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Year-to-year changes in unfertilized meadows of great species richness detected by point quadrat analysis

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Abstract

An experimental study site in an unfertilized meadow of great species richness at Negrentino (820 m) in Southern Switzerland has been investigated by successive point quadrat analysis since 1988. Two different managements, traditional mowing and abandonment, were realized on 3 × 6 plots of 200 × 220 cm. On each plot point frequency (sensu Goodall 1952) was sampled at spaces of 10 cm using

Fig. 1. Study site in June 1990.

the same 11 × 16 points every year. On all the plots 71 species were recorded within the four year period of 1988–1991.

Small spatial differences and vegetational changes in time are interpreted on an ordination diagram of correspondence analysis. Differences between successional and fluctuational changes are recognized already in the early phase. On one plot a peak of phytocyclic fluctuation connected with a mass development of *Trifolium repens* was observed.

Many species show significant year-to-year frequency changes. Taxa positively and negatively affected by abandonment are presented.

Management and dry weather conditions in April and May are considered to be the main causes of trends and fluctuations.

Nomenclature: for vascular plants: Binz & Heitz (1986), Schul- und Exkursionsflora für die Schweiz, Schwabe, Basel; for syntaxa: Ellenberg (1978), Vegetation Mitteleuropas mit den Alpen, Ulmer, Stuttgart.

Introduction

In Ticino, Southern Switzerland, the area of unfertilized meadows of great species richness has quickly declined within the last forty years because of substantial changes in landuse practices. Whereas farming of meadows in the valley-bottom has been intensified by chemical fertilizers, inclined areas in the montane zone have most often been abandoned. As in other parts of temperate Europe, abandonment reduces the species diversity (Bakker 1989). Former meadows have changed into species-poor grasslands dominated by *Brachypodium pinnatum*, or turned into shrub and woodlands.

The main idea of starting a field experiment in one of the few remaining meadows of great species richness where hay-making is still practised, was to observe the early phases of secondary succession. It is the aim of this paper to summarize the results of the first period, 1988–1991. Many more years will be necessary to answer the main questions:

- How quickly do the different plant species change, when traditional mowing is stopped?
- After what time can the process of secondary succession still be reversed without the loss of many plant species?

Study site

The study site is located at an elevation of 820 m, close to the old church of San Carlo di Negrentino (Valle di Blenio, Southern Switzerland). It is embedded in a south facing slope of up to 20°. Annual rainfall (about 1300 mm) is distinctly lower than in surrounding alpine and Insubrian areas. The grass is cut by local farmers twice a year, around the end of June and in fall.

The species composition of the study site reflects features of *Mesobromion* communities. As the soils are moderately acid, pH = 5.4 (top of soil sample, measured in water), deeply weathered (thickness of A- and B-horizons: 105 cm) and of a rather low nutrient content, there is a high abundance of *Festuca tenuifolia* and *Danthonia decumbens*, both indicating poor soils. Nevertheless some species of a slightly manured *Trisetion* community situated close by are also present. The varying occurrence of big rocks within the soil creates more or less dry micro-environmental conditions.

The species density of the meadow is very high, and most of the species appeared to be quite evenly distributed. Areas of up to 50 vascular plant species per square meter can be found. The structure of the meadow in June is rather complex (Stampfli 1991).

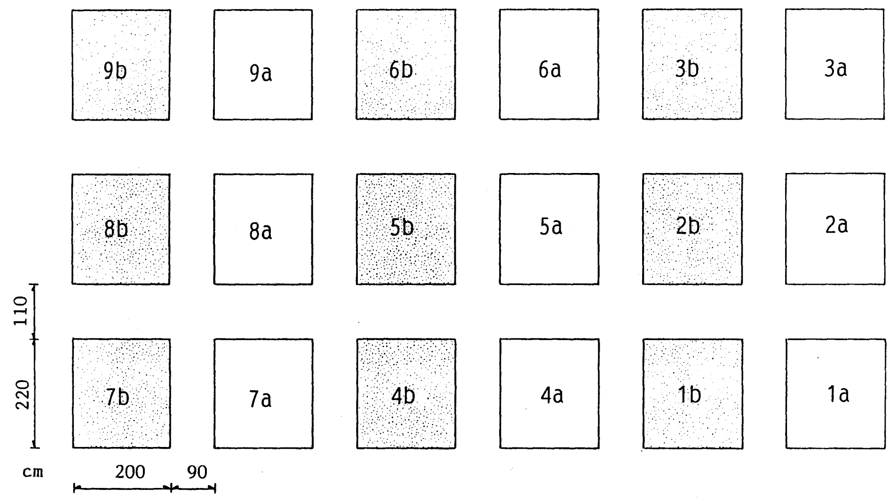

Fig. 2. Experimental design showing a-plots (mown) and b-plots (abandoned).

Experimental design and method

Enclosed within a fence, the study site consists of 18 plots of 4.4 square meters separated by small pathways (Fig. 1, Fig. 2). A regular experimental design was choosen to prove spatial gradients. Whereas mowing is continued on a-plots using a scythe, b-plots were abandoned after the first analysis in June 1988.

So far the point quadrat method has not been widely used for permanent plot studies in meadows of great species richness, probably because of time expense. In this study on year-to-year changes it has been preferred because other methods are less accurate (cover estimates), unsuitable (frequency determination using small quadrats) or even more time-consuming (charting plant locations, biomass measurements of standing crop by species).

All the plots include a main area, where frequency sensu Goodall (1952) is sampled using the same 176 points at a distance of 10 cm every year (Fig. 3). The sampling equipment including a needle of 3 mm in diameter, an apparatus of high rigidity, a water-level, guide lines and permanent marks for exact needle localization, a greenhouse to protect from wind and rain, as well as further details concerning the method and its accuracy were recently described (Stampfli 1991).

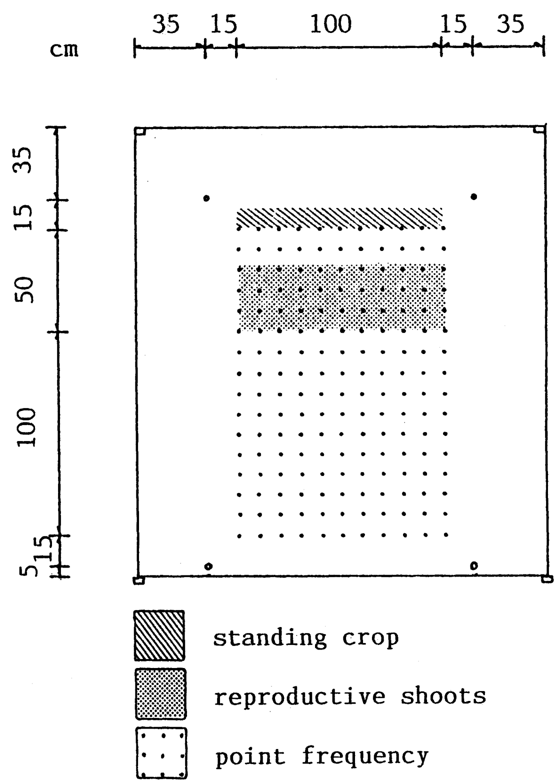

Fig. 3. Single plot area (covered by greenhouse) including four permanent marks and different sampling areas. 'Standing crop' samples are restricted to mown plots, 'reproductive shoots' refer to sampling of tall grass culms and 'point frequency' samples include 176 points.

Sampling was done in the same period every year in the middle of June, beginning on plots 1a and 1b, and terminating on plots 9a and 9b. At this time most species have passed over their flowering optimum and phenological changes in the structure of the meadow have slowed down.

To get an idea of the phenological state, the beginning of flowering of *Bromus erectus* on plot 1a has been recorded every year. In 1990 this was before 1 June, about 10 days earlier than in other years.

The point frequency analysis is completed by counting of rare species in spring, density determination of culms of tall grasses and (on mown plots) standing crop measurements before cutting. Standing crop samples consisting of one strip per plot are taken with a small lawn-mower (Fig. 3). In addition to point frequency data only results of standing crop measurements will be used in this paper.

Results

In this preliminary evaluation of changes occurring on the study site in a first period between 1988–1991, two quick approaches are applied. The first, an ordination of time series of multi-species data to prove spatial differences and temporal trends, was used by van der Maarel (1969) and Austin (1977). This method is only successful for little heterogeneous data sets (Swaine & Greig-Smith 1980). The second approach is a simple 'trend analysis' of single taxa. It is based on significant year-to-year changes, which can be determined since the methodical error is quantitatively known (Stampfli 1991).

On the 18 plots 71 taxa were recorded by the point quadrat technique within the four years. Nine rare species were not recorded. On a single plot the average of recorded taxa was about 36 per year.

Spatial differences and vegetational trends in time

All the plots are ordinated by species frequency values using correspondence analysis (CANOCO, version 2.2 by C. J. F. ter Braak 1988). The data set consists of 72 plots and 71 taxa. The eigenvalues of the first ordination axes are relatively small ($\lambda_1 = .13$, $\lambda_2 = .10$), suggesting a small heterogeneity within the data set (Ter Braak 1987).

On the ordination diagram no clustering can be observed among the plots of 1988 (Fig. 4). The variation along the first axis can be interpreted as a spatial gradient.

Whereas the plots located at the bottom of the study site (1a,b; 4a,b; 7a,b) are mainly placed to the left, the plots located at the top of the study site (3a,b; 6a,b; 9a,b) are mainly placed to the right in the ordination diagram. The latter seem to be influenced by manure, which was spread close to the study site in former times: Plot 3a, at the extreme right in the ordination diagram, includes species of fertilized meadows (*Silene vulgaris* and *Trifolium repens*); *Festuca rubra ssp. rubra* is most abundant here. Plot 4a, at the extreme left, includes a rock at the soil surface and species of unfertilized sites (*Sedum sexangulare* and *Koeleria macrantha*); *Helianthemum nummularium* is most abundant here.

Most abandoned plots are progressively shifting in about the same direction along the second ordination axis. Four plots (1b, 3b, 7b, 9b) already show a considerable change after the first year. By 1990 a distinct separation between mown and abandoned plots (8b not included) can be

Table 1. Taxa positively affected by abandonment (1988–1991) and number of mown (a) and abandoned (b) plots showing positive (+) and negative (−) trends. 0 marks no trend or species laking.

Taxa	Mown			Abandoned		
	−	0	+	−	0	+
Brachypodium pinnatum	8	1		1	1	7
Agrostis tenuis		6	3		1	8
Anthoxanthum odoratum	3	3	3		5	4
Avenula pubescens		9			6	3
Sanguisorba minor	1	8			7	2
Campanula rotundifolia	2	7			8	1
Trofolium repens	2	7		1	6	2
Dactylis glomerata		9			7	2

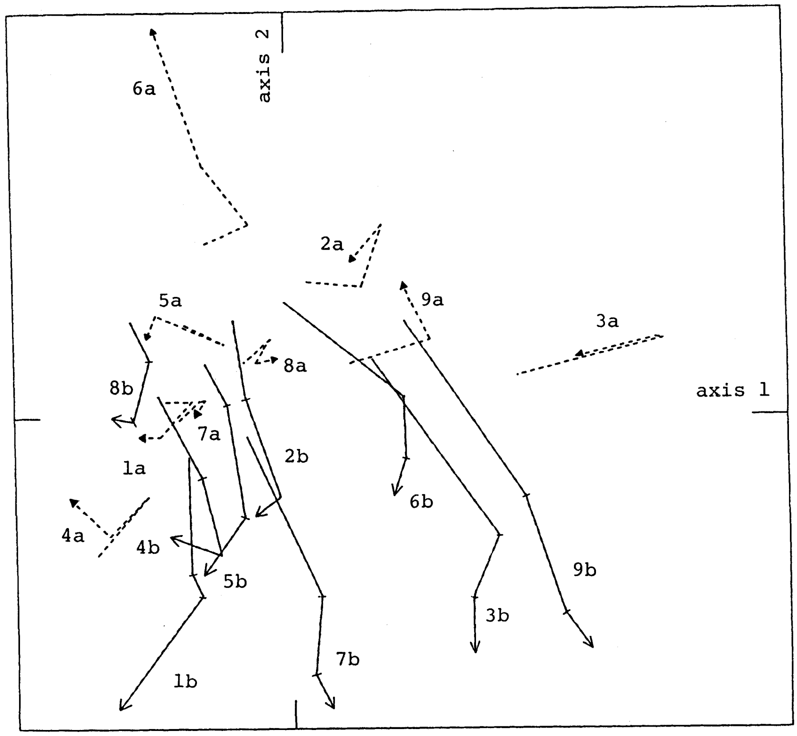

Fig. 4. Ordination by correspondence analysis. Time series, 1988–1991, of mown (a) and abandoned plots (b).

observed. On plot 8b, where a rock is present at the soil surface, the floristic composition is slightly different and the progression is not as strongly marked.

Most of the mown plots reveal minor changes which are differently directed from year to year. On plot 6a, however, where gaps within the sward most evidently increased and the standing crop most evidently decreased, a remarkable trend opposed to changes on abandoned plots can be observed since 1989. On plot 3a mass development of *Trifolium repens* in 1989 provoked a distinct shifting which was reversed when *Trifolium repens* died off during the next two years (see below).

Trends of single taxa

A change in species frequency within an interval t_1-t_2 is considered 'significant' when the difference between the frequency value $f_{(t1)}$, $f_{(t2)}$ exceeds confidence limits of methodical error. As such error is smaller compared to the error of random sampling (Stampfli 1991), the equation valid for random sampling was used for a conservative estimation of the significance of year-to-year changes.

Positive and negative trends are determined for all the taxa on every plot by addition of significant positive and negative year-to-year changes (Fig. 5).

Positive and negative effects of abandonment (E) are determined for all the taxa by calculation of the difference between number of abandoned B and mown A plots showing positive (+) or negative (−) trend, by use of the following equation:

$$E = B(+) - B(-) - A(+) + A(-)$$

Taxa most distinctly affected by abandonment are displayed in Table 1 and Table 2. Many taxa declined on both plots. Taxa showing highest negative decline on mown (and negative decline on abandoned) plots are displayed in Table 3.

Anthoxanthum odoratum and *Plantago lanceo-*

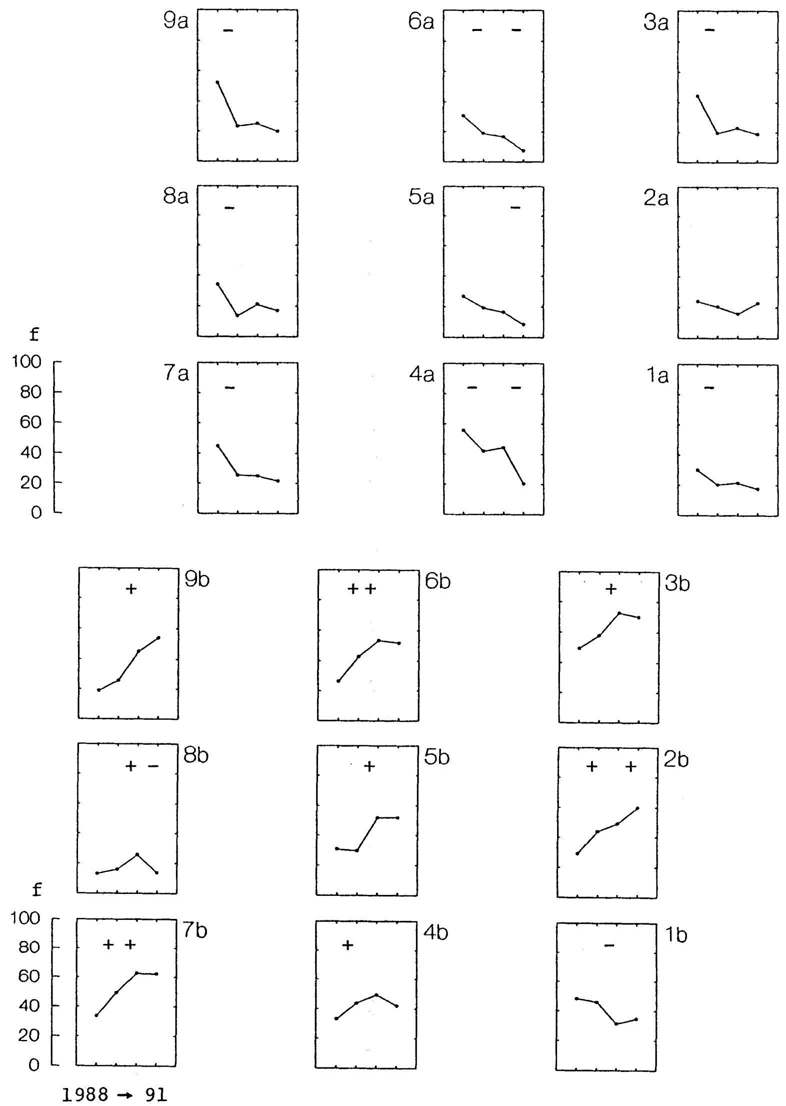

Fig. 5. Frequency (f) changes of ***Brachypodium pinnatum*** on mown (a) and abandoned (b) plots (1988–1991). Significant positive (+) and negative (−) year-to-year changes are marked. Trends on eight a-plots are negative; no trend on plot 2a. Trends on seven abandoned plots are positive, on plot 1b negative; no trend on plot 8b.

lata reveal distinct fluctuation peaks in 1989 (Fig. 6a), the same year when *Trifolium repens* showed a mass development on plot 3a (f_{1988} = 12%, f_{1989} = 33%, f_{1990} = 3%, f_{1991} = 0%). No similar peak however was evident on other plots.

Discussion

By use of ordination differences between succession and fluctuation can be detected already in an early phase. Successional changes are more or less 'uni-directed' and progressive, fluctuational changes are 'multi-directed' and regressive. Most typically regressive change occurred in the case of 'phytocyclic fluctuation' (in the sense of Rabotnov 1974) connected with the mass development of *Trifolium repens* on plot 3a. Four years however are not enough to decide whether a vegetational change on a single plot is fluctuational or successional. Repeated droughts in successive

Table 2. Taxa negatively affected by abandonment (1988–1991) and number of mown (a) and abandoned (b) plots showing positive (+) and negative (–) trends. 0 marks no trend or species lacking.

Taxa	Mown			Abandoned		
	–	0	+	–	0	+
Anthyllis vulneraria		5	4	5	4	
Trifolium montanum		8	1	8	1	
Danthonia decumbens	2	7		6	3	
Salvia pratensis		9		2	7	

years may also provoke progressive vegetational change on plots highly sensitive to limited water supply (see plot 6a, Fig. 4).

Before changes of single taxa can be discussed some methodical remarks must be stated:

(1) Point frequency is a quantitative measure related to cover (see Goodall 1952 for errors due to needle diameter). Although a correlation to above ground biomass and number of shoots can be supposed for plants of similar size and shape within certain limits, frequency changes should not be interpreted as changes of biomass and number of shoots in a strict sense.

(2) Frequency changes may be a result of changing leave angles caused by different treatments, as was observed for *Hypochoeris radicata* with horizontally spread leaves on mown plots. On abandoned plots the leave position of this species was sometimes almost vertical, thus the chance of contacts with the needle is reduced. Informations about changing architecture of a taxa are an important source for the interpretation of frequency changes.

(3) Phenological records may also provide important information to interprete disparate developments on quadrats recorded at different times within the sampling period of about 17 days. 'Peculiar' fluctuation peaks of *Agrostis tenuis* on plots 9a and 9b in 1990

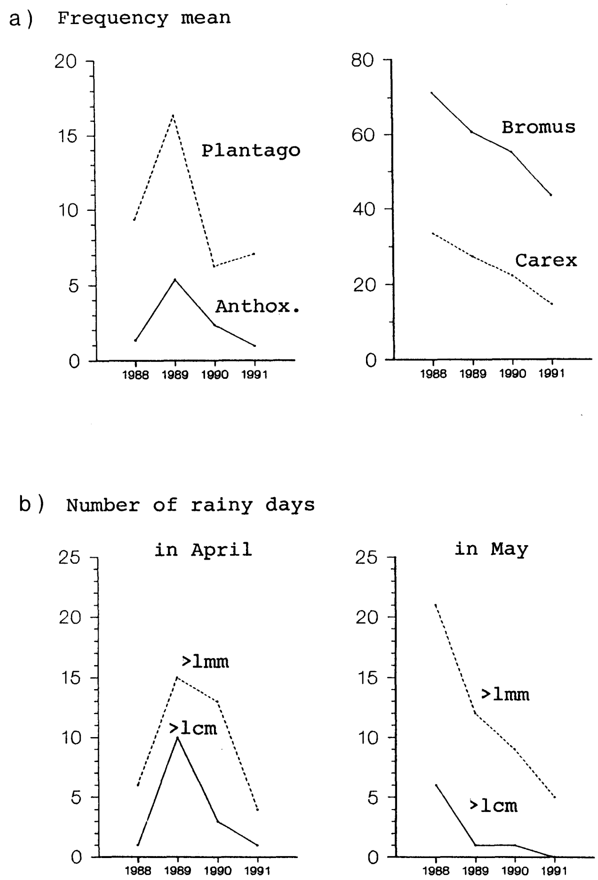

Fig. 6. a. Fluctuating taxa, *Plantago lanceolata*, *Anthoxanthum odoratum*, and declining taxa, *Bromus erectus*, *Carex verna*, on mown plots 1988–1991 (means of frequency values). b. Number of rainy days in April and in May recorded at the nearby SMA-station at Comprovasco, 1988–1991. 'Rainy days' are based on two different sums of diurnal precipitation (> 1 mm, > 1 cm).

Table 3. Taxa negatively affected on mown and abandoned plots (1988–1991) and number of mown (a) and abandoned (b) plots showing positive (+) or negative (–) trends. 0 marks no trend or species lacking.

Taxa	Mown			Abandoned		
	–	0	+	–	0	+
Bromus erectus	9			9		
Festuca tenuifolia	7	2		9		
Carex verna	7	2		8	1	
Briza media	4	5		6	3	
Luzula campestris	4	5		3	6	
Lotus corniculatus	4	5		2	7	

are an example of such a phenological effect: *A. tenuis* is the only grass which usually flowers after the analysis in late June. In 1990 however it had opened its panicles already before the ultimate plots were analysed. This resulted in a rise of frequency on the ultimate plots, which is not confirmed by other plots investigated earlier.

The disparate behaviour of many taxa on mown and abandoned plots is attributed to abandoning. The increase of *Brachypodium pinnatum* is considered a result of its competitive vigour. Other species also increased because of their ability to use the improved nutrient and water resources in abandoned plots: *Agrostis tenuis*, *Anthoxanthum odoratum*, *Avenula pubescens*, *Dactylis glomerata*, *Trifolium repens*, *Sanguisorba minor* and *Campanula rotundifolia*. The negative reactions of *Anthyllis vulneraria*, *Trifolium montanum*, *Danthonia decumbens* and *Salvia pratensis* are attributed to light deficiency caused by litter accumulation.

The declining trends of many taxa on mown plots within the four year period 1988–1991 are considered a result of weather conditions for the most part. Optimal conditions are reflected in a relatively high standing crop in 1988 (first plus second cut: 500 ± 80 gm^{-2}, $n = 8$). Weather conditions became worse in the following years reflected by a progressively declining standing crop (first plus second cut in 1990: 200 ± 75 gm^{-2}, $n = 9$).

The decline of many taxa is progressive, comparable to the decline of standing crop. As the number of rainy days in May similarly declines, it is suggested that the weather in May is a key factor for the development of these species (e.g. *Bromus erectus*, *Carex verna*, Fig. 6). For other species (*Plantago lanceolata*, *Anthoxanthum odoratum*) the weather in April seems to be determinative (Fig. 6).

The relationship between weather conditions and the behaviour of species in meadows is not yet well known (Bakker 1989, p. 371).

Proper correlations between climatic factors and the behaviour of plant species will be possible after more years of successive sampling.

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