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Similarity of ground beetle communities of extensively managed orchards depending on management regimes

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Abstract

From April 1995 to November 1997 investigations were carried out in orchards in South-West Germany (48°36'N/9°23'E): data were collected on the type and frequency of grassland use and data on the carabid fauna. 17 sample plots were selected. Part of the plots had 25 years of unchanged management regimes which were three-cutting meadows (3), two-cutting meadows (3), mulched meadows (4), abandoned meadows (3), a horse pasture, a sheep pasture with rotational grazing, a continuously grazed sheep pasture, and a sheep pasture abandoned in 1994. On nearly all studied plots the relative frequency of dominant species changed. 3-cutting meadows frequently show a one-sided activity dominance structure. A cluster analysis depending on Wainstein Index demonstrates: the carabid communities of plots under succession and 3-cutting meadows were distinct and hardly similar to other cultivation plots. The composition of the carabid communities was less constant on the plots compared to the vegetation community. The communities of neighbouring study plots with different management treatment were therefore often more similar compared to plots which had the same management treatment but were further apart. The management of sub growing in orchards and its influence on ground beetle communities is briefly discussed.

Key words: spatial and temporal patterns, similarities, grassland management, species colonisation, ground beetle communities, orchards, biodiversity.

Introduction

Vegetation and fauna of extensively managed orchards are mainly determined by the site and its maintenance, the type of grassland management and its land use intensity (Deuschle *et al*., 2002).

Until now animal communities of extensively managed orchards have not been analysed based on the direct comparison of different forms of grassland management in the same area (Deuschle and Glück, 2001). Forms like continuous and rotational grazing (sheep, horses) have not been taken into account. There are few investigations dealing with the influence of management systems on arthropod communities in extensively managed grassland (Southwood and van Emden, 1967) whereas the effects of grazing have been documented more frequently (Hanssen and Hingst, 1995; Maelfait *et al*., 1988; Rushton *et al*., 1989; Schnitter, 1994).

The dominance structures of communities allow a direct comparison and are independent of external influences (e.g. weather) as the activity density. Therefore it is well suitable to characterize habitats. Species with low colonizing density are argued to have a high potential to colonize new areas (Gravesen and Toft, 1987; Deuschle and Glück, 2005). Carabid communities on areas of intensive grassland management show a low number of species and a one-sided dominance structure with a few eudominant species such as *Pterostichus melanarius* (Illiger) or *Clivina fossor* (L.) (Tietze, 1987; Frank, 1991).

Besides, describing representative field studies the character of carabid communities were analyzed with the assistance of different methods of multivariate data analysis in the last years. Abiotic and management specific characters and gradients have been worked out (Baguette, 1993; Bauer, 1989; Butterfield and Coulson, 1983; Dennis *et al*., 1997; Dufrene and Legendre, 1997; Eyre *et al*., 1990; Huhta, 1979; Luff *et al*., 1992; Luff, 1996; Mc Ferran *et al*., 1994; Morris and Rispin, 1987; Preiszner, 1996; Rode 1993).

So far it is not quite clear whether the same or related grass management regimes will favour identical or similar carabid communities in the same area (Glück and Deuschle, 2005). Another point is the influence of neighbouring plots with other management treatments. To what extent is the community of a single plot influenced by neighbouring plots compared to other plots?

The aim of this paper is to characterize the carabid community on plots with different management treatments of grass cutting in orchards (meadows: two or three cuttings a year, pastures: continuous and rotational grazing with horses and sheep, mulched meadows, abandoned meadows).

The similarity of carabid communities on the study area was investigated on the basis of an agglomerative cluster analysis. The group specification contains the species as well as the dominance identity of the studied plots (Wainstein Index).

Methods

Census and registration of land use

From the beginning of April until the middle of October 1997 the following parameters were recorded weekly or every two weeks in the study area orchards in the nature reserve "Limburg" (48°36'N/9°23'E), South-West Germany: type of use, time of mowing, "mowing device", "whereabouts" of mowed grass, and number of grazing animals. The amount of ground shading by trees under perpendicular solar radiation was estimated and assigned to following categories (0%, 1-20%, 21-40%, 41-60%, 61-80%, 81-100% shading).

All areas, which are mowed completely on a regular basis every year and where the plant material was removed, will be called "typical meadows". On "mulched meadows" the cut grass remained regardless of the mowing device and mowing frequency. "Continuous grazing" defines the management type of pastures, where the grazing animals were found permanently on the same area, while "rotational grazing" is the type, where a particular area was grazed for a period of only a few days, but several times a year. Combinations of the three types of management can also be found in the extensively managed orchards of the nature reserve area.

Selection of sample plots and population census of carabidae

In 1995 nine sample plots which had been under the same management treatment for more than 25 years except one sheep pasture which was abandoned in 1994 were selected. Furthermore eight plots were additionally investigated in 1997 (table 1, figure 1).

Six pitfall traps were placed in a single line 10 m apart through the centre of each sampling plot. Ethylene glycol (50%) was used as preservative solution, with detergent added to reduce surface tension. A cover made of Perspex (120 by 120 mm) was installed 30 to 50 mm above ground level. In 1995 (5th April to 1st November) traps were controlled and emptied regularly every week. In 1996 (5th May to 4th November) and 1997 (8th April to 4th November) the control interval was two weeks (Deuschle and Glück, 2001).

Analysis of data and statistical methods

All registered data concerning management practices, vegetation, soil condition, and carabid population were integrated into a database. After examining the necessary conditions the following statistical tests were applied: U-test by Mann and Whitney (MWU-test), and χ^2-test. The rank correlation was calculated according to Spearman and the coefficients were tested on their significance. Cluster analysis: the similarity of carabid communities on the study plots were characterised by the aim of an agglomerative cluster analysis. The greater the distances between groups the more dissimilar are the studied communities. The so called Wainstein Index is regarded as a measure of the (beta) diversity. With the beta diversity changes along a gradient between the habitats conditions can be shown. The software package used was STATISTICA 5.0.

Table 1. Study plots in the investigated area (48°36'N/9°23'E).

Plot	Land use	Type of land use	Area (Ar)	Circumference (m)	Altitude (mNN)	Shading categories (%)	Sampling period
3CM2	3-cutting meadow	Meadow	26	209	405	0-20	'97
3CM3	3-cutting meadow	Meadow	51	287	425	0-20	'97
3CM1	3-cutting meadow	Meadow	16	204	392	0-20	'95, '96, '97
2CM3	2-cutting meadow	Meadow	40	446	415	61-80	'97
2CM1	2-cutting meadow	Meadow	10	218	445	41-60	'95, '96, '97
2CM2	2-cutting meadow	Meadow	15	250	410	41-60	'97
SPA	abandoned sheep pasture (continuous grazing), see text	Pasture	34	234	405	41-60	'95, '96, '97
SPC	Sheep pasture (continuous grazing)	Pasture	15	213	415	61-80	'97
HP	Horse pasture	Pasture	124	580	400	0-20	'95, '96, '97
SPR	Sheep pasture (rotational grazing)	Pasture	11	259	445	0-20	'95, '96, '97
MMI	Mulched meadow (4 - 6 cuttings)	Mulched meadow	12	162	455	0-20	'95, '96, '97
MME1	Mulched meadow (3 cuttings)	Mulched meadow	47	380	440	81-100	'97
MME2	Mulched meadow (2 - 3 cuttings)	Mulched meadow	29	217	420	41-60	'95, '96, '97
MME3	Mulched meadow with 1 cutting	Mulched meadow	25	206	517	61-80	'97
AMR	Recently abandoned meadow (4 years)	Succession	13	153	445	0-20	'95, '96, '97
AMO	Old abandoned meadow (10 years)	Succession	13	202	420	81-100	'95, '96, '97
WDL	Woodland	Succession	13	222	520	81-100	'97

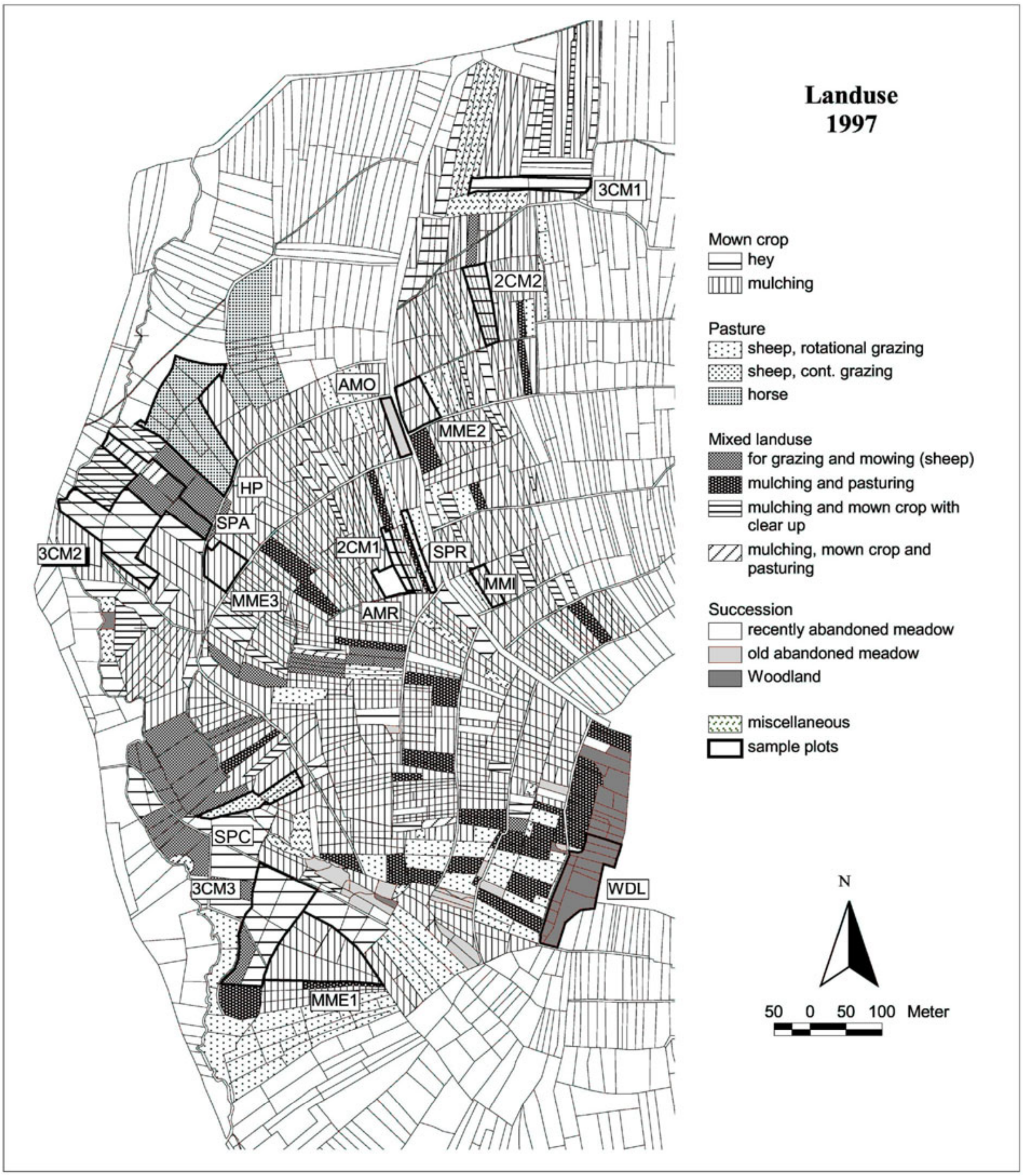

Figure 1. Land use intensity of grassland in the study area during the vegetation period of 1997 and the sample plots (abbreviations see table 1, plot 2CM3 is located outside the area shown).

Results

Distribution of species on the areas

The number of species and individuals differ on the study plots. They seem to be dependent on the management intensity of the areas (rank correlation coefficient of the studied plots ($n = 17$): number of species and management = -0.87, $p < 0.01$, number of individuals and management = -0.82, $p < 0.01$). With increasing management intensity the numbers of species and individuals decrease.

The percentage of the most frequent species compared to the number of all individuals, does not indicate any connection between number of species or individuals and the management treatment. The maximal and minimal values are given on three year investigated plots on the abandoned sheep pasture (SPA, 58.4%) in 1997 and on the horse pasture (HP, 13.9%) in 1996 (table 2).

On the one year investigated plots the 3-cutting meadow (3CM3) indicated with 16.4% the lowest value, the likewise 3-cutting meadow (3CM2) with 49.4% the highest value. Eleven different species built up the most frequent carabids on the three year investigated plots. *Harpalus latus* (L.) was seven times, whereas *Leistus*

Table 2a. Density of species, activity abundance, Berger-Parker index, area specific proportions of main and accessory species and the most frequent species each in the perennial sample plots (1995 – 1997). **Table 2b.** Density of species, activity abundance, Berger-Parker index, area specific proportions of main and accessory species and the most frequent species each in the perennial sample in 1997. (abbreviations see table 1).

a)

Area		3CM1	2CM1	SPA	HP	SPR	MMI	MME2	AMR	AMO
Number of species	1995	23	24	18	22	18	19	19	17	12
	1996	17	20	20	20	18	16	15	17	7
	1997	21	20	20	24	16	16	16	16	11
Number of individuals:	1995	226	144	226	200	76	95	86	84	81
	1996	64	58	81	130	69	49	41	82	56
	1997	125	75	267	234	87	106	113	60	58
Percentage of main species: (%)	1995	26.1	31.8	27.8	36.4	55.6	42.1	52.6	41.2	66.7
	1996	58.8	65.0	35.0	45.0	50.0	56.3	66.7	41.2	85.7
	1997	42.9	50.0	25.0	37.5	62.5	62.5	31.3	50.0	72.7
Percentage of accessory sp.: (%)	1995	73.9	68.2	72.2	63.6	44.4	57.9	47.4	58.8	33.3
	1996	41.2	35.0	65.0	55.0	50.0	43.8	33.3	58.3	14.3
	1997	57.1	50	75.0	62.5	37.5	37.5	68.8	50.0	27.3
Berger-Parker index (%):	1995	25.5	31.3	39.4	18.0	31.6	33.7	29.1	16.7	37
	1996	15.6	22.4	25.9	13.9	18.8	18.4	29.3	24.4	48.2
	1997	31.2	21.3	58.4	29.1	18.4	19.8	28.3	30.0	24.1
Most frequent species:	1995	*A. binotatus*	*H. latus*	*P. melanarius*	*C. fossor*	*C. ullrichii*	*C. fossor*	*H. latus*	*A. binotatus*	*A. parallelepipedus*
	1996	*A. binotatus*	*H. latus*	*P. melanarius*	*P. vernalis*	*C. ullrichii*	*C. fossor*	*H. latus*	*H. latus*	*M. elatus*
	1997	*A. binotatus*	*C. ullrichii*	*P. melanarius*	*P. melanarius*	*C. ullrichii* *P. ovoideus*	*L. ferrugineus*	*H. latus*	*H. latus*	*A. parallelus* *H. latus*

b)

Area	3CM2	3CM3	2CM3	2CM2	SPC	MME1	MME3	WDL
Number of species	21	30	22	19	27	13	19	18
Number of individuals	804	274	353	87	260	37	163	341
Percentage of main species	23.8	36.7	31.8	47.4	22.2	38.5	47.4	27.8
Percentage of accessory sp	76.2	63.3	68.2	52.6	77.8	61.5	52.6	72.2
Berger-Parker index (%):	49.4	16.4	31.1	21.8	20.4	45.9	25.1	36.1
Most frequent species	*P. melanarius*	*P. cupreus*	*N. brevicollis*	*B. obtusum*	*P. melanarius*	*C. ullrichii*	*A. Parallelus*	*A. parallelepipedus*

Table 3. Rank correlation coefficient of percentages of species of different distributions centres of carabid communities with area specific parameters (1995/96: n = 9; 1997: n = 17; level of significance: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$).

	percentages of species	management	area	circumference	shading
1995	fresh grassland sp.	−0.55	−0.35	0.38	0.12
"	wet grassland sp.	−0.50	0.35	0.61	−0.55
"	forest sp.	0.90***	0.10	−0.49	0.25
1996	fresh grassland sp.	−0.54	−0.24	0.60	−0.02
"	wet grassland sp.	−0.19	−0.01	0.39	−0.63
"	forest sp.	0.67*	−0.05	−0.78*	0.35
1997	fresh grassland sp.	−0.21	0.03	−0.14	−0.21
"	wet grassland sp.	−0.69**	0.46	0.22	−0.60*
"	forest sp.	0.77***	−0.31	−0.10	0.77***

ferrugineus (L.) and *Molops elatus* (F.) were only one time the most frequent carabids of the nine investigated plots.

In all three years, only on the areas 3CM1, MME2 and SPA the same species reached the highest frequency [*Anisodactylus binotatus* (F.), *H. latus* and *Carabus ullrichii* Germar]. From the other species *C. ullrichii*, *C. fossor*, *A. binotatus*, *Pterostichus vernalis* (Panzer) and *Pterostichus ovoideus* (Sturm), *Poecilus cupreus* (L.) and *Bembidion obtusum* (Audinet-Serville) were high steady and occurred on nearly all other plots. *P. melanarius* and *Abax parallelepipedus* (Piller et Mitterpacher) were only registered on a few plots (table 2). The arrangement of the most frequent and second most frequent species did not show any affinity to compatible or to neighbouring management treatments.

The individual "ecotypes" on the intensity of management react contrary (table 3). With decreasing management impacts on the plots the percentage of typical wetland species decreases significantly. A comparable tendency was also demonstrated in 1995 ($r_S = -0.5$, n.s.) with less numbers of studied plots (n = 9). The shading of the plots seems to influence the presence of the wetland species. With increasing shading the percentage decreased, in 1997 the corresponding correlation was significant. The area specific percentages of the woodland species increase significantly with less management intensity (table 3).

Similarity of communities based on different land use managements

On the three year studied plots the cluster analysis separates on a high fusion level two main groups (figure 2). The first group reflects constantly the plots 3CM1, HP and SPA, the second group the plots AMO, AMR, MME2, and 2CM1. The fusion level of both main groups is in 1996 lower than in 1995, the carabid communities of both groups were in 1996 more similar than in 1995. In 1997 the fusion level is significantly higher compared to 1995 and 1996. The remaining plots SPR and MMI did not belong constantly to any group. The first main group contains without exception open areas with a highly intensive mowing or grazing. The horse pasture was in 1995 more similar to the plots 3CM1 and MMI than to the neighbouring sheep pasture (SPR). The second main group contains also plots, which are cultivated with low intensity. The further subdivision of the dendrogram from this main group is marked heterogeneous: 1995 the community of the 2-cutting meadow (2CM1) is closely related to the extensive mulching meadow MME2. In 1996 the carabid community of the plot 2CM1 was more similar to the community of the plot AMR. The similarity to this plot was lower in the other years. The carabid community of the rotational sheep pasture (SPR) changed in all three years between the two main groups. In 1995 it was more similar to the areas 2CM1 and MME2, 1996 it was grouped to all other pastures. In 1997 it was closest to the 50 m in westerly direction 2-cutting meadow 2CM1. Also the intensive mulched meadow MMI changed the grouping in 1997 and is no longer grouped to the typical intensively used open areas, but the carabid community was very similar to the cluster of the 2CM1 and SPR (figure 2).

On the plots studied for three years a usage directed cluster forming is realized only in promises. The neighbouring connections of the plots seemed to have great influence on the composition of communities. In 1997 it is shown clearly that the cluster unity and the relation levels extensively represent the area dependent neighbouring of the plots in the study area (figures 2, 5).

The essential structures of groups of the single years are maintained, summarising all three years in one cluster: The similarities of the communities on the two continuous grazing plots and on the 3-cutting meadow deviate considerably from the remaining plots. The abandoned plot AMO and the extensively mulched meadow MME2 are separated. In the remaining group were the neighbouring plots 2CM1, SPR, MMI and in larger distance the plot AMR (figure 3).

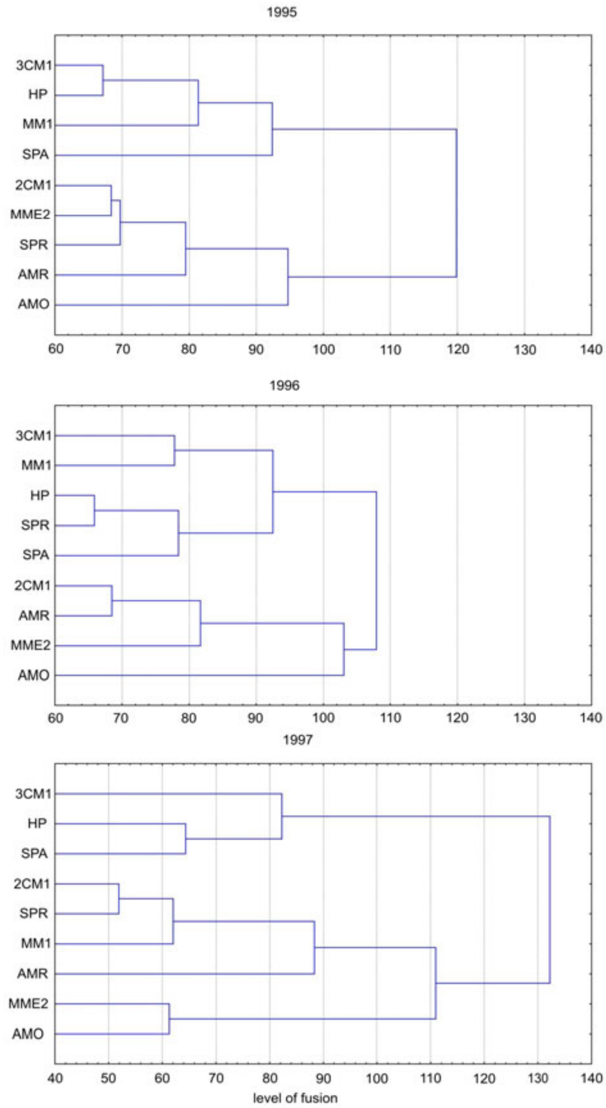

Figure 2. Dendrogram of similarity of all plots investigated for three years (each year separated) fusion after the minimum variance method (Ward, 1963; abbreviations see table 1).

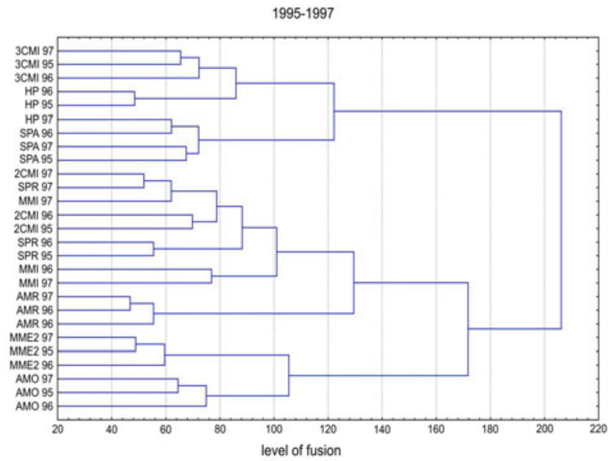

Figure 3. Dendrogram of biological similarity after Wainstein - Indices of all plots investigated for three years (1995-1997), fusion after the minimum variance method (Ward, 1963; abbreviations see table 1).

The entire comparison of all ground beetles allows an analysis of the constancy in time in the community of every study area. The carabid communities of MMI, SPR and 2CM1 formed own groups in 1995 and in 1996. In 1997 the data of these plots were more similar to each other than to the data gained in former years.

Also in 1997 the community of the horse pasture is more similar to the sheep pasture SPA, compared to the community of the years before (figure 3).

Regarding the extended sample size in 1997, the classification of all studied plots in 1997 separated three main groups on high fusion level: the first main group consists of the pastures HP and SPA, and the newly investigated sheep pasture SPC and the cutting meadows 3CM3, 3CM2 and 2CM2, additionally the reference area 2CM3 outside the main study area is grouped. The second group mainly contains the neighbouring plots 2CM1, SPR, MMI and AMR, added are the cutting meadows 2CM2 and 3CM1. Third cluster contains the abandoned meadow (AMO) and the woodland (WDL), as well as all three investigated extensively mulched meadows (MME2, MME3, MME1, figure 4).

Comparing the dendrograms of all plots investigated in 1997 and that of their spatial arrangement it is obvious that the plots 2CM1, SPR, MMI and AMR lie close together (figures 1, 5). Regarding the similarity of the carabid community (figure 4) it is clearly shown that the communities of the neighbouring plots 2CM1, SPR, MMI are very similar despite of their different management regimes. In cases of very short distances between plots, this indicates a neighbouring edge effect. But the communities of the other plots depend more on the different management treatments than on the neighbouring ones. So each management regime favours its own carabid community which is naturally based on the resources given by the plot and the management itself.

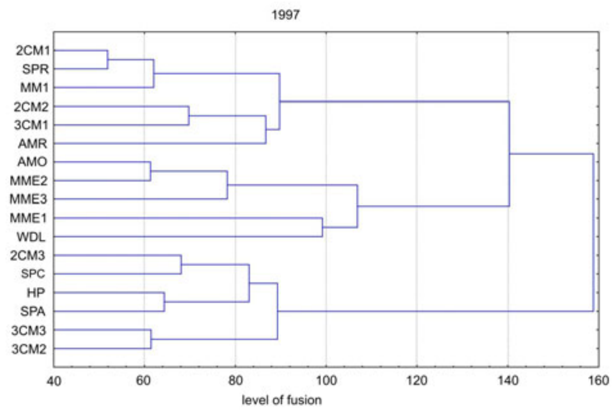

Figure 4. Dendrogram of biological similarity after Wainstein - indices of all plots investigated 1997, fusion after the minimum variance method (Ward, 1963; abbreviations see table 1).

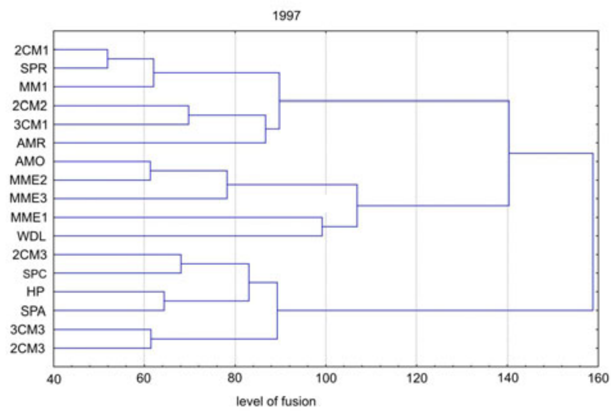

Figure 5. Dendrogram of the cluster analysis of the distances between the plots in meters (single-linkage procedure, abbreviations see table 1).

Discussion

Some areas respective management forms are only low attractive to several species. The used similarity analysis carried out on the basis of the Wainstein indices contains also the dominance identity. The biocoenotic relationship of neighbouring area specific communities is therefore not only influenced in quality but also in quantity. Therefore, the occurring neighbouring aspects are not only caused by the accidental presence of single exploring individuals. Rather are parts of populations obviously present on several plots and management forms within the area specific communities (Desender *et al.*, 1989; Maelfait *et al.*, 1988).

In single years (1995 - 1997) the communities of neighbouring areas of different usage were frequently more similar to plots used the same kind (figures 2, 5). Above all it seems that neighbouring aspects strongly dominate over the influence of management. Regarding the prolonged sample size in 1997 the selective influence of the different management forms is evident: on nearly all extensively used or abandoned plots (mulched meadows: MME2, MME3, MME1, abandoned plots: AMO, WDL, except: MMI, AMR) the communities built their own cluster and therefore they are more similar to each other than compared to other plots. The same applies to the intensively maintained plots (pastures: SPC, HP, SPA and 3-cutting meadows: 3CM3, 3CM2, except: 3CM1, SPR, figure 4).

Also a low distance between different used plots leads to stronger approximation of the areas in the clusters (figure 2). Frequently species with habitat preferences which do not agree with the management usage are registered on the plots. *P. melanarius*, a typical inhabitant of intensively managed 3-cutting meadows and pastures, for example was also registered on the only once a year mulched meadow MME3 (Deuschle and Glück, 2001). Especially the different used but neighbouring areas 2CM1, AMR, SPR and MMI are composed to one cluster in most analysis. These plots are small, mostly enlarged in length and slender and they have short distances to each other (figures 2, 5). Species specific range of mobility and individual home ranges of medium sized and large species are larger than the distance between the study plots 2CM1, AMR, SPR and MMI (Franceschini *et al*., 1997; Loreau and Nolf, 1994; Lys and Nentwig, 1991; 1992). In the investigated carabid communities medium sized species predominate. So for more than half of the species in the whole study area the borders or the treatments of the plots are no absolute barriers for the beetles. The individual home range seems to be enlarged over several plots and frequently over several management forms and can also comprise areas with pessimal living conditions.

The biocoenotic similarity in the communities of the plots distinguishes from year to year, but some areas (AMO, MME2 and 3CM1) are grouped comparatively constant (see cluster of single analysis of the years 1995 - 1997, figure 2). Especially the carabid community of the abandoned plot AMO is constantly separated from most of the other plots. On this area euritopic woodland species dominated [*A. parallelepipedus*, *Abax parallelus* (Duftschmid)] meanwhile, which were only registered in low population density on other areas. Therefore, on the abandoned meadow a specific community is well established which is quite different to the communities of other plots. This seems to be also promoted by the high isolation of the plot, which is surrounded by asphalt or gravel ways on three sides and also borders a small garden area. This situation may prevent the immigration of typical species of open land.

In contrary the abandoned sheep pasture is assigned to different clusters in all years of study (figure 2). The reason therefore is an extensive change in the dominant species: For example *Nebria brevicollis* (F.) was the second frequent species in 1995 with a rate of 30% of all detected individuals but could not be registered any more in 1997. Moreover numerous species registered in 1995 were no more present the following years. Whereas in 1996 and in 1997 12 species were registered on this plot for the first time. Obviously changes in treatment in the years investigated on this plot lead to an extensive change in the composition of the ground beetle community in contrast to the other study plots with no changes in treatment. This shows that carabid communities can react very quickly on changing management regimes and adjust to altered living conditions.

In all three years of investigation the communities of the plots AMO, MME2, 3CM1 and AMR are more similar to each other than to other plots with different management forms. Thus the yearly changes in the spectrum of species and in the activity on the areas were lower than between these areas (figure 3). The management impacts on the plots AMO, AMR, MME2 were only scarce. Obviously the timely composition of the community shows the constancy and static living conditions on these plots. All three areas attract attention by their small number of species (table 2), so this constancy is obviously not supporting the species richness on the plots.

The treatment of the remaining study plots with more frequent cutting or grazing activities (2CM1, SPR, MMI, HP, SPA) leads to an increase of a higher management impact. The change of similarities on these plots is more extensive and their arrangement and the composition of the clusters are more heterogeneous over the three years of investigation. The heterogeneous timely composition of the community shows the low constancy and dynamic living conditions on these plots.

Also the communities of mulching meadows are far-reaching independent of the numbers of cuttings closer to the abandoned meadows or the woodland areas as to the traditional cultivated meadows or pastures (except: MMI, figures 2 - 4). The frequency of cuttings therefore forms the composition of the carabid community only in a less extent. More considerably is the remaining of the mowing material. This influences not only the number of species but also the composition of the community. Microclimatic extremities or differences on the soil surface based on management impacts may be buffered by the mulching layer. The living conditions on the mulched meadows therefore are more stable and constant compared to mowed meadows with the same number of cuttings. This leads to a nearly continuous presence of some species on mulched meadows (Glück and Deuschle, 2003).

Conclusions

The activity and the mobility of carabids decreases the precise separation of the management forms in the cluster analysis, but they explain the neighbouring effects registered in the cluster composition and they show the high influence of the surrounding area on the number of species of the carabids on the study plots.

The more plots border an area, the higher is the probability of the presence of treatments forms with species rich carabid communities in the surrounding. Therefore, a small-patterned plotting may balance the effects of pessimal treatment forms to a certain degree and can reduce the management specific isolation of single areas. So a mosaic-like arrangement of the management forms with positive effects on the carabid community is a main requirement to protect the diversity of the carabid coenoses. The arrangement of these plots needn't be constant in time and may vary from year to year which gives place for dynamic changes. So a potential extinction of local populations might be balanced quickly.

This decreases the probability of the extinction of the entire ground beetle population and therefore ensures its continuous existence.

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