with our previous studies on secondary succession of drained fens, based on chronosequence of habitats (Kajak *et al.* 1985, Kajak and Okruszko 1990, Pętal 1991). We showed before that the biotic components involved in rapid dissipation of energy became less abundant with time, while those enhancing humification became more important. Comparing the same places after 15 years, we found the same trends, very clear in grassland situated on soil originated from alder peat, where mineralization processes after drainage were most intense.

4. CONCLUDING REMARKS

1. The decomposition rate and the community structures in fen soil originated from alder peat (AP) differed significantly from the two soils originated from sedges (sedge moss peat SMP and tall sedge peat TSP), drained at the same time. The water holding capacity, above and below-ground plant biomass were the lowest in the AP soil. Mineralization rate of nitrogen, and N content in plants were negatively related to water content and were the highest in the AP site, but decomposition rate of new detritus was retarded. The last finding corresponded with differences in soil biota. The numbers of bacteria, the activity of enzymes, the total invertebrate biomass were also lower in the AP soil, than in the other grasslands.

2. The analysis of trends along time, in composition of faunal groups performing different functions, suggests that decomposition processes are slowing down with time. The highest rate of change, namely the highest decrease in the density of groups stimulating organic matter mineralization and increase in those stimulating humification, was found in the soil originated from alder peat. At the early stage of secondary succession biota stimulating mineralization were most abundant in this soil.

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5. SUMMARY

The objective of our investigations was to compare, changes in soil properties, mineralization rate of nitrogen and biotic structures, during secondary succession, in three drained grassland soils, originated from sedge-moss (SMP), tall-sedge (TSP) and alder peat (AP). Two periods were compared – 30 (a) and 15 (b) years after fen drainage.

The rate of nitrification was negatively related to soil moisture, being the highest in soil originated from alder peat (Tables 1and 2). The process of nitrogen oxidation, soil acidification and release of cations to soil solution, was also the highest in AP soil. This grassland differed significantly from the two others. Live plant biomass and aboveground plant production was the lowest there. It was accompanied by the highest accumulation of plant detritus above- and belowground (Table 3). The decomposition of plant detritus was retarded, although nitrogen concentration in plants, was higher than in other grasslands. The lowest numbers of bacteria and of enzymatic activity as well as the lowest invertebrate biomass were assessed in this soil (Tables 5 and 6).

The highest content of humus acids was found in AP soil. Contradictory, the density of humus forming invertebrates was the lowest in this soil (Tables 1 and

8). It is likely, that a humus rich soil was formed in fertile sedge tussocks of alder carr forest and it is decomposed gradually after drainage. Our suggestions can be confirmed by findings, that in soils derived from alder peat, humus content was higher in deeper i.e. older peat horizons than in moorsh in the top layer. Opposite trends were found in soils derived from sedges (Okruszko and Kozakiewicz 1975, Okruszko 1993).

In both compared periods soil properties remained significantly different between study sites, but differences in respect to biota were lower 30 years after drainage. The density of the taxa enhancing mineralization rate such as Actinomycetes, plant parasitic and microbivorous nematodes decreased in the AP site, where their abundance was in the earlier period significantly higher than in the two other grasslands (Tables 5 and 7). Invertebrates participating in humus forming processes, such as earthworms, showed a tendency to increase in density in all compared grassland soils (Table 8). Based on changes in biota, it may be assumed that the mineralization rate was slowing down, especially at AP site, and that this process concerned mostly newly formed, dead plant material.

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