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Orthoptera communities of differently managed meadows in Ticino

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During the summer periods 1989, 1990 and 1991 abundance data on adult Orthoptera were collected on 22 meadows of the montane belt on the southern slope of the Swiss Alps, using a semiquantitative transect method. The abundance of 32 species (except the families Tetrigidae and Gryllidae) was estimated in 4 categories: rare, present, abundant, very abundant. 8 sites were meadows completely abandoned since some 10 years, 9 were extensively (mown once a year, not manured) and 4 more intensively exploited (mown twice a year, manured, occasionally grazed), and 1 was used only as a pasture. With cluster analysis (CA) and canonical correspondence analysis (CCA) it was possible to show the difference between the orthopteran communities living in these differently managed meadows. The environmental variables region, habitat structure, management intensity, morphology, and moisture were introduced into the CCA for each of the 22 sites. The first 3 of them are the most important ones for the ordination of the sites and the species in the diagrams, the sites being displayed along two gradients: the first one being determined by the region and the second one by habitat structure and management intensity. In the montane belt, extensively managed meadows as well as intensively managed ones provide a suitable habitat for many Caelifera, the latter being much less exploited than in the bottom of the valleys or north of the Alps. Abandoned meadows during the first stages of secondary succession are of importance mainly for Ensifera needing more complex habitat structures.

Key words: Orthoptera, habitat, multivariate analysis, Ticino

INTRODUCTION

The low altitude grasslands of central Europe are ecosystems of anthropogenic origin, and their cultivation started several centuries ago. The exploitation methods used to follow traditionally fixed patterns which remained unchanged for centuries, thus allowing the development of semi-natural ecosystems with a great biological diversity, being stable under such anthropogenic influence. Still nowadays we can observe unmanured meadows in the canton Ticino with a diversity of 50 plant species per m^2 (STAMPFLI, 1991). The species numbers of invertebrates living in these habitats are also considerable: up to 20 Orthoptera, up to 40 Lepidoptera, 54 Araneae, and 50 Heteroptera (HÄNGGI, 1992; ANTOGNOLI *et al.*, 1995).

Since the second world war we witnessed the reclamation of vast areas leading to the disappearance of many natural and semi-natural habitats. The use of machinery and the application of chemicals (pesticides, herbicides, insecticides, mineral fertilizer, etc.) has brought an intensive soil exploitation at lower altitudes. The most inaccessible areas have been abandoned due to poor soils or difficult terrain (WALTHER, 1984). These facts are the reason for the almost total disappearance of unmanured meadows and extensively managed pastures from the countryside of central Europe (KLEIN & KELLER, 1983). The characteristical mosaic structure of such a landscape with its linkages between forests and extensively managed open spaces is endangered, including its large biodiversity.

On the abandoned grasslands the cessation of the traditional agricultural management (manual mowing, extensive pasture) initiates a process of secondary vegetation succession eventually leading to woodlands. This is accompanied by an impoverishment in herbaceous species, but a temporary enrichment in arthropods such as Lepidoptera, Orthoptera, and Araneae can be observed during the same time (ERHARDT & THOMAS, 1991; ANTOGNOLI *et al.*, 1995). The reasons for an increased faunistic diversity are a more diverse structure of the habitat due to invading woody plants, the cessation of anthropogenic disturbance (mowing, grazing), and the role of these habitats as refuge within intensively cultivated areas (DETZEL, 1985; ANTOGNOLI *et al.*, 1995).

An inventory of the xeric sites of the canton Ticino in 1987 demonstrated that 30% of the unmanured meadows on the mountain belt were no longer used by farmers. A multidisciplinary research program has been set up by the Geobotanical and Zoological Institutes of the University of Berne in order to gain the scientific data needed for the conservation of these species rich grasslands; beside the biological topics some points of agronomic interest were treated with regard to their conservation (STAMPFLI *et al.*, 1992, 1994; LÖRTSCHER *et al.*, 1994; ANTOGNOLI *et al.*, 1995).

Faunistical, ecological and biogeographical data on the Orthoptera communities of the investigated sites are given by ANTOGNOLI (1994). The present paper deals with the analysis of these community data and their relation to different habitat characteristics.

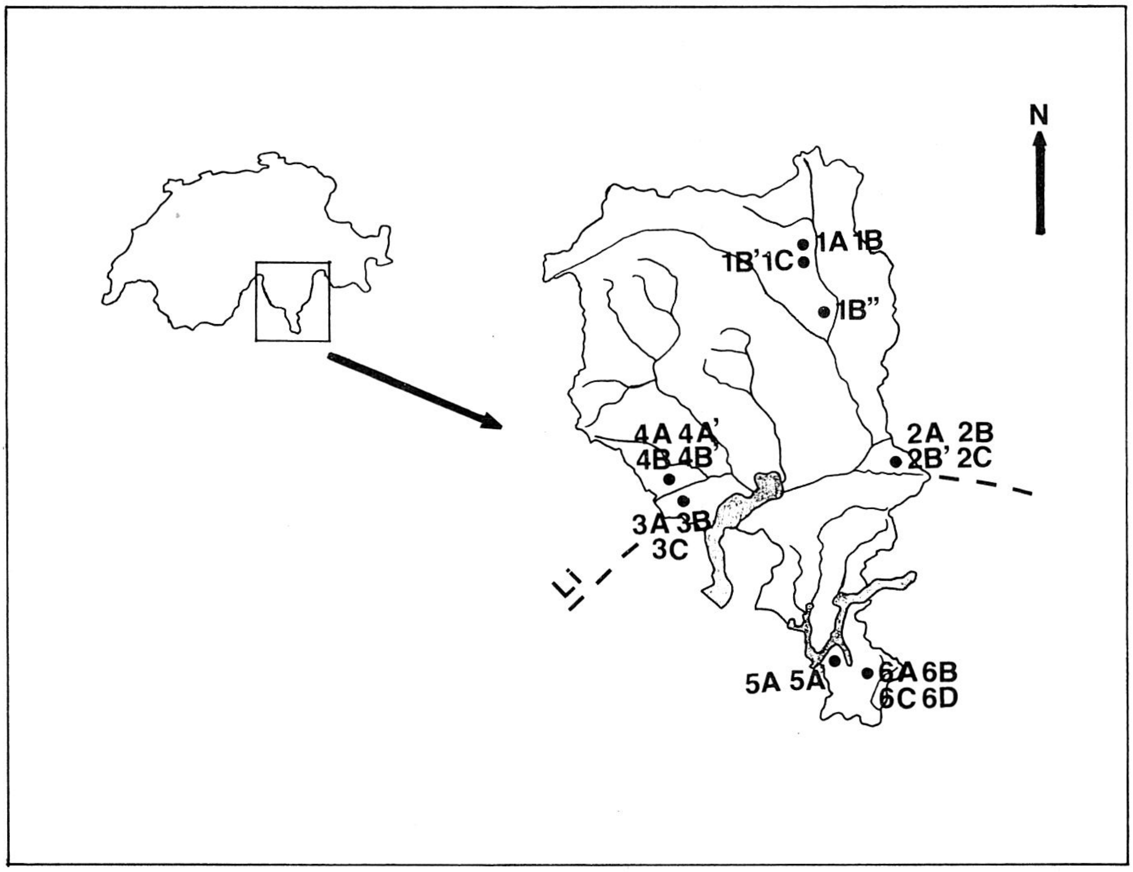


Fig. 1 – Switzerland and canton Ticino with location of the 22 study sites (Li = insubric line). Site codes see Tab. 2.

METHODS

Study sites

Grasshoppers and bush crickets were collected on 22 sites at altitudes between 700 and 1000 m a.s.l., representing the 3 most common grassland types on the mountain belt on the southern slope of the Swiss Alps (Fig. 1). 16 sites are situated on cristalline bedrock in the northern part of the canton Ticino, 6 are south of the insubric line on limestone. The exposition of 16 sites is south to west, for 6 sites it is between north and east. 8 sites are meadows completely abandoned since some ten years (all A-sites in Tab. 2). Today they are dominated by a single grass species (either *Molinia arundinacea* or *Brachypodium pinnatum*), and shrubs and trees are already growing on some of the sites. 9 sites are regularly exploited in a traditional manner by farmers; they are not manured and mown only once a year (= extensively

Tab. 1 – Score system used to calculate the environmental variables for each sites.

environmental variables	conditions	points
REG: region	northern Ticino	0
	southern Ticino	1
MAN: agricultural management	abandoned	1
	grazing	2
	unmanured	3
	manured	4
STR: habitat structure		
bushes:	few bushes	1
	several bushes	2
vegetation covering:	vegetation covering 80 - 90%	1
	vegetation covering < 80%	2
ratio herbs / grasses:	% herbs > % grasses	1
number of plant species:	25 - 75% of recorded plant species on all sites	1
	> 75% of recorded plant species on all sites	2
costancy of structure:	high (no one intervention= abandonment)	2
	rather high (mown once a year)	1
MOR: morphology	exposition NW - NE	1
	and if slope 1° - 15°	-0.5
	and if slope 16° - 45°	-1
	exposition ENE - ESE	2
	exposition WSW - WNW	2
	exposition SE - SW	3
	and if slope 1° - 15°	0.5
	and if slope 16° - 45°	1
MOI: moisture	arid	1
	semi-arid	2
	fresh	3
	humid	4
	wet	5

Tab. 2 – Study sites with their elevation, exposition, slope, area, environmental variables scores (REG = region, MAN = management intensity, STR = structure of habitats, MOR = morphology, MOI = moisture), number of recorded Ensifera and Caelifera species. Sites code: 1 to 6 is the code for the locality and A to D for the meadow types (A = abandoned, B = unmanured, C = manured, D = pasture). * = management has been changed during the investigation, therefore the characterization at the beginning of the study is given.

cod	region	elev.	exp.	slope	area	meadow	environmental variables					Caelifera	Ensifera
		m a.s.l.			m²	type	REG	MAN	STR	MOR	MOI	n	n
1A	V.Blenio	980	SE	20°	2464	abandoned	0	1	5	4	4	9	6
1B	"	1000	WSW	10°	1467	unmanured	0	3	3	2	2	11	3
1B'	"	820	S	15°	849	"	0	3	4	3.5	1	7	2
1B"	"	860	NE	25°	3806	"	0	3	3	0	3	6	1
1C	"	790	ENE	20°	1373	manured	0	4	3	2	2	5	2
2A	V.Morobbia	1060	SSW	30°	1115	abandoned	0	1	6	4	3	11	9
2B	"	1020	SSW	25°	990	unmanured*	0	1	3	4	2	11	4
2B'	"	1020	SSW	25°	807	"	0	3	3	4	2	11	3
2C	"	980	SSW	20°	1332	manured	0	4	1	4	2	10	2
3A	Centovalli Pa	870	NNE	20°	2500	abandoned*	0	2	4	0	2	9	4
3B	"	760	N	15°	10097	unmanured	0	3	3	0.5	2	9	4
3C	"	680	NNE	5°	2959	manured	0	4	1	0.5	2	5	1
4A	Centovalli Li	860	SE	30°	2058	abandoned	0	1	5	4	2	9	6
4A'	"	940	SE	30°	3938	"	0	1	6	4	3	7	5
4B	"	810	SSE	25°	1992	unmanured	0	3	4	4	2	10	5
4B'	"	880	E	30°	3225	"	0	3	4	2	3	8	6
5A	M.te S.Giorgio	1040	SSW	15°	2297	abandoned	1	1	3	3.5	3	9	9
5A'	"	920	SW	20°	1221	"	1	1	7	4	2	7	7
6A	M.te Generoso	1000	SSE	20°	1402	abandoned	1	1	5	4	3	5	5
6B	"	980	S	20°	1312	unmanured	1	3	3	4	2	6	0
6C	"	970	SSW	25°	4900	manured	1	4	2	4	2	6	1
6D	"	1000	S	25°	2196	grazed	1	2	3	4	2	9	4

managed, all B-sites in Tab. 2). They are classified as Mesobromion (after ELLENBERG, 1978) and very rich in plants of value for science and nature conservancy. 4 sites are mown twice a year, manured and occasionally grazed (= intensively managed, all C-sites in Tab. 2). One site was used as a pasture for the last 20 years (site 6D in Tab. 2). The manured meadows of the mountain belt of the canton Ticino are distinctly different from the fertilized meadows north of the Alps. They have been exploited in the same manner for centuries, fertilized with manure only, mown twice a year and occasionally grazed in spring or autumn. In spite of such an agricultural use, they contain many typical Mesobromion species (A. STAMPFLI, pers. comm.), and their structure is quite differenciated.

Tab. 2 summarizes for all sites the variables region, altitude, exposition, slope, habitat type, the environmental variables, and the number of orthopteran species found. The management of the sites 2B' and 3A has been changed during the investigation, therefore, in Tab. 2 the characterization at the beginning of the study is given.

Climate

The central and southern Ticino is characterized by an insubric climate, i.e. winters are dry and sunny with frequent periods of "favonio" (northerly wind). The precipitations are concentrated in spring and autumn, but at times heavy snowfall can occur during winter. The summers are sunny and warm with short but very heavy thunderstorms. In the valleys of the northern Ticino the climate is temperate and humid (COTTI *et al.*, 1990).

The climatic conditions of the years 1989, 1990 and 1991 were comparable, being characterized by long, dry and warm periods and a low degree of cloudiness (SPINEDI, 1990, 1991, 1992). The temperatures were higher than the ten years mean, except for April 1989, April and December 1990, February, May and October 1991. A lack of precipitations was recorded particulary in the central and southern Ticino during July and August. The autumn of 1989 was dryer than usual, but more rain than the ten years mean fell in April 1989, June 1990 and March 1991, and the same is true for the autumns (September and October) of 1990 and 1991. A low degree of cloudiness was recorded mostly in winter, when its influence on insolation is low due to the narrow and deep valleys.

Sampling methods

During the summer period the presence and the abundance of adult Orthoptera (except of the families Tetrigidae and Gryllidae) were recorded on all sites. From June to September the sites were visited 10 times in 1989, 6 times in 1990 and 4 times in 1991.

Densities were estimated by a transect method: While slowly walking along defined routes, each species was classified in one of the four categories "rare", "present", "frequent" and "very abundant", being identified on sight and acoustically (stridulating males). Only critical taxa were collected and determined in the laboratory, using HARZ (1957, 1969, 1975). A precise counting, as it was carried out by VOISIN (1986) and ERHARDT (1985), proved to be impossible because of high densities and the large number of species often similar to each other.

Data analysis

The Orthoptera communities in the 3 grassland types (abandoned, unmanured and manured meadows) were analyzed with cluster analysis and canonical correspondence analysis.

For cluster analysis (CA), the abundance data were processed by the program CLUSTER.BAS (LUDWIG & REYNOLDS, 1988), using all available distance indices and clustering strategies. Finally, the percent dissimilarity (PD) was chosen, as advised by the authors (with the relative euclidean distance measures); the clusters were established using the group-average strategy.

For canonical correspondence analysis (CCA), the data were treated with the package CANOCO 3.01 (TER BRAAK, 1987, 1990). This software was used first to carry out a principal components analysis (PCA) and a correspondence analysis. These methods provide an ordination of species and sites without constraining the axes to particular treatments. On the ordination diagrams obtained, sites and species are displayed in groups revealing a structure in the data set.

A series of canonical correspondence analysis (CCA) on the full data set (presence/absence and abundance classes) and on certain environmental variables were carried out by the standard procedure of CANOCO 3.01, including data transformation, different scalings of ordination scores, downweighting of rare species and elimination of anomalous samples. The statistical significance of the eigenvalue of the first ordination axis and the sum of all eigenvalues were tested by Monte Carlo permutation tests included in the package CANOCO 3.01 (TER BRAAK, 1990).

5 environmental variables were introduced into the analysis: "region", "agricultural management", "habitat structure", "site morphology" (combination of exposition and slope), and "moisture".

The variable "region" (REG) represents the influence of the species distribution, as some species are only present in the southern part of Ticino (Monte San Giorgio and Monte Generoso); the variable has a nominal character (JAGER & LOOMAN, 1987). The variable "agricultural management" (MAN) quantifies the intensity of the agricultural management (mowing, grazing, manuring, abandonment). The variable "habitat structure" (STR) gives information on the complexity of the habitat structure because the number of species is expected to be proportional to the habitat complexity, as sites rich in niches are able to cover the requirements of more species. The variable "site morphology" (MOR) has been calculated combining the exposure with the slope of the sites, which should give an indication of the potential solar irradiation. The variable "moisture" (MOI) shows the degree of the soil humidity. This is an estimate obtained by classifying the sites into five categories of humidity on the basis of the data of other contributors to the project (M. LÖRTSCHER, pers. comm.).

Tab. 1 shows the system used to calculate the scores, and in Tab. 2, the scores of the used environmental variables are presented for all sites.

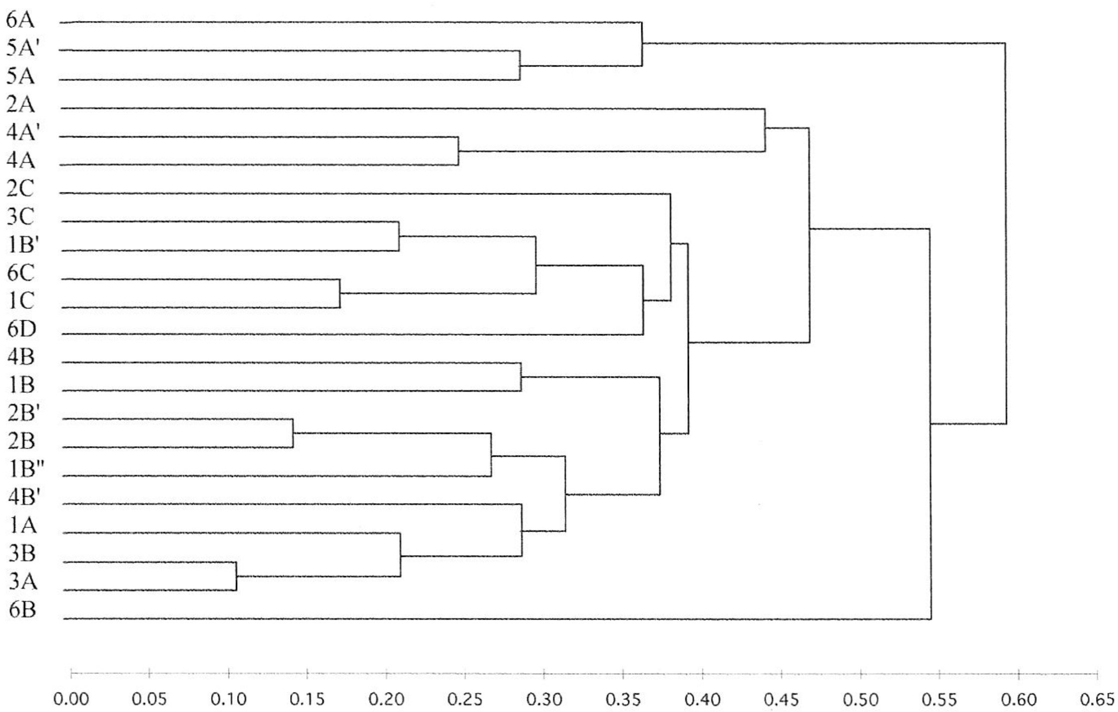


Fig. 2 – The 22 sites displayed in a dendrogram of the cluster analysis (CA), carried out with the percent dissimilarity index and group-average clustering strategy (LUDWIG & REYNOLDS, 1988). Site codes see Tab. 2.

RESULTS

Cluster analysis (CA)

In the dendrogram obtained by the CA, the sites are assembled in clusters representing the 3 grasslands types (Fig. 2): all abandoned meadows (A) are grouped together, the unmanured meadows (B) form a second cluster and all manured sites (C) a third one. Of the 22 sites investigated, 4 are grouped in a wrong cluster: the abandoned sites 1A and 3A join the unmanured meadows, the unmanured site 1B' is found in the cluster of the manured meadows, and the unmanured meadow 6B joins the abandoned sites.

Canonical correspondence analysis (CCA)

The environmental variables introduced in the CCA are not strictly correlated with each other, the absolute values of the correlation coefficients being < 0.70.

The correlation between all the variables introduced in the analysis and the first two ordination axes are 0.883 and 0.881, respectively, by abundance data, and 0.853 and 0.858, respectively, by incidence data (presence/absence).

Tab. 3 – Recorded grasshopper species with estimated density (1 = rare, 2 = present, 3 = frequent, 4 = very abundant), frequency, substrates (a = arboricol, g = graminicol, t = terricol) and microclimatic preferences of adults (x = xerophilous, m = mesophilous, i = hygrophilous) (ANTOGNOLI, 1994). Nomenclature according to NADIG & THORENS (1991).

species	sample sites																						frequency	substrate	microclimate
	1A	2A	3A	4A	4A'	5A	5A'	6A	1B	1B'	1B'	2B	2B'	3B	4B	4B'	6B	1C	2C	3C	6C	6D			
Barbitistes obtusus	1	1				1	1																18.2	a	m
Metrioptera bicolor						3	2																9.09	g	m
Pholidoptera apt. aptera		1		1	1	1		1															22.7	t/a	m
Pholidoptera fallax						1	1	1															13.6	t	x
Antaxius pedestris		1																					4.5	t/a	x
Ephippiger terr. bormansi		3																					4.5	a	x/m
Ephippiger vicheti						2	3																9.1	a	x/m
Aiolopus strepens						2	1																9.1	t/a	x/m
Leptophyes laticauda						1										1							9.1	a	m
Platycleis grisea grisea	1		1	2	1				3	1				1	1	2							40.9	t	x
Pholidoptera griseoaptera	1	1	1	1		1	1	1						1	1	1							45.4	t/a	m
Mantis religiosa				1	2	2	1								1	1							27.3	g	x
Miramella formos. formosanta		2				2						1	1										18.2	a	m
Psophus stridulus	1								1														9.1	t	x/m
Oedipoda caerulescens	1		1						1					1	1								22.7	t	x
Omocestus haemorrhoidalis			1	1					3					2	1	3							27.3	g	x
Polysarcus denticauda																						1	4.5	t/g	m
Pholidoptera littor. insubrica						2																	4.5	t	m/i
Phaneroptera falc. falcata	1	1	2	1	2							1	1	1		2			1				45.4	a/g	x/m
Tettigonia viridissima	1	1							1			1			1			1					27.3	a/g	m
Decticus verruci. verrucivorus	1	1	3	1	1				2	1	3	2	3	3	2	3		2		1	1	1	77.3	t	x/m
Metrioptera fedtsch. minor		3						3				2	1						1			1	27.3	g	m/i
Parapleurus alliaceus		1										2	1						1				18.2	g	i/m
Arcyptera fusca		1		2	3							2	1		1	1			1			1	40.1	t	x/m
Chrysochraon brachyptera	4	4	3	2	3	4	2	4	1	2	3	3	2	2	1	1	1	2	1		2	3	95.4	g	m
Stenobothrus lin. lineatus	2	1	1	1	1	2	3	3	3	1		1	2	1	2	1	1	1	1		1	2	90.9	g	x
Omocestus rufipes		1		1					1		2	2	2		3		1		3		1	1	50	g	m
Gomphocerippus rufus	3	3	3			3	3	3	1	1		2	1	1					1	1		1	63.6	a/g	x/m
Chorthippus scalaris	4	3	4	2	4	2	1		1	2	3	4	4	4	1	3			1	1		1	81.8	g	x/m
Chorthippus mollis mollis	3	1	2	1	1	1			3	3	3	1	2	3	4	2	2	3	4	2	3	3	90.9	g	x/m
Chorthippus dors. dorsatus	4	2	3	1	1	2	1	1	2	4	3	3	3	4	3	3	1	4	4	4	2	1	100	g	m/i
Chorthippus parall. parallelus	2	2	4	1	2	4	1	3	2	3	4	3	3	4	4	3	1	2	4	4	2	2	100	g	m/i

Tab. 4 – Correlations between the environmental variables and the first two axes of the ordination diagram obtained with canonical correspondence analysis (CCA, standard procedure) by incidence and abundance data (TER BRAAK, 1990). Eigenvalues of the first two axes of the CCA, carried out with the full data set and without the 5 most frequent species (recorded in >90 % of sites).

	abundance data		incidence data	
	axis 1	axis 2	axis 1	axis 2
REG region	0.755	0.438	0.784	0.312
MAN agricultural management	-0.612	0.570	-0.435	0.578
STR habitat structure	0.450	-0.605	0.311	-0.716
MOR morphology	0.355	-0.267	0.230	0.148
MOI moisture	0.280	-0.381	0.213	-0.539
eigenvalues of CCA 1)	0.266	0.119	0.231	0.100
eigenvalues of CCA 2)	0.443	0.173	0.374	0.159

1) carried out with full data set

2) carried out without the 5 most frequent species (frequency > 90%, see table 3)

Axis 1 of the ordination diagram is mainly determined by the variable REG (being in the first rank: correlation 0.784 by incidence data and 0.755 by abundance data) and by MAN and STR in the second rank.

Axis 2 is correlated with STR and MAN by coefficients of –0.716 and 0.578, respectively, for incidence data and –0.605 and 0.570, respectively, for abundance data (Tab. 4). It has to be noticed that for the second axis, the correlations of STR are both negative, as well as for MOI.

The percentage of the variance of the data explained by the first two axes of the analysis is 73.2 % (first axis: 50.6 1%, second axis 22.6 %) for abundance data and 68.7 % (first axis: 48.0 %, second axis: 20.7 %) for incidence data. The eigenvalues, which indicate the statistical importance of the ordination axes, can be improved by removing the five species present in at least twenty sites (frequency >90 %) from the analysis (Tab. 4).

DISCUSSION

Cluster analysis (CA)

In contrast to CCA, environmental variables were excluded in CA. The dendrogram subdivides the sites into three groups according to their management. Most of the exceptions can be explained. Among the abandoned meadows the sites south of the insubric line (5A, 5A', 6A, with similar faunistic composition) clearly separate from all other abandoned ones: on Monte San Giorgio and Monte Generoso, 6 species occur which are not found further north (sites in Valle di Blenio, Valle

Morobbia, Centovalli), due to biogeographical reasons or because they do not find their suitable climatic conditions (insubric climate) (NADIG, 1991; ANTOGNOLI, 1994).

Two abandoned sites (1A and 3A), clustering together with the unmanured meadows, can be explained by the following facts: site 1A was abandoned only recently and, because of a sale, site 3A was recovered as a sheep pasture during the three years of the survey.

The group of intensively managed meadows (manured meadows) differs only slightly from that of the unmanured sites; as an exception the unmanured site 1B joins group C. It is a small marginal site adjacent to a large and more intensively managed area not included in the study. It is mown a second time per year whenever the development of the vegetation allows. This additional mowing, even if not regular, might have an effect on the Orthoptera fauna, rendering it more similar to that of the manured meadows.

Site 6B has a special position in the dendrogram. This unmanured meadow is colonized only by 6 grasshopper species, 5 of them being very common and present in more than 90 % of the sites.

These results are confirmed by another, similar CA carried out in the frame of the synthesis of the whole research program and comprising the data on Orthoptera, Carabidae, Rhopalocera, Heteroptera, and Arachnida. Orthoptera and Carabidae provided a better discrimination between managed and unmanaged meadows than Arachnida, Rhopalocera, and Heteroptera. In Heteroptera, biogeographical aspects are of greater importance (ANTOGNOLI *et al.*, 1995).

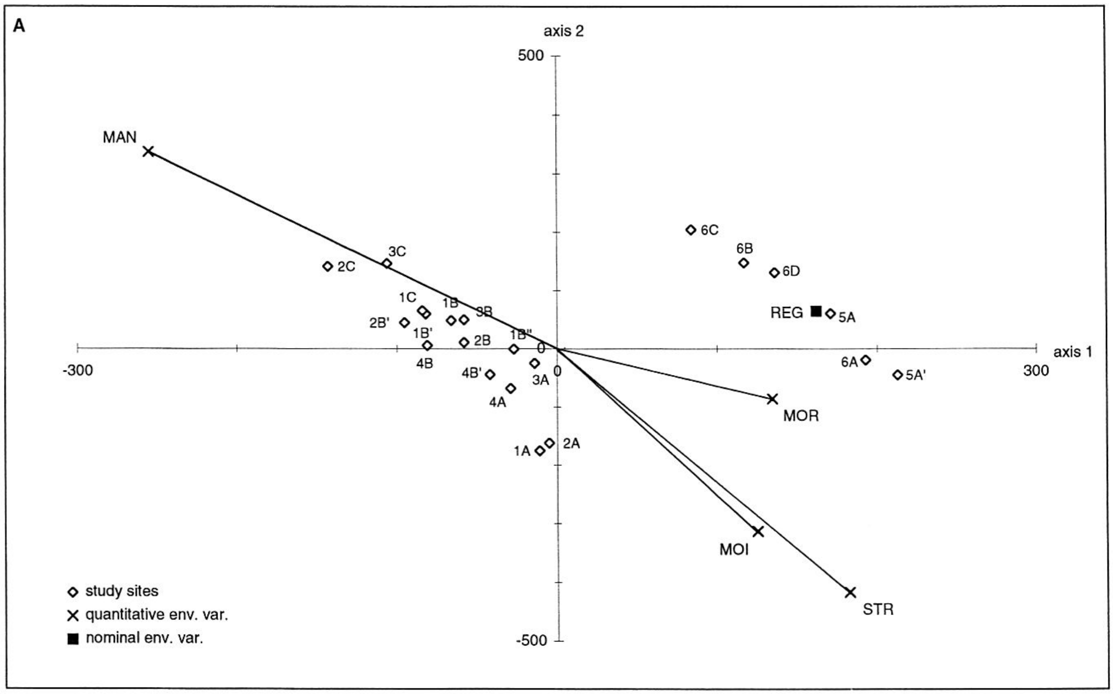
Canonical correspondence analysis (CCA)

In contrast to CA, this ordination is not only based on the Orthoptera data, but includes also the environmental variables attributed to each site (REG, MAN, STR, MOR, MOI), which become responsible for the differences between the clusters obtained by the two methods.

The ordination diagram clearly shows two gradients along which the sites and the species are displayed (Fig. 3). On one side, the meadows of the southern Ticino 5A, 5A', 6A, 6B, 6C and 6D (Monte San Giorgio and Monte Generoso) are separated along a geographical gradient (Figs 3A, 3C). This separation is the result of the integration of the nominal variable REG into the analysis, being the first determinant among the environmental variables for the ordination of both the sites and the species (by abundance and incidence data). On the other side, all sites and species are located along a gradient which is determined by the variables MAN and STR, and the sites are separated into the three groups of abandoned, unmanured, and manured meadows.

The most important environmental variables determining the distribution of the data are therefore REG, followed by MAN and STR. In fact, REG shows the highest correlation with the first ordination axis, while the variables MAN and STR are more correlated with the second one (Tab. 4). MAN and STR are slightly negatively correlated (coefficient –0.69), because an intensification of the management leads to a reduced diversity of structural elements.

The other two variables, MOR and MOI, seem to play a more marginal role in the analysis, even if it has to be pointed out that MOI is on the same side and has practically the same direction as STR. By the incidence data, the variable MOI is also correlated with the second axis in a similar way as the variable STR (Tab. 4).



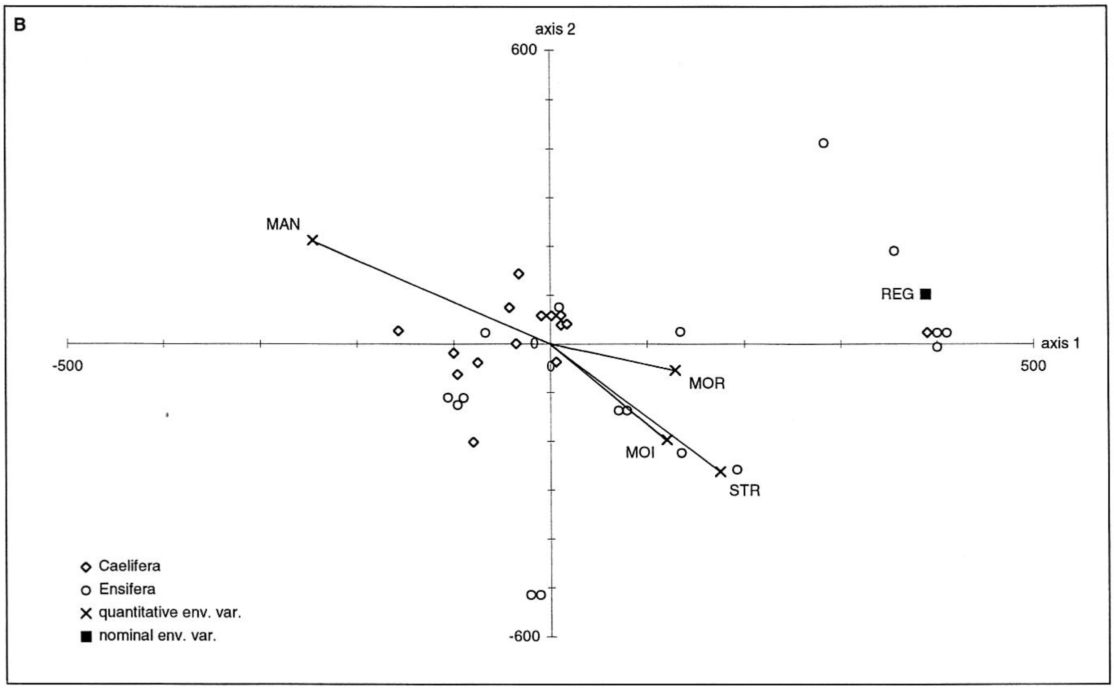
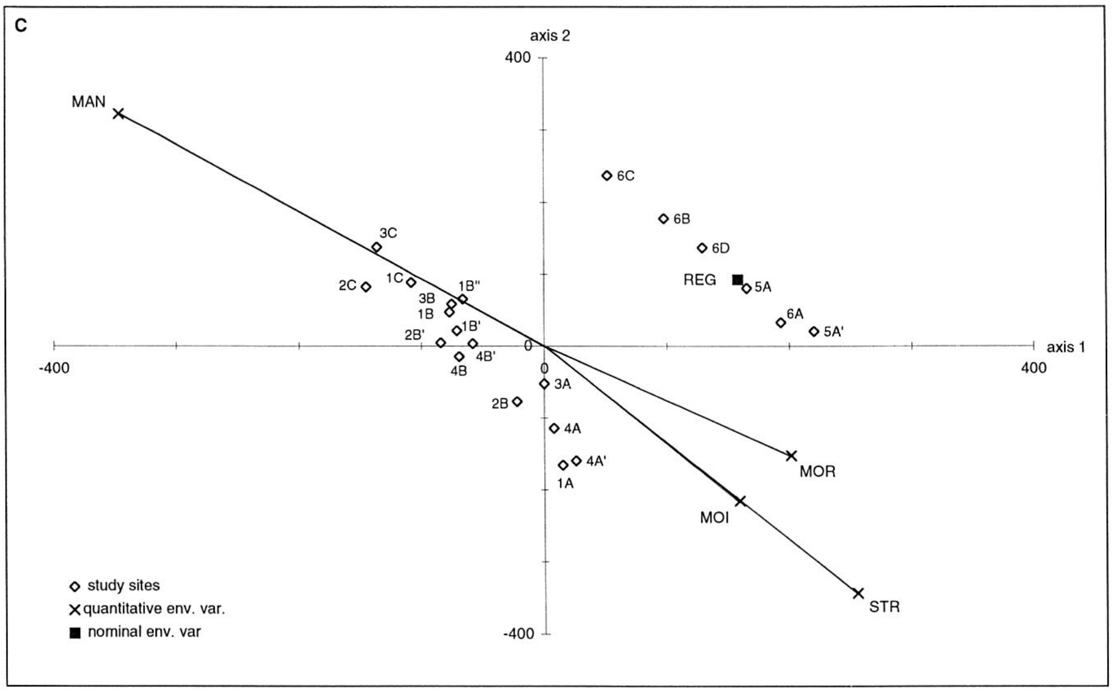
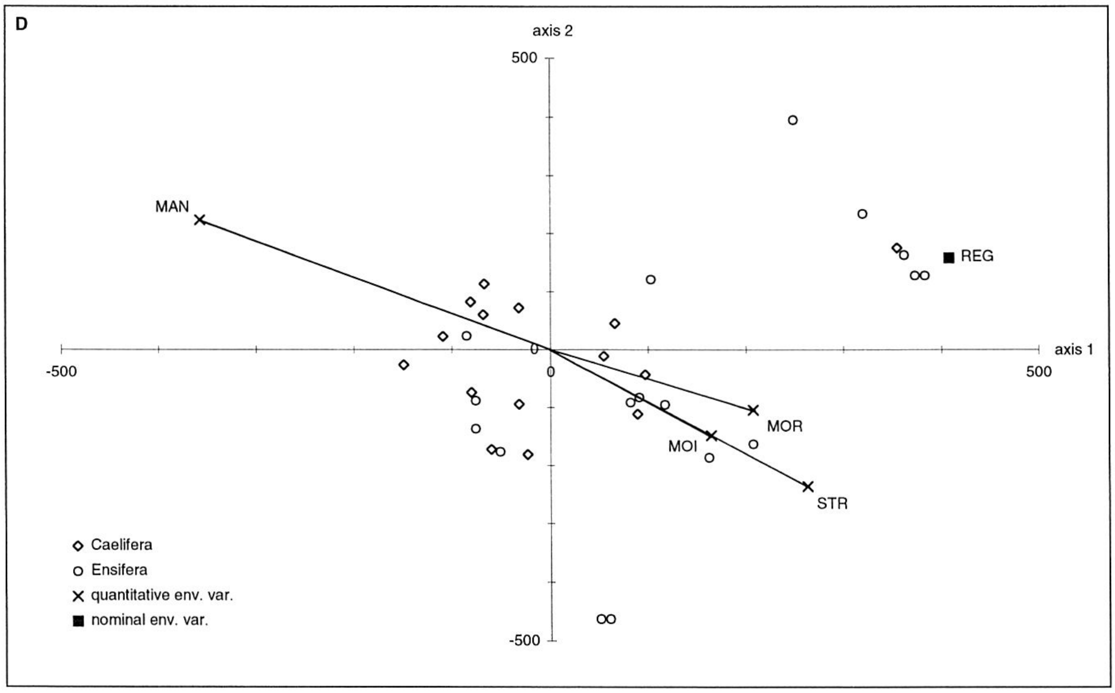


Fig. 3A–D – Ordination diagrams of the canonical correspondence analysis (CCA), carried out by standard procedure (TER BRAAK, 1990). 3A: ordination of the 22 sites by incidence data. 3B: ordination of the 32 species





by incidence data. 3C: ordination of the 22 sites by abundance data. 3D: ordination of the 32 species by abundance data.

In fact, the sites with more complexe structure (i.e. with shrubs or trees) have frequently an increased soil humidity.

Site 1A, which in the CA was in the group of the unmanured meadows, is joining the correct cluster with CCA (figs. 3A, 3C). Site 3A is grouping together with the abandoned sites, but is situated in the vicinity of the unmanured meadows (Figs 3A, 3C). This is probably due to the fact, like in CA, that it has been reused as pasture during the study.

Site 1B', in the dendrogram of the CA within the group of the manured meadows, changes to the correct group of the unmanured meadows (B), where it occupies a central position (Figs 3A, 3C).

Site 6B, with its special position in the dendrogram of the CA, is being displayed along the gradient determined by the variables MAN and STR. It is positioned at the same level of the other unmanured meadows, but joins the sites of the southern Ticino (Figs 3A, 3C).

Site 6D, instead of being in the group with the manured meadows as in the dendrogram of the CA, takes an intermediate position between abandoned meadows and unmanured meadows (Figs 3A, 3C).

The species data are not separated in a clear manner, but nevertheless, two main groups can be discerned. A first one is formed by the species collected exclusively on abandoned meadows, and amongst them the species present only in the southern Ticino are remarkable (Monte San Giorgio and Monte Generoso, Fig. 3D). In the second group, we find all other species, being either present on abandoned and unmanured meadows only or in all three types of meadows (Tab. 3). The species are also displayed along the same two gradients: geographical gradient, determined by the environmental variable REG, and managemental/structural gradient, determined by the variables MAN and STR; a subgroup dominated by Ensifera tends to separate into a cluster in direction of the insubric species (Figs 3B, 3D).

There are no species collected exclusively in manured or unmanured meadows (Tab. 3); thus it is impossible to obtain a clear ordination of these remaining species.

In the analysis, the 5 most common species (frequency > 90%) show a tendency for an aggregation. Therefore, it is not surprising that by withdrawing them from the analysis, the eigenvalues of the first two axes of the ordination are increased (Tab. 4), gaining a greater statistical importance.

CONCLUSION

The Orthoptera communities in 3 investigated grassland habitats (abandoned, unmanured, and manured meadows) on the mountain belt of the canton Ticino are different. On abandoned meadows, Ensifera, dependent upon trees and shrubs, are present; species preferring tall grass, ubiquitious species, and those being more typical for traditional unmanured meadows, but finding a refuge in abandoned sites (lacking in unmanured meadows). In unmanured meadows, Caelifera of traditionally managed meadows can be found, as well as Ensifera occasionally appearing from transitional habitats, and the ubiquitious species. In manured meadows, the more common Caelifera species are present, together with a few Ensifera as occasional guests. Only in the abandoned meadows it was possible to single out species occurring exclusively in one grassland type (ANTOGNOLI, 1994).

The present study is a first contribution to the conservation and the management of these endangered grassland habitats and their fauna. It was possible to show that, during their first successional stages, abandoned meadows are very interesting habitats for Orthoptera and other invertebrates. It is important that their structure is preserved, being the main reason for their increased diversity.

A diverse habitat structure with trees and shrubs, many herbaceous species and some open soil satisfy the requirements of a greater number of Orthoptera and other invertebrates (ERHARDT & THOMAS, 1991; ANTOGNOLI, 1994; LÖRTSCHER *et al.*, 1994; ANTOGNOLI *et al.*, 1995).

The abandoned meadows are endangered by spontaneous reafforestation: the farmers leave the meadows (because of reduced profitableness), and within a few years they become forests. As the number of abandoned meadows with typical mosaic structure is quickly shrinking, it is important to study suitable measures for their management, as it was proposed by STAMPFLI *et al.* (1992, 1994) and LÖRTSCHER *et al.* (1994), to prevent them from becoming woods sooner or later. The canton Ticino is already the part of Switzerland with the largest forest cover (COTTI *et al.*, 1990).

The unmanured managed meadows of the Ticino are endangered by abandonment and spontaneous reafforestation, and not by intensification of the agricultural management as it is the case north of the Alps. Because of the increased difficulties of treatment with machinery and the loss of profitableness, the farmers abandon these sites. In 1987, 450 ha of unmanured grasslands were observed during the preparation of the inventory of the xeric sites of the canton Ticino, but 50 % of these were already invaded by shrubs or trees. A number of these meadows must be saved as elements of the traditional agricultural landscape, representing important habitats for invertebrates as well as for birds, reptiles, and mammals. Some manured meadows are rather suitable habitats for Orthoptera, confirming the ecological difference between such habitats in the montane belt of southern Switzerland and the manured meadows in the bottom of the valleys north of the Alps, which are exploited in a much more intensive way (ANTOGNOLI *et al.*, 1995).

ZUSAMMENFASSUNG

Während der Sommerperioden 1989, 1990 und 1991 wurden auf 22 Wiesen und Weiden in der montanen Stufe des Kantons Tessin semiquantitative Daten über adulte Heuschrecken erhoben. Die Abundanz von 32 Arten (ohne die Familien Tetrigidae und Gryllidae) wurde in 4 Klassen geschätzt: selten, vorhanden, häufig, sehr häufig. 8 Standorte waren ca. 10jährige Brachen, 9 extensiv genutzte Magerwiesen (einschürig, ungedüngt), 4 intensiver genutzte Wiesen (zweischürig, beweidet, gedüngt), und eine wurde nur beweidet. Mit Hilfe von Clusteranalyse (CA) und Kanonische Korrespondenzanalyse (CCA) war es möglich, Unterschiede zwischen den Heuschreckenzönosen der unterschiedlich bewirtschafteten Wiesen aufzuzeigen. In der CCA wurden die Umwelt-Variablen Region, Habitatstruktur, Nutzungsintensität, Morphologie und Feuchtigkeit verwendet. Die ersten drei beeinflussen die Verteilung der Standorte und Arten in den Diagrammen am meisten; die Standorte werden entlang von 2 Gradienten (Region und Habitatstruktur/Nutzungsintensität) dargestellt. Sowohl einschürige und ungedüngte als auch zweischürige und mit Mist gedüngte Wiesen erwiesen sich als günstige Habitate für Caelifera, wobei letztere in der montane Stufe des Tessins eine wesentlich geringere Nutzungsintensität aufweisen als nördlich der Alpen. Aufgelassene Flächen sind nach unseren Untersuchungen für Heuschrecken, aber auch für Schmetterlinge und Spinnen, während der ersten Stadien der Sekundärsukzession am wertvollsten, insbesondere für Ensifera und andere Taxa, welche auf komplexe Vegetationsstrukturen angewiesen sind.

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